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SCIENCE DIRECT®
Brain and Language 93 (2005) 46–54
Brain and Language
www.elsevier.com/locate/b&l

The role played by the right hemisphere in the organization of complex textual structures

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Accepted 4 August 2004
Available online 23 September 2004

Abstract

Eleven patients with right hemisphere damage (RHD), 11 left hemisphere damaged (LHD) nonaphasic subjects, and 11 neurologically intact controls were given three story description tasks. The two brain-damaged groups had no language, visuospatial, memory, or conceptual deficits on standardized neuropsychological testing. In the first experiment, the subjects were asked to retell previously read stories. In the second they had to tell stories which were depicted in cartoon-like fashion. In the third experiment, the story content was also depicted but pictures were given unordered so that the participants had first to arrange them in a plausible sequence. The elicited narratives were analyzed with a method which allowed examining within-sentence (lexical selection and syntactic complexity) and between-sentence (cohesion and coherence) processing abilities of the three groups. In the first experiment all groups performed quite well on both within- and between-sentence measures. In the two picture description tasks, however, the performances of the right hemisphere damaged subjects were poorer than those of normal controls when examined in terms of information content or coherent and cohesive aspects of narrative production. These findings agree with the hypothesis that RHD subjects are impaired in deriving from visual information the mental model of a story. They also indicate that clinical methods for analyzing structural aspects of discourse are suitable to identify these symptoms.

Keywords: Discourse processing; Right hemisphere damage; Left hemisphere damage

1. Introduction

A number of studies have been carried out to investigate the nature of the relationship between linguistic functions and damage to particular neural structures. One of the most everyday-used linguistic functions is the ability to produce narrative discourse. Producing narrative discourse can be considered as a complex dynamic cognitive function consisting of the interaction of different levels of processing (Caplan, 1992; Kintsch & Van Dijk, 1978). In particular, three main levels of processing can be distinguished: A within-sentence or microlinguistic level, responsible for intra-phrasal functions; A between-sentence or macrolinguistic dimension, responsible for the inter-phrasal ones; A level of global meaning processing, i.e., the generation of the mental model of a text (Glosser & Deser, 1992; McKoon & Ratcliff, 1992; Van den Broek, 1988, 1990; Van Dijk & Kintsch, 1983). The microlinguistic dimension organizes phonological or graphemical patterns into morphological strings and words, and determines the syntactic context each word requires in order to produce well-formed sentences. The macrolinguistic dimension, on the other hand, completes by means of cohesive and coherent ties the intra-phrasal processing by establishing locally the connections among sentences and globally the relations among all the meanings conveyed by the text (Halliday

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doi:10.1016/j.bandl.2004.08.002

& Hasan, 1976; Kintsch & Van Dijk, 1978; Van Dijk & Kintsch, 1983). Furthermore, the comprehension or production of a text is assumed to be achieved by means of the generation of a mental model, the general meaning or gist of the text itself which provides conceptual organization of information (Johnson-Laird, 1980). As a result of this complex interaction, the sentences that form a written or a spoken discourse can be perceived as a coherent and contextually appropriate whole and not simply as a disordered set of scrambled pieces of information. All these levels can be analyzed separately (e.g., Davis, O'Neil-Pirozzi, & Coon, 1997).

While the role played by some structures of the left hemisphere in microlinguistic processing is well-established, the same cannot be said about the right hemisphere. Several studies aimed to investigate the contribution of the right hemisphere in the processing of language by studying production and comprehension of discourse (Beeman, 1993; Joanette & Goulet, 1990; Myers, 1984). However, results have often proved controversial. Some studies on right hemisphere damaged subjects, for instance, report problems in lexical (Joanette, Goulet, Ska, & Nespoulous, 1986) as well as in semantic processing (Uryase, Liles, & Duffy, 1989). Nonetheless, in other experiments no such problems have been found (Frederiksen & Stemmer, 1993). On the contrary at the macrolinguistic level of processing results are much more homogeneous, showing a general impairment in the coherent organization of the propositions that form a text (Bryan, 1988; Delis, Wapner, Gardner, & Moses, 1983; Hough, 1990; Schneiderman, Murasugi, & Saddy, 1992). Furthermore, right hemisphere damaged subjects seem to be impaired in the generation (Brownell, Gardner, Prather, & Martino, 1995; Hough, 1990; Rehak et al., 1992) and/or modification (Frederiksen & Stemmer, 1993; Stemmer & Joanette, 1998) of a narrative's mental model. Such an impairment has been referred to as a selective deficit in integrating pieces of information by means of inferences derived from the situational context (Beeman, Bowden, & Gernsbacher, 2000; Carol, Baum, & Pell, 2001; Delis et al., 1983; McDonald & Wales, 1986). Difficulties in dealing with nonliteral expressions (sarcasms, proverbs, idioms, and indirect requests) have also been reported (Stemmer, Giroux, & Joanette, 1994; Van Lancker & Kempler, 1987). Not all studies, however, have confirmed this set of results, both at the coherence (Glosser, Deser, & Weisstein, 1992) and more general levels of text processing such as mental models (Frederiksen & Stemmer, 1993; see also Roman, Brownell, Potter, Seibold, & Gardner, 1987 on script knowledge).

On the whole, the right hemisphere seems to be involved in the organization of information at the pragmatic-communicative level as well as in the generation (and modification) of mental models that fit the text. Unfortunately, patients' difficulties in these respects are not easy to detect and quantify as shown by the contrasting results reported on both micro- and macrolinguistic levels. A possible explanation of the difference in results can be due to nonhomogeneous research methods which used different experimental conditions or measures (Cherney & Canter, 1993; Davis et al., 1997). For instance, Davis et al. (1997) have shown that the occurrence of deficits in referential cohesion, logical coherence, and accuracy of narration depended on the condition in which the narrative was produced. Furthermore, most of these studies have focused on isolated aspects of linguistic processing, without providing a complete view of how different linguistic skills interact in right hemisphere damage (RHD) subjects. Indeed, if a deficit at the macrolinguistic level may cause problems on the microlinguistic level of text processing, the reverse can also be true. Another possible explanation for the different results reported in the literature may lay in the necessity of performing a set of neuropsychological tests in order to exclude from the experiments subjects having global or selective cognitive deficits, such as visuospatial cognitive impairments, that may affect the quality of the description of picture sequences (Joanette et al., 1986; Rivers & Love, 1980).

In the actual study an attempt to describe the linguistic abilities of right hemisphere damaged subjects in the processing of complex textual structures is presented. The narratives produced by a group of right hemisphere damaged subjects in three different experimental conditions were compared to those provided by left hemisphere damaged and normal subjects. The elicited narratives were analyzed using a method of discourse analysis which allowed to evaluate both micro- and macrolinguistic aspects of processing. We hypothesized that such a detailed analysis would highlight aspects of impaired macrolinguistic processing in the RHD subjects. We also assumed that the presence of these impairments may be dependent on the task conditions. When a subject is requested to retell a previously read story, the story elements are provided by micro- and macrolinguistic arrangement which may cue the generation of a mental model. When the story elements are provided in cartoon-like fashion, the mental model corresponding to the story has to be generated by the subject without such cues. Finally, if the subject has to first arrange the depicted story elements in a plausible sequence, the cognitive load further increases as multiple story models have to be checked until the correct arrangement is obtained. Therefore, we predicted that selective effect of right hemisphere damage on macrolinguistic aspects of discourse would not appear in story retelling. Instead, it would be evident in stories depicted in cartoon-like fashion where a mental model of the story had to be generated from pictorial information.

2. Materials and methods

2.1. Subjects

Thirty-three right-handed subjects matched for age and education were included in the study (Table 1). The control group included 11 neurologically intact controls. Eleven nonaphasic left hemisphere damaged subjects (LHD) were also included in order to control for unspecific effect of brain damage. The experimental group consisted of 11 subjects with a focal right hemisphere lesion (RHD).

All subjects suffered from an ischemic lesion confined to only one cerebral hemisphere as a consequence of a first cerebrovascular accident resulting in a mild to moderate hemiparesis. The size of the lesions could not be determined as only written reports of CT scans were available. The localization of the lesions and the time post-onset are reported in Table 2 showing that the two brain damaged groups were sufficiently matched for anterior/posterior or cortical/sub-cortical distribution. The mean time post-onset was of 4.8 months ($SD = 2.4$) for the RHD group and 4.6 months ($SD = 2.4$) for the LHD group with no significant statistical difference.

No RHD subject presented hemineglect or consistent visuospatial disorders. No LHD subject presented aphasic disturbances although six of them had mild dysarthria. For one LHD subject (IC) mild ideomotor apraxia was noticed.

The medical records of all subjects had been previously reviewed in order to exclude cases of history of mental illness, alcohol or drug dependency.

Table 1
Means and (standard deviation) of age and level of formal education in the three groups

	RHD	LHD	C
Age	63.4 (8.7)	62.5 (11.2)	63.1 (7.9)
Education	8.4 (5.4)	10.6 (4.7)	10.6 (4.4)

Table 2
Clinical data for the brain-damaged subjetcs[a]

Subject	Time p.o. (months)	Lesion localization
Right-brain-damaged group		
1 L.A.	4	R T–P
2 G.U.	5	R Th.
3 C.An.	5	R BN
4 I.L.	2	R P
5 B.R.	4	R CSO
6 B.I.	3	R BN
7 D.B.G.	3	R T–P
8 C.A.	2	R T
9 O.S.	5	R T–P
10 L.U.	5	R T–P
11 M.C.	2	R IC
Left-brain-damaged group		
1 I.V.	3	L T
2 C.W.	2	L P
3 R.A.	4	L F–T
4 M.B.	5	L T
5 M.G.	2	L CSO
6 P.A.	2	L P
7 G.V.	5	L Th.
8 C.A.	3	L BN
9 I.C.	5	L F–P
10 R.L.	4	L CR
11 T.M.T.	3	L P

[a] Lesion localization: L, left; R, right; F, frontal; P, parietal; CSO, centrum semiovalis; CR, corona radiata; T, temporal; IC, internal capsula; Th., thalamus; and BN, basal nuclei.

2.2. Materials

Standardized psychometric assessment had been previously performed on the subjects by means of the Mental Deterioration Battery (Carlesimo et al., 1996). This battery included eight tests which evaluate the functional efficiency of various cognitive areas, i.e., verbal (word fluency and sentence construction), visuo-constructive (freehand copying design and copying designs with landmarks), immediate visual memory, short and long term verbal memory (Rey's memory test), and visuospatial reasoning (Raven's progressive colored matrices).

Three experiments were performed. In the first experiment the subjects were asked to read aloud four stories and repeat them to an apparently naïve listener. These stories contained on average 78, 75 words and 10.25 thematic units (see below for assessing informational content of the stories). This allowed assessing the abilities of the subjects to retell a story whose micro- and macrolinguistic elements had already been provided. The second experiment consisted of producing short narratives on the basis of four stories arranged in cartoon-like fashion (six pictures each). In this case, the concepts included in the story (11.75 on average) were visually presented. This allowed evaluating subjects' abilities to derive stories whose conceptual structure had been only visually given. In the third experiment, subjects were asked to arrange into a plausible sequence three unordered cartoon picture stories (six pictures each). Each story contained on average 13.3 thematic units. After the arrangement, the subjects had to tell the resulting story to a naïve listener. This allowed assessing the ability of the subjects to generate (and eventually modify) a mental model incorporating the pictures into a coherent plot. Furthermore, they had to provide the conceptual model of the story with an adequate micro- and macrolinguistic structure.

2.3. Scoring procedure

Each story telling was tape-recorded, transcribed verbatim including phonological fillers, false starts, and

extraneous utterances (Miceli, Mazzucchi, Menn, & Goodglass, 1983). Both micro- and macrolinguistic aspects of the narratives were analyzed in order to retrieve information about the subjects' verbal productivity, grammatical encoding, informativeness, and textual organization. Both simple values and ratios were considered to account for the difference across narratives. The scores were attributed by two independent raters and then compared. Differences were resolved through discussion.

The analysis of productivity was meant to investigate abilities in selecting and producing well-formed lexical items. The productivity was measured following the method of microanalysis of discourse proposed in Haravon, Obler, and Sarno (1994). The total number of *units* (including all verbalizations, irrespective of their linguistic or contextual correctness or appropriateness) and the number of *words* (excluding those which were phonological fillers or errors) produced by the subjects for each story were considered. A *ratio of lexical selection* was obtained dividing the number of words by the number of units. This ratio allowed assessing the ability of the subjects to retrieve phonologically well-formed words.

The within-sentence grammatical organization was measured following the method proposed in Shewan (1988). After having assessed the total number of utterances and complex sentences for each narrative, a *ratio of syntactic complexity* could be calculated dividing the number of complex sentences produced by the amount of utterances. Following Shewan (1988), we considered as complex only those sentences that were formed by at least one independent and one dependent clause. Conjoined sentences were not considered as complex sentences.

The informative content of each narrative was measured in order to obtain numerical evaluation of lexical–semantic appropriateness in describing thematic units that pertain to the story. The lexical–semantic appropriateness was determined counting all the words that constituted the *lexical information units* (LIUs). Words or word sequences that could be classified as semantic or verbal paraphasias, fillers, paragrammatisms or tangential utterances (i.e., utterances that were somehow deviating from the main stream of information about the stories) were excluded from the count of the LIUs. As for the thematic informativeness, for each story the total number of possible thematic units was identified by presenting the story to 200 students of the faculty of Arts of the Second University of Roma "Tor Vergata." The students were asked to identify for each picture–story up to 15 thematic units. The data were checked in order to get for each story a comprehensive amount of thematic units. Those thematic units that had been identified by at least the 80% of the subjects were included in the list. In this way, it was possible to measure the *rate of thematic units* for each story dividing the number of thematic units in the subjects' speech by the total amount of thematic units that could be obtained by the story.

As for the textual organization, the analysis aimed to quantify the level of cohesion and coherence of the texts produced by the subjects by means of a negative score. Having assessed the total amount of cohesive and coherence errors, two different ratios could be determined for each narrative produced. A *rate of cohesive errors* was obtained dividing the total amount of cohesive errors by the number of utterances that formed the text. A cohesive error was scored each time a cohesive function word was used in the wrong way, an ambiguous coreference was established or whenever number and/or gender agreement over utterance boundaries could not be detected. Furthermore, also the presence of unfinished utterances whose meaning was continued in the following utterance was considered as a cohesive error.

Similarly, a *rate of coherence errors* was drawn dividing the total amount of coherence errors by the number of utterances produced. A coherence error was counted each time absence of referent, semantic shifts or tangential utterances occurred.

In the third experiment, a preliminary set of data were derived from the *order of arrangement of the pictures*. This was assumed to indicate the way the subjects had drawn the mental model of the story.

3. Results

On the neuropsychological assessment with the Mental Deterioration Battery (Carlesimo et al., 1996) all subjects performed over the cut-offs after the correction for the relevant demographic variables (age and educational level) on the basis of normative data. Table 3 reports the means and standard deviations of the raw scores of the three groups of subjects for the eight performance scores obtained by means of the Mental Deterioration Battery. Results were examined by separate one way ANOVAs which failed to show significant differences between the groups on any measure.

A two-way ANOVA with *group* as between-subject factor and *story* as within-subject factor was performed for each experiment on six measures (lexical selection, syntactic complexity, LIU, thematic selection, ratio of absence of cohesion, and ratio of absence of coherence). Since the *story* × *group* interaction was never significant, the mean score for each experiment was taken into account. Thus, only the main effect of group was reported, and, when significant, post hoc Tukey's test was performed. The criterion for significance of differences was $p < .05$.

Table 3
Results of neuropsychological testing: Raw means and standard deviations

	RHD	LHD	Controls
Phrase construction	14.06 (6.5)	18.52 (6)	18.96 (5.7)
Word fluency	13.91 (4.5)	11.91 (5.4)	15.82 (4.6)
Immediate recall of Rey's 15 words	37.53 (9.5)	34.97 (7.1)	37.65 (7)
Delayed recall of Rey's 15 words	9.05 (2.6)	9.32 (2.6)	8.93 (2.5)
Raven's progressive colored matrices	27.37 (4.6)	30.14 (2.9)	28.41 (7.4)
Immediate visual memory	20.01 (2.5)	20.05 (1.6)	21.29 (1)
Freehand copying of drawings	8.23 (2.1)	8.66 (1.7)	9.22 (2.2)
Copying drawings with landmarks	66.26 (2.7)	66.67 (4.5)	67.05 (3.5)

3.1. Results of Experiment 1: Retelling of previously read stories

The mean values for each group of the variables used in the present study are reported in Table 4. No group related differences were found neither at the levels of productivity and grammatical organization nor at the level of informativeness. With respect to the ratio of cohesive errors, a significant group effect was found [$F(2, 30) = 6.408$; $p = .005$]. The post hoc test revealed that the group of LHD subjects performed much worse than controls (Tukey's $p = .004$). At the level of coherence no differences were found.

Results of Experiment 2: Description of ordered cartoon stories

As to the second experiment the mean values for each group are reported in Table 5. No group related differences were found at the levels of productivity and grammatical organization.

Different results were obtained in the analysis of the levels of informativeness. As to the thematic selection, a significant group effect was found [$F(2, 28) = 4.022$; $p = .029$]. Post hoc test revealed that the group of RHD subjects described a significantly lower number of thematic units than controls (Tukey's $p = .022$). A significant group effect was found also for the Lexical Information Units [$F(2, 28) = 4.422$; $p = .021$]. The post hoc test revealed that the difference was significant between the controls and the RHDs (Tukey's $p = .034$). With respect to the ratio of cohesive errors, a significant group effect was found [$F(2, 28) = 3.585$; $p = .041$] and the RHDs made more errors than controls (Tukey's $p = .032$). As for the ratio of coherence errors a significant group effect was found [$F(2, 28) = 4.781$; $p = .016$]. The RHD subjects could not organize the propositions coherently if compared to controls (Tukey's $p = .015$).

Table 4
Mean values in the first experiment

Group	RHD	LHD	C
Words	35.64	43.14	40.02
Lexical selection	0.96	0.95	0.95
Syntactic complexity	0.32	0.35	0.41
LIUs	31.27	38.93	38.84
Thematic selection	0.93	1	1
Absence of cohesion	0.26	0.37	0.10
Absence of coherence	0.13	0.12	0.07

Table 5
Mean values in the second experiment

Groups	RHD	LHD	C
Words	34.8	44.81	41.6
Lexical selection	0.98	0.96	0.97
Syntactic complexity	0.25	0.29	0.28
LIUs	26.34	36.61	39.08
Thematic selection	0.43	0.53	0.67
Absence of cohesion	0.15	0.10	0.01
Absence of coherence	0.18	0.10	0.06

3.2. Results of Experiment 3: Arrangement and description of unordered cartoon stories

As for the third experiment the mean values for each group are reported in Table 6. Subjects were previously asked to arrange a set of pictures in order to form a coherent story. While the LHDs and the controls arranged correctly 75.8 and 78.8% of the stories, respectively, the 11 RHD subjects could correctly arrange only 36.4% of them. Nonetheless, as in Experiments 1 and 2, the three groups produced an equivalent amount of units and words. This led that they did not differ for productivity and lexical selection. The examination of syntactic complexity also failed to show significant differences.

Table 6
Mean values in the third experiment

Groups	RHD	LHD	C
Words	33.51	44.13	41.3
Lexical selection	0.98	0.96	0.95
Syntactic complexity	0.28	0.26	0.28
LIUs	24.51	34.38	38.45
Thematic selection	0.43	0.55	0.58
Absence of cohesion	0.11	0.09	0.03
Absence of coherence	0.25	0.11	0.05
Number of correctly ordered stories	12	25	26

Differences were observed on the analysis of informativeness. As to the thematic selection, a significant group effect was found [$F(2, 29) = 5.049$; $p = .013$]. The RHDs were not able to spot and describe an adequate number of thematic units with respect to the control group (Tukey's $p = .014$). Similarly, a significant group effect was found with respect to the production of the Lexical Information Units [$F(2, 29) = 5.144$; $p = .012$], and again the RHDs could not produce enough main information units if compared to controls (Tukey's $p = .011$). A significant group effect was found for the ratio of cohesive errors [$F(2, 29) = 4.254$; $p = .024$] since the RHD subjects did badly compared to controls (Tukey's $p = .024$). A significant group related effect was found also for the ratio of coherence errors [$F(2, 29) = 4.997$; $p = .014$]. The RHDs differed significantly from the controls (Tukey's $p = .027$).

4. Discussion

This study examined the abilities in producing narratives in three groups of subjects. The narratives produced by a group of 11 patients with right hemisphere damage were compared to those produced by 11 left hemisphere damaged subjects, and 11 neurologically intact controls. Previous neuropsychological assessment allowed excluding from the experiments subjects with cognitive deficits that could affect performance. (Joanette et al., 1986; Rivers & Love, 1980). In the first experiment these subjects were asked to retell previously read stories whereas the second and the third experiments required the subjects to construct a story from ordered and unordered cartoon stories, respectively. Textual analysis of the narratives was performed focusing on productivity, informativeness, micro- and macrolinguistic processing.

A direct comparison among experiments was not undertaken as the effect of individual stories and tasks on performance was assumed to be too large. Instead, we focused on the differences between groups within each experiment. However, statistical analysis found particular group-related differences within each experiment.

In the first experiment, the subjects were asked to read aloud a set of four stories and then repeat them to a person who declared himself ignorant of their contents. Therefore, the micro- and macrolinguistic organization of the stories to be retold had previously been provided. The three groups produced texts characterized by adequate levels of lexical, syntactic, and informative organization. This result was expected since none of the two groups of neurologically impaired subjects had problems in microlinguistic processing. Furthermore, with respect to the level of text organization, all subjects retold coherently organized stories. The descriptions of the RHD subjects were normally cohesive while those by the LHDs were not. A possible explanation may be that these subjects, even if not aphasic (as confirmed by performance at verbal fluency test as well as the absence of microlinguistic problems), could be impaired in organizing with cohesive ties previously provided linguistic structures. An alternative explanation points to our impression that the LHDs tried to reproduce the previously read stories exactly as they remembered them. Apparently, they failed in the attempt to arrange at the cohesive level all the thematic units that they had clear in mind. Consistent with this hypothesis is that they produced an adequate amount of thematic units and organized them in the correct order as shown by normal score on coherence and semantic content. Furthermore, the LHD subjects were shown to be competent in using cohesive devices in the other two experiments where they had to tell story from pictorial information. These findings suggest that the cohesive problem shown by the LHDs may not be due to a top–down processing deficit. Rather, it may be a problem in bottom–up processing of textual information, i.e., in the recruitment of microlinguistic elements for cohesive purposes.

The right hemisphere damaged subjects performed like the controls in this experiment, thus suggesting that at the level of global meaning processing, they were able to draw a coherent mental representation from a written text. This result is consistent with previous findings by Huber and Gleber (1982) who found that the RHD patients were able to integrate verbal information in a cohesive and coherent text. Our findings are not in agreement with those by Davis et al. (1997) who found that cohesion ratios of RHDs were significantly lower than the normal control group for the retelling condition. However, in the experiment of these authors subjects retold stories which had been read by the examiner. This suggests that in their experiment accuracy in producing cohesive ties could be biased by the fact that apparently the listener had knowledge of the story development. This could make sometimes unnecessary to state referents explicitly and a number of cohesion errors were scored (see also Uryase, Duffy, & Liles, 1991 for similar findings).

In the second experiment, subjects were asked to describe a set of four cartoon stories. The group of left hemisphere damaged subjects performed well at both micro- and macrolinguistic levels of processing, providing descriptions endowed with an adequate number of lexical entries, a good syntactic organization, and informativeness as well as a cohesive and coherent organization of the generated propositions. This supported the hypothesis that our non-aphasic LHDs were fully able to organize cohesive and coherent structures of a story while they could fail when its linguistic structure has been previously provided (see above).

Different results were obtained in the analysis of the narratives produced by the right hemisphere damaged subjects which were characterized by normal microlinguistic aspects but low levels of informativeness (reduced LIUs and thematic selection) and macrolinguistic organization (increased number of cohesive and coherent errors). Reduced propositional content in the narratives of the RHDs was also found by Joanette et al. (1986). The narratives of their RHD subjects contained a smaller amount of information which was not correlated to reduced verbal output or to neglect. The authors proposed that this result could be explained either by perceptive difficulties or by problems in the organization of narratives at discourse level. The last hypothesis is warranted by the present results as in our cohort the RHDs had not visuo-perceptive disorders. Even in absence of word finding difficulties, the RHD subjects in our study omitted many thematic units. Furthermore, they filled their stories with irrelevant details and comments so that their descriptions sounded only barely coherent. Deficits were also observed in establishing cohesive ties. This result confirms that reported by Bloom (1994), who also found the RHDs impaired in producing cohesive ties. They indeed showed increased number of incomplete ties for narration in an experiment involving picture description task. These deficits of right brain damaged subjects were not found in the first experiment, thus suggesting that RHD patients have difficulty in organizing informational content and in retrieving a general story schema from pictorial information but not from the linguistic one.

In the third experiment, the subjects were asked to arrange for each story a set of unordered pictures representing a story and then to describe it. This was the most complex condition, since it required the construction of a plausible sequence for the gist of the story and then linguistic encoding. Nonetheless, the LHDs did not have any problem in arranging the pictures into a well-formed story (i.e., in generating the mental model from the visual information provided by the pictures) and describing it. These findings agree with those by Huber and Gleber (1982) who found that mild LHDs, even with mild aphasic symptoms, have quite normal performance in arranging pictures illustrating a story in the correct sequence.

The right hemisphere damage subjects produced narratives endowed with adequate microlinguistic structure but scarcely informative, coherent, and cohesive. They also failed in arranging the pictures into coherent sequences. In particular, while trying to arrange the stories, they left apart one or two pictures. These were on occasion included in the sequence without following a plausible development of the story. Furthermore, during their story-telling, they understood that something was missing or could not fit with the picture sequence they had organized. This could also happen with normal controls and LHDs who were able to modify the story schema in order to include the incoming information. The RHDs, instead, simply omitted some of the elements depicted in the pictures. This prevented them from producing an adequate amount of lexical information units, correctly using cohesive ties, and devising coherent organization of discourse information content. This particular aspect suggests that RHDs have problems in generating adequate mental models that fit with the visual information from the pictures. Nor it is possible for them to modify a previously generated model in order to include upcoming events or states in the correct order.

Some hypotheses can be formulated. Visual–pictorial processing does not seem to be the main determinant of discourse performance in RHD subjects: A comparative inspection of the respective results in tasks involving verbal and pictorial stimuli showed a lack of correspondence, thus giving support to the intervention of another factor out of the visuospatial processing level. It is also possible to give an explanation of performance of the RHD subjects in terms of the strategy they used to describe visually presented stories in the second experiment. Contrary to experiment one (story retelling) where they were able to produce well-formed narratives, in the second experiment their narratives were shown poor in information content and macrolinguistic organization. We argue that in the first experiment providing them with referential, cause–consequence, and spatial relationships linguistically encoded in the text could cue generating an appropriate mental model of the story. This was used for producing well-formed narratives. On the contrary in telling stories depicted in a cartoon-like fashion they could not order the states and events in a mental model that could fit with all the information provided by the pictures. Then, they omitted those events that they found difficult to include in a barely organized mental model. These problems had a counterpart at the macrostructure level of text organization, implying the production of utterances that were not coherent and cohesive and showed reduced informative content. Note that in the study by Davis et al. (1997) the RHDs did not show cohesive errors in telling stories from cartoons. In this case, however, the patients were cued by the experimenter who explicitly invited them to carefully look to each picture in the sequence before speaking. This likely assisted the RHDs in this study in generating a more detailed mental model of the story.

5. Conclusions

A relevant aspect of text processing is the generation of a mental model based on the integration of information and world knowledge (Garnham, Oakhill, & Johnson-Laird, 1982; Johnson-Laird, 1980). This conceptual inte-

gration is the result of linguistic and conceptual processes. In producing a mental model it is necessary to organize concepts to say (or to understand) so that they correspond to a logically coherent and cohesive structure. During the comprehension of a written text, the mental model is generated linking the actions, scenes, and characters that build up the narrative (or other type of discourse) by means of spatial, temporal, modal, and relational inferences. When describing a story depicted in cartoon-like fashion, the mental model is generated integrating non-linguistic visual information and world knowledge in a coherent conceptual representation of the story.

The production of descriptions from different sources in a group of healthy controls, a group of RHD subjects and a group of LHDs has been investigated. The results suggest that the LHDs included in the study do not have relevant problems in the comprehension and reproduction of written texts as well as cartoon-picture stories. They only showed a selective problem in the cohesive organization of texts whose linguistic structure had already been provided, while performing well in the conditions in which they had to generate original texts based on cartoon stories. The RHDs showed the opposite pattern, with spared abilities to reformulate texts whose linguistic structure and organization had already been provided but failing in the description of cartoon-stories and in arranging unordered pictures in a coherent sequence. These results allow speculating that the right hemisphere plays a relevant role in complex linguistic skills as organizing a mental model for producing narratives. The fact that the right hemisphere damaged subjects did not have generalized cognitive deficits nor they exhibit difficulties at the microlinguistic level of discourse processing further warrants that the problems they encountered in their descriptions are due to a selective problem in the generation of mental models.

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