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Neuropsychological Determinants of Social Functioning in Patients with Right Hemisphere Ischemic Damage – Clinical Applications

Abstract:

In recent times the social dimension of patients with acquired brain dysfunctions functioning has become an important area of interest for neuroscientists and clinical neuropsychologists. Empirical analyses using different methods reveal the role of the right hemisphere in many processes responsible for interpersonal behavior.

The study was designed to assess the state of social cognition and its hypothetical compounds with observable social behavior. A group of patients with ischemic right hemisphere dysfunction and comparison groups took part in it. The results point to disturbances of various forms of social cognition in patients with right hemisphere damage, and also confirmed the presence of significant correlations between social cognition and behavior. The possibilities for applying the results were also discussed.

Keywords: neuropsychology, social cognition, right hemisphere, ischemic stroke

Introduction

In recent decades patients with acquired brain dysfunctions social behavior has become a significant challenge to the clinical practice of neuropsychologists, neurologists, psychiatrists and specialists in the field of neurorehabilitation (Lezak,

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1986; Morton, Wehman, 1995; Ylvisaker et al., 2005). As O'Shanic and O'Shanic remark (1994), so-called "personality change" resulting from brain damage and manifested mainly within interpersonal behaviors, are considered by family and friends as the the patient's most serious problem, whether or not the damage occurs after 1, 5, or 15 years. Publications dealing with the rehabilitation of patients with vascular brain lesions also support the thesis that the most serious problem for patients with acquired brain dysfunctions is their coping with interpersonal relationships and with the social environment (Glass et al., 1993).

Neuropsychological studies, focussing on the location of brain structures -- the failure of which specifically interferes with social functioning disturbances -- have emphasized the regulative role of the brain's frontal lobes and right hemisphere(Borod et al., 1983; Stuss, Benson, 1984; Malloy et al., 1993; Tompkins, 1997; Eslinger, Geder, 2000; Herzyk, 2000). Initially neuroscientists were interested in the functions associated with right hemisphere, determined by Perecman as a "buried treasure" (Perecman, 1983), with attention focused primarily on that hemisphere's regulation of specific linguistic functions, visuospatial functions, and the its role in generation of affect and emotional regulation (Moscovitch, 1983; Borod et al., 1983; Osiejuk, 1994). Currently, one may notice extensive research concerning right hemispheric involvement in social cognition, and relationships between social cognition and communication, pragmatics, discourse and the various dimensions of social functioning (Brownell et al., 1986; Brownell et al., 2000; Happé et al., 1999; Winner et al, 1998) and, as a relatively new theoretical approach: neuropsychoanalysis - relationship between structure and functions of the right hemisphere and social attachment, namely coping with stress (Schore, 1994; Krukow, 2008).

Right hemisphere participation in the organization of social cognition is interpreted in a number of models and concepts. According to Weed et al. (2010) social cognition, and particularly Theory of Mind (ToM), namely understanding another's internal states, is closely related to, or even dependent on the pragmatics of communication and language. All acts of communication such as using metaphors, humor, irony, sarcastic phrases and conversational ability to make issues understandable for all of its members requires constant awareness of the participants' state of mind (eg, knowledge and beliefs). In turn, according to Sperber and Wilson's Relevance Theory (1986), mentalization is the basis for all communicative acts. Research on this issue is ongoing; currently it is difficult to point out which demand is more accurate: perhaps combining ToM competence *is* communication interaction and correlation, not a directional dependence. One cannot deny that both pragmatics and social cognition, though functionally independent, share the same brain structures, which are their neural basis (Champagne-Lavau, Joanette, 2009).

Analyses conducted on brain damaged patients, and investigations using functional neuroimaging have so far brought a lot of information in the field of social cognition neuronal organization. Authors of neuroimaging studies emphasize the role of different frontal areas, the superior temporal sulcus (STS) and temporo-parietal junction. STS is activated in tasks when a subject perceives biological motion. This neural structure is considered crucial to anthropomorphizing, which probably initiates the process of social cognition, and is its most fundamental dimension (Grossman et al., 2000; Weed et al ., 2010). A typical experimental stimulus that causes spontaneous anthropomorphization is a film developed in the 40's by Heider and Simmel (as: Heberlein, Adolphs, 2004), with moving geometric shapes, active for about two minutes, that are perceived by healthy people as animate beings even having intentionality and personality . Studies show that the amygdala also plays an important role in anthropomorphizing (Heberlein, Adolphs, 2004).

Despite the fact that the observed activation may be bilateral in nature, experimental works have confirmed a right-hemisphere advantage for identifying biological motion (Saxe et al., 2004; Saxe, 2006). By analogy to STS, clinical and experimental studies authors have pointed to the role of the temporo-parietal junction in social cognition and the *mirror neurons*, localized in the premotor ventral cortex and partly in the parietal lobe (Rizzolatti et al, 1996a; Rizzolatti et al., 1996b .) In addition to theoretical studies and proposals whose aim was to clarify how the right hemisphere regulates social behavior by indicating different, localized right hemispheric areas , there were also suggested explanations referring specifically to the functional specificity of the brain's right hemisphere in general. This hemisphere is dominant for bodily perception , its image, and bodily sensations are the primary basis for generating affective experience. The mentioned claim was on the one hand extensively documented by Devinsky (2000); on the other hand it is the main thesis of the so-called neurosomatic concepts, which emphasize the specific contribution of somatic, visceral processes in the brain's organization of cognition and affect . The best-known concept that belongs to the current neurosomatic trend is the somatic marker hypothesis by Antonio Damasio (1999). Besides Damasio's proposition, Adolphs et al (2000) also explained the problem. In their experiments 108 patients with confirmed and localized brain damage (right or left-side) participated. Tasks these patients faced included recognition of emotions from facial expressions, determining emotional intensity and sorting out emotional expressions in the patients' proposed categories. The aim of the analysis was to findthe exact location of brain damage, since its effect was to disrupt all types of emotions. It was found to be the somatosensory cortex, predominantly in the right hemisphere. Authors also observed that disturbances

of emotion recognition and comparison identified in patients with somatosensory cortex were significantly correlated with abnormalities in the perception of somatic and tactile stimuli. This compound occurred only in patients with right-sided lesions. The authors presented the following conclusions: a) somatosensory representation is critical for emotion recognition, b) somatosensory information available to the observer corresponds to his emotional state and is therefore able to recognize the perceived emotion. Important in this context are the results of Iacoboni and others (1999) who showed that the brain's' right parietal cortex plays a key role in imitating an individual's observed behavior. It can be assumed that the current state of knowledge describing right hemispheric participation in social cognition and behavior may be summarized as follows: Functional specificity of the right hemisphere, particularly its participation in somatic, motor and affective experiences as well as in global, contextual information processing is enriched by the functional characteristics of individual structures (occurring in the brain on both sides) involved in social cognition, causing that that area may have a functional advantage over its left hemisphere counterpart. The effect of this advantage is its significantly stronger activation in experimental tasks using functional neuroimaging methods or the occurrence of serious disturbances in social functioning following patient injury.

Right hemispheric dominance in regulatinginterpersonal performance, however, is not an indisputably proven fact. In social cognition studies, and research regarding other mechanisms regulating behavior and their disorders published after 2000, patient groups with left hemisphere damage usually do not participate (Griffin et al., 2006; Champagne-Lavau, Joanette, 2009 ; Weed et al., 2010), and therefore disturbances listed in the clinical groups may result from brain damage itself, not just its lateralization. Results obtained in other studies (Surian, Siegal, 2001) show that patients with damage to both right and left hemispheres have similar results regarding the first-degree Theory of Mind; the difference became significant only at the second and third degree Theory of Mind. In the same study it was found, however, that patients with right-sided damage may get better results if they have both visual and linguistic experimental material. All these results indicate potential multilateral relations and relationships between described processes; these compounds may take on a neural network character in which various systems cooperate to regulate different social aspects. This cooperation can take place at the level of neuroanatomical structures, functional systems and neurochemical modulation.

An important problem is the potential contribution of other cognitive processes in social cognition. It is also postulated that tasks activating Theory of Mind require mobilization of some executive subsystems, such as cognitive plasticity,

working memory, inhibition of selected stimuli for benefitting others and the ability to use representations and metarepresentations (Frith, Frith, 2000a, 2000b; Aboulafia-Brakha et al, 2011). Another finding impeding description and explanation of social cognition is the heterogeneity of patient populations with right hemisphere dysfunctions in social cognition, pragmatic competence, and executive functions (Champagne-Lavau, Joanette, 2009).

Of both theoretical and practical importance is the participation and neuropsychological disturbances in generating abnormal social behavior observed in a patient's daily functioning. Despite the already large number of publications concerning the in the social cognition and communication, there are relatively few studies focusing on interpersonal behavior changes in an environment relatively natural for patients. In the *Science Direct* database this author did not find a single publication which described the relationship between social cognition and the broad spectrum of interpersonal behavior in right hemispheric dysfunctional patients. One research paper, by Ammerlaan et al. (2008), described the relationship between social cognition and behavior without comorbid psychiatric disorders. It mentioned patient dependency after an amygdalohippocampectomy because of drug-resistant epilepsy. Nine people took part in the study: four after operations in areas of the left hemisphere and five with right-sided lesions. The authors suggested that despite removing brain structures considered crucial for social cognition (the amygdala), that part of the brain continued toborder on statistical significance, while the same correlation between social cognition and behavior proved to be weak and fragmentary, limited only to the recognizable expression of surprise. Ammerlaan and his coworkers concluded that the group sampled may have been too small and that usage of a self-descriptive evaluation tool may have produced false or incomplete results.

Taking into account the current challenges of clinical practice, it seems necessary to verify social cognition estimated by a standardized method which explores a broad set of social cognition competencies, and especially its relationship with observable, interpersonal behavior. One of the largest patient populations with right hemisphere damage are those who have suffered a unilateral ischemic stroke in the area of the right middle cerebral artery vasculature. The middle cerebral artery ensures an adequate blood supply mainly to the lateral and dorsal cortical areas of the hemisphere and subcortical structures, namely to the caudate nucleus and lenticular nucleus (mainly the middle parts). A stroke from the middle cerebral artery can damage the cortical areas -- such as the temporal insula, lateral temporal cortex, and lateral and posterior areas of the frontal lobe and areas of the temporo-parietal junction -- which according to experimental studies are involved in social cognition (Iskra, 2007). To examine the state of social cognition and be-

havior in a relatively homogeneous patient group after an ischemic stroke of the right middle cerebral artery is the main objective of this work.

Materials and Methods

Participants

The study involved 60 people, including 22 adult patients with neuroradiologically confirmed right hemisphere ischemic damage, described as ischemic stroke in the the middle central artery vasculature (RHD group). In the study only persons participated who did not have left hemisphere damage, diffuse brain pathology or bilateral dysfunctions. Exclusion criteria in the clinical group were left-handedness (an evaluation based on an interviews, and observations during administration of experimental trials), uncorrected vision problems, epilepsy prior to vascular brain damage, spatial neglect evaluated by the Clock Drawing Test and the "A" part of the Trail Making Test, chronic alcohol disease, motor limitations of preventing the execution of tests and experimental trials, and advanced cognitive deterioration obstructing or preventing contact with the investigator (the result of the Mini-Mental State Examination - MMSE score below 18 points).

Patients were examined in neurological rehabilitation wards, mainly in the Upper Silesian Rehabilitation Centre "REPTY" in Tarnowskie Góry and in Lublin hospitals. Due to subject assessments (described below), it took at least one year between the stroke and the neuropsychological survey. It was assumed that this period was sufficient to reveal disturbances in social functions resulting from brain damage.

The first control group consisted of 20 neurologically healthy subjects dwelling in the rehabilitation ward during the study. They were patients with rheumatic diseases (nHC group). Exclusion criteria in this group were the same as in the previous one. Due to signals in the introduction necessary to control the neuroanatomical variables, the study also involved an additional control group: patients diagnosed with multiple sclerosis (MS group, n = 18). The neuroanatomical criterion for inclusion in this group consisted of subcortical demyelinating changes in both hemispheres of the brain. Inclusion of the MS group was to check whether any social disturbances in the clinical group resulted from specific right-hemispheric damage, or nonspecific brain damage regardless of lateralization. Potentially, patients from all groups could manifest disturbances in social adjustment associated with the disease itself, hindering or preventing the satisfaction of psychological needs and the subjects' social independence. All subjects were informed about the

study purpose and gave their formal consent. The research project itself received a positive evaluation by the faculty ethics committee at the author's workplace.

General cognitive assessment

With regard to the need for control of selected independent cognitive variables, several domains were assessed in the current study: a) the overall level of cognitive functioning measured by the MMSE, b) and speed of visual-spatial stimuli processing (Trail Making Test, part "A"), cognitive plasticity and working memory (Trail Making Test, part "B") (Reitan, 1958; Steuden, 2000). The execution parameter of the Trail Making Test was performance time. " The analogies", an experimental-clinical trial, was used to control the abstract thinking level, this method having been taken from a set of clinical pathopsychology methods (Rubinsztejn, 1967). In this task the patient is given sets of words pairs which are connected by a logical principle. The subjects aim to find this principle (e.g., opposites, size ratioe, or its function), and by analogy to indicate a similar logical rule in another word set. Persons in this trial can achieve anywhere from 0 to 18 points.

Social cognition

Social cognition was evaluated as follows: identifying the state of mind of the first degree (e.g., what the person in the picture thinks, wants, and wishes ?), state of mind of the second degree (e.g. what the person thinks that the other wants?), third degree state of mind (e.g. what the person thinks the other is thinking concerning a third person's intentions?), deception recognition, recognizing and understanding the reciprocity rule (e.g., what the individual would expect from another [who previously had done him a favor]), and the pathological mental narratives. Assessing these processes was done using the Theory of Mind Picture Stories (ToMPS). The original method was developed by Professor Martin Brüne from the Ruhr-Universität Bochum in Germany (Brüne, 2003a; Brüne, 2003b). It is a fully standardized clinical experimental trial, and the results can be analyzed both qualitatively and quantitatively. In the original Brüne et al. studies (2003a) the Theory of Mind Stories Picture differentiated between healthy individuals and those with psychotic disorders who were having problems functioning socially. Due to the group's specificity, for which the tool was prepared (and the fact that it had not been used in studies of persons with acquired brain dysfunction), there was a need to adapt this method for patients with acquired brain damage but with no prior psychiatric disorders. This study took place in the Cracow Rehabilitation Center[2]. It was attended by 12 patients with vascular brain damage; in all patients (aged 45-76 years) lesions were confirmed by neuroimaging, which dis-

[2] Courtesy of Professor Maria Pąchalska.

played right frontal lobe lesions. This study was conducted primarily to find out if the examination itself was a major handicap for patients with acquired brain damage, and whether the instructions and questions contained in the task were understandable (Kądzielawa, 1990). The adaptations were approved by the author of the original version and with consent for its use in this study. The applied ToMPS version consists of five images in each series, from which a subject's task is to arrange them in a meaningful story. The ability to sequence the pictures properly depends entirely on the different states of the protagonists' mind recognition. After placing images in succession, they are asked questions. Their answers also test mentalization. An additionally assessed variable in ToMPS are pathological narratives - their indicator is 1) when pictures are improperly sequenced 2) and when aberrant image narrativesshow no reference to the picture. In Theory of Mind Picture Stories the subject can receive 0 to 48 points.

Another method for assessing social cognition was to recognize facial emotions. Photographs from the Ekman and Friesen set (1978) were used for this task. Each photo (100 × 83 mm) was laser printed on a white sheet of A4 paper. A chosen set of photographs contained 14 pieces, six of them showing basic emotions (surprise, disgust, joy, anger, fear, sadness). This set was used six images of male and female faces, and two neutral faces (one male and one female). To control facial recognition accuracy at least two questions were used regarding the sex of the person in the picture: the wrong answer given twice excluded a person from further research and statistical studies.

In addition, subjects underwent experimental examinations with a clinical trial "The figures". This trial assessed expression recognition (expressed mental states were request, resentment, arrogance, thoughtfulness, anger, helplessness) (Argyle, 2002). These were presented graphically, as simplified body schemas formed with black lines on white backgrounds. The tested person was supposed to name the perceived mental states. The following responses were considered as wrong: giving a different mental state than the correct one, no answer, or describing the stimulus without a mental interpretation.

The range of social cognition variables also included self-criticism -- an indicator of self-awareness, which was recognized as a form of social cognition. The subject of this knowledge is its own person and subject behavior. The method for assessing self-criticism was to compare a patient's self-evaluation of a task execution with his/her objective performance level (Sherer et al., 1998, Sherer et al., 2003). In this comparison a 1 / 1 ratio was the result of a fully adequate self-assessment regarding the single task, a rating of less than 1 indicateddecreased self-criticism, and higher than 1 increased self-criticism.

Social behavior

Due to the lack of a standardized test -- and therefore none adapted for Polish-speaking people – for assessing changes in a patient's social functioning, author independently prepared a procedure. Its final version was approved by a competent judge before being using. The structurated clinical interview in which a person close to the patient (usually a family member) and staying with the patient in the last three months prior to the study, assessed the severity of behavioral problems in the following areas: 1) disruptions of self-control, 2) emotional indifference, 3) disorders of attachment, 4) interpersonal withdrawal, 5) interpersonal disorientation, 6) communication difficulties, 7) and overall behavior rating. These areas of behavioral disturbance were taken from Eslinger et al. (1995) and from "The Emotional and Social Dysfunction Questionnaire" developed and described by Andrews et al. (2003a, 2003b), in which the authors enumerate the most common disturbances in social adaptation of patients with brain damage resulting from different etiologies. Furthermore, with respect to clinical group specificity, two additional behavioral dimensions were added: communication inefficiency and reduction of attachment behaviors. Behavioral assessment proceeded as follows: The examiner mentioned behavior (at least five in each area) associated with dysfunction of a given range, and the patient's relative was to make a note of that behavior on a behavioral problem severity scale. For example, examples of disrupted self-control were outbursts of anger, tears, laughter, inappropriate comments, and suggestions, and lack of inhibitions in social interaction. Examples of emotional indifference : no feelings directed toward close ones, lack of concern regarding other's emotions, neutral approach to other people in emotional situations, inability to empathize, and lack of response to relatives expressions. Behavior indicating attachment disorders: lack of differentiation of emotional behavior depending on whether the patient is either in a relationship with someone close or emotionally neutral, the treatment of their loved ones as well as foreign persons, and limiting intrinsic emotional behavior reserved for loved ones. The following behavior examples were chosen as representative ofinterpersonal withdrawal: aversion to interpersonal relationships, closing in on oneself, inhibition in interpersonal situations, avoidance of other people and relationships with them, and not maintaining new friendships. The dependent variable assigned to interpersonal disorientation: reactions inadequate to the social context, limiting understanding of other persons' behavior, loss of and / or lagging behind in behavior and communication by people in a relationship with the patient, interpersonal awkwardness. Included in communication difficulties: reducing opportunities to express the subjects' thoughts and needs, difficulties comprehending irony,

humor, metaphors, and behavior showing that the patient does not understand the message addressed to him. Control over assessment took the following form: when the person evaluating a patient exhibiting extreme judgments had to give concrete examples of that patient's dysfunctional behavior. Evaluators might also ask questions to clarify individual areas of social functioning.

The study used several statistical methods . To assess differences between groups: a student t test, and in the case of variables without normal distribution characteristics – the Mann-Whitney U test. A Kruskal-Wallis H test was applied to make multigroup nonparametric comparisons, and the Spearman Rho rank coefficient to analyse correlations between variables. All statistical analyses were carried out in an SPSS 17.0 Statictics package.

Results

Table 1 contains the subjects' demographic and cognitive characteristics. All groups had the same sex ratio percentage (65% male, 35% women). In terms of age and education there were no significant differences between the clinical group RHD and comparison nHC group, although patients in the clinical group were slightly older. Patients who comprised a second comparison group (SM) were significantly younger than people in other groups. This is due to the specificity of multiple sclerosis, which usually begins between ages 20 - 30 (Ropper et al., 2005); therefore, a majority of patients in SM being aged 50 years or more may not have been able to perform neuropsychological testsbecause of sensory and motor limitations.

In Table 1, in terms of basic cognitive variables (MMSE, TMT, "The analogies") there were significant differences between the clinical group and control group nHC: patients with right hemisphere brain damage obtained lower cognitive function scores on: the general level of cognitive function, cognitive plasticity, processing visual-spatial speed material and abstract thinking. The SM group received a lower evaluation of the overall effectiveness of cognitive measure and abstract thinking than the group of neurologically healthy individuals, but these differences are statistically borderline. Analysis of cognition based on visual-spatial material (TMT) showed that patients with SM performed better than the clinical group . Taking into account the medical and neuropsychological groups' specificity, it can be concluded that those results are typical.

Patients with right hemisphere brain damage obtained significantly lower scores than neurologically healthy individuals in all the social cognition variables (Table 2). The difference between the clinical and the SM group is no longer so clear. Compared to patients with multiple sclerosis, patients in the RHD group

Table 1. Demographic and cognitive characteristics of the examined groups

	RHD (n = 22)	nHC (n = 20)	p	SM (n = 18)	RHD – SM p	nHC – SM p
Age	54.8 (7.9)	49.5 (12.6)	0.165	38.4 (10.2)	0.0001	0.006
Education (years)	11.3 (0.5)	12.1 (1.9)	0.143	12.1 (1.7)	0.191	0.934
Post onset (month)	15.3 (20.4)	-		120.4 (97.1)	0.0001	-
MMSE	26.9 (1.9)	28.9 (1.5)	0.0001	27.6 (2.1)	0.225	0.046
TMT A	89.5 (56.5)	41.8 (12.7)	0.0001	49.9 (24.4)	0.013	0.548
TMT B	191.6(108.2)	72.5 (27.0)	0.0001	103.0(33.6)	0.003	0.018
"The analogies"	9.4 (6.0)	15.1 (4.5)	0.0001	10.1 (7.4)	0.593	0.036

achieved worse results in terms of recognizing the state of mind in degrees 1, 2, and 3, and in deception recognition. They also received a fewer points in general measures of ToMPS performance, that is, points for picture sequencing, verbal answers and in the ToMPS total points. At the same time, SM patients and patients after right hemisphere ischemic damage did not differ regarding in understanding the reciprocity rule and in pathological narrations. This may mean that decreased efficiency in social rules understanding and pathological response to the test material is characteristic not only for patients with right-sided dysfunctions, but is a general feature of people with brain damage. The dominant number of social-cognition differences indicated that damage to the right hemisphere specifically disrupts understanding, especially the recognition of intention, knowledge and expectations. Recognition of emotional facial expressions was also impaired in patients with right hemisphere pathology. They achieved lower scores in that area than did those with two comparison groups. There were somewhat different results concerning the identification of emotional schematic pose expressions. In this case, statistically significant differences occurred between all groups. Patients from the RHD group obtained the lowest scores, patients in SM had higher results but lower than the neurologically normal individuals. Thus, pose expression identification differentiates all of the groups, but again patients with right hemisphere damage received the lowest scores,. Also, self-criticism was a variable

differentiating all three groups, just as proportions were varied in pose expression recognition.

Table 2. Social cognition and social behavior comparisons

Social cognition:	RHD	nHC	SM	Kruskal-Wallis H	Between groups comparison
ToM 1°	2.0 (0.8)	2,9 (0,2)	2.6 (0,7)	17.92**	RHD < nHC, SM
ToM 2°	2.6 (0.9)	3.7 (0.5)	3.6 (0,6)	18.82**	RHD < nHC, SM
ToM 3°	0 (0.3)	0.7 (0.4)	0.6 (0,5)	19.69**	RHD < nHC, SM
Deception recognition	3.9 (1.9)	5.6 (0.9)	5.5 (0,7)	16.26**	RHD < nHC, SM
Reciprocity rule	2.5 (0.6)	3.0 (0.0)	2.7 (0,4)	10.02**	RHD, SM < nHC
ToM sequencing	17.8 (8.9)	28.6 (2.4)	26.7 (3.1)	20.48**	RHD < nHC, SM
ToM verbal answers	11.7 (3.8)	17.1 (1.8)	16.1 (2.2)	27.60**	RHD < nHC, SM
Pathological narrations	0.8 (1.1)	0 (0.2)	0.1 (0.3)	11.45**	RHD, SM < nHC
ToMPS total points	29.9 (12.0)	45.8 (3.4)	42.8 (5.3)	24.33**	RHD < nHC, SM
Facial expression recognition	7.1 (2.0)	9.5 (2.1)	9.1 (0.7)	13.92**	RHD < nHC, SM
Pose expression recognition	2.4 (1.6)	4.4 (1.7)	3.9 (0.6)	17.98**	RHD < nHC > SM
Self-criticism	5.4 (1.1)	7.3 (1.8)	6.3 (2.0)	17.10**	RHD < nHC > SM

Social behavior:	RHD	nHC	SM	Kruskal-Wallis H	Between groups comparison
Disruptions of self-control	1.8 (0.9)	1.6 (0.7)	1.8 (1,0)	0.52	RHD, nHC, SM
Emotional indifference	2.3 (1.1)	1.2 (0.4)	1.8 (0,6)	12.85**	RHD, SM > nHC
Disorders of attachment	1.7 (0.8)	1.0 (0.0)	1.4 (1,0)	18.23**	RHD > SM > nHC
Interpersonal withdrawal	2.1 (1.1)	1.3 (0.6)	1.7 (0,7)	6.60*	RHD, SM > nHC
Interpersonal disorientation	2.2 (1.2)	1.0 (0.2)	1.7 (0,9)	15.76**	RHD, SM > nHC
Communication difficulties	2.1 (0.9)	1.2 (0.4)	1.7 (0,9)	11.11**	RHD, SM > nHC
Overall behavior rating	67.0 (29.2)	92.5 (11.7)	80.0 (18.6)	9.95**	RHD, SM < nHC

Note: ** $p < 0,01$; * $p < 0,05$; ToMPS – *Theory of Mind Picture Stories*

Summarizing social cognition assessment, it is also worth mentioning that raw scores in the clinical group did not indicate a total inability to read a variety of mental states. The presence of significant differences between groups does not necessarily mean very profound deficits in social cognition in the RHD group.

Social functioning analysis indicates the existence of a less-specific dysfunction of social cognition in the RHD group. However, intergroup comparisons indicate an important difference in behavior between the clinical and nHC group, except for disruptions of self-control - otherwise there were no significant differences in this area. For the other social behavior dimensions a significant difference can be noticed between the clinical and nHC group (including the overall behavior rating) -- with the exception, however, of one case: in disorders of attachment, where there was no difference between the RHD and the SM group. This result can be interpreted as an argument for social behavior abnormalities in right hemisphere damaged patients, but also – to some extent – in patients with any sort of brain dysfunction. In the light of these results only disrupted attachment behaviors can be regarded as specific for patients with right hemisphere damage.

To further analyze the potential impact of the independent variables (level of cognitive function: cognitive plasticity, abstract thinking and the various social cognition dimensions) in the RHD group, a correlation analysis was conducted between the mentioned variables. The results are presented in Table 3.

Table 3. Correlations between cognitive characteristics and social cognition parameters in RHD group

	MMSE	TMT A	TMT B	"The analogies"
ToM 1°	0.491*	- 0.400	- 0.414	0.279
ToM 2°	0.360	- 0.299	**- 0.724****	0.288
ToM 3°	0.367	- 0.362	- 0.509*	0.313
Deception recognition	0.464*	- 0.365	**- 0.769****	0.398
Reciprocity rule	0.266	- 0.323	**- 0.628****	0.012
ToM sequencing	**0.717****	- 0.414	- 0. 542*	0.533*
ToM verbal answers	0.586**	- 0.478*	**- 0.736****	0.398
Pathological narrations	**- 0.684****	**0.671****	**- 0.636****	- 0.356
ToMPS total points	**0.703****	- 0.464*	**- 0.606****	0.507*
Facial expression recognition	**0.660****	- 0.390	- 0.200	0.196
Pose expression recognition	**0.619****	- 0.505*	- 0.477*	0.379
Self-criticism	0.534*	**- 0.602****	- 0.314	0.306

Note: ** $p < 0{,}001$; * $p < 0{,}05$; bold numbers: high correlations

Most significant correlations between cognitive measures and the ability to mentalize happened between MMSE and the general parameters of intention recognition in ToMPS, and the recognizedand interpreted emotions and other mental

states based on facial expressions and poses. In this case, one can identify several high correlations, the highest being the relationship between MMSE and points in ToMPS for picture sequencing. Cognitive plasticity, measured in part "B" of the Trail Making Test proved to be highly associated with the Theory of Mind Picture Stories execution, and especially of ToM 2° (understand how the other person understand another), recognition of deception, and ToMPS verbal answers. These are the parameters considered as most specific for social cognition measurement (Brüne, 2003b).

These results reflect the presence of a strong relationship between social cognition measured by ToMPS and cognitive plasticity. The least significant correlation occurred between social cognition and "The analogies" (which measures abstract reasoning based on verbal material. This result can be interpreted in two ways: 1) social cognition, as assessed by ToMPS is not associated with abstract thinking, 2) for patients with right hemisphere damage, visuospatial disturbances may be more specific, with these problems perhaps causing deterioration in the efficiency of other processes related to the right hemisphere. Correlation between "The analogies" task and two measures of social cognition also was low: for ToM sequencing $p < 0.011$, for ToMPS total points $p < 0.016$. In summary, those results can be the basis for the statement that there were significant associations of social cognition and several non-social cognitive parameters. The speed of visuospatial stimuli (TMT Part "A") with social cognition were less specific, the highest correlations between these variables and social cognition involving pathological narrations and self-criticism.

As stated earlier, the main objective of this paper is to analyze how patients with vascular right hemisphere damage function socially. Table 4 evaluates the correlations between indices of interpersonal behavior and the independent variables, including social cognition. Statistically significant correlations -- the overall assessment of social behavior relationships and various social and cognitive independent variables -- related to stories in ToMPS , and to the total test performance score. Correlations are high, which means a strong relationship exists between cognition and social behavior. A high correlation also appeared between MMSE and overall interpersonal functioning, and therefore the overall cognitive function level was related to the adequacy of social behavior; additionally behavior can be affected by abstract thinking, as evidenced in the moderately significant correlation with "The analogies". There were no significant correlations between overall social functioning and recognizing facial expressions and poses, which is relatively surprising in the light of the extensive literature on facial-expression recognition disorders in right hemisphere damaged patients.

Table 4. Correlations of social behavior, cognitive characteristics and social cognition.

	Disruptions of self-control	Emotional indifference	Disorders of attachment	Interpersonal withdrawal	Interpersonal disorientation	Communication difficulties	Overall behavior rating
Cognitive characteristics:							
MMSE	- 0.129	- 0.584**	- 0.578**	0.127	- 0.522*	- 0.453*	**0.634****
TMT A	0.054	0.364	0.529*	- 0.157	**0.652****	0.305	- 0.360
TMT B	0.013	0.461*	**0.667****	- 0.190	0.455*	0.174	- 0.363
"Analogies"	- 0.469*	- 0.470*	- 0.462*	0.131	- 0.350	- 0.535*	0.510*
Social cognition parameters:							
ToM 1°	- 0.017	- 0.531*	- 0.226	0.207	- 0.409	- 0.243	0.407
ToM 2°	- 0.144	- 0.474*	**- 0.610****	0.316	0.090	- 0.008	0.233

ToM 3°	- 0.094	- 0.387	- 0.361	0.146	0.001	- 0.196	0.415
Deception recognition	- 0.220	- 0.480*	**- 0.630****	0.243	- 0.238	- 0.253	0.398
Reciprocity rule	0.045	0.012	- 0.298	0.152	- 0.209	0.147	0.021
ToM sequencing	- 0.263	**- 0.792****	**- 0.635****	0.260	- 0.400	- 0.394	**0.721****
ToM verbal answers	- 0.179	- 0.575**	**- 0.620****	0.308	- 0.209	- 0.187	0.451*
Pathological narrations	0.153	0.573**	0.445*	- 0.102	**0.643****	0.285	- 0.554**
ToMPS total points	- 0.209	**- 0.784****	- 0.626**	0.224	- 0.390	- 0.369	**0.689****
Facial expression recognition	- 0.262	- 0.363	- 0.413	0.402	- 0.422	- 0.152	0.397
Pose expression recognition	- 0.223	- 0.355	- 0.507*	- 0.051	**- 0.612****	- 0.417	0.417
Self-criticism	- 0.150	- 0.338	- 0.280	0.143	- 0.536*	- 0.222	0.307

Note: ** $p < 0,01$; * $p < 0,05$; bold numbers: high correlations

There was also no statistically significant association between social functioning and self-criticism. These results may suggest that merely observing social cognition disturbances does not necessarily mean that they will effect changes in patient behavior. The highest correlation one can find between different parameters and variables is emotional indifference and disorders of attachment. Thus, patients having problems in understanding mental states at the same time evinced the strongest emotions within their range of emotional behavior and attachment. Interpersonal disorientation in turn correlated with parameters such as execution time TMT part A, MMSE, besides pathological narrations in ToMPS, pose and expression recognition rate and self-criticism. Disturbances in these variables co-occur with confusion in social situations. There were no significant correlations between social cognition and behavioral assessment of communication skills, although lack of correlation between social behavior and emotional facial expression may be surprising. Interpersonal withdrawal has no links with the independent variables tested; this indicates that avoidance of interpersonal relationships may have different determinants than social cognition, cognitive plasticity, memory and abstract thinking.

In order to verify the specificity of cognition and social behavior, a correlational analysis of dependent and independent variables, as in Table 4, was conducted on the neurologically healthy subjects (nHC). This analysis can be summarized as follows:- There were no significant correlations between social cognition as an indicator of emotional indifference and attachment behavior disturbances,- There were two correlations at the significance level of $p < 0.001$ between social cognition and interpersonal withdrawal (with facial expression recognition $R = - 0.630$; and pose expression recognition $R = - 0.590$),- There were significant correlations between indices of communications difficulties and social cognition, with ToMPS total points $R = - 0.539$, $p < 0.014$ and pose expression recognition $R = - 0.726$, $p < 0.0001$.At the same time overall rating of behavior correlated with only two parameters of social cognition: Facial expression recognition $R = 0.637$, $p < 0.003$ and pose and expression recognition $R = 0.574$, $p < 0.008$. In conclusion analyses of social cognition and behavior compounds specific for the RHD group should be emphasized as having significant, moderate and high correlations between the overall behavior rating and various indicators of social cognition, and as having a number of important high and negative correlations between social cognition and interpersonal behavior disturbances such as emotional indifference and attachment disorders.

Discussion

Results on the determinants of interpersonal functioning in patients with right hemisphere vascular lesions make it possible to present specific clinical phenomena affecting social behavior. Comparisons of patients from the RHD group with the other groups can be recapitulated as follows:

– In the clinical group social cognition processes were distorted .

– Negative changes in social cognition related to understanding intentions, mental states degrees 1, 2 and 3, deception recognition and identification of emotion in facial expressions.

– In terms of social behavior, the RHD group results differed disadvantageously against the results of neurologically healthy subjects.

– The only behavioral abnormality characteristic of a clinical group was the disorder of attachment. Regarding the other interpersonal behavior variablesno differences were found between the RHD and the SM groups.

These results indicate the need for an additional second group (with some type of brain damage) to be compared with healthy subjects as the main comparison group in further explorations of the various interpersonal problems. Especially important seems to be a summing up of intergroup differences regarding social cognition in social functioning. When social cognition in the clinical group was compared with the other two groups, social cognition turned out to be specifically impaired in the RHD group, although the compared social behavior ratings did not allow one to recognize specific disorders only in patients with right hemisphere lesions: the majority of the social behavior parameters did not appear to significantly distinguish the RHD and MS groups. The only area specifically impaired in patients with right hemisphere vascular damage were negative changes in the attachment behaviors.

Correlation analysis confirmed the hypothesis regarding social cognition and behavior compounds. Overall behavior rating is indeed associated with the parameters of social cognition measured by Theory of Mind Picture Stories. This compound has potential relevance to clinical practice, described in more detail in a later discussion. Assessment of correlation between indices of social cognition and behavior resulted in rather unexpected results. One of them is the lack of any connection among communication difficulties and any measures of social cognition. It seems that this phenomenon can be explained by reference to the used methods. It is possible that communication competencies disturbances contained in interpersonal functioning was incomplete or incomprehensible to patients' family members.

Numerous, strong and high level statistical correlations between social cognition and emotional social behavior disorders can be considered as a further result; such correlations would be difficult to predict in the light of data cited in the introduction. These results indicate a particularly important aspect of research on right hemisphere dysfunctions, and probably also in cases of other brain damages. Family members, who often live with and care for patients, are able to pay attention to other social behaviors than can laboratory researchers and clinicians.

That disruptive behaviors aimed at maintaining social ties have been evaluated as the most inappropriate for evaluating patient behavior suggests that the quality of interpersonal relationships -- its individuality, uniqueness -- is the main determinant for evaluating social functioning. This is a potentially relevant inclination for further neuropsychological investigation: One should examine not only patients' cognitive as well as other regulatory processes, but their relationships with people with whom they interact at different levels of intimacy. This analysis should assess their behavior with a strong emphasis on ecological validity.

Strong relations between social cognition and interpersonal relationships emotional dimension also may indicate specific neuropsychological processes associated with the right hemisphere. According to the neuroanatomical and neurophysiological work conducted by Galaburda (1995) and Gur et al. (1980), the exchange of information in the right hemisphere is primarily between regions unlike the left hemisphere, in which the information analysis takes place within the anatomical and functional systems; it should be also noted that the right hemisphere has more associative areas than the left. These characteristics may at least partly explain the relationship between social cognition disturbances and disorders of attachment - however, these processes have a different psychological organization, where disruption of one of them causes the disorder of the second. These compounds may be due to special aspects of neuroanatomical and functional right hemisphere development. According to Schore (1994, 2003) the right hemisphere develops in the first two years primarily as a result of the child–mother attachment relationship. This relationship is peculiarly stimulating, and within its framework various child abilities are developed: first, perceiving and then distinguishing the mother from other people, especially her face, and later, recognizingther intentions and other competences related to mentalization capacities. In this way, attachment is developmentally related to social cognition. Shore's theoretical approach is still rather a set of hypotheses that are rooted in separate neurophysiological and neuropsychological research on developmental and neuropsychiatric disorders. Its application to explain changes in how a person with acquired right hemisphere damage functions requires further clinical research.

The obtained results should be regarded as incomplete and burdened with potential error. It has been derived mainly from applying the patient social functioning method, which is primarily rooted in knowledge based on clinical neuropsychological studies. However, its psychometric properties have not been estimated. Another shortcoming is failure to account for patients with left hemisphere brain damage resulting from ischemic stroke. RHD and SM group comparisons suggested that some changes observed in patients with right hemisphere damage are not specific only for this group. Also, the neuroanatomical characteristics of RHD group patients varies considerably. Although this group is etiologically homogeneous, persons with damage to the selected areas of frontal, temporal and parietal lobes, as well as to cortical and subcortical structures took part in the study. Some anomalous results reported in the study specifically require additional verification.

Applications of the obtained results to clinical practice

The aforementioned results are potentially important for clinical neuropsychologists and psychologists. Their diagnosis and treatment of patients with right hemisphere damage may include the following indications:

1. *Theory of Mind Picture Stories* as adapted by the author of this text may be used to diagnose patient social cognition: patients with right hemisphere lesions obtained lower results than neurologically healthy patients and the SM group. RHD patients points in ToMPS were not scored close to 0, which could indicate that the trial performance was within patient capabilities.
2. In the clinical group there was a significant association between social cognition and social functioning, which means that for patients with right hemisphere damage one can estimate the probable level of social cognition effectiveness. It should, however, be noted that in other clinical groups such association may or may not occur. In Milders et al. (2003) study, where social behavior and cognition were also assessed -- but in patients following severe traumatic brain injury -- the negative results were obtained regarding occurrence of the mentioned relations.
3. Patients with brain dysfunctions family members, which often are their primary caregivers, may identify slightly different problems in interpersonal functioning than some of researchers and clinicians. It seems that in the clinical assessment and treatment process, as well new method development, regarding this aspect of the behavior, also the perspective of family members and carers should be incorporated.
4. Neuropsychological rehabilitation programs developed for patients with right hemisphere damage should apply not only to aspects of cognitive and communication disturbances. However, nowadays more and more rehabilitation programs use the holistic approach, often taking into account that interpersonal

aspect (Łojek, 2008), interdisciplinary cooperation can develop programs combining cognitive therapy with a range of neuropsychoanalysis methods (Kaplan-Solms & Solms, 2001).

5. It seems advisable to patient caregivers and family members, who contribute to neuropsychological therapy, that they should pass a psycho-education course (or rather "neuropsychoeducation") in the aspect of disorders that are often the result of damage to these brain areas. Correlation of cognition and social behavior indicates that patients who have difficulties in recognizing and understanding intentions and emotions are also judged as more emotionally indifferent and not exhibiting behaviors associated with emotional bonds. This may be the result of different processes: on the one hand, patients who do not receiving intentional behaviors of others (eg, due to perceptual aprosodia) are not able to respond in the manner expected. It is also possible, however, that they have disrupted attachment directly as a result of right hemisphere damage. Attachment research indicates that right hemisphere activity provides the expression of separation reactions (Dowson et al., 2001; Gillath et al., 2005; Ragnoni et al., 2008); so it is not excluded that this behavior may disappear as the result of right hemisphere lesions.

6. Diagnosis and therapy should take into account patient interpersonal relationships (not only their behavior outside the social context), and in particular, the ecological dimensions of neuropsychological assessment (Pąchalska, 2007) of patients with a dysfunctional regulating system (which the right hemisphere can be called).

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