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Recovery from Aphasia: A Longitudinal Study on Language Recovery, Lateralization Patterns, and Attentional Resources

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ABSTRACT

Despite the large body of evidence on the neural basis of the recovery from aphasia, the role of either cerebral hemisphere remains controversial. This paper reports the results of a longitudinal single-case study on the patterns of lateralization for lexical semantic processing during the recovery from aphasia. The experimental protocol included a lateralized lexical decision task (LDT), an attentional task and a language test. There was no presentation site effect on the LDT, and the performance was jointly influenced by attentional and language factors. These findings suggest that the recovery of lexical semantic processing may be sustained by both cerebral hemispheres, and highlights the importance of experimental protocols that allow examining both language and attentional factors modulating the recovery from aphasia.

INTRODUCTION

The hypothesis of a right hemisphere take-over of language processing was first raised by Gowers in 1887. Since, clinical evidence (Basso, Gardelli, Grassi, & Mariotti, 1989; Henschen, 1926; Lecours et al., 1987; Lee, Nakada, Deal, Lin, & Kwee, 1984; Levine & Mohr, 1979; Mazzocchi & Vignolo, 1979; Moutier, 1908; Nielsen, 1946; Nielsen & Raney, 1939), and activation studies (Calvert et al., 2000; Cappa et al., 1997; Karbe et al., 1998) have report an increased metabolic right hemisphere (RH) activation concurrently with the recovery from aphasia.

However, the issue remains controversial. Specifically regarding clinical studies, much of the evidence could be explained in terms of diaschisis (Andrews, 1991; Von Monakow, 1914). With regards to activation studies, it has been shown that when metabolic recovery concerns the LH, recovery from aphasia is much better achieved (Weiller et al., 1995); furthermore, some authors claim that the increased RH metabolism observed in some activation studies (Calvert et al., 2000; Cappa et al., 1997; Karbe et al., 1998), could reflect a maladaptative process responsible for residual language deficits, rather than for the degree of recovery (Samson et al., 1999).

Nonetheless, the fact that the RH has proven to be sensitive to specific linguistic variables suggests that its participation in the recovery from aphasia may as well be specific to language.

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Using divided field presentations, researchers have shown an attenuation, and even the absence of the habitual Rvh/LH advantage with visual presentations of high imageability words, in nonbrain damaged populations (Day, 1977, 1979; Young & Ellis, 1985). Day (1979) showed that the RH of normal subjects is capable of processing high imageability nouns, whereas verbs and low imageability nouns are processed by the LH. Other studies, however, have reported no significant effect of these variables (e.g., Boles, 1983; Howell & Bryden, 1987; Koening, Wetzel, & Caramazza, 1992). The lack of consistency between studies can be attributed to methodological issues regarding the control over lexical frequency (Nieto, Santacruz, Hernandez, Camacho-Rosales, & Barroso, 1999) and grammatical class (Eviatar, Menn, & Zaidel, 1990).

Aphasic subjects have shown an advantage of the left over the right ear with lateralized auditory presentations (Castro-Caldas & Bothelo, 1980; Johnson, Sommers, & Weidner, 1977; Petit & Noll, 1979), and this finding has been interpreted as evidence of RH take-over during the recovery from aphasia. Castro-Caldas and Bothelo (1980) argue that RH take-over occurs when prerolandic operators responsible for LH dominance are damaged. Accordingly, only patients presenting anterior lesions would be likely to show a switch to RH dominance for language, whereas one would not expect a RH take-over in patients with Wernicke's aphasia that, typically, show preserved frontal structures (Castro-Caldas & Bothelo, 1980). However, given that the auditory fibers are both ipisilateral and contralateral, it is not possible to ascertain a complete lateralization of auditorily presented stimuli, and thus no strong conclusions about language lateralization can be drawn from dichotic listening studies.

The divided visual field paradigm is more suitable to examine cerebral asymmetries, given that the visual fibers are only contralateral, and thus lateralization of stimuli is possible. Schweiger and Zaidel (1989) report a RH take-over in a patient with Broca's aphasia and deep dyslexia who showed a Lvh-RH advantage with isolated high imageability words. However, the authors (Schweiger & Zaidel, 1989) failed to control for attentional factors that may have caused the Lvh-RH superiority. More precisely, according to Kinsbourne (1970), a Lvh-RH advantage may result from a LH lesion effect, resulting in an attentional shift to the left visual hemifield, with no implications regarding the participation of the RH in language recovery from aphasia. Recently, Ansaldo, Arguin, and Lecours (2002b) reported a Lvh-RH advantage on word processing in a patient with Broca's aphasia followed over time. The authors (Ansaldo et al., 2002b) report a close and inverse relation between the evolution of attention, and the RH performance, and thus argue that the RH advantage observed cannot be attributed to attentional factors (Ansaldo et al., 2002b). The present paper reports the results of a similar study, in a case of Wernicke's aphasia. The factors: of time elapsed after aphasia, attentional resources, degree of imageability and grammatical class of the word were examined in relation to the role of the RH in the recovery from aphasia.

CASE REPORT

MJ, a 52-year-old, right-handed man, suffered an embolic CVA in the territory of the left middle cerebral artery. He had no previous history of cerebrovascular disease, no history of left-handedness; and he was French-speaking. A CT scan practiced 2 days after the stroke showed an infarct in the distribution of the left-middle cerebral artery. The lesion involved the perisylvian regions of the left parietal lobe and the left temporal lobe, including Wernicke's area, but not Broca's area. Unfortunately there was no control CT scan performed after the acute phase, and thus it is not possible to determine the lesion margins with time elapsed. MJ was examined with the M-T Beta Protocol for the assessment of aphasia (Béland & Lecours, 1990). He showed a Wernicke's aphasia with severe auditory comprehension deficits and anomia, and better preserved written comprehension (see Table 1). MJ presented no clinical signs of hemianopia or visual neglect according to the Bell Test (Gauthier et al., 1989). He received 3 hr sessions per week of speech-therapy, throughout the duration of the present longitudinal follow-up. Therapy was provided by a speech therapy that was not a member

Table 1. Correct Responses on Subtests of the M-T Beta Protocol at Each Time of Measurement.

	T1	T2	T3	T4
Oral word comprehension	3/9	9/9	9/9	9/9
Oral sentence comprehension	0/38	10/38	11/38	24/38
Written word comprehension	5/5	5/5	5/5	5/5
Written sentence comprehension	0/8	7/8	8/8	8/8
Oral picture naming	1/31	20/31	26/31	27/31
Written picture naming	1/31	14/31	29/31	30/31
Reading words aloud	1/33	17/33	22/33	18/33

Note. T1: 1 months postaphasia onset, T2: 5 months postaphasia onset, T3: 10 months postaphasia onset, T4: 14 months postaphasia onset.

of the research team. Furthermore, the experimental testing was completed by a person who was blind to MJ's involvement in language therapy.

MATERIALS AND METHODS

The experimental protocol consisted of three tasks already used in previous studies by Ansaldo et al.: (see Ansaldo, Arguin, & Lecours, 2002a; Ansaldo et al., 2002b, for details on the protocol and procedure): The protocol consisted on the Beta-Montreal-Toulouse Aphasia Protocol (Béland & Lecours, 1990), a lateralized lexical decision task (LDT), and the Nonverbal Stroop Test (Beauchemin, Arguin, & Desmarais, 1996). Repeated measures were obtained at 1, 5, 10, and 14 months postaphasia onset (i.e., T1, T2, T3 and T4). The order of presentation of the tasks was the same at each test period.

Data Analysis

Montreal-Toulouse Aphasia Protocol

For each experimental period we considered the number of correct responses on each subtest, and the type of errors. Results are outlined in Table 1.

The results with the Beta M-T (Béland & Lecours, 1990) showed that MJ evolved from a severe Wernicke's aphasia at T1, to an anomic aphasia with some auditory comprehension deficits at the phrase level at T4. The type of errors most frequently observed were: contaminations, neologisms and phonemic paraphasia at T1, and anomia, phonemic paraphasia, semantic paraphasia, semantic paralexia and semantic paragraphia at T2, T3 and T4; the number of errors decreased over time. At T4, MJ had attained a functional level of communication in everyday life, but he still showed anomia, as well as comprehension and production difficulties with long and syntactically complex sentences.

Lexical Decision Task

An overview of the results from the lexical decision task is presented in Table 2. Only the data with were stimuli of correct responses has been considered for analysis. There was a significant reduction of global error rates (ER) with time elapsed after aphasia ($\chi^2 = 0.34$, $p < .05$). This reduction was verified with Lvh presentations ($\chi^2 = 8.71$, $p < .05$), and with Rvh presentations ($\chi^2 = 14.58$, $p < .05$), but not with CV displays. Furthermore, ER decreased significantly over time with nouns ($\chi^2 = 9.48$, $p < .05$), and with high imageability words ($\chi^2 = 27.3$, $p < .01$). However, these effects may have resulted from the particularly high ER observed at T2 (see Table 2), in comparison to a rather stable pattern on ER at T1, T3 and T4.

Average response times (RT) to correct answers were also gathered. Trials on which the RT was more than two standard deviations away from the mean RT of the condition it belonged to were eliminated from analysis (0.75% of correct RT at T1, 4% at T2, 1% at T3, and 1% at T4). The resulting sample of correct RT was submitted to a $4 \times 3 \times 2 \times 2$ ANOVA including the factors of Time Post-Aphasia Onset (T1, T2, T3, and

Table 2. Lexical Decision Task: Correct Response Times (ms) and Error Rates (%) With Central Vision, Left Visual Field and Right Visual Field Displays at Each Time of Measurement.

	T1	T2	T3	T4
Lvf				
Average RT	1286	955	1109	1117
SD	315	124	145	178
ER (%)	7.5	19	6.5	11.5
CV				
Average RT	1124	919	982	944
SD	236	168	140	129
ER (%)	6	7	3	3
Rvh				
Average RT	1145	948	1018.5	981.5
SD	259	135	120	159
ER (%)	5	24.5	10.5	13
Global				
Average RT	1186	939	1041	1013
SD	280	146	145	173
ER (%)	6	15.5	8	9

T4), Presentation Site (left visual hemifield/Lvh, central vision/CV, and right visual hemifield/Rvh), Grammatical Class (noun or verb), and Imageability (low or high).

The ANOVA applied on correct RT revealed a triple interaction of Grammatical Class × Imageability × Presentation Site, $F(2, 794) = 3.13$, $p < .05$. Further analysis of the triple interaction revealed an interaction of Grammatical Class × Degree of Imageability with Lvh presentations, $F(1, 794) = 8.05$, $p < .01$, but not with Rvh$(1, 749) = 0.49$, $p = .49$, or CV displays, $F(1, 749) = 0.86$, $p = .57$. More precisely, when targets were presented to the Lvh, RT with low imageability nouns were faster than with low imageability verbs, $F(1, 794) = 14.43$, $p < .001$. There was no effect of grammatical class with high imageability words, $F(1, 749) = 0.02$, $p < .9$ (see Fig. 1).

There was also a main effect of time elapsed after aphasia on RT, $F(3, 794) = 63.02$, $p < .01$ (see Fig. 2). This effect resulted from the particularly slow RT observed at T2 (Post hoc Tukey (a) Test: $a = 0.05$). Spearman correlation coefficients were used to examine the possibility of a speed-accuracy trade-off, which seemed particularly plausible at T2. None of the correlations reached significance (at T1: $r = .3162$, $p = ns$; at T2: $r = .9487$, $p = ns$; at T3: $r = .6325$, $p = ns$, and at T4: $r = .6325$, $p = ns$). No other interactions or main effects were significant.

We used Spearman correlation coefficients to look at the relation between the performance with CV displays and the performance with stimuli lateralized to either visual hemifield (i.e., either cerebral hemisphere) over time. The average RT as a function of grammatical class and imageability that were obtained with CV presentations for each test session were correlated with the corresponding average RT with Lvh displays, and with Rvh displays. A positive correlation between the performances with CV and Lvh displays was found at T2 (Spearman correlation coefficients: $d_2 = 1.00$, $p = .001$), and also at T3 (Spearman correlation coefficients: $d_2 = 1.00$, $p = .001$). No other correlation achieved significance.

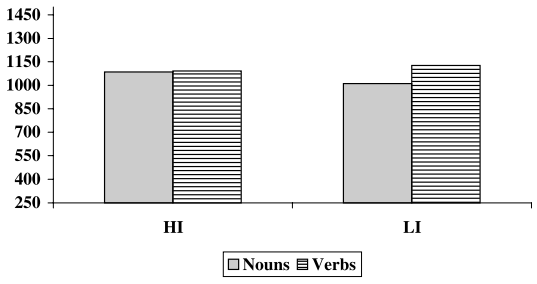

Fig. 1. Lexical Decision Task: Grammatical class × Imageability interaction with Lvh displays.

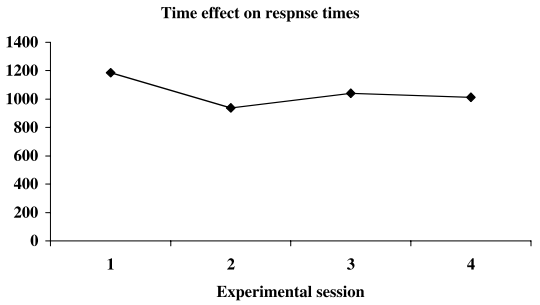

Fig. 2. Lexical Decision Task: Main effect of time elapsed after aphasia on RT.

Nonverbal Stroop Task

Table 3 presents the results from the NVST. Error rates for the orientation task in the incongruent condition were close to chance level at every session. This suggests that the patient may have misunderstood the orientation task, and responded to the location of the target instead. Hence, data from the incongruent

Table 3. Nonverbal Stroop Test Correct Response Times (ms), Error Rates (%) and Congruency Effect With the Location and Orientation Tasks in the Congruent and Incongruent Conditions at Each Time of Measurement.

	T1	T2	T3	T4
Location task				
Congruent				
RT	402.5	301	337	382
SD	136	99	134.5	60
ER	0	0	0	0
Incongruent				
RT	424	339	361.5	406
SD	130	97	145	192
ER	0	0	0	0
Orientation task				
Congruent				
RT	368	365	339	443
SD	78	53	53	124
ER	4	0	2	2
Incongruent				
RT	554	539	626	563
SD	160	140	180	200
ER	50	58	52	50
Congruency effect				
Location	22	38	24	24
Orientation	186	174	297	120

condition was not considered any further. Conversely, performance was very good throughout the location task, and error rates were too low to be analyzed by chi-square.

A 4×2 ANOVA with the factors of time elapsed after aphasia (T1, T2, T3, and T4), and congruence between location and orientation information (congruent and incongruent) was applied to correct RT. It showed an interaction time $\times$ congruence, $F(3, 486) = 13.23$, $p < .01$. The congruence between location and orientation information affected performance at every experimental session (at T1: $F(1, 486) = 5.12$, $p < .05$); at T2: $F(1, 486) = 5.\ 06$, $p < .05$; at T3: $F(1, 486) = 5.49$, $p < .05$, and at T4: $F(1, 486) = 43.73$, $p < .01$. RT with the congruent condition improved at T2 and remained stable in subsequent sessions.

The magnitude of the congruence effect varied across sessions. It was slightly higher at T2 than at T1 and remained stable at T3 and T4.

Relationship Between the Results on the Lexical Decision and the Attentional Tasks

In order to examine the relation between the evolution of attentional resources and the evolution of lexical semantic abilities in MJ, correlations between the LDT and the NVST were gathered. Thus, average RT to correct answers obtained at T1, T2, T3 and T4, were correlated to the congruence coefficient of the NVST for the same experimental sessions. There was a significant correlation between the performance with CV presentations and the performance with the Nonverbal Stroop Task (Spearman correlation coefficients: $d_2 = 1.000$, $p > .001$). Correlations between the performance with lateralized presentations (Lvh and Rvh) and the performance with the Nonverbal Stroop Task did not reach significance.

DISCUSSION

The purpose of this study was to examine the role of the RH during recovery from aphasia in MJ, a 52-year-old man who suffered from Wernicke's aphasia resulting from an embolic CVA in the left temporal and parietal lobes. The results indicate a global recovery of language with time elapsed after aphasia. No presentation site effect on the LDT was observed throughout the experiment; the performances with CV and Lvh/RH presentations were correlated at T2 and T3. The factors of grammatical class and degree of imageability influenced MJ's performance particularly with regards to presentations in the Lvh/RH. Finally, there was an improvement of attention over time, and a correlation between this improvement and the performance with CV displays on the LDT.

MJ's performance on the LDT was quite stable throughout the experiment, except for T2, when global RT were particularly low, and ER particularly high. These results indicate that MJ privileged speed over accuracy at T2. Consequently, the time effect on RT does not correspond to a real improvement on speed of response overtime but results from a different strategy implemented by MJ to accomplish the LDT at T2. Furthermore, given that RT were already within the values found among nonbrain damaged subjects (Walter, 1995) already at T1, a ceiling effect on the LDT can not be discarded. Language recovery observed with the Beta M-T was not captured by the LDT, given that the latter task concerned isolated written word comprehension only.

The absence of presentation effect on the LDT over time implies that MJ's recovery of lexical semantic processing at the word level had a bilateral substrate. Furthermore, the results of the present study are in line with Castro-Caldas and Bothelo (1980) who claim that RH take-over occurs when the lesion that causes aphasia includes prerolandic operators in the LH. Hence, MJ's lesion spared the frontal lobe. In previous studies, Ansaldo et al. (2002a; 2002b) reported a switch to RH control of lexical semantic processing in two aphasic patients with lesions involving the left frontal lobe.

Despite the absence of lateralization, the correlation between the performance with CV displays and the performance with Lvh/RH displays at T2 and T3 suggests that lexical semantic processing in CV was more dependent upon RH than LH resources. Musso et al. (1999) reported a correlation between the recovery of language comprehension, and a bilateral increase in activation on the posterior regions of the brain, in a group of chronic patients with temporo-parietal lesions and Wernicke's aphasia. Interestingly, the increase in activation was more important in the RH than in the LH (Musso et al.). Musso et al. concluded that recovery of language comprehension depended upon a

bilateral network, in which the RH components of the network played a major role. In line with this perspective, the results of the present study indicate that recovery of word comprehension in MJ was sustained by both cerebral hemispheres, but relied particularly on RH resources.

However both language and attentional factors seem to play a role in MJ's recovery. On one side, the grammatical class × imageability interaction with Lvh displays indicates that the RH contribution is modulated by linguistic factors. On the other side, the correlation between RT with CV displays and the performance on the attentional task, suggest the MJ'S *global* performance on the LDT was influenced by attentional factors. Thus, whereas the RH contribution to recovery reflects RH language capacities, MJ's global performance is modulated by attentional factors as well. The recovery of language comprehension following aphasia has been related to working memory factors (Just & Carpenter, 1992), and to conscious /unconscious processes (Waters & Caplan, 1992). The results of present study show that attentional abilities may as well contribute to the recovery of language comprehension after aphasia. Finally, given that the RH performance with high imageability words was similar to that described with normal populations (Nieto et al., 1999), and given that the interaction did not include the time factor, these results do not reflect functional reorganization, but indicate premorbid RH language abilities in this particular subject.

In summary, the results of the present study indicate that recovery of word comprehension in MJ was sustained by a bilateral network, and relied upon language and attentional resources.

The fact that MJ's lesion spared the left frontal lobe may have prevented switching to the RH, observed in patients with left frontal damage (Ansaldo, et al., 2002a, 2002b; Castro-Caldas & Bothelo, 1980). Despite the bilateral substrate of recovery, RH influenced global performance on the LDT more than the LH. Specifically, the RH contributed to the processing of high imageability nouns and verbs. This contribution is likely to reflect premorbid RH language abilities in this particular subject. In line with previous findings (Ansaldo et al., 2002a, 2002b), the results of the present study indicate that high imageability words are good candidates for RH take-over, and should be particularly considered when planning speech therapy.

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