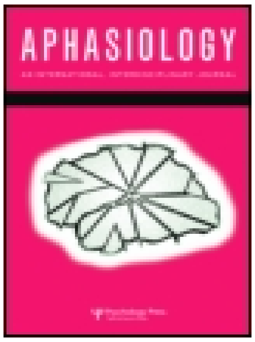

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Initial right hemisphere take-over and subsequent bilateral participation during recovery from aphasia

Ana Inés Ansaldo, Martin Arguin & Andréroch Lecours

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Ana Inés Ansaldo, Martin Arguin, & André Roch Lecours

Institut universitaire de gériatrie de Montréal, and Université de Montréal, Canada

Background: In 1887, Gowers proposed that supplemental action by the right frontal cortex could sustain language following aphasia. Since then, many studies using a wide variety of experimental paradigms have examined the role of the right hemisphere in the recovery from aphasia.

Aims: This study examines the right hemisphere's participation in the recovery from aphasia between four and sixteen months following brain damage.

Methods & Procedures: RJ, a young woman with severe Broca's aphasia resulting from a left fronto-temporal hematoma, was followed up at four-month intervals with a divided visual field presentation lexical decision task (LDT). At each time of measurement, we examined her performance with high- and low-imageability nouns and verbs, directed to either cerebral hemisphere and in central vision. A language test was used to examine the pattern of language recovery over time, and a non-verbal version of the Stroop test (NVST) served to follow up changes in attention. The results obtained with the LDT and the NVST were analyzed with ANOVAs; the changes in the pattern of language recovery and the results on the attentional task were also considered in the analysis.

Outcomes & Results: There was a left visual field advantage with high-imageability words, regardless of their grammatical class, at four months post stroke. The right hemisphere advantage extended to low-imageability words at eight months after aphasia onset. Concurrently, language comprehension tasks made a significant recovery, whereas language expression tasks recovered only slightly. Furthermore, there was no significant improvement on the attentional task within the same time period. One year after the stroke, RJ's pattern of lateralization changed; there was a marginally significant central vision advantage on word processing, and no significant difference in her performance on lateralized presentations. There was a remarkable recovery on oral expression tasks, and some improvement on the attentional task within the same period.

Conclusions: The results of the present study indicate that recovery from aphasia may be sustained by both cerebral hemispheres. The participation of either hemisphere may vary with time elapsed. Our results suggest that high-imageability nouns and verbs may constitute a good target for speech therapy during the first months post stroke, in order to benefit from right hemisphere takeover capacities. Furthermore, low imageability nouns and verbs are candidates for right hemisphere takeover as well, if enough time is allowed. Finally, the results of this study suggest that right hemisphere involvement in language recovery may occur in the absence of a concurrent improvement of attention. In line with previous studies, our results indicate that the recovery of oral expression coincides with the improvement of

Address correspondence to: Ana Inés Ansaldo, Centre de recherche, Institut universitaire de gériatrie de Montréal, 4565 Queen Mary, Montréal, Quebec, Canada H3W 1W5. Email: ana.ines.ansaldo@umontreal.ca

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left hemisphere function. Hence, the fact that language expression started to improve one year after the stroke suggests that recovery from a severe language expression deficit is a long process, and may require long-term follow-up.

The identification of the neural substrate underlying recovery from aphasia is a long-standing issue in the aphasiology literature. Two main explanations have been offered to account for the recovery from aphasia following a lesion in the left hemisphere in right-handers. One emphasises the role of the undamaged areas in the dominant left hemisphere (LH) (Déjèrine, 1914) the other proposes a take-over of language processing by homologous right hemispheric (RH) regions contralateral to the affected hemisphere (Henschen, 1926), The possibility of supplemental action by the right frontal cortex as a substrate of language processing in aphasia was already being discussed at the end of the 19th century (Gowers, 1887). Since then, an RH take-over in patients recovering from aphasia has been inferred from (a) cases in which a left-side lesion causes aphasia, the patient recovers, and a subsequent right-side lesion reinstates the aphasia (Basso, Giardelli, Grassi, & Mairotti, 1989; Cambier, Elghozi, Signoret, & Hennin, 1983; Lee, Nakada, Deal, Lin, & Kwee, 1988; Nielsen, 1946), and (b) cases of language suppression following anaesthesia of the right hemisphere in patients recovering from aphasia (Czpof, 1979; Kinsbourne, 1971). Notwithstanding the interest of these clinical reports, the validity of these studies is limited by methodological issues related to the techniques used (e.g., hemispheric anaesthesia) and the lack of detailed information on the patients' language profiles.

More recently, a variety of techniques and experimental paradigms have been used to examine the hypothesis of a right hemisphere take-over in recovery from aphasia. Electrophysiological studies have shown a greater right than left hemisphere activation in aphasic subjects given verbal tasks (Moore, 1987; Papanicolau, Moore, Deutsch, Levin, & Eisemberg, 1988; Sivestrini et al., 1993). Longitudinal activation studies with PET have reported that metabolic recovery of the right hemisphere is associated with improvement on neuropsychological scores (Cappa et al., 1997). Along the same lines, regional cerebral blood flow studies have found a greater RH than LH increase in regional blood flow in recovering aphasic subjects (Demeurisse & Capon, 1987; Knopman et al., 1984; Metter et al., 1989). These findings have been considered as evidence of an RH take-over of language processing following aphasia.

The behavioural paradigm most widely used to examine the role of each hemisphere in language processing is lateralised presentation. Dichotic listening studies with aphasic subjects have shown an attenuation or even a reversal of the right-ear advantage found among normal subjects (Moore & Weidner, 1975; Niccum, 1986). Niccum (1986) reported a left-ear advantage in 4 out of 24 cases of aphasia. Furthermore, 25 cases studied by Petit and Noll (1979) showed an increase in the left-ear advantage with time elapsed after aphasia onset. Altogether, these findings point to the interest of longitudinal studies and raise the question of the proportion of aphasic subjects who may show a transfer of language processing to the RH.

The degree of RH take-over has been related to aphasia type and lesion site. Castro-Caldas and Silveira Bothelo (1980) claimed that non-fluent aphasia favours an RH take-over, whereas Niccum (1986) argued that it is not aphasia type but the integrity of the left auditory cortex that determines the right/left ear difference. In summary, the results of dichotic listening studies suggest that the degree of RH take-over may be influenced by the time elapsed after aphasia, lesion site, and type of aphasia. However, methodological issues concerning the anatomical arrangement of the human auditory pathway limit the validity of these findings. More precisely, given that the auditory pathways are both direct and crossed, even in cases of left-ear advantage, a partial LH contribution to language processing cannot be excluded. Consequently, the evidence from dichotic listening studies should be considered with caution and should not lead to any strong conclusions about the role of the RH in recovery from aphasia.

The method of divided visual field presentations appears to be a more suitable way of examining hemispheric dominance for language processing. Given that all the nerve fibres carrying visual stimuli presented in a visual hemifield project to the contralateral hemisphere, it is possible to selectively direct verbal stimuli to either cerebral hemisphere and compare their performances. Using the divided visual field paradigm, Schweiger and Zaidel (1989) have shown a left visual hemifield (Lvh) superiority in a patient with chronic Broca's aphasia and deep dyslexia when performing a visual lexical decision task. The Lvh advantage was interpreted as evidence for an RH take-over in this recovering aphasic subject. Furthermore, the authors argued that the fact that the patient produced semantic paralexias indicated an RH preponderance as well (Schweiger & Zaidel, 1989). Indeed, semantic paralexias are often considered to be a manifestation of RH reading (Landis & Regard, 1983) and the expression of the RH lexical semantic abilities, which have been widely described among normal subjects (Joanette, Goulet, & Hannequin, 1990). However, Kinsbourne claimed that the Lvh advantage displayed by aphasic subjects on verbal tasks may result from attentional factors. More specifically, Kinsbourne argued that a lesion in the LH causes a leftward bias of attention, which may result in an Lvh advantage that is not specific to language processing (Kinsbourne, 1970). Given this claim, studies should control for attentional factors if they are to demonstrate that there is an RH take-over specific to language processing.

Researchers have tried to identify other factors concerning the verbal stimulus itself that could influence hemispheric dominance for language. The most extensively studied variable affecting language lateralisation is imageability (Ellis & Shepherd, 1974). Thus, some researchers have shown that the RH of normal subjects can process concrete—i.e., imageable—words (Day, 1979) However, the literature is not unanimous with respect to the role of imageability in language lateralisation. Some studies have reported that high-imageability words may reduce or even reverse the left/right differences observed among normal subjects (see Joanette et al., 1990, for a review), while others have failed to obtain any imageability effect with lateralised presentations. According to Day (1979), the limits of the RH's receptive vocabulary in the intact brain may be a function of both imageability and grammatical class. Thus, Day (1979) showed that the RH of a normal subject is capable of processing high-imageability nouns but not high-imageability verbs, and interpreted this grammatical class effect as the result of the lower imageability ratings of high-imageability verbs in comparison to nouns. However, some authors have argued that the number of kinaesthetic associations that a particular verb arouses (Eviatar, Menn, & Zaidel, 1990), its morphological complexity, or the fact that it may belong to more than one word category (Caplan, Holmes, & Marshall, 1971) may result in a grammatical class effect, regardless of its degree of imageability. The results obtained with normal populations suggest that, following LH damage, the RH could more easily take over the processing of high-imageability words than of low-imageability words, and more easily take over the processing of nouns than that of verbs. Furthermore, the degree of RH take-over has also been related to time elapsed after LH damage (Cappa et al., 1997; Petit & Noll, 1979), with a more important RH participation in the sub-acute period of recovery from aphasia.

The purpose of the present study was to examine the role of the RH in recovery from aphasia. Thus RJ, a young recovering aphasic patient, was given a series of tasks at 4-month intervals over a period of 1 year. The results of the experiment are discussed with reference to the hypothesis of an RH take-over following aphasia.

METHOD

Case report

RJ was an 18-year-old formerly dextral female with no familial history of sinistrality and no history of vascular disease. She was unilingual, French-speaking; she was a high-school graduate and was studying photography. On 22 May, 1996, she presented with convulsions, sudden coma, and right hemiplegia. A CT scan showed a left fronto-parietal haematoma and severe endocranial hypertension. The patient underwent neurosurgery and the haematoma was removed. A CT scan performed 6 days later revealed a large left fronto-parietal lesion which extended from the insula to the corona radiata and the central grey nuclei. An arteriography showed a small aneurysm on the left internal choroid artery. In September 1996, 4 months after stroke, RJ was given the MT Beta Protocol (Béland & Lecours, 1990). Her language profile was consistent with Broca's aphasia. More specifically, RJ presented a severe reduction of speech, with preserved auditory comprehension at the simple sentence level and preserved written comprehension at the word level. Furthermore, she showed no clinical signs of hemianopia or visual neglect. RJ received three hour sessions per week of speech-therapy, throughout the duration of the present longitudinal follow-up. Therapy was provided by a speech-pathologist who was not a member of the research team. Furthermore, experimental testing was completed by a person who was blind to RJ's involvement in language therapy.

Experimental design

The experimental protocol made use of three tasks:

(a) A language test, the Montreal-Toulouse Protocol (Béland & Lecours, 1990), which was used to determine RJ's pattern of aphasia.
(b) A lateralised lexical decision task (LDT), in order to compare RJ's performance on left visual field–RH, right visual field–LH, and central-vision presentations of isolated words.
(c) An attentional task, the non-verbal Stroop Test (Beauchemin, Arguin, & Desmarais, 1996), which served for the assessment of attention.

Repeated measures were obtained at 4, 8, 12, and 16 months post-aphasia onset. These repeated measures are labelled T1, T2, T3, and T4, respectively. The order of presentation of the tasks was the same throughout the experiment. In this way, possible order effects were controlled. Each task will now be described in detail.

(a) The Montreal-Toulouse-86 Beta Version of the Montreal-Toulouse Aphasia Battery (Béland & Lecours, 1990)

The MT Battery was devised for the clinical assessment of adult French speakers with language disorders. It includes 22 tasks for the appraisal of linguistic abilities at both encoding and production of oral and written language. Even though the MT Battery was administered in its complete version, only the results of a subset of tasks which provide information about RJ's language comprehension and oral language expression abilities are reported. These tasks were:

(1) Oral word comprehension: On nine trials, the subject had to point to the picture corresponding to an auditorily presented word. The examiner presented a card with six drawings on it, and asked the subject to point to the picture representing the stimulus word. The verbal stimuli were high-frequency, high-imageability nouns. The drawings on the card depicted the stimulus word and five distractors: a semantic distractor, a phonological distractor, a visual distractor, and two distractors unrelated to the target.

(2) Oral sentence comprehension: On 38 trials, the subject had to point to the picture representing an auditorily presented sentence. The examiner presented a card with four drawings, and asked the subject to point to the picture corresponding to the stimulus sentence. The drawings on the card depicted the stimulus sentence and three distractors. The stimuli were sentences that varied in syntactic complexity and length: there were non-reversible short sentences (n = 4) and reversible long sentences (n = 32). For non-reversible sentences, the distractors depicted semantic alternatives to the target. For reversible sentences, the distractors depicted reversible alternatives to the target, or sentences in which either the subject had been changed (simple subject vs complex subject) or the predicate had been changed (direct object vs indirect object; simple predicate vs complex predicate). The examiner stopped the task after three consecutive errors.

(3) Written word comprehension: Fifteen cards, each with pictures of six objects, were presented to the subject one at a time. The subject was given a card with the written name of the target and had to match it with the corresponding picture. Each set of six drawings included the target picture, a semantic distractor, a phonological distractor, a visual distractor, and two distractors unrelated to the target.

(4) Written sentence comprehension: On eight trials, the subject had to match a written sentence with the corresponding drawing. The examiner gave the subject a card with a written sentence and a card with four drawings. The subject was asked to match the written card with the corresponding picture. The stimuli were written sentences that varied in syntactic complexity and length: non-reversible short sentences (n = 3) and complex reversible long sentences (n = 5). One of the drawings corresponded to the written sentence and the three others were distractors. For non-reversible sentences, the distractors depicted semantic alternatives to the target; for reversible sentences, the distractors depicted reversible alternatives to the target, or sentences in which either the subject had been changed (simple subject vs complex subject) or the predicate had been changed (direct object vs indirect object; simple predicate vs complex predicate). The examiner stopped the task after three consecutive errors.

(5) Oral picture naming: On 31 trials, the subject had to name a picture corresponding to a noun (n = 25) or a verb (n = 6). The task was stopped after three consecutive errors.

(6) Written picture naming: On 31 trials, the subject had to write down the name corresponding to a picture. Targets were 25 nouns and six verbs. The task was stopped after three consecutive errors.

(7) Reading aloud: On 33 trials, the subject had to read aloud words (n = 30) and sentences (n = 3). The task was stopped after three consecutive errors.

(b) Lexical decision task

The lexical decision task (LDT) was run on a Macintosh computer. The subject was asked to indicate whether a string of letters presented in isolation on a computer screen corresponded to a word in French.

Stimuli and procedure. A total of 240 words and 240 non-words served as experimental stimuli. Non-words were generated by altering one or two letters in a real word and were matched to words for digraph frequency (Mayzner & Tresselt, 1965). The non-words were pronounceable; they were formally and phonologically close to French words. The words, which varied in grammatical class, were either nouns (n = 120) or verbs (n = 120). Within each grammatical category, words were either of high imageability (n = 60) or low imageability (n = 60). Words and non-words were matched for length, which varied from five to eight letters. As the lexical frequency of nouns systematically tends to be higher than that of verbs (Beaudot, 1990), grammatical classes could not be matched for lexical frequency. However, within each grammatical class, low- and high-imageability words were matched pairwise according to lexical frequency (nouns: 270 vs. 295 per million for high and low imageability, respectively; verbs: 64 vs 67 per million for high and low imageability, respectively). Mean imageability was 6.69 for highly imageable words, and 4.15 for low-imageability words. The degree of imageability of nouns was determined according to Hogenraad's norms of imageability (Hogenraad & Oranne, 1981). As no norms of imageability for verbs were available in French, 28 judges were asked to rate 250 verbs on a 7-point scale, using a French translation of Paivio, Yuille, and Madigan's (1968) instructions for rating nouns, which were slightly modified for rating verbs.

The resulting 480 stimuli were divided into five blocks, each containing 48 words (24 nouns and 24 verbs; 12 high-imageability stimuli and 12 low-imageability stimuli for each grammatical category), and 48 non-words. A total of 20 practice stimuli (10 words and 10 non-words) were constructed in the same manner and used in a practice block, which was administrated prior to the experimental blocks.

A black dot presented at the centre of the display screen served as a fixation point. The stimuli were presented in 24-point, bold, lower-case Geneva; they were oriented horizontally and shown in black on a white background. The target items were either presented at the centre of the screen or lateralised to one side or the other of the fixation point. For lateralised presentations, the distance between the fixation point and the closest extremity of the stimulus was 1.5 degrees of visual angle at a viewing distance of 60 cm. In the case of central presentations (Cv), the central letter of the word was aligned with the centre of the screen.

The subject was seated in a chair at a distance of 60 cm from the screen. She was asked to respond by pressing with her left index finger on the "yes" or the "no" button, which corresponded to keys 4 and 6 of the keyboard connected to the computer, to indicate that the target was a word or a non-word respectively. She was encouraged to do so as quickly and as accurately as possible.

Stimuli were randomly presented to either the left or the right of the fixation point, which appeared at the centre of the screen at the beginning of each trial. RJ was trained to always look at the fixation point. A mirror placed behind the screen allowed the experimenter to monitor eye movements and to control for ocular fixation at the beginning of each trial. If an eye movement was detected while the target was being presented, the trial was rejected on-line by the experimenter and it was repeated at the end of the current block. Each experimental session began with a practice block during which the optimal presentation time for the target stimuli to be used in the experimental trial was determined. The first stimulus from the practice block was presented for 971 ms. The next stimulus would be presented at 971 − 21 ms if the first answer was correct, or 971 + 21 ms if the first answer was incorrect. Subsequently, the value by which exposure duration was changed for the next trial was halved whenever a correct response followed an error on the previous trial or when an error followed a correct answer. By the end of the practice block, the optimal presentation time had been determined and it was kept constant during the experimental session. The optimal presentation time was 950 ms at T1, and 929 ms at T2, T3, and T4.

(c) Non-Verbal Stroop test (NVST)

The non-verbal Stroop test (Beauchemin et al., 1996) is a visuospatial version of the Stroop task. The Stroop task examines the interference effect that may be observed when two competing pieces of information are presented simultaneously and only one of them may be used as a basis for response (McLeod, 1991). In order to give the correct answer, the subject has to attend to one particular aspect of the stimulus and ignore the irrelevant information that it also contains. Given that the conventional Stroop task consists of a colour/word interference paradigm, results are largely a function of reading abilities. The non-verbal version of the Stroop task permits the assessment of attentional abilities within a non-verbal paradigm because it uses graphic, non-verbal stimuli and requires a manual response.

Stimuli and procedure. The NVST was controlled by a Macintosh computer. The stimuli were circles (1 cm wide) and arrows pointing to the left or right. They were shown in black on a white background. During two separate training blocks, the subject responded to the location of a circle presented to the left or the right of a central fixation point, or to the direction to which an arrow pointed, where the arrow itself was displayed at the fixation point. Next, in two separate experimental blocks of 64 trials each, the subject performed either the location or the direction task on arrows pointing left or right, which were displayed to the left or right of the fixation point. For each task, we contrasted a condition where the direction of the arrow and its location were incongruent, with another condition where both sources of information were congruent. The subject responded with her left hand by pressing one of two keys that were aligned horizontally, pointing to the left or to the right, respectively. A practice block (n = 16) including both congruent and incongruent trials preceded each experimental session.

RESULTS

(a) Montreal-Toulouse Protocol

For each test session (T1, T2, T3, and T4), the number of correct responses on each subtest as well as the types of errors made (e.g., type of paraphasia, type of paralexia) were considered. These results are outlined in Table 1.

There was a substantial recovery of language over time. RJ evolved from a Broca's aphasia at T1 and T2 to a moderate anomic aphasia at T3 and a mild anomic aphasia at T4. Her comprehension improved during the course of the longitudinal follow-up. More specifically, at T1, RJ showed good language comprehension at the single word and simple phrase level, in both the oral and written modalities. Starting at T3, there was an improvement in the comprehension of syntactically complex sentences, particularly in the oral modality. Further improvement in this respect was also observed at T4. With regard to language expression, there was a severe reduction in oral output at T1. Some improvement was observed at T2 (see Table 1), but the major recovery was observed at T3 and T4. Thus, at T1, oral production was characterised by severe anomia, agrammatism, and phonemic transformations. At T2, RJ produced isolated words in

TABLE 1
Correct responses on subtests of the MT beta protocol at each time of measurement

	T1	*T2*	*T3*	*T4*
Oral word comprehension	9/9	9/9	9/9	9/9
Oral sentence comprehension	16/38	18/38	24/38	26/38
Written word comprehension	12/15	12/15	15/15	15/15
Written sentence comprehension	3/8	5/8	6/8	8/8
Oral picture naming	0/31	5/31	20/31	26/31
Written picture naming	0/31	6/31	21/31	21/31
Reading words aloud	0/33	8/33	18/33	25/33

T1 = 4 months post-aphasia onset, T2 = 8 months post-aphasia onset, T3 = 12 months post-aphasia onset, T4 = 16 months post-aphasia onset.

conversation; she could name seven pictures corresponding to seven highly imageable nouns and write the names of five pictures which corresponded to highly imageable nouns as well, but she rarely produced complete sentences. Furthermore, RJ produced semantic and formal paralexias at the word and simple sentence level, and substituted or omitted grammatical words and morphemes on reading tasks. In summary, the language pattern observed at T2 was consistent with Broca's aphasia and with deep dyslexia.

It was at T3 that RJ showed a major recovery of verbal output. Oral and written confrontation naming improved significantly, although naming difficulties were still observed during conversational discourse. RJ was able to produce complete sentences and her syntax was generally correct; however, she substituted and omitted grammatical particles in conversation. There was also a major improvement in her oral reading. RJ could read words and simple sentences without difficulty. However, she still produced semantic paralexias and substitutions or omissions of closed-class words when reading text. She was aware of her reading difficulty and provided very good descriptions of her difficulties with written material.[1] At T4, RJ obtained excellent scores on oral and written comprehension tasks. Her conversational discourse was fluent, characterised by mild anomia in the context of grammatically correct sentences. Anomia had little impact on RJ's ability to communicate; there were no semantic paralexias in oral text reading, but substitutions of grammatical words were still frequent.

(b) Lexical decision task

An overview of the results from the lexical decision task is presented in Table 2. Only the data with word stimuli have been considered for analysis. There was a significant reduction in global error rate (ER) over time ($\chi^2 = 28.28$, $p < .01$). This reduction was verified with every site of stimulus presentation as well (Lvh: $\chi^2 = 10.74$, $p < .05$; Cv: $\chi^2 = 15.51$, $p < .01$; and Rvh: c2 = 11.02, $p < .05$). The reduction in ER was particularly evident between T1 and T2. At T3, however, two different patterns were observed: the ER with Cv and Lvh displays remained stable with reference to T2, but the ER with Rvh displays relapsed to the same level observed at T1. Finally, at T4, there was some improvement in ER with Rvh displays, while ER with Lvh and Cv displays remained

[1] When commenting on her reading difficulty, RJ explained that reading was no longer a pleasure but a "big job". She commented that she no longer enjoyed reading essays, and that she now preferred "things that go straight to the point".

TABLE 2
Lexical decision task

		T1	*T2*	*T3*	*T4*
Lvf	Average RT	1050.0	1038.0	835.0	1008.5
	SD	522.5	226.0	130.3	250.2
	ER (%)	31.3	14.0	15.0	16.0
Cv	Average RT	897.0	1040.0	741.0	876.5
	SD	305.0	248.5	124.5	270.5
	ER (%)	25.0	12.5	15.5	17.0
Rvf	Average RT	1201.5	1135.5	854.5	1019.5
	SD	598.5	317.5	149.5	264.5
	ER (%)	26.5	17.5	24.5	22.5
Global	Average RT	1044.5	1062.5	809.0	960.5
	SD	499.5	282.0	144.0	269.5
	ER (%)	33.0	15.0	20.5	20.0

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.

stable with reference to T3. Time elapsed after aphasia onset led to a significant reduction in ER with nouns ($\chi^2 = 13.14$, $p < .01$) and with verbs ($\chi^2 = 17.01$, $p < .01$). Time elapsed after aphasia onset also improved accuracy with high-imageability words ($\chi^2 = 17.01$, $p < .01$) and with low-imageability words ($\chi^2 = 12.83$, $p < .01$).

Average response times (RT) for correct answers were also gathered. Trials on which the RT was more than two standard deviations away from the mean RT for the condition they belonged to were eliminated from the analysis (4% of correct RT at T1, 3% at T2, 3% at T3, and 3% at T4). For each time of measurement, correlations between RT and ER were gathered. There was no speed–accuracy trade-off at any time of measurement (at T1: $r = 0.85$, n.s.; at T2: $r = 0.74$, n.s.; at T3: $r = 0.60$, n.s.; and at T4: $r = 0.65$, $p = n.s.$). 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 T4), Presentation Site (left visual field [Lvf], central vision [Cv], and right visual field [Rvf]), Grammatical Class (noun or verb), and Imageability (low or high).

The ANOVA applied on correct RT revealed a triple interaction of time $\times$ presentation site $\times$ imageability, $F(6, 700) = 2.21$, $p < .05$. Further analysis of this triple interaction revealed an interaction of presentation site $\times$ imageability at T1, $F(2, 700) = 5.33$, $p < .01$, and a significant effect of presentation site at T2, T3, and T4, i.e., T2: $F(2, 700) = 3.36$, $p < .05$; T3: $F(2, 700) = 2.81$, $p < .05$; and T4: $F(2, 700) = 4.70$, $p < .01$. No other interactions or main effects were observed.

The analysis of the presentation site $\times$ imageability interaction observed at T1 showed that the presentation of high-imageability words led to shorter RT with Lvh than with Rvh displays: Post-hoc Tukey (a) Tests: $\alpha < 0.01$, see Figure 1, while the difference between RT with Lvh and Cv displays of high-imageability words was not significant. With low-imageability displays, there was a Cv advantage over lateralised presentations, Post-hoc Tukey (a) Tests: $\alpha < 0.01$ (see Figure 1), and no difference between RT with Lvh and Rvh presentations. No other main effects or interactions reached significance at T1.

At T2, there was an Lvh superiority for RT which was not affected by grammatical class or imageability. The RT difference between with Lvh and with Rvh displays was

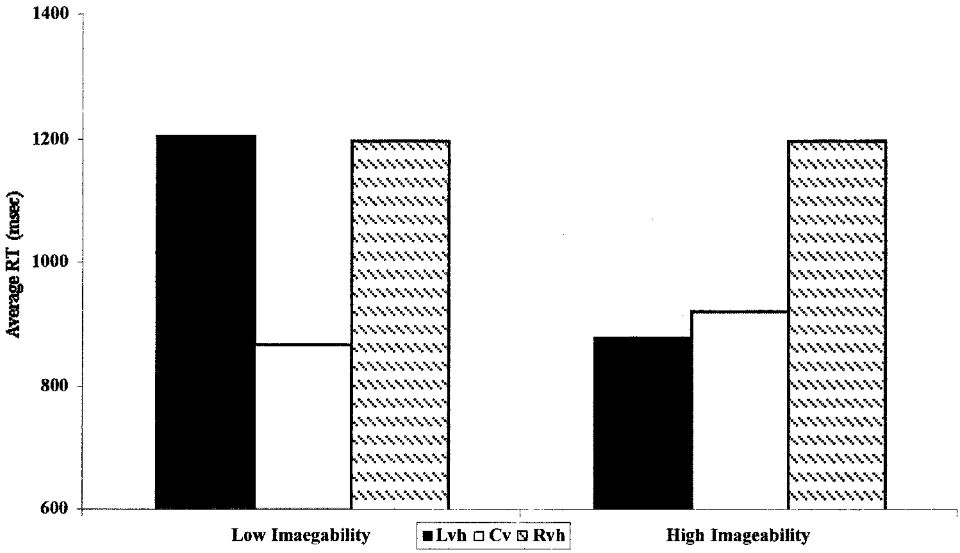

Figure 1. Lexical decision task: Presentation site × imageability interaction at T1.

significant, Post-hoc Tukey (a) Test: $\alpha < 0.05$ (see Figure 2), while the RT difference between with Lvh and Cv displays was not, Post-hoc Tukey (a) Test: $\alpha < 0.5$ (see Figure 2). At T3, there was a marginally significant Cv advantage over lateralised presentations, Post-hoc Tukey (a) Test: $\alpha = 0.056$ (see Figure 3). Furthermore, the difference between RT with Lvh and Rvh displays did not achieve significance at T3, Post-hoc Tukey (a) Test: $\alpha = 0.6$ (see Figure 3).It may also be noted that RTs were substantially lower at T3 than at T2 for all presentation sites (see Table 2). Finally, at T4, the Cv advantage on RT

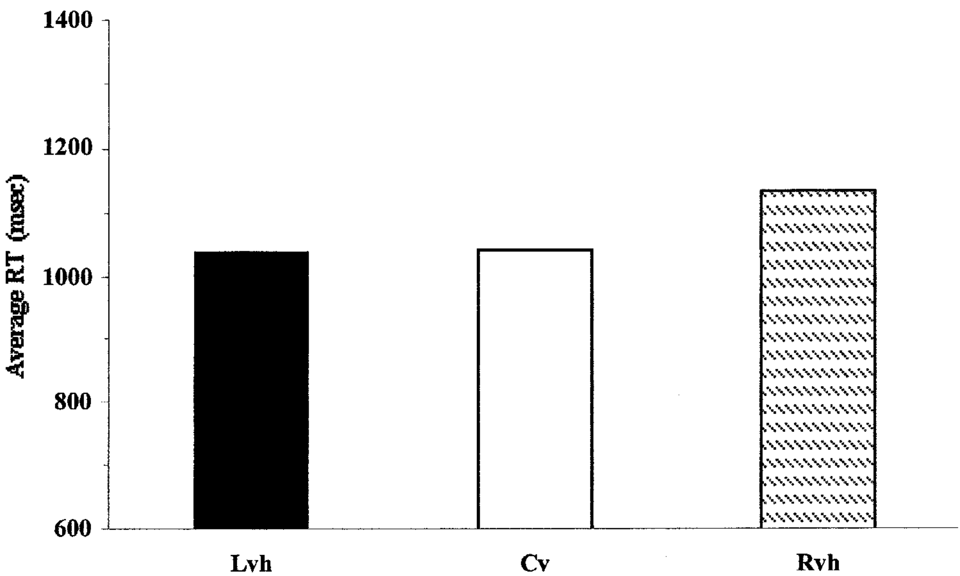

Figure 2. Lexical decision task: Presentation site effect at T2: Lvh advantage on RT.

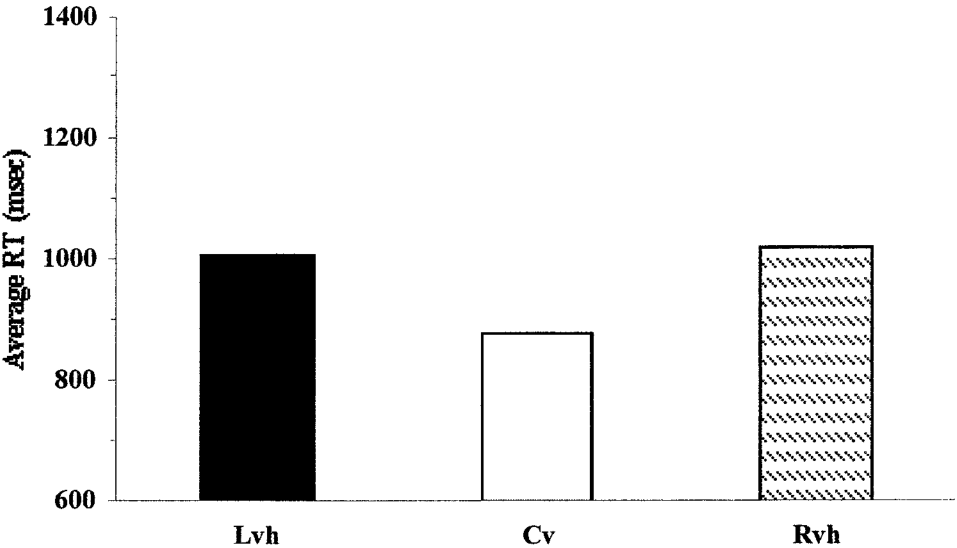

Figure 3. Lexical decision task: Presentation site effect at T3: Cv advantage on RT.

over lateralised displays already present at T3 became clearly significant, Post-hoc Tukey (a) Test: $\alpha < .05$, while the difference between RT with Lvh and Rvh displays remained non-significant, Post-hoc Tukey (a) Test: $\alpha = 0.6$, n.s.

In order to examine the relationship between performance with Cv presentations and performance with stimuli lateralised to either visual hemifield (i.e., either cerebral hemisphere) over time, Spearman Correlation Coefficients were used. For each test session, average correct RT as a function of grammatical class and imageability that were obtained with Cv displays for each test session were correlated with the corresponding average correct RT with Rvf and Lvf displays. There was a positive correlation between the performance with Cv and Lvh displays at T1 (Spearman Correlation Coefficients: $\delta_2 = 1.00$, $p < .01$), and at T3 (Spearman Correlation Coefficients: $\delta_2 = 1.00$, $p = .01$). No other correlation achieved significance.

(c) Non-verbal Stroop task

Table 3 presents the results from the NVST. It should be noted that the error rates for the orientation task in the incongruent condition were at chance on every test session whereas they were very low in the congruent condition. This suggests that the patient may have misunderstood the orientation task and responded according to the location of the target instead. Consequently, the results from the orientation task will not be considered any further.

By contrast, performance was very good throughout in the location task, and error rates were too low to be analysed by chi-square.

A 4×2 ANOVA with the factors of Time elapsed after aphasia (T1, T2, T3, and T4) and Congruence between the location and orientation information (congruent vs incongruent) was applied to the correct RT observed in the location task. It showed an interaction of time $\times$ congruence, $F(3, 485) = 23.58$, $p < .01$. The congruence between the location and orientation information affected performance at every experimental

TABLE 3
Non-verbal Stroop test

		T1	*T2*	*T3*	*T4*
Location task					
Congruent	RT	648.0	388.5	516.0	373.5
	SD	201.0	101.5	153.5	78.5
	ER	0	0.1	0	0.1
Incongruent	RT	842.0	682.0	688.0	492.0
	SD	312.5	244.5	393.5	182.0
	ER	0.1	0.2	0.1	0.6
**Orientation task*					
Congruent	RT	593.5	448.5	541.0	442.5
	SD	312.0	195.5	182.5	101.5
	ER	0.1	0.2	0.1	0.6
Incongruent	RT	679.0	751.5	557.0	605.0
	SD	201.5	193.0	203.5	198.5
	ER	45.5	53.0	50.0	50.0
Congruency effect					
Location		194	294	172	118.5
*Orientation		86	303	16	162.5

Non-verbal 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.

* The chance level performance in the incongruent condition of the orientation task suggests that the subject misunderstood the instructions and that she tended to respond to the location of the target instead of its orientation. Consequently, the data on the orientation task were not considered in our interpretation of the subject's attentional capacities.

session: at T1: $F(1,485) = 22.00$, $p < .01$; at T2: $F(1,485) = 50.35$, $p < .01$; at T3: $F(1,485) = 17.39$, $p < .01$; and T4: $F(1,485) = 8.18$, $p < .01$. RTs with the congruent condition were shorter than with the incongruent condition throughout the experiment, which shows that the patient was capable of processing the information concerning the orientation of the target. The magnitude of the congruence effect varied across sessions: it was slightly higher at T2 than at T1, T3, or T4, being particularly low at T4.

Relationship between the results on the lexical decision and attentional tasks

It has been argued that an LH lesion may cause a shift of attentional resources to the left visual hemifield and thus result in a left-side advantage on language tasks (Kinsbourne, 1970). Furthermore, other authors have proposed that an Lvh advantage on language tasks may result from the superior attentional abilities of the RH (Seron & Jeannerod, 1994). From this perspective, the observation of a presentation site effect in recovering patients given divided visual field language tasks would be considered to reflect attentional processing and would have no implications for the linguistic abilities of either cerebral hemisphere. In the case reported here, the performance variations on the LDT and the NVST suggest that the changes in lexical semantic abilities and in attentional resources were independent, and that therefore the lateralisation pattern observed on the LDT cannot be attributed to attentional factors. Thus, the shortest RTs on the LDT were observed at T3, whereas the lowest congruence effect (i.e., superior attentional abilities) was observed at T4. At T2, the correlation between the Lvh and Cv performances and the lack of any significant RT difference between them suggest that the RH made a major contribution on the LDT. However, this contribution is not likely to reflect attentional factors, given that it coincides with the largest Stroop effect observed throughout the experiment (see Table 3). Consequently, it is considered that the pattern observed with the LDT reflects language processing and is independent from fluctuations in attention.

DISCUSSION

The purpose of this study was to examine the role of the RH in the recovery from aphasia in RJ, a young female who suffered from aphasia following a left fronto-parietal lesion. The results show that RJ's performance on the lateralised lexical decision task was jointly influenced by several factors: degree of imageability, presentation site, time elapsed since aphasia onset, and grammatical class. Furthermore, RJ's global performance on the LDT and the NVST followed different patterns; thus, the minor fluctuations observed on the NVST, assumed to reflect variations in attentional capacities, could not account for the major changes in lateralisation patterns observed over time with the LDT. Concurrently with the changes in the lateralisation patterns, there were major changes in RJ's aphasia pattern. Thus, a significant recovery of language was observed over time. So RJ evolved from a severe Broca's aphasia with deep dyslexia to a mild anomic aphasia with few errors on text reading. We shall first discuss the results on the LDT, starting with the ER data. Then we shall move on to a discussion of RT data, and relate the patterns of lateralisation and main effects observed to the results with the NVST and the aphasia pattern obtained with the Montreal-Toulouse protocol.

Globally, ER with all word types decreased with time elapsed after aphasia, particularly at T2. ER with Lvh–RH and Cv displays followed a similar pattern: there was a major reduction at T2, which was maintained until the end of the experiment. With Rvh–LH displays, the pattern was different: the lowest ER was obtained at T2; at T3, the ER relapsed to the same level observed at T1; there was some improvement at T4, but still the difference between the ER at T1 and T4 was only 4% with Rvh–LH displays, whereas it was much more sustained with Lvh–RH and Cv displays. Given that the evolution of ER with Rvh–LH and Cv displays followed a similar pattern over time, it is likely that the improvement in ER with Cv displays was mainly dependent on the performance of the RH.

The analysis of the time × presentation site × imageability interaction revealed different patterns at different times. At T1, there was an Lvh–RH advantage over Rvh displays on RT with high-imageability nouns and verbs, and a Cv advantage over lateralised presentations on RT with low-imageability words. According to Day (1979), the RH of normal subjects can process high-imageability nouns, but verbs would be processed by the LH regardless of their degree of imageability. Congruently, Nieto, Santacruz, Hernandez, Camacho-Rosales, and Barroso (1999) found that female subjects present an LH advantage with high-imageability nouns. In the light of these results, the fact that RJ showed an RH advantage in the processing of high-imageability nouns may reflect premorbid RH capacities. However, the Lvh–RH advantage with high-imageability verbs shown by our patient provides evidence of an RH take-over in the processing of high-imageability verbs during recovery from aphasia. Moreover, with regard to the processing of low-imageability words, normal subjects present an Rvh–LH superiority, regardless of the grammatical class (Day, 1979) or the subject's gender (Nieto et al., 1999). Within this framework, the Cv advantage with low-imageability words observed in RJ suggests that, after LH damage, the joint participation of both cerebral hemispheres is particularly beneficial for the processing of low-imageability words. The aphasia pattern at T1 corresponded to Broca's aphasia. RJ was much better at the oral and written word comprehension tasks of the MT protocol than the naming and oral reading tasks.

According to the literature on normal subjects, the RH can process lexical semantic information but performs poorly on language expression tasks (Joanette et al., 1990). Hence, at T1 both the pattern of language recovery (a good level of comprehension but poor expression capacities), and the pattern of lateralisation with the LDT (an Lvh–RH advantage with high-imageability nouns and verbs) indicate an RH predominance for language processing. It seems unlikely that the RH's superiority at T1 may have resulted from non-specific (i.e., attentional) factors, as RH's performance on the LDT was sensitive to the linguistic factors of grammatical class and degree of imageability.

At T2, the only significant effect obtained was an Lvh–RH advantage over the Rvh–LH on RT. Thus, whereas the RH advantage on RT concerned only high-imageability words at T1, it was extended to encompass all word types at T2. These findings indicate that the RH augmented its linguistic processing capacity between T1 and T2. The fact that the RH took over the processing of all words, regardless of their degree of imageability and grammatical class, goes well beyond the level of RH language processing capacities that has been described among normal subjects and suggests that the RH may display these resources when the LH is severely damaged. It may also be noted that the difference between RT with Cv and Lvh–RH displays at T2 was not significant, and that there was a positive correlation between RT with Lvh displays and RT with Cv displays. These findings indicate that, 8 months after the stroke, lexical semantic processing of isolated words presented to central vision was largely dependent on the RH. Concerning language patterns, RJ produced some isolated high-frequency words on naming tasks; she produced semantic paralexias and omitted or substituted closed-class words on oral reading tasks. According to Schweiger and Zaidel (1989), this pattern of language recovery, together with an Lvh–RH advantage on RT, indicates an RH take-over during the recovery from aphasia. However, according to Kinsbourne (1970), the Lvh advantage on RT found among patients recovering from aphasia may result from an attentional bias to the Lvh, as a consequence of the LH lesion. In that case, the Lvh advantage would have no implications for the role of the RH in the recovery of language following aphasia. Schweiger and Zaidel (1989) did not control for attentional factors, and thus the possibility that an attentional bias was at the origin of the Lvh advantage reported cannot be excluded. In the case reported here, the Lvh–RH advantage on RT across word types observed at T2 coincided with the weakest performance on the attentional task (i.e., largest congruency effect), and thus the possibility of an attentional account of the LDT performance seems unlikely. In summary, the results obtained at T2 indicate that, 8 months after RJ's stroke, the RH had improved its performance in relation to T1; it was faster than the LH in the processing of high- and low-imageability nouns and verbs, and it largely sustained the lexical semantic processing of words presented to Cv. Thus, these results show that, during the acute period following LH damage, the RH may demonstrate language-processing abilities that are beyond the scope observed in normal individuals.

At T3, there was a reduction in RT with all three sites of presentation and the pattern of lateralisation changed relative to T2: there was a marginally significant Cv superiority relative to lateralised presentations on RT. However, the difference between RTs with Lvh and Rvh presentations did not attain significance. In other words, the performance of both cerebral hemispheres was equivalent in terms of speed of response. There was also a marked recovery on the oral expression tasks and oral sentence comprehension tasks of the Montreal-Toulouse protocol. Finally, there was a reduction of the Stroop effect on the NVST, which indicates a recovery of attention.

The results from the LDT are somewhat ambiguous with respect to a possible improvement of the linguistic capacities of the LH at T3. Thus, while RT with Rvf–LH displays were improved with respect to T2, the corresponding ER was greater at T3 than T2, thereby indicating no improvement of word/non-word discrimination capacity in the LH at T3. This pattern also coincided with an improved attentional performance on the NVST at T3 relative to T2, suggesting a possible influence of attentional factors on the LDT. On the other hand, the pattern of language recovery observed at the same time on the MT protocol does suggest a recovery of LH function. Hence, RJ showed a dramatic improvement on the oral expression tasks of the MT Beta during the same period, which would be difficult to explain on a purely attentional basis. The recovery of oral expression has been consistently related to the recovery of language by the left hemisphere (Demeurisse & Capon, 1987; Demeurisse, Capon, & Verhase, 1985; Karbe et al., 1997; Kertesz, 1988). Given that RJ's lesion involved the left frontal lobe but spared Wernicke's area, it is possible that the severe reduction in oral expression observed at T1 and T2 was caused by intrahemispheric diaschisis resulting from the left frontal lesion. More specifically, it may be suggested that intrahemispheric diaschisis had a distant effect on Wernicke's area, resulting in severe expressive aphasia early on. Later, the regression of diaschisis at T3 resulted in a remarkable recovery of language expression and functional oral expression abilities in RJ. The global pattern of results we have observed at T3 highlights the advantage of experimental protocols that combine lateralised paradigms, language tests, and attentional tasks, in order to avoid the over-interpretation of lateralisation effects observed among recovering aphasic subjects. Thus we find that RJ's performance on the LDT is likely to have been jointly influenced by language processing and attentional factors.

At T4, there was a stabilisation of the pattern observed at T3. Language expression attained a functional level: RJ obtained high scores on oral and written naming tasks, her anomia was mild, morphological paralexias were still observed but their impact on functional communication was weak. As discussed in the previous paragraph, the regression of diaschisis may account for the dramatic recovery of oral expression observed between T3 and T4. As for the results with the LDT, the marginally significant Cv advantage over lateralised presentations on RT observed at T3 became clearly significant at T4, and the difference between RTs with presentations to the Lvh vs Rvh remained non-significant. This RT pattern, as a function of display site, suggests that lexical semantic processing of isolated words was sustained by both cerebral hemispheres, with no predominance of one over the other. However, once again, it is possible that the results from the LDT depend on attentional factors. More precisely, at T4 we observed the weakest Stroop effect on the NVST since the beginning of the experiment. These results indicate that the recovery of attention observed at T3 continued at T4 and that it may have influenced RJ's performance on the LDT. However, the ongoing recovery of oral expression observed with the MT protocol and during spontaneous communication indicates that the LH recovered language function at T4, and thus it is possible that both attentional and language factors contributed to the lateralisation pattern observed on the LDT at T4. Globally speaking, recovery of language function was very good, and RJ attained a functional level of communication.

Recovery was probably favoured by the young age of the subject and the fact that she pursued intensive language therapy throughout the duration of the experiment. However, the possible effects of therapy on the changes in the patterns of lateralisation observed over time are difficult to examine.

In summary, the first 8 months following RJ's stroke were characterised by an RH superiority for lexical semantic processing of isolated words. The RH predominance was language-specific, as it was affected by the linguistic factors of imageability and grammatical class at T1, and it occurred concurrently with the poorest performance on the attentional task at T2. It is possible that a premorbid factor contributed to the RH advantage with high-imageability nouns observed at T1, as this pattern of RH performance has been observed among normal subjects. However, the RH superiority with high-imageability verbs does suggest an RH take-over, as verbs (even high-imageability ones) are normally processed by the LH. At T2, the RH advantage on RT affected all word types. Equally, this observation indicates an improvement in the RH's performance between T1 and T2. Particularly in the case of low-imageability words, the RH advantage on RT indicates an RH take-over, as among normal subjects, the processing of low-imageability words has been consistently related to LH function. Altogether, the results obtained at T1 and T2 show that, following a lesion in the language areas on the LH, the RH was capable of taking over language processing, which is normally accomplished by the LH. The improvement in language comprehension and the poor recovery of oral expression observed within the same time period suggest that the RH was able to take over lexical semantic processing but was unable to compensate for oral expression deficits. One year after the brain damage, the pattern of lateralisation changed: RTs with left and right hemifield presentations were equivalent, whereas RTs with Cv displays were faster. The deterioration in the ER with Lvf presentation, together with the recovery of attention observed concurrently, suggests that attentional factors may have influenced RJ's performance on the LDT at T3 and T4. However, the recovery of linguistic function by the LH is also a likely factor, as RJ showed a dramatic recovery of oral expression within the same period. The regression of intrahemispheric diaschisis in the LH may account for this striking recovery of language function. Hence, the global pattern at T3 and T4 suggests that both attentional factors and recovery of LH function influenced RJ's performance on the LDT.

To conclude, the results of the present study show that lateralisation patterns displayed by recovering aphasic subjects on the LDT change with time elapsed after aphasia. Both a recovery of language-processing abilities and attentional factors appeared to be involved in the evolution of this young aphasic patient. The evidence reported here indicates that language-specific RH take-over occurred during the first 8 months of recovery. With more time elapsed, the pattern of lateralisation changed, and RTs with left and right visual presentations were equivalent. Attentional factors and partial recovery of LH function may have determined this pattern of lateralisation. Furthermore, recovery of LH function may have resulted from a regression of intrahemispheric diaschisis in the LH, causing a dramatic improvement of oral expression at T3 and T4. An initial RH superiority followed by an LH recovery has been reported among recovering aphasic subjects studied with evoked-related potentials (Thomas, Altenmüler, Marckmann, Kahrs, & Dichgans, 1997) and PET (Cappa et al., 1997; Karbe et al., 1998). Specifically Karbe et al (1998), reported that, during a repetition task, severe aphasic patients with lesions that involved the left superior temporal area (LST) showed an activation of the right inferior frontal cortex homologous to Broca's area, as well as an activation of left supplementary motor area. A follow-up, 12 months after stroke, showed that the activation of RH regions had disappeared whereas an activation of the LST was now observed. Karbe et al. (1998) concluded that the recovery within the LST cortex led to a reduction of the compensatory activity of the RH. RJ's lesion preserved the LST area and the longitudinal lateralisation pattern she displayed was similar to that reported by Karbe et al. (1998). The fact that our results are based entirely on a behavioural technique calls for prudence in the interpretation of results. However, the convergence between our results and Karbe's observations (Karbe et al., 1998) using PET provides physiological support to our findings.

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REFERENCES

Basso, A., Giardelli, M., Grassi, M.P., & Mairotti, M. (1989). The role of the RH in the recovery from aphasia. Two case studies. *Cortex*, *25*, 555–566.

Beauchemin, M.J., Arguin, M., & Desmarais, F. (1996). Increased non-verbal Stroop interference in ageing. *Brain and Cognition*, *32*, 255–257.

Beaudot, J. (1990). *Fréquence d'utilisation des mots en Français*. Montreal: Presses de l'Université de Montréal.

Béland, R., & Lecours, A.R. (1990). The MT-86 ß aphasia battery: A subset of normative data in relation to age and level of school education. *Aphasiology*, *4*, 439–462.

Cambier, J., Elghozi, D., Signoret, J.L., & Hennin, D. (1983). Contribution de l'hémisphère droit au langage des aphasiques. Disparition de ce langage après lesion droite. *Revue Neurologique*, *139*, 55–63.

Caplan, D., Holmes, J.M., & Marshall, J.C. (1971). Word classes and hemispheric specialization. *Neuropsychologia*, *12*, 331–337.

Cappa, S.F., Perani, D., Grassi, F., Bressi, M., Alberoni, M., Franceschi, M., Bettinardi, V., Todde, S., & Fazio, F. (1997). A PET follow-up study of recovery after stroke. *Brain and Language*, *56*, 55–67.

Castro-Caldas, A. & Silveira Bothelo, M. (1980). Dichotic listening in the recovery of aphasia after stroke. *Brain and Language*, *10*, 145–151.

Czpof, D. (1979). The role of the non-dominant hemisphere in speech recovery in aphasia. *Aphasia, Apraxia and Agnosia*, *2*, 27–33.

Day, J. (1979). Visual half-field word recognition as a function of syntactic class and imageability. *Neuropsychologia*, *17*, 515–519.

Déjèrine, J. (1914) *Sémiologie des affections du système nerveux*. Paris: Masson.

Demeurisse, G., & Capon, A. (1987). Language recovery in aphasic stroke patients: Clinical, CT and CBF studies. *Aphasiology*, *1*, 301–315.

Demeurisse, G., Capon, A., & Verhas, M. (1985). Prognostic value of computed tomography in aphasic stroke patients. *European Neurology*, *24*, 134–139.

Ellis, H.D., & Shepherd, J.W. (1974). Recognition of abstract and concrete words presented in left and right visual fields. *Journal of Experimental Psychology*, *103*, 1035–1036.

Eviatar, Z., Menn, L., & Zaidel, E. (1990). Concreteness: Nouns, verbs, and hemispheres. *Cortex*, *26*, 611–624.

Gowers, W.R. (1887). *Lectures on the diagnosis of diseases of the brain*. London: Churchill.

Henschen, S.E. (1926) On the function of the right hemisphere of the brain in relation to the left in speech music and calculation. *Brain*, *49*, 110–123.

Hogenraad, R., & Oranne, E. (1981). Valences d'imagerie de 1130 noms de la langue française parlée. *Psychologica Belgica*, *20*, 21–30.

Joanette, Y., Goulet, P., & Hannequin, D. (1990). *Right hemisphere and verbal communication*. New York: Springer.

Karbe, H., Herholz, K., Kessler, J., Weinhard, U., Pietrzyk, K., & Heiss, W.D. (1997). Recovery of language after brain damage. *Advances in Neurology*, *73*, 347–358.

Karbe, H., Thiel, A., Weber-Luxemburger, G., Herholz, K., Kessler, J., & Heiss, W.D. (1998). Brain plasticity in poststroke aphasia: What is the contribution of the right hemisphere? *Brain and Language*, *64*, 215–230.

Kertesz, A. (1988). What do we learn from recovery from aphasia? In S.G. Waxman (Ed.), *Advances in neurology, Vol. 47: Functional recovery in neurological disorders* (pp. 277–292). New York: Raven Press.

Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta Psychologica*, *33*, 193–201.

Kinsbourne, M. (1971). The minor cerebral hemisphere as a source of aphasic speech. *Archives of Neurology*, *25*, 302–306

Knopman, D., Selnes, O., Niccum, N., Rubens, A., Yock, D., & Larson, D. (1984). A longitudinal study of speech fluency in aphasia: CT correlates of recovery and persistent nonfluency. *Neurology*, *33*, 1170–1178.

Landis, T., & Regard, M. (1983). Semantic paralexia: A release of right hemispheric function from left hemispheric control? *Neuropsychologia*, *21*, 359–363.

Lee, H., Nakada, T., Deal, J.L., Lin, S., & Kwee, I.L. (1988). Transfer of language dominance. *Annals of Neurology*, *15*, 304–307.

McLeod, C.M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, *109*, 163–203.

Mayzner, M.S., & Tresselt, M.E. (1965) Anagram solution times: A function of multiple-solution anagrams. *Journal of Experimental Psychology*, *71*, 66–73.

Metter, E.J., Kempler, D., Jackson, C., Hanson, W.R., Mazziotta, J.C., & Phelps, M.E. (1989). Cerebral glucose metabolism, Wernicke's, Broca's and conduction aphasia. *Archives of Neurology*, *46*, 27–34.

Moore, W.H. Jr. (1987). Hemispheric alpha asymmetries in fluent and disfluent aphasics during linguistic and resting conditions. *Cortex*, *23*, 123–133.

Moore, W.H. Jr., & Weidner, W.E. (1975). Dichotic word perception of aphasic and normal subjects. *Perceptual and Motor Skills*, *39*, 1003–1011.

Niccum, N. (1986). Longitudinal dichotic listening patterns for aphasic patients. Description of recovery curves. *Brain and Language*, *28*, 273–288.

Nielsen, J.M. (1946). *Agnosia, apraxia, and aphasia. Their value in cerebral localization.* New York: Hoeber.

Nieto, A., Santacruz, R., Hernandez, S., Camacho-Rosales, J., & Barroso, J. (1999). Hemispheric asymmetry in lexical decisions: The effects of grammatical class and imageability. *Brain and Language*, *70*, 421–436.

Paivio, A., Yuille, J.C., & Madigan, S. (1968). Concreteness, imagery, and meaningfulness value for 925 nouns. *Journal of Experimental Psychology, Supplement*, 76 [monograph].

Papanicolau, A., Moore, B., Deutsch, G., Levin, H., & Eisemberg, H. (1988). Evidence for right hemisphere involvement in recovery from aphasia. *Archives of Neurology*, *45*, 1025–1029.

Petit, J.M., & Noll, J.D. (1979). Cerebral dominance in aphasia recovery. *Brain and Language*, *7*, 191–200.

Schweiger, A., & Zaidel, E. (1989). Right hemisphere contribution to lexical access in an aphasic with deep dyslexia. *Brain and Language*, *37*, 73–89.

Seron, X., & Jeannerod, M. (1994). *Neuropsychologie humaine*. Liège: Mardaga.

Silvestrini, M., Caltagirone, C., Lupini, L.M., Matteis, M., Troisi, E., & Bernardi, G. (1993). Activation of healthy hemisphere in poststroke recovery: A transcranial Doppler study. *Stroke*, *24*, 1673–1677.

Thomas, C., Altenmüler, E., Marckmann, G., Kahrs, J., & Dichgans, J. (1997). Language processing in aphasia: Changes in lateralization patterns during recovery reflect cerebral plasticity in adults. *Electroencephalography and Clinical Neuropsychology*, *102*, 86–97.