Université de Montréal

Hémisphère droit et aphasie : étude longitudinale sur le traitement des mots selon leur degré d'imageabilité et leur classe grammaticale

Par Ana Inés Ansaldo

École d'orthophonie et d'audiologie
Faculté de médecine

Thèse présenté e à la Faculté des études supérieures
en vue de l'obtention du grade de Philosophæ Doctor (Ph.D.)
en sciences biomédicales (option orthophonie)

février 2002

0-612-75891-5

Université de Montréal

Faculté des études supérieures

Cette thèse intitulée :

Hémisphère droit et aphasie : étude longitudinale sur le traitement des mots selon leur degré d'imageabilité et leur classe grammaticale

présentée par : Ana Inés Ansaldo

a été évaluée par un jury composé des personnes suivantes

Sylvie Belleville
Président-rapporteur

Martin Arguin
Directeur de recherche

André Roch Lecours
Codirecteur de recherche

Julien Doyon
Membre du jury

Stefano F. Cappa
Examinateur externe

Richard Patry
Représentant du doyen de la FES

Sommaire

L'étude des soubassements neurobiologiques de la récupération de l'aphasie a, depuis longtemps, été une source de réflexion et de recherche en aphasiologie. Ce travail s'intéresse au rôle que joue l'hémisphère droit dans la récupération de l'aphasie. Les trois études qui constituent le corps de cette thèse visent à examiner la contribution de l'hémisphère droit au traitement des mots lors du processus de récupération après une aphasie par lésion de l'hémisphère gauche. Dans le premier chapitre, les principales hypothèses sur le rôle de l'hémisphère droit dans la récupération de l'aphasie sont brièvement rappelées, ainsi que les éléments théoriques ayant motivé les études rapportées dans cette thèse. Le travail de recherche effectué est ensuite rapporté sous forme de chapitres distincts. Chaque étude rapporte les résultats d'une étude utilisant le paradigme de décision lexicale en présentation latéralisée des stimuli visuels. Le protocole expérimental inclut également une évaluation des habiletés langagières de même qu'une appréciation de l'attention non-verbale, le tout dans des devis expérimentaux de cas unique à mesures répétées. Les résultats font l'objet d'une discussion d'ensemble centrée sur les implications cliniques et théoriques des observations.

Les observations rapportées dans le premier article (Chapitre 2) de la thèse permettent une analyse critique de l'une des hypothèses classiques sur la récupération de l'aphasie. Celle-ci, connue comme l'hypothèse de Broca, postule que la récupération de l'aphasie est sous-tendue par une prise en charge du traitement du langage par l'hémisphère droit. Les résultats de cette expérience confirment cette hypothèse en ce qui concerne le traitement lexico-sémantique des mots de haut degré d'imageabilité. Par contre, c'est l'hypothèse alternative proposée par Dejèrine qui mieux rend compte des observations relatives à la récupération de l'expression orale. Plus précisement cette dernière apparaît associée à une amélioration fonctionnelle de l'hémisphère gauche. De plus, les résultats de cette étude indiquent que, suite à une aphasie, l'hémisphère droit peut prendre en charge le traitement des mots de basse imageabilité et des verbes, un traitement normalement accompli par l'hémisphère gauche. Ces résultats plaident en faveur d'une réorganisation fonctionnelle avec une prise en charge par l'hémisphère droit pour le traitement du langage, au cours de la recupération de l'aphasie.

Les résultats de la deuxième étude (Chapitre 3) montrent que la prise en charge du traitement des mots par l'hémisphère droit est indépendante de l'évolution des habiletés attentionnelles. Cette observation va à l'en contre d'une autre hypothèse sur le rôle de l'hémisphère droit dans la récupération de l'aphasie, selon laquelle l'avantage démontré par l'hémisphère refléterait des processus attentionnels découlant de la lésion de l'hémisphère gauche et non pas une réorganisation fonctionnelle spécifique au traitement du langage. Par ailleurs, les résultats de ces deux études montrent que la contribution respective de chaque hémisphère à la récupération de l'aphasie varie avec le temps écoulé après la lésion et touche à des domaines du langage différents. Finalement, dans la troisième étude, (Chapitre 4), une participation équivalente des deux hémisphères dans le traitement des mots tout le long de l'expérience est notée. Une fois de plus, l'hémisphère droit se montre sensible au degré d'imageabilité des mots et l'amélioration de l'expression orale coïncide avec la récupération fonctionnelle de l'hémisphère gauche. De plus, on observe que l'amélioration de l'attention peut moduler la performance en décision lexicale.

Dans le chapitre 5, l'ensemble des résultats obtenus est discuté dans le cadre d'une perspective à la fois clinique et théorique. Plus spécifiquement, ce chapitre permet d'aborder les éventuelles applications cliniques à partir des observations rapportées. La discussion situe ces observations dans le cadre des perspectives classiques sur les soubassements de la récupération de l'aphasie. C'est ainsi qu'il y est constaté que chacune des hypothèses classiques prises isolément ne permet de rendre compte que d'une partie des observations rapportées, sans pouvoir expliquer l'ensemble de phénomènes observés. Une vision plus dynamique des principes sous-jacents à la récupération de l'aphasie y est ensuite discutée. Cette dernière prend appui sur le concept de coopération hémisphérique qui après avoir été brièvement décrit, est présentée comme une alternative intéressante aux hypothèses classiques univoques qui ne semblent pas permettre la juste description des soubassements neurobiologiques de la récupération de l'aphasie.

Mots clés: aphasie, récupération, hémisphère droit, hemisphère gauche, imageabilité, classe grammaticale, longitudinale

Summary

The study of the basis of recovery from aphasia has interested researchers since the XIX century. This thesis focuses on the role of the right cerebral hemisphere in the recovery from aphasia. The three studies that form the body of this thesis focus on the role of the right cerebral hemisphere in the processing of isolated words during recovery from aphasia following a lesion in the left hemisphere.

The first chapter discusses the main hypothesis about the role of the right hemisphere in the recovery from aphasia, and briefly presents the theoretical issues that motivated the studies reported in this thesis. The three studies are reported in separate chapters. Each study reports the results of a single-case longitudinal experiment using a lexical decision task, in divided visual field presentations. The experimental protocol includes a non-verbal attentional task and a language test. The results are discussed from both a clinical and theoretical perspective.

The results reported in the first article (Chapter 2) lead to a critical discussion about one of classical the hypothesis on the recovery from aphasia. This hypothesis, known as Boca's hypothesis, postulates that the recovery from aphasia is sustained by a right hemisphere take-over of language processing. The results of this experiment confirm this hypothesis with regards to the processing of lexical semantic information at the word level, particularly in the case of high image ability words. Conversely, it is the alternative hypothesis, proposed by Dejèrine that better explains the evolution and recovery of oral expression. More precisely, the latter is related to the functional recovery of the left hemisphere. Furthermore, the results of this experiment show that the right cerebral hemisphere can take-over the processing of low imageability words and verbs, a level of language processing normally accomplished by the left hemisphere. Thus, these results suggest that the right hemisphere can take-over specific aspects of language processing during the recovery from aphasia.

The results of the second experiment (Chapter 3) show that the right hemisphere take-over of word processing may be independent of the evolution of attentional abilities. This observation provides evidence against another hypothesis about the role of the right hemisphere during the recovery from aphasia, according to which the right hemisphere advantage results from attentional processes following the left hemisphere lesion, and does not imply a specific-specific take-over by the right hemisphere. Furthermore, the results of both studies show that the contribution of either cerebral hemisphere to recovery varies with time elapsed after aphasia onset and regards specific aspects of language processing. Finally, in the third study (Chapter 4), an equivalent participation of both cerebral hemispheres is observed throughout the experiment. Once again, the right hemisphere is sensitive to the degree of imageability of words, and the improvement of oral expression coincides with the functional recovery of the left hemisphere. There is also an improvement of attention, and this has an impact on the performance with the lexical decision task.

In chapter 5, the results are discussed from both a clinical and theoretical perspective. More precisely, this chapter presents the clinical implications of the results obtained. The results are discussed within the frame of the classical perspectives on the basis of the recovery from aphasia. Thus, it is concluded that each of these hypothesis can account for the results in a partial manner, but none can provide an explanation for the ensemble of the observations. A more dynamic perspective of the principles underlying the recovery from aphasia is then presented. This perspective is based on the concept of hemispheric cooperation, which is briefly presented and suggested as an alternative to the classical hypothesis that do not allow a proper appreciation of the neurobiological basis of the recovery from aphasia.

KEY WORDS: Recovery, aphasia, right hemisphere, left hemisphere, imageability, grammatical class, longitudinal.

Table des matières

Liste des tableaux

Liste des figures

Remerciements

D'abord merci à mon directeur de recherche, Dr. Martin Arguin, pour ses conseils toujours intelligents, pour l'originalité de ses approches, pour m'avoir sensibilisé à l'importance de la rigueur scientifique, pour sa générosité dans le partage de ses connaissances, pour sa patience et son respect.

Merci aussi à mon co-directeur, Dr. André Roch Lecours, pour m'avoir apporté sa vision d'une recherche qui intègre les aspects théoriques et cliniques, pour son soutien constant tout au long de mes études doctorales, pour son enthousiasme, pour sa générosité et son appui inconditionnel.

Ensuite, merci à toutes les personnes qui ont collaboré à ma formation doctorale. Au Dr. Yves Joanette, pour m'avoir suggéré un thème de recherche qui m'a passionné tout au long de mes études et qui continuera à le faire encore longtemps. Au professeur Xavier Seron, pour les riches échanges sur des aspects épistémologiques au début de mon doctorat. À Francine Giroux, pour ses recommandations et sa qualité professionnelle.

Puis merci aussi aux orthophonistes qui ont collaboré avec moi au cours de la période expérimentale. Plus particulièrement, à Danièle Forte pour son enthousiasme et sa collaboration.

J'exprime aussi ma reconnaissance au Consejo Nacional de Ciencia y Técnica de la República Argentina ainsi qu'à la Faculté des études supérieures de l'Université de Montréal pour m'avoir fourni des moyens financiers nécessaires à la poursuite de mes travaux doctoraux.

Finalement, merci à tous mes amis (es) du Centre de recherche de l'Institut universitaire de gériatrie de Montréal. Premièrement, à ceux qui m'ont accueilli les bras ouverts à mon arrivée d'Argentine: à Frédérique Gardye et Marc Filaretos, pour leur amitié et leur générosité, à Marianne Corre, pour sa complicité et son amitié, à Brigitte Damien et Jo Marino, pour leur présence chaleureuse, à Michelyne Hubert et Sylvain Chartier, à Ana Paula Delgado et tous ceux qui m'ont accompagné avec leur affection pendant toutes ses années. Merci aussi à Begoña Bilbao pour son amitié inconditionnelle que j'apprécie autant, à Nathalie Walter pour son appui et sa générosité, et merci enfin à ma famille pour leur amour et leur soutien.

Dédicaces

A mamá y papá que me enseñaron a caminar y me mostraron el camino.

Gracias por su amor incondicional que me acompañará para siempre.

A Mamáma, Julio y Roberto, por abrirme la puerta.

Gracias por vuestra generosidad y por haber confiado en mí.

A mi querida hija, Ana Victoria, que ilumina mi camino con su sonrisa y su mirada celeste. Gracias por darle sentido a mi caminar.

A Yves, que camina junto a mi.

Gracias por tus gestos que transmiten el amor y por tu mirada que me llena de confianza.

The question " What is a thing? " is a historic question. It has to be posed and answered considering its inherent historic character. Considering its possibilities, we have to accept the limitations of the answers given.

Martin Heidegger (Die Frage nach dem Ding).

Chapitre 1

Introduction : aphasie et récupération

L'aphasie est un trouble acquis de l'expression et/ou de la compréhension du langage oral et écrit. Le concept d'aphasie est nécessairement rattaché à celui de langage; leur évolution doit être intimement reliée (Joanette & Ansaldo, 2000). Compte tenu de la place privilégiée qu'occupe le langage dans la majorité des formes d'interaction humaine, l'aphasie constitue une importante source de handicap pour la personne qui en souffre ainsi que pour son entourage (Wade et al., 1985; Petersen et al., 1995).

L'aphasie est souvent le résultat d'une lésion cérébrale focale, généralement d'origine vasculaire. Toutefois, des tableaux aphasiques peuvent se présenter en l'absence d'anomalies macroscopiques du cerveau, comme par exemple suite à une intoxication ou encore dans le contexte de maladies chroniques et évolutives (p. ex., maladie d'Alzheimer). Ce travail s'intéresse à l'aphasie résultant d'une lésion aiguë, unique et d'origine vasculaire, survenue chez des individus droitiers et unilingues, et plus spécifiquement aux mécanismes qui sous-tendent sa récupération. La mise à l'écart des gauchers et des bilingues, entre autres, est imputable au fait que ces individus présentent une organisation cérébrale particulière pour le traitement du langage (Joanette, Goulet & Hannequin, 1990, Boller, 1968; Paradis, 1993), et constituent par conséquent un groupe distinct.

Le traitement du langage est soutenu par un réseau complexe et distribué au niveau cortical et subcortical et, chez la majorite des individus droitiers, ce réseau est largement latéralisé dans l'hémisphère cerebral gauche. Les régions où une lésion est plus largement associée à une aphasie sont le gyrus temporal supérieur, connu comme l'aire de Wernicke, ou plus précisément les deux tiers du gyrus temporal postérieur et la moitié supérieure équivalente du gyrus moyen au gyrus frontal supérieur gauche, ou l'aire de Broca (Lecours et al., 1987).

La récupération de l'aphasie est fréquente mais à des degrés variables selon le cas. Il y a généralement un certain degré de récupération spontanée chez la majorité des individus devenus aphasiques. Ce processus de récupération naturelle augmente lorsque le patient bénéficie d'une intervention orthophonique (Seron & Jeannerod, 1994). Une telle intervention débute habituellement par une évaluation de l'aphasie. Après avoir posé le diagnostic sur le type d'aphasie et la nature des troubles présents, il est alors d'usage d'émettre un pronostic de récupération et de traiter le problème du langage. Les stratégies d'intervention orthophonique utilisent une gamme d'approches diverses, destinées à réduire le handicap de communication (OMS-CIDIH) et à faciliter la réinsertion sociale de la personne aphasique (Lesser & Milroy, 1993).

Dans la plupart des cas, le versant réceptif du langage récupère mieux et plus rapidemenmt que le versant expressif (Kertesz, 1988). Chez un certain nombre d'individus aphasiques, la récupération du langage peut être relativement complète et s'accompagner d'un retour quasi-normal des habiletés de communication. Par contre, chez la majorité des individus, le processus de récupération, spontanée ou avec l'aide de l'intervention orthophonique, n'est pas complet, laissant ainsi des séquelles constituant un handicap communicationnel. La perte de la faculté de désigner les objets, ou anomie, est parmi les séquelles les plus fréquentes (Kertez, 1988). Ces observations suggèrent que le traitement lexico-sémantique s'appuie sur une représentation cérébrale, moins focalisée que l'expression orale, ce qui favorise la récupération. Malgré les nombreuses études sur les caractéristiques cliniques pouvant avoir un impact sur le pronostic de l'aphasie, on ne dispose toujours pas de prédicteurs de récupération fiables (Kertez, 1988), notamment parce que les mécanismes sous-jacents à la récupération du langage après une lésion cérébrale sont mal connus.

La question des bases neurobiologiques de la récupération de l'aphasie a intéressé les chercheurs depuis le XVIII[e] siècle. L'intérêt de cette question réside dans la recherche qu'elle engendre et qui est susceptible d'augmenter notre compréhension du fonctionnement du cerveau en présence d'une lésion. Les connaissances ainsi générées peuvent éventuellement mieux cibler les stratégies d'intervention pour favoriser la diminution du handicap de communication et faciliter la réinsertion sociale des personnes atteintes d'aphasie. Le présent travail aborde la question des bases neurobiologiques de la récupération après une aphasie en s'intéressant à la possible participation de l'hémisphère droit dans la récupération de l'aphasie. En particulier, l'objectif principal des études composant ce travail est d'explorer la possibilité que l'hémisphère droit prend en charge le traitement des mots lors de la récupération de l'aphasie.

Deux sections forment le chapitre d'introduction de cette thèse. La première présente diverses propositions qui ont été faites quant aux bases neurobiologiques de la récupération de l'aphasie. La deuxième section discute des aspects théoriques et méthodologiques qui nuisent à l'interprétation des résultats pertinents a cette question qui ont été rapportés dans la littérature, motivant de la sorte les études rapportées dans les trois articles de cette thèse.

1. Les bases neurobiologiques de la récupération de l'aphasie

Suite à une lésion cérébrale, les mécanismes de récupération impliquent des transformations qui s'effectuent à plusieurs niveaux, des membranes cellulaires jusqu'aux systèmes neuraux distribués. Pour ce qui est des mécanismes neuronaux en réaction à une lésion, la recherche dépend essentiellement des études chez l'animal. C'est ainsi qu'il a été démontré que la présence d'une lésion dans le système nerveux central est à l'origine d'une série de mécanismes cellulaires jugés compensatoires : régénérescence axonale, bourgeonnement synaptique, hypersensibilisation et/ou augmentation de la densité des récepteurs (Finger & Stein, 1982). Toutefois, il apparaît évident que l'état actuel des connaissances ne permet pas d'extrapoler l'impact de ces mécanismes sur la réorganisation fonctionnelle d'habiletés cognitives qui auraient été affectées par une lésion, tel le langage.

L'intérêt pour la question des bases neurologiques de la récupération de l'aphasie existe depuis les débuts de l'aphasiologie. Deux propositions formulées à l'aube de la recherche en aphasiologie ont dirigé l'interprétation des résultas obtenus depuis plus d'un demi-siècle. La première de ces propositions, formulée entre autres par Dejerine (1914), suggère que la récupération de l'aphasie dépend de l'intégrité des régions adjacentes à la zone du langage endommagée ou de l'intégrité partielle de cette zone. La seconde proposition, exprimée par Broca (1865), suggère que, lorsque la zone du langage est endommagée, ce sont des aires homologues à celles-ci dans l'hémisphère droit qui soutiennent la récupération de l'aphasie. Les lignes qui suivent permettront d'analyser chacune de ces propositions à la lumière des faits de la littérature publiée depuis.

1.1 La proposition de Dejerine

«C'est sur l'intégrité relative
de telle ou telle partie de la zone du langage
ou de la corticalité adjacente par laquelle la lésion
peut, jusqu'à un certain degré, être compensée...»
Dejerine, 1914; p. 114

Près d'un siècle après cette affirmation, l'imagerie fonctionnelle nous fournit des outils technologiques qui permettent de constater que Dejerine (1914) suivait une bonne piste. Or, les techniques de neuroimagerie fonctionnelle offrent un potentiel intéressant dans l'étude des bases neurobiologiques de la récupération de l'aphasie car elles permetttent au mieux d'observer directement certains des mécanismes compensatoires qui sont mis en œuvre dans le cerveau d'un individu ayant subi une lésion cérébrale.

Toutefois, la grande majorité des études publiées jusqu'à présent examinent le traitement cognitif chez des sujets non cérébrolésés. Or, les chercheurs examinent les modifications observées au niveau du débit sanguin cérébral (c.-à-d. SPECT, TEP et

IRM fonctionnelle) et du métabolisme cérébral (c.-à-d. TEP) pendant des tâches cognitives diverses, afin d'identifier les régions les plus actives lors de la réalisation de la tâche demandée.

La littérature est moins abondante relativement à l'utilisation de ces mêmes techniques pour l'étude des bases de la récupération de l'aphasie. La majorité des études publiées jusqu'à présent ont utilisé la tomographie à émission monophotonique (SPECT) ou les mesures de débit sanguin cérébral en tomographie à émission de positons (TEP). La plupart des travaux montrent que c'est la réactivation des zones du langage dans l'hémisphère gauche qui est essentielle à récupération de l'aphasie. Une des premières études sur la récupération de l'aphasie avec la TEP a été publiée par Cappa et al. (1997). Les auteurs rapportent une augmentation bilatérale du métabolisme chez des sujets aphasiques chroniques ayant présenté une bonne récupération de l'aphasie. À l'opposé, la persistance d'un hypométabolisme dans la région temporo-pariétale gauche été associée à une mauvaise récupération de l'aphasie. Ces résultats suggèrent (Cappa et al. 1997) qu'une bonne récupération de l'aphasie est associée à une augmentation du métabolisme dans les régions postérieures de l'hémisphère atteint.

Dans une autre étude utilisant la TEP, Warburton et al. (1999) démontrent que la récupération de l'aphasie coïncide avec une augmentation du métabolisme cérébral dans des zones non lésées du lobe temporal latéral inférieur gauche. Dans leur étude utilisant le SPECT, Heiss et al. (1999) démontrent que c'est la récupération fonctionnelle de l'aire temporale gauche qui assure la récupération de l'aphasie (Heiss et al., 1999). Dans une autre étude avec la TEP, cette fois-ci longitudinale, Heiss et al. (1997) démontrent chez deux patients présentant une lésion étendue de la région péri-sylvienne gauche et un diagnostic d'aphasie globale, qu'une petite activation du gyrus temporal gauche est corrélée avec une bonne récupération de l'aphasie. Par ailleurs, les auteurs (Heiss et al. 1997) rapportent des activations importantes dans l'hémisphère droit chez cinq autres patients avec le même diagnostic, dont la récupération du langage était très limitée. Ces observations amènent Heiss et al. (1997) à conclure que la récupération de l'aphasie est possible seulement si les régions du langage dans l'hémisphère gauche sont relativement fonctionnelles.

Les conclusions des études en imagerie par résonance magnétique (IRM) fonctionnelle sont moins tranchées en ce qui concerne l'importance de la récupération fonctionnelle de l'hémisphère gauche dans la récupération de l'aphasie. Ainsi, Calvert et al. (2000) et Cao et al. (1999) considèrent que la récupération de l'aphasie est toujours plus importante lorsqu'on observe une activation des régions du langage ou des régions adjacentes à la lésion, dans l'hémisphère gauche. Toutefois, ils considèrent que la récupération de l'aphasie pourrait être soutenue par un réseau bilatéral comportant des régions intactes dans l'hémisphère gauche et des régions homologues dans l'hémisphère droit (Calvert, 2000; Cao et al. 1999).

En résumé, certaines études d'imagerie fonctionnelle offrent des résultats qui sont compatibles avec la proposition de Dejerine (1914). Toutefois, les études plus recentes utilisant la IRM fonctionnelle les conclusions sont moins tranchés. Malgré l'intérêt de ces études et leur contribution à notre compréhension de la question qui nous intéresse, force est de constater que le paradigme d'activation pose des problèmes qui compliquent l'interprétation des résultats. En effet, les mécanismes neurobiologiques qui sous-tendent les activations demeurent mal connus et il est peu probable qu'un AVC, qui entraîne des anomalies métaboliques au repos (Cappa et al. 1997), ne perturbe pas également les activations. Par conséquent, les activations observées chez des patients aphasiques pourraient avoir, au niveau de la récupération, des effets neutres, positifs, ou négatifs, selon la manière dont elles interagissent avec l'organisation cérébrale préalable du langage de chaque sujet aphasique (Samson et al. 1999). En d'autres termes, les activations sont trop souvent considérées comme la conséquence naturelle du comportement testé, mais notre connaissance actuelle des mécanismes neuro-biologiques qui les sous-tendent ne nous permet pas d'assurer que ce soit le cas.

1.2 La proposition de Broca

«Comment se fait-il donc que l'individu rendu aphémique par la destruction partielle ou totale de la troisième circonvolution frontale gauche n'apprenne pas à parler avec l'hémisphère droit... »

Broca, 1865

Le premier cas rapporté dans la littérature où la récupération de l'aphasie est soutenue par l'hémisphère droit remonte à 1887. À l'époque, Gowers (1887) rapporte le cas d'un sujet droitier devenu aphasique comme conséquence d'une lésion de l'hémisphère gauche. Celui-ci récupère de l'aphasie et perd ensuite ce langage récupéré suite à une deuxième lésion, cette fois-ci dans l'hémisphère droit. Cette observation conduit Gowers (1887) à proposer que la récupération de l'aphasie dépend de l'hémisphère droit. Depuis, d'autres cas similaires à celui de Gowers (1887) ont été rapportés dans la littérature (Moutier, 1908; Henschen, 1926; Nielsen & Raney 1939; Nielsen, 1946; Levine & Mohr, 1979; Cambier, Elghozi, Signoret & Hennin, 1983; Basso, Giardelli, Grassi & Mairotti, 1989). Malgré l'intérêt de ces travaux, il se pourrait que les observations rapportées soient le résultat du phénomène de diaschisis, (Von Monakow, 1914). Or, la diaschisis correspond à l'effet exercé par l'aire lésée sur des aires fonctionnellement connectées. Cette lésion fonctionnelle peut récupérer à des degrés variables et entraîner la récupération fonctionnelle. Or, dans les observations rapportées par Gowers, (1887) Moutier, (1908) Henschen, (1926) Nielsen & Raney (1939) Nielsen, (1946), Levine & Mohr, (1979) Cambier, Elghozi, Signoret & Hennin, (1983), et Basso, Giardelli, Grassi & Mairotti, (1989), la possibilité d'un effet de diaschisis contralatéral à la lésion droite ne peut être écartée. Par conséquent, ces observations ne sont pas nécessairement indicatives d'une prise en charge par l'hémisphère droit pendant la récupération de l'aphasie suite à la prémière lésion gauche

D'autres travaux ont utilisé la technique d'inactivation pharmacologique pour examiner la participation des hémisphères cérébraux dans la récupération de l'aphasie

(Kinsbourne, 1971; Czpof, 1972). Selon Kinsbourne (1971), l'inactivation de l'hémisphère droit dans des cas d'aphasie sévère et chronique conduit à la disparition des paraphasies. Par contre, ces modifications au niveau du langage aphasique ne sont pas observées lorsque l'inactivation concerne l'hémisphère gauche (Kinsbourne, 1971). Czpof (1972) démontre que, dans des cas d'aphasie sévère et chronique, l'inactivation de l'hémisphère droit entraîne la suppression du langage. Toutefois, lorqu'il s'agit de cas d'aphasie légère et récente, c'est l'inactivation de l'hémisphère gauche qui provoque la détérioration du langage. En conclusion, les résultats obtenus avec la technique d'inactivation pharmacologique suggèrent que l'hémisphère droit soutient la récupération dans des cas d'aphasie sévère. Le fait que ce soit dans les cas d'aphasie chronique qu'on observe les effets d'une inactivation de l'hémisphère droit suggère par ailleurs que le transfert des fonctions demande un certain temps pour être effectif. D'autres études ayant examiné le rapport entre l'étendue de la lésion gauche et la récupération de l'aphasie (Cummings et al. 1977; Landis & Regard, 1983; Cambier et al. 1983) concluent que c'est l'étendue de la lésion dans l'hémisphère gauche qui détermine le degré auquel l'hémsphère droit participe à la récuperation de l'aphasie (Cummings et al. 1977; Landis & Regard, 1983; Cambier et al. 1983).

Dans les cas décrits plus haut (Kinsbourne, 1971; Czpof, 1979; Cumming et al., 1977; Landis & Regard, 1983; Cambier, 1983), il est possible toutefois que ce soit la contribution de l'hémisphère droit au traitement du langage avant la lésion qui est observée plutôt qu'une prise en charge de l'hémisphère droit suite à l'aphasie (Kertesz 1988; Petit et al. 1979; Ellis 1984). Or, on sait que chez les individus non cérébrolésés, l'hémisphère droit peut traiter de l'information verbale au niveau léxico-sémantique .

Plus spécifiquement, des études faisant appel au paradigme de présentation latéralisée des stimuli visuels démontrent que l'hémisphère droit est capable de traiter des mots concrets, de haut degré d'imageabilité [1] (e. g. Day, 1977; 1979; Ellis & Shepherd, 1974, Manhaupt, 1983, Young & Ellis, 1985) et des noms plutôt que des verbes (Day 1979). Toutefois, d'autres études n'ont pas trouvé d'effet d'imageabilité ou

---

[1] Le degré d'imageabilité correspond à la facilité avec laquelle un mot peut évoquer une image visuelle.

de la classe grammaticale (Boles, 1983; Eviatar et al., 1990; Koening et al, 1992). En ce qui concerne la production du langage, les études avec des sujets non-cérébrolésés montrent que les capacités de l'hémisphère droit sont minimes sinon nulles (Gainotti, 1993). Toutefois, les études chez des patients ayant subi une section de la commissure inter-hémispherique donnent des résultats non concluants. En effet, les premières observations par Gazzaniga et Sperry (1967) et une étude ultérieure de Zaidel (1976; 1978) démontrent que l'hémisphère droit est incapable d'accéder aux mécanismes de production verbale. Toutefois, des résultats obtenus plus récemment ont conduit Gazzaniga à changer d'opinion. Selon Gazzaniga (1983; 1984), les compétences langagières de l'hémisphère droit seraient variables d'un individu à l'autre et chez certains patients commisurotomisés. De plus, Gazzaniga (1984) avance que l'hémisphère droit pourrait contribuer au développement du langage expressif avec le temps écoulé après la commissurotomie.

Si on considère les données provenant des études en présentation latéralisée chez les sujets normaux, ainsi que les premières études avec des patients commissurotomisés, la contribution de l'hémisphère droit à la récupération de l'aphasie pourrait se limiter à des aspects réceptifs du traitement du langage. Par contre, si l'on considère les résultats obtenus par la suite par Gazzaniga (1983; 1984), il se pourrait que l'hémisphère droit contribue lui aussi à la récupération de l'expression orale.

La littérature sur la latéralisation du traitement du langage chez des patients aphasiques est limitée et les résultats obtenus sont inconcluants. La majorité des études de cas font usage du paradigme d'écoute dichotique dont une meilleure performance avec des stimuli présentés à une oreille suppose une latéralisation du traitement dans l'hémisphère contralatéral. En se servant de cette approche, Castro-Caldas et al. (1980) démontrent que l'augmentation de l'avantage relatif d'une oreille sur l'autre varie en fonction du type d'aphasie. Ainsi, les auteurs (Castro-Caldas et al 1980) concluent que la récupération dans des cas d'aphasie non fluente est contrôlée par l'hémisphère droit, tandis que dans les cas d'aphasie fluente, c'est l'hémisphère gauche qui sous-tend la récupération. Niccum et al. (1986) n'ont pas réussi à reproduire les résultats de Castro-

Cladas et al (1980), en utilisant la même approche; ils rapportent une amélioration parallèle des deux oreilles, donc une absence de latéralisation pour le traitement du langage dans la récupération de l'aphasie (Niccum, 1986). En résumé, les résultats des études en écoute dichotique suggèrent que l'hémisphère droit pourrait, dans certains cas sous-tendre la récupération de l'aphasie. Il est toutefois à souligner que l'interprétation des résultats de ces études est compliquée par les caractéristiques de la voie auditive. En effet, seulement deux tiers des fibres consituant la voie auditive sont croisées et, par conséquent, la latéralisation complète des présentations auditives a un hemisphère cérébral donné est impossible. En conclusion, les effets de latéralisation observés avec la technique d'écoute dichotique demandent à être interprétés avec prudence.

La présentation latéralisée des stimuli visuels est plus adequat à cet égard car les voies visuelles sont complètement croisées. La seule étude qui se sert de ce paradigme pour examiner les modèles de latéralisation chez des sujets aphasiques est celle de Schweiger & Zaidel (1989). Les auteurs utilisent une tâche de décision lexicale latéralisée avec des présentations visuelles tachistoscopiques pour examiner la latéralisation du traitement lexico-semantique chez un patient avec diagnostic d'aphasie de Broca et dyslexie chroniques. Schweiger & Zaidel (1989) démontrent un avantage de l'hémichamp visuel gauche en décision lexicale, concomitante avec une importante récupération du langage en général, et de l'expression orale en particulier. Les auteurs (Schweiger & Zaidel 1989) concluent que la récupération du langage a été la conséquence d'une prise en charge du traitement du langage par l'hémisphère droit. Bien que les résultats de cette étude démontrent que l'hémisphère droit peut soutenir la récupération de l'aphasie, la nature du rôle de l'hémisphère droit reste à être précisée. Ainsi, chez les sujets cérébrolésés comme les aphasiques, il est possible que les effets de latéralisation observés dans des tâches verbales soient la conséquence d'un déplacement de l'attention vers le champ visuel ipsilatéral à la lésion. Selon Kinsbourne, (1970) comme l'hémisphère gauche, chez le sujet normal, est prépondérant pendant le traitement du langage, la présentation des stimuli verbaux cause un état d'activation préparatoire de l'hémisphère gauche, une inhibition du même ordre de l'hémisphère droit et un déplacement de l'attention vers l'hémichamp visuel droit, et ce même si le point de fixation central est maintenu. Kinsbourne (1970) propose que la lésion gauche peut modifier cette dynamique de sorte que l'inhibition de l'hémisphère droit ne soit plus complète et que l'attention se déplace vers l'hémichamp gauche. Si tel est le cas, la suprématie de l'hémisphère droit observé pendant des tâches visuelles chez des aphasiques chroniques n'exprimerait que des processus de déplacement de l'attention, sans aucune implication concernant la prise en charge par l'hémisphère droit du traitement du langage.

2. Problématique

Les résultats des recherches rapportés dans la littérature ne sont pas concluants quant au rôle précis de chacun des hémisphères pour la récupération de l'aphasie. Plusieurs avenues de recherche se sont ouvertes depuis un siècle, mais le rôle respectif des hémisphères cérébraux dans la récupération de l'aphasie demeure incertain. En ce qui concerne les propositions de Dejerine (1914) et Broca (1865), elles ont été confirmées et réfutées, selon les cas. De fait, il se pourrait qu'une partie des difficultés d'interprétation des résultats rapportés dans la littérature provienne de la nature même des propositions faites pour expliquer les données dans la littérature. Ainsi, lorsque Dejerine (1914) et Broca (1865) ont avancé ces propositions, on assistait aux débuts de la recherche sur les bases neurobiologiques du traitement du langage, sur l'aphasie et sur les mécanismes de récupération suite à une lésion cérébrale. Les connaissances ont évoluées depuis. Plus précisément, en ce qui concerne le traitement du langage, on sait aujourd'hui que ce dernier dépend de l'activite orchestrée de plusieurs régions du système nerveux. Pour ce qui est des mécanismes de récupération suite à une lésion du système nerveux, les travaux les plus recents suggèrent que les modifications métaboliques coexistentes avec l'aphasie et celles concomitentes à sa récupération pourraient se définir en termes des réseaux cortico-sous-corticaux bilatéraux (Cao et al., 1999; Calvert, 2000). Il se pourrait donc qu'une partie de la difficulté d'interprétation des résultats des recherches existantes provienne du caractère dichotomique des propositions qui ont servi de cadre d'interprétation jusqu'à présent.

Une autre raison pouvant expliquer le manque de convergence dans la littérature se trouve dans les limites des approches méthodologiques utilisées. En ce qui concerne les études de neuroimagerie (Heiss et al., 1997; Cao et al., 1999; Calvert, 2000), les connaissances des mécanismes qui sous-tendent les processus d'activation en général et ceux de l'activation en présence d'une lésion en particulier nous obligent à demeurer prudents dans l'interprétation des résultats. Quant aux conclusions découlant des études de cas de patients aphasiques (Gowers, 1887; Kinsbourne, 1971; Czpof, 1972; Cummings et al., 1977; Landis & Regard, 1983), elles restent mitigées par la possibilité du phénomène de diaschisis (Von Monakow, 1914). Par ailleurs, les études en écoute dichotique (Castro-Caldas et al., 1980; Niccum et al., 1986) n'assurent pas entièrement la latéralisation hémisphériques des stimuli présentés et par conséquent, les conclusions concernant les patrons de latéralisation chez des sujets aphasiques en récupération demeurent discutables. Quant aux études dont la présentation latéralisée se fait par la voie visuelle (Gazzaniga, 1984, Zaidel, 1978), elles permettent une bonne latéralisation des stimuli et par conséquent, des effets de latéralisation plus fiables. Toutefois, lorsque ce paradigme a été appliqué à l'étude de la récupération de l'aphasie (Schweiger & Zaidel, 1989), bien que l'avantage de hémichamp visuel gauche suggère une prédominance de l'hémisphère droit dans le traitement lexico-sémantique, le manque de contrôle de l'attention ne permet pas d'écarter que celui-ci soit le résultat d'un déplacement de l'attention secondaire à la lésion hémispérique gauche (Kinsbourne, 1970).

D'autres choix méthodologiques pourraient expliquer le manque de convergence pour ce qui est du rôle de l'hémisphère droit dans la récupération de l'aphasie. Plus précisement, les études de groupes de patients aphasiques qui ne permettent pas le contrôle du facteur de variabilité interindividuelle pour ce qui est des capacités langagières de l'hémisphère droit chez le sujet normal (Joanette, et al., 1990) Finalement, le caractère transversal de la majorité des études ne permet pas d'examiner l'impact du temps écoulé après la lésion cérébrale en tant que facteur pouvant moduler la participation de l'hémisphère droit dans le traitement du langage, tel qu'observé chez des sujets commissurotomisés (Gazzaniga, 1983).

En conclusion, la problématique du rôle de l'hémisphère droit dans la récupération de l'aphasie se heurte à des limites qui sont à la fois de nature théorique et méthodologique. La limite théorique se manifeste par l'impossibilité de rendre compte des données dont on dispose en se servant des cadres théoriques utilisés jusqu'à present. Par ailleurs, il existe des limites méthodologiques aux études rapportées qui ne nous permettent pas de tirer des conclusions sur les effets de latéralisation observés en relation avec le rôle des hémisphères cérébraux dans la récupération de l'aphasie.

Cette thèse rapporte les résultats de trois études de cas sur le rôle de l'hémisphère droit dans la récupération de l'aphasie. Le protocole expérimental permet d'examiner les modèles de latéralisation du traitement lexico-sémantique en cours de récupération. Les faiblesses méthodologiques potentielles du paradigme utilisé sont palliées par l'utilisation de tâches complémentaires qui permettent le suivi de la récupération du langage en général et de l'évolution de l'attention. La discussion générale présente une alternative aux propositions classiques qui rend compte des résultats des expériences rapportées ici et permet d'expliquer les contradictions apparentes dans la littérature.

Chapitre 2

Article 1

Initial Right Hemisphere Take-over and Subsequent Bilateral Participation During Recovery from Aphasia

Ana Inés ANSALDO, Martin ARGUIN & André Roch LECOURS

Accépté pour publication dans Aphasiology, décembre 2001

Running Title: RIGHT AND LEFT HEMISPHERE PARTICIPATION IN THE RECOVERY FROM APHASIA

ABSTRACT

This paper reports the results of a longitudinal study of hemispheric lateralization patterns of visual lexical processing during recovery from aphasia. RJ, a young woman who suffered from a left fronto-parietal lesion, was given a lateralized lexical decision task, a language test and an attentional task, at four-month intervals over a period of one year. The performance of both cerebral hemispheres on the lexical decision task varied with the time elapsed since the stroke: the right hemisphere played a preponderant role in the acute and subacute phases of recovery. More precisely, the right hemisphere took over processing of high-imageability verbs four months after aphasia onset, and extended the take-over across all word types four months later. Furthermore, the analysis of the global pattern for the lexical decision and the attentional tasks indicate that the right hemisphere superiority observed in the subacute phase cannot be attributed to attentional factors, but rather reflects a take-over specific to language processing. One year after aphasia onset, signs of left hemisphere recovery were observed: there was a reduction in response times with Rvh displays in the lexical decision task. This occurred concurrently with a dramatic improvement in language expression on the language tests. Given that RJ's lesion did not involve Wernicke's area, it is possible that a regression of intrahemispheric diaschisis resulted in the recovery of oral expression observed by the end of the experiment. This study shows that, following aphasia due to a left hemisphere lesion, the right hemisphere can take over lexical semantic processing normally accomplished by the left hemisphere. Furthermore, the results of this experiment are in line with previous research suggesting that the recovery of language expression in aphasia depends on the integrity of Wernicke's area.

Keywords: aphasia, recovery, right hemisphere, left hemisphere, imageability, grammatical class, longitudinal

INTRODUCTION

The identification of the neural substrate underlying the 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 contralaterai to the affected hemisphere (Heschen, 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 (Nielsen, 1946; Basso et al., 1989; Lee et al., 1988; Cambier et al., 1983) 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 the recovery from aphasia. Electrophysiological studies have shown a greater right than left hemisphere activation in aphasic subjects given verbal tasks (Sivestrini et al., 1995; Moore, 1987; Papanicolau et al., 1988). 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, 1984; Metter, 1989). These findings have been considered as evidence of an RH take-over of language processing following aphasia.

The behavioral paradigm most widely used to examine the role of each hemisphere in language processing is lateralized 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 et al. (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 & Silveira Bothelo (1980) claimed that non-fluent aphasia favours a RH take-over, while 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 the dichotic listening studies should be considered with caution and should not lead to any strong conclusions about the role of the RH in the 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 fibbers 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 a RH take-over in this recovering aphasic subject. Furthermore, the authors argued that the fact that the patient produced semantic paralexias indicated a 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 lateralization 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 lateralization. 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 lateralized 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 normal subjects 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 (Gazzaniga et al., 1970), or the fact that it may belong to more than one word category (Caplan, 1974) 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 (Petit, 1979; Cappa et al., 1997), 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 the recovery from aphasia. Thus, RJ, a young recovering aphasic patient, was given a series of tasks at four-month intervals over a period of one year. The results of the experiment are discussed with reference to the hypothesis of an RH take-over following aphasia.

METHODS

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 May 22, 1996, she presented with convulsions, sudden coma and right hemiplegia. A CT scan showed a left fronto-parietal hematoma and severe endocranial hypertension. The patient underwent neurosurgery and the hematoma was removed. A CT scan performed six 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, four 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 lateralized 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 four, eight, 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 is described in detail below.

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:

a.1. Oral word comprehension: On nine trials, the subject had to point to the picture corresponding to an auditory 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 distracters: a semantic distracter, a phonological distracter, a visual distracter, and two distracters unrelated to the target.

a.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 distracters. 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 distracters depicted semantic alternatives to the target. For reversible sentences, the distracters 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.

a.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 distracter, a phonological distracter, a visual distracter, and two distracters unrelated to the target

a.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 distracters. For non-reversible sentences, the distracters depicted semantic alternatives to the target; for reversible sentences, the distracters 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.

a. 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.

a. 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.

a.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 Power Macintosh 7300/180 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: Two hundred and forty 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. Since 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 seven-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. Twenty practice stimuli (10 words and 10 non-words) were constructed in the same manner and used in a practice block, that was administrated prior to the experimental blocks.

A black dot presented at the centre of 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 lateralized to one side or the other of the fixation point. For lateralized 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 in 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 Power 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 to 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.

Insert Table 1 here

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 conversation; she could name 7 pictures corresponding to 7 highly imageable nouns and write the names of 5 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.[2] 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 on Reading tasks 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 has been considered for analysis. There was a significant reduction in global error rate (ER) over time (c2 = 28.28, $p < 0.01$). This reduction was verified with every site of stimulus presentation as well (Lvh: c2 = 10.74, $p < 0.05$; Cv: c2 = 15.51, $p < 0.01$; and Rvh: c2 = 11.02, $p < 0.05$). 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 stable with reference to T3. Time elapsed after aphasia onset led to a significant reduction in ER with nouns (c2 = 13.14 $p < 0.01$) and with verbs (c2 = 17.01, $p < 0.01$). Time elapsed after aphasia onset also improved accuracy with high-imageability words (c2 = 17.01, $p < 0.01$) and with low-imageability words (c2 = 12.83, $p < 0.01$).

Insert Table 2 here

[2] 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."

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: $r = 0.85$, $p = n.s.$; at T2: $r = 0.74$ $p = n.s.$; at T3: $r = 0.60$, $p = n.s.$; and at T4: $r = 0.65$, $p = n.s.$). The resulting sample of correct RT was submitted to a 4 x 3 x 2 x 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 x presentation site x imageability ($F(6,700) = 2.21$, $p < 0.05$). Further analysis of this triple interaction revealed an interaction of presentation site x imageability at T1 ($F(2,700) = 5.33$, $p < 0.01$), and a significant effect of presentation site at T2, T3 and T4 (i.e. T2: $F(2,700) = 3.36$, $p < 0.05$; T3: ($F(2,700) = 2.81$, $p < 0.05$; and T4: ($F(2,700) = 4.70$, $p < 0.01$). No other interactions or main effects were observed.

The analysis of the presentation site x 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: $a < 0.01$, 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 lateralized presentations (Post-hoc Tukey (a) Tests: $a < 0.01$, see Figure 1), and no difference between RT with Lvh and Rvh presentations. No other main effects or interactions reached significance at T1.

Insert Figure 1 here

At T2, there was an Lvh superiority for RT which was not affected by grammatical class or imageability. The RT difference between Lvh and Rvh displays was significant (Post-hoc Tukey (a) Test: $a < 0.05$, see Figure 2), while the RT difference between with Lvh and Cv displays was not (Post-hoc Tukey (a) Test: $a < 0.5$, see Figure 2). At T3, there was a marginally significant Cv advantage over lateralized presentations (Post-hoc Tukey (a) Test: $a = 0.056$, see Figure 3). Furthermore, the difference between RT with Lvh and Rvh displays did not achieve significance at T3 (Post-hoc Tukey (a) Test: $a = 0.6$, see Figure 3).It may also be noted that RT were substantially lower at T3 than at T2 for all presentation sites (see Table 2).

Insert Figures 2 and 3 here

Finally, at T4, the Cv advantage on RT over lateralized displays already present at T3 became clearly significant (Post-hoc Tukey (a) Test: $a < 0.05$), while the difference between RT with Lvh and Rvh displays remained not significant (Post-hoc Tukey (a) Test: $a = 0.6$, *n.s.*).

In order to examine the relationship between performance with Cv presentations and performance with stimuli lateralized 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: $d_2 = 1.00, p < 0.01$), and at T3 (Spearman Correlation Coefficients: $d_2 = 1.00, p = 0.01$). 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.

Insert Table 3 here

A 4 x 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 x congruence ($F(3,485) = 23.58$, $p < 0.01$). The congruence between the location and orientation information affected performance at every experimental session (at T1: $F(1,485) = 22.00$, $p < 0.01$; at T2: $F(1,485) = 50.35$, $p < 0.01$; at T3: $F(1,485) = 17.39$, $p < 0.01$; and T4: $F(1,485) = 8.18$, $p < 0.01$). RT 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.

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

It has been argued that a 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 with 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 lateralization pattern observed on the LDT cannot be attributed to attentional factors. Thus, the shortest RT 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 lateralized 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 lateralization patterns observed over time with the LDT. Concurrently with the changes in the lateralization patterns, there were major changes in RJ's aphasia pattern. Thus, a significant recovery of language was observed over time. Thus, 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 lateralization 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 x presentation site x 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 lateralized 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 et al. (1999) found that female subjects present an LH advantage with high-imageability nouns. In the light of these results, the fact that RJ showed a 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 lateralization with the LDT (a 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, since the 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, while 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, eight 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 (Kinsbourne, 1970). 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, eight 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 lateralization changed relative to T2: there was a marginally significant Cv superiority relative to lateralized presentations on RT. However, the difference between RT 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 suggests 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 (Kertez, 1988; Demeurisse et al., 1985; Demeurisse & Capon, 1987; Karbe et al., 1997). 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 lateralized paradigms, language tests and attentional tasks, in order to avoid the over-interpretation of lateralization 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 lateralized presentations on RT observed at T3 became clearly significant at T4, and the difference between RT 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 upon 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 lateralization 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 favored by the young age of the subject and the fact that she pursued intensive language therapy throughout the duration of th experiment. However, the possible effects of therapy on the changes in the patterns of lateralization observed overtime are difficult to examine.

In summary, the first eight months following RJ's stroke were characterised by an RH superiority for lexical semantic processing of isolated words. The RH predominance was language-specific, since 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, since 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 since 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, since 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 lateralization changed: RT with left and right hemifield presentations were equivalent, whereas RT 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, since 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 lateralization 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 lateralization changed, and RT with left and right visual presentations were equivalent. Attentional factors and partial recovery of LH function may have determined this pattern of lateralization. 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 subjcets studied with evoked-related potentials (Thomas et al., 1997) and PET (Cappa et al., 1997, Karbe 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 lead to a reduction of the compensatory activity of the RH. RJ's lesion preserved the LST area and the longitudinal lateralization pattern she displayed was similar to that reported by Karbe et al (1998). The fact that our results are based entirely on a behavioral technique calls for prudence in the interpertation of results. However, the convergence between our results and Karbe's observations (Karbe et al. 1998) using PET provides physiological support to our findings.

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*. Montréal: 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.

Cappa, 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.

Dejerine, J. (1914). Sémiologie des affections du sytème nerveux. Masson. Paris

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.

De Renzi, E. & Vignolo, L. (1962). The Token Test: A sensitive test to detect disturbances in aphasics. *Brain*, 85; 665-678.

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.

Kertez, 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.

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.

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

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., Cupini, C.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.

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 = months post–aphasia onset, T2 = months post–aphasia onset, T3 = 10 months post–aphasia onset, T4 = months post-aphasia onset

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	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

Table 3

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

			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

Figure Captions

Figure 1 : Lexical Decision Task: Presentation Site x Imageability Interaction at T1

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

Figure 1

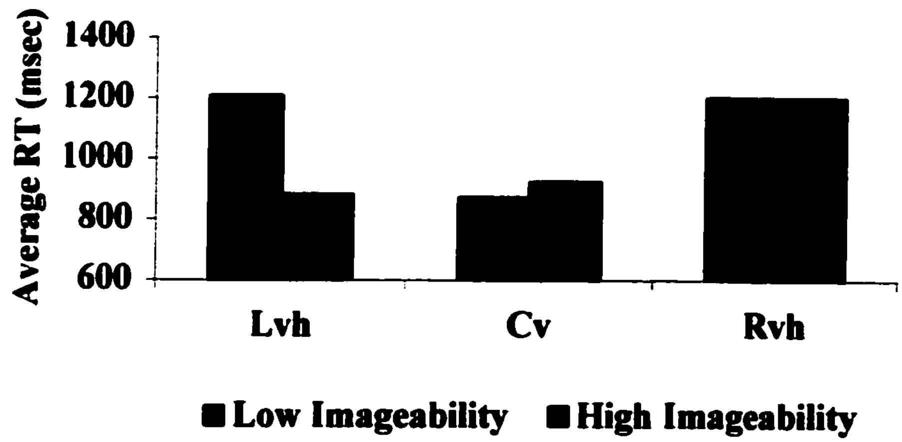

Average RT (msec)
1400
1200
1000
800
600
Lvh
Cv
Rvh
Low Imageability
High Imageability

Figure 2

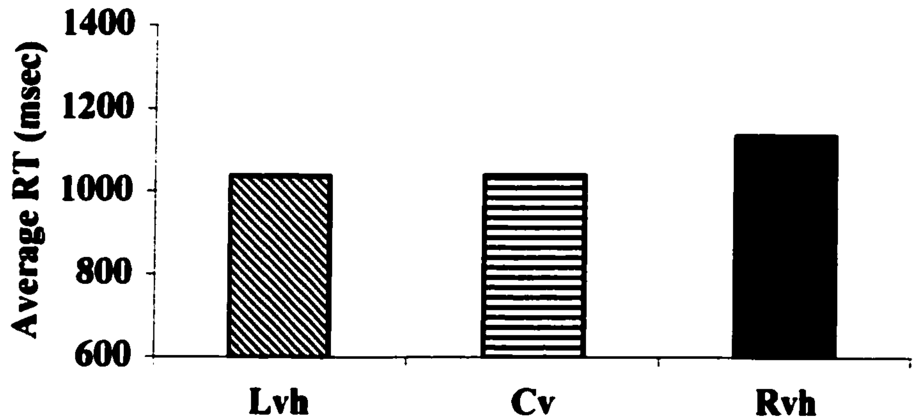
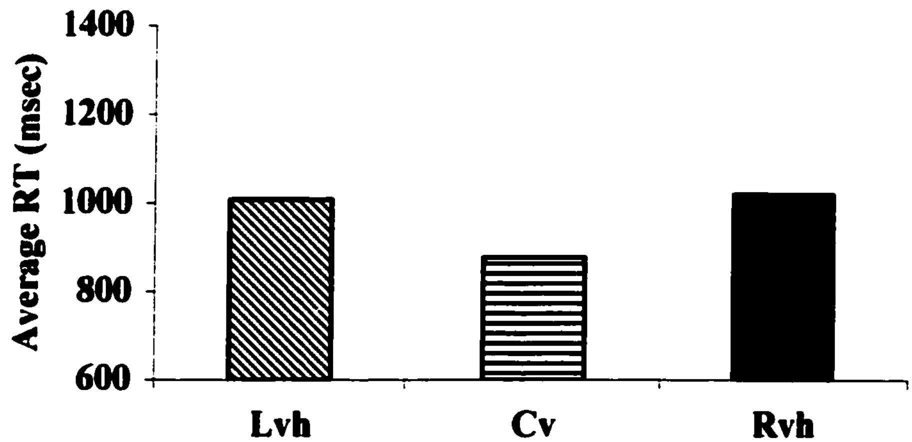


Figure 3



Acknowledgments

This work was made possible by the financial support of Consejo Nacional de Investigación en Ciencia y Tecnología de la República Argentina (A.I.A.), as well as a group grant (M.A.) and a team grant (A.R.L.) from the FCAR. Martin Arguin is a research fellow under the Fonds de la recherche en santé du Québec. This work was done in partial fulfillment of the requirements for Ana Inés Ansaldo's Ph.D. dissertation.

Chapitre 3

Article 2

The contribution of the right cerebral hemisphere to the recovery from aphasia: A single longitudinal case study

Ana Inés ANSALDO, Martin ARGUIN & André Roch LECOURS

Accepté pour publication dans Brain and Language, Janvier 2002

Running title: RIGHT HEMISPHERE AND RECOVERY FROM APHASIA

ABSTRACT

We examined the role of the right cerebral hemisphere in the recovery from aphasia of HJ, a 50-year-old right-handed and unilingual man who suffered from severe aphasia caused by an extensive left hemisphere (LH) lesion. He was followed-up over 10 months at four-month intervals, with a lateralized lexical decision task (LDT), an attentional task, and a language battery. Testing started when HJ was two months post-stroke. In the LDT, words were presented to central vision or lateralized to the left or right visual hemifield. At each test period, we examined the effect of the degree of imageability (high vs. low), and the grammatical class (noun vs. verb) of the targets on HJ's response times and error rates, with left visual field, right visual field and central vision presentations. The results of the experiment showed that the pattern obtained with the LDT could not be accounted for by fluctuations in attention. There was an interaction of grammatical class with degree of imageability with left visual field displays only. The right hemisphere (RH) was faster with high-imageability words than with low-imageability words, regardless of their grammatical class. There was also an overall RH advantage on response times at two and six months after onset. This RH predominance coincided with a major recovery of language comprehension and the observation of semantic paralexias, while no major change in language expression was observed at that point. Ten months after onset, the pattern of lateralization changed, and response times for the LDT with either presentation site were equivalent. This LH improvement coincided with some recovery of language expression at the single-word level. The results of this study suggest that, in cases of severe aphasia caused by extensive LH lesions, the RH may play an important role in the recovery process. Furthermore, these results show that the contribution of the two cerebral hemispheres to recovery may vary over time and affect specific aspects of language.

Keywords: aphasia, recovery, right hemisphere, imageability, grammatical class, longitudinal

INTRODUCTION

Aphasia caused by left hemisphere damage in right-handed subjects is generally followed by some degree of language recovery. It has proven difficult to identify the mechanisms underlying this recovery. Determining the neural substrate for recovery and its relationship with specific aspects of word processing may provide cues for language intervention. This paper reports on a literature review of the issue and then a study of language recovery in an aphasic patient.

It is generally accepted that the brain may use either of two ways to cope with language impairment following cerebral damage: the recovery of the language-relevant areas in the left hemisphere (LH), or the reorganization of the language-relevant network by recruiting supplementary brain areas in the left or right hemisphere (RH). The former hypothesis was first proposed by Wernicke (1874), while the latter was advanced by Broca (1865), who raised the theoretical question of why a patient who became aphemic following a lesion in the left third frontal convolution could not learn to talk with his RH.

More than one century ago, Gowers (1887) provided empirical evidence of the role played by the RH in the recovery from aphasia, when he reported the case of a right-handed subject who became aphasic following a LH lesion, recovered language as time elapsed after his aphasia, and then lost this recovered language following a second lesion in the RH. Accordingly, Gowers proposed that recovery from aphasia could result from RH takeover of language aspects previously committed to the damaged regions of the LH. Since then, much clinical and experimental evidence has indicated that the RH may sustain a recovery from aphasia, particularly in cases of severe left cerebral damage.

Among clinical investigations, a series of studies similar to that of Gowers (1887) have reported cases of aphasic subjects who recovered some language functions and then lost the recovered language following a new lesion in the RH. These findings have consistently been interpreted as evidence for RH takeover following aphasia (Moutier, 1908; Henschen, 1926; Nielsen & Raney, 1939; Nielsen, 1946; Levine & Mohr, 1979; Cambier, Elghozi, Signoret & Hennin, 1983; Basso, Giardelli, Grassi & Mairotti, 1989). In spite of the interest of such clinical studies, one should interpret their observations with regard to the RH's role in recovery from aphasia with caution. The pattern described in these studies could very well result from diaschisis (Von Monakow, 1914), a neurophysiological phenomenon that causes a disruption of brain activity in cerebral regions that are distant from the damaged areas. Hence, the deterioration of a previously improved language function after a new RH lesion could result from the effect exerted by the latter upon the homologous regions in the LH, rather than from the destruction of newly acquired RH language functions after left brain damage. Given that the earlier studies reported changes in the aphasic condition in the short term following an RH lesion, the possibility that diaschisis may be responsible for the loss of recovered language cannot be excluded.

In a different type of clinical report, Cummings, Benson, Walsh and Levine (1977) described the recovery of auditory comprehension and automatic speech in an individual who had become globally aphasic following an embolic infarction in the distribution of the left middle cerebral artery. Computerized tomography (CT) showed the total destruction of the LH language areas. From this, the authors concluded that the RH necessarily sustained the recovered language. As reported by Cummings et al., it is likely that the RH plays an important role in language recovery when aphasia results from the massive destruction of the LH; however, this may not be so when damage to the LH is not extensive. Residual portions of the LH may be responsible for language recovery in such cases.

Congruently, neuroimaging and neurophysiological studies have found that there is an inverse correlation between the size of the LH lesion and the degree of language recovery (Demeurisse & Capon & Verhas, 1985; Heiss, Kessler, Karbe, Fink & Pawlik, 1993). This observation supports the claim that the residual portions of the LH are crucial for the recovery from aphasia. For instance, Heiss et al. (1993) used positron emission tomography (PET) to study a group of acute aphasic subjects. They found that the resting metabolism of the LH outside the area of infarct was the single most important predictor of language performance on a word repetition task four months after stroke. Demeurisse & Capon (1987) conducted a longitudinal study in which they examined the correlation between clinical recovery and the changes in regional cerebral blood flow which signal cerebral activation. The authors found that the recovery of oral expression was positively correlated with the number of activated LH regions three weeks after the stroke. In contrast to the previous studies, however, bilateral participation in the recovery from aphasia was claimed by Weiller et al. (1995), who studied a group of recovering aphasics using PET and functional magnetic resonance imaging (fMRI). Over time, these authors found an increased activation in the left frontal language areas and right perisylvian areas of their subjects, during continuous silent lexical search and silent repetition of verbs. According to the authors, these findings indicate that both cerebral hemispheres contribute to the recovery from aphasia. Notwithstanding the interest of this study, given that the authors used a silent task, it is not possible to ascertain the extent to which the aphasic subjects could accomplish the task, and thus the interpretation of the results should be prudent.

Another experimental paradigm that has been used to examine the performance of the two cerebral hemispheres during the recovery from aphasia involves divided auditory or visual field presentations. Aphasic subjects given lateralized tasks have shown a left-ear advantage on auditory tasks (Castro-Caldas & Silveira Bothelo, 1980; Niccum et al., 1986), and a left visual field advantage on visual tasks (Schweiger & Zaidel, 1989). The left-side advantage has been taken as evidence of a RH takeover of language processing following aphasia. However, a left-side advantage may also have resulted from a shift of attentional resources to the left hemifield as a consequence of the LH lesion (Kinsbourne, 1978). The above observations therefore do not provide definitive evidence of an RH takeover specific to language processing.

In summary, the literature is not unanimous with regard to the role of the RH in the recovery from aphasia. Neurophysiological and neuroimaging studies (Demeurisse & Capon, 1985 ; Heiss et al., 1993) suggest that it is the preservation of the LH that determines recovery, whereas clinical evidence (Moutier, 1908; Henschen, 1926; Nielsen & Raney, 1939; Nielsen, 1946; Levine & Mohr, 1979; Cambier et al., 1983; Basso et al., 1989), and lateralization studies (Schweiger & Zaidel, 1989; Castro-Caldas & Silveira Bothelo, 1980; Niccum et al., 1986) suggest that the RH may play a role in the recovery from aphasia.

Evidence from studies of neurologically intact subjects indicates that their RH is sensitive to lexical semantic information. Thus, divided field studies with normal subjects have found that the habitual right visual field advantage–LH superiority (Rvf-LH) attenuates or even disappears with visual presentations of concrete and/or high-imageability words (Day, 1977, 1979; Ellis & Shepherd, 1974; Hines, 1976; Mannhaupt, 1983; Young & Ellis, 1985). More specifically, Day (1979) found no difference between response times to left and right visual field presentations of high-imageability nouns, but found an Rvf-LH advantage with low-imagery nouns and verbs, regardless of their degree of imageability. The author concluded that the RH can process high-imageability nouns, while low-imageability nouns and verbs are exclusively 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; Lambert & Beaumont, 1983; McMullen & Bryden, 1987; Eviatar, Menn & Zaidel, 1990).

This lack of consistency between studies may result from such methodological issues as the lack of control over lexical frequency Hence, Nieto, Santacruz, Hernandez, Camacho-Rosales and Barroso (1999) found an imageability effect with both nouns and verbs, arguing that Day (1979) failed to find an imageability effect with verbs because he did not control for lexical frequency in the verb category. Furthermore, Nieto et al. claim that Eviatar et al. (1990) failed to find a differential effect of grammatical class or imageability across the Rvf-LH and the left visual field–right hemisphere (Lvf-RH) because the set of verbs they used was actually made up of words that are both nouns and verbs. In summary, the results of lateralization studies with normal populations show that imageability, word class, and word frequency should all be taken into consideration and strictly controlled for when examining the role of the RH in the recovery from aphasia.

The purpose of the present study was to examine this very issue. We examined longitudinally the impact of degree of imageability and grammatical class on the lexical decision performance in HJ, a severely aphasic subject who suffered from a large lesion in the LH. HJ was followed at four-month intervals for a period of ten months, using a lateralized lexical decision task, an attentional task, and an aphasia test battery. The results of this experiment are discussed with reference to the RH's role in the recovery from aphasia.

CASE REPORT

HJ, a 50-year-old right-handed, French-speaking man was admitted in May 1997 for assessment of a right hemiplegia and aphasia. In April 1997, HJ had undergone a coronary bypass, after which he suffered sudden right hemiplegia and aphasia resulting from occlusive CVA. HJ had no history of cerebrovascular disease and no family history of left-handedness. He was French-speaking and had a university degree. A CT scan conducted in May 1997 showed a large infarct in the distribution area of the left middle cerebral artery. The infarct comprised the cortical perisylvian regions of the left frontal, parietal and temporal lobes, thus including all of Broca's and Wernicke's areas. In June 1997, HJ underwent the Montreal-Toulouse protocol for language assessment (Béland & Lecours, 1990: see description below). Oral comprehension was limited to isolated words (5/9 correct on oral word comprehension), and he could discriminate between written words and non-words (10/10 correct). There were no paraphasias or neologisms. Speech consisted of monosyllables and was effortful with some articulatory difficulty, but it remained intelligible, though meaningless. Oral word reading was impossible (0/5). HJ showed no clinical signs of hemianopia or visual neglect. HJ received language therapy during the ten months of follow-up. Therapy was provided by a speech-language pathologist and consited on tasks aimed at improving communication abilities. Both language comprehension and language expresion were stimulated since the begining of language therapy which coincided with T1, and stimualtion of both aspects continued until the end of the experiment, and for two years after aphasia onset. Given the severity of HJ's aphasia, the main efforts were concentrated on developping alterantive functional communication via gestures and communication boards. HJ received four language therapy sessions of 60 minutes per week. Experimental testing was provided by someone blind to HJ's involvement in language therapy.

MATERIALS AND METHODS

The experimental protocol made use of three tasks:

a. An aphasia test battery: the Montreal-Toulouse Aphasia Battery (Béland & Lecours, 1990), which served to determine HJ's pattern of aphasia.

b. A lateralized lexical decision task (LDT), in order to compare HJ's performance on Lvf-RH, Rvf-LH and central vision presentations of isolated words.

c. An attentional task: the Non-Verbal Stroop Test (Beauchemin, Arguin & Desmarais, 1996), which served as an assessment of attentional resources.

Repeated measures were obtained on all three tasks at two, six, and 10 months post–aphasia onset. These repeated measures are labeled T1, T2, and T3, respectively. The order of presentation of the tasks was the same at each test period. In this way possible order effects were controlled throughout the experiment. Each task is described in detail below.

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 in both encoding and decoding oral and written language. Even though the MT Battery was administered in its complete version, only the results of a subset of tasks are reported here, because they provide information about HJ's language comprehension and oral language expression abilities, which were the focus of this study. 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. 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. 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, distractors depicted semantic alternatives to the target. For reversible sentences, 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[1], each with pictures of six objects, were presented to the subject one at a time.[2] The subject was given a card with the name of the target and had to match it with the corresponding picture. Each

[1] The original task includes five trials. Given that there was a ceiling effect at baseline, 10 trials were added in order to examine the development of word comprehension habilitiis over time.

[2] The items used in the written comprehension subtest are different from those used in the oral comprehension subtest.

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. 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, distractors depicted semantic alternatives to the target; for reversible sentences, 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[3]. 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.

[3] The items used in the oral and written naming subtests are the same

B. LEXICAL DECISION TASK: The LDT was run on a Power Macintosh 7300/180 computer. The subject was asked to indicate whether or not a letter string presented by itself on a computer screen corresponded to a word in French.

Materials and Stimuli: Two hundred and forty words and 240 non-words were selected for use as experimental stimuli. Non-words were generated by altering one or two letters in a real word and were matched to words on digraph frequency (Mayzner & Tresselt, 1965). Non-words were pronounceable, and they were formally and phonologically close to French words. 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. Since 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). 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 seven-point scale, using a French translation of the instructions of Paivio, Yuille and Madigan (1968) for rating nouns, as modified for rating verbs. Mean imageability was 6.69 for highly imageable words, and 4.15 for low-imageability words.

The resulting 480 stimuli were divided into five blocks, each containing 48 words (24 nouns and 24 verbs; 12 high-imageability foils and 12 low-imageability foils for each grammatical category), and 48 non-words. Twenty practice items (10 words and 10 non-words) were constructed in the same manner and served as a practice block.

A black dot presented at the center 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 in the center of the screen or lateralized to either side of the fixation point. For lateralized 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 center of the screen.

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

Stimuli were randomly presented either to the left or the right of the fixation point, which appeared on the center of the screen at the beginning of each trial. HJ 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 vice versa. By the end of the practice block, the optimal presentation time was determined and it was kept constant during the experimental session. The optimal presentation time proved to be 950 ms at T1, and 929 ms at T2 and 950 at T3.

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 a particular aspect of the stimulus, and ignore the irrelevant information that it also contains. Given that the conventional Stroop task consists in a color/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 Power 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 tasks on arrows pointing left or right, which were displayed to the left or right of fixation. For each task, we contrasted a condition where the direction of the arrow and its location were incongruent and another condition where both sources of information were congruent. The subject responded with his left hand by pressing on 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 (T1, T2, and T3), the number of correct responses on each subtest as well as the types of errors committed (i.e. type of paraphasia, type of paralexia) were considered. These results are outlined in Table 1.

Insert Table 1 here

There was an improvement in comprehension over time, in both the oral and written modalities. Specifically, it concerned written word and oral sentence comprehension, and was mainly observed between T1 and T2 . Oral and written naming were severely impaired at T1, as was reading aloud. HJ showed some improvement in these language tasks over time (see Table 1). At T2, HJ could give semantic alternatives to the target. Hence, he said *light* for *lamp* and *stairs* for *ladder* on the oral naming task. When reading words aloud, the only answers given were semantic paralexias (e.g. *book* for *school*, and *father* for *parents*). At T3, semantic errors persisted, and HJ was able to provide some correct answers, specifically on the naming tasks (see Table 1). Thus, HJ produced 9/31 correct responses on the oral naming task, plus 5/31 semantic paraphasias, and 9/33 correct on the oral reading task plus 8/33 semantic paralexias.

In summary, both language comprehension and language expression improved with time, but comprehension improved more between T1 and T2, whereas language expression started to improve at T3. By the end of the experiment, HJ showed functional oral comprehension abilities. Oral expression remained reduced and limited to single-word utterances and automatic speech.

B. Lexical Decision Task

An overview of the results from the lexical decision task is shown in Table 2. There was a significant reduction in the global error rates (ER) over time (x^2 (2) =

12.24, $p < 0.01$). This ER reduction with time was verified with lateralized presentations (Lvf: $x^2 = 10.74$, $p < 0.05$, and Rvf: $x^2 = 11.07$, $p < 0.05$), but not with Cv displays ($x^2 = 3.1$, *ns*). ER with Rvf displays were much higher than ER with Lvf or Cv presentations at T1 (x^2 (2) = 1.3, $p < 0.001$), at T2, (x^2 (2) = 7.5, $p < 0.01$), and T3 (x^2 (2) = 10.5, $p < 0.01$); in fact, accuracy with Rvf displays was at chance at T1 (x^2 (2) = 12.54, $p < 0.1$), but above chance at T2 ($x^2 = 11.08$ $p < 0.05$) and T3 ($x^2 = 11.05$, $p < 0.01$). Furthermore, ER decreased significantly over time with nouns ($x2 = 10.03$ $p < 0.01$) and with high-imageability verbs ($x^2 = 9.69$, $p < 0.05$). However, time elapsed after aphasia did not improve accuracy significantly with low-imageability verbs ($x^2 = 0.5$, $p = ns$).

Insert Table 2

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 for the condition they belonged to were eliminated from the analysis (4.5% of correct RT at T1, 3% at T2, and 3% at T3). 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: $x^2$2) = 0.845, $p = ns$; at T2: $x^2$2) = 0.737, $p = ns$, and at T3: $x^2$2) = 0.650, $p = ns$). The resulting sample of correct RT was submitted to a 3 x 3 x 2 x 2 ANOVA including the factors of Time Post–Aphasia Onset (T1, T2, and T3), 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 grammatical class x imageability x presentation site ($F(2,438) = 3.81$, $p < 0.05$), as well as a triple interaction of time x grammatical class x presentation site ($F(4,438) = 2.56$, $p < 0.05$). Moreover, there was a main effect of time elapsed after aphasia on RT ($F(2,438) = 32.04$, $p < 0.001$).

The only statistically significant effect obtained with the simple effects analysis of the grammatical class x imageability x presentation site interaction was an interaction of grammatical class x imageability with Lvf displays (F(1,438) = 8.23, $p < 0.01$, see Fig. 1). Thus, with Lvf displays, the degree of imageability had a clearly significant effect on RT with verbs (F(1,438) = 4.50, $p < 0.05$), whereas the effect with nouns was marginally significant (F(1,438) = 3.78, $p \leq 0.052$). Hence, when targets were presented in the Lvf, RT with high-imageability verbs and nouns were faster than with low-imageability verbs and nouns, respectively. No other main effect or interaction in the tests performed with respect to the three-way interaction of grammatical class x imageability x presentation site reached significance.

Insert Figure 1 here

Analysis of the simple effects of the time x grammatical class x presentation site interaction led to the following results: at T1, the only statistically significant effect was a main effect of presentation site (F(2,438) = 5.24, $p < 0.01$) (see Figure 2). A post hoc Tukey (a) Test showed an advantage on Cv over Rvf displays ($p < 0.01$) and also on Lvf over Rvf displays ($p < 0.01$), but no difference between the performance on Cv and Lvf presentations.

Insert Figure 2 here

A similar pattern was observed at T2. Thus, there was an effect of presentation site (F(2,438) = 5.73, $p < 0.01$, see Figure 3), and a post hoc Tukey (a) Test showed an advantage on Cv over Rvf displays ($p < 0.01$), but no difference between performance on Cv and Lvf displays ($p < 0.01$). As in the previous session, there was also an Lvf advantage over the Rvf ($p < 0.05$).

Insert Figure 3 here

In contrast, no effect of presentation site on RT was observed at T3 ($F(2,438) = 1.38$, *ns*) (see Table 2). However, there was a grammatical class effect at T3 ($F(1,438) = 8.27$, $p < 0.01$), with shorter RT for nouns (1014 ms) than for verbs (1124 ms).

In order to examine the relationship between performance on the LDT with Cv presentations and performance with either cerebral hemisphere over time, Spearman Correlation Coefficients were used. Thus, average correct RT across grammatical class x imageability factors obtained with Cv displays at T1, T2 and T3 were correlated with the corresponding average correct RT with Rvf and Lvf displays respectively. None of the correlations reached 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 tended to respond 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 analyzed by chi-square.

Insert Table 3 here

A 3 x 2 ANOVA with factors of Time elapsed after aphasia (T1, T2, and T3) and Congruence between the location and orientation information (congruent vs. incongruent) was applied on the correct RT observed in the location task. It showed an interaction of time x condition ($F(1,485) = 8.18$, $p < 0.01$). The congruence between the location and orientation information affected performance at every experimental session (at T1: $F(1,357) = 35.38$, $p < 0.001$; at T2: $F(1,357) = 4.72$, $p < 0.05$; at T3: $F(1,357) = 8.90$, $p < 0.01$). Thus, RT with the congruent condition were shorter than with the incongruent condition throughout the experiment. The magnitude of the congruence effect varied across sessions; specifically, it was slightly higher at T2 than at T1 and T3, which did not differ.

D. RELATIONSHIP BETWEEN THE RESULTS ON THE LEXICAL DECISION AND ATTENTIONAL TASKS

It has been argued that presentation site effects on language tasks in recovering aphasics may result from attentional factors with no implications for the linguistic abilities of either cerebral hemisphere. Thus, it has been claimed that a left-side advantage for language tasks may result from a shift of attentional resources to the left hemifield, as a consequence of the LH lesion (Kinsbourne, 1979), or simply from the superior attentional abilities of the RH (Seron & Jeannerod, 1994). In the case reported here, the results obtained with the LDT and those with the NVST tend to be closely related, but inversely. Thus, at T2, when RT with the LDT are shortest, the performance on the NVST is the worst (i.e. largest congruency effect). These inverse patterns suggest that performance variations on the LDT cannot be attributed to the recovery of attention.

DISCUSSION

The goal of this study was to examine the role of the RH in the recovery from aphasia of HJ, who suffered from a severe aphasic disorder. The results show that HJ's performance on the lateralized lexical decision task was jointly influenced by degree of imageability, presentation site, time elapsed, and grammatical class.

Time elapsed after aphasia contributed to a reduction in the ER with all word types except low-imageability verbs. There was also a reduction in the ER over time for Lvf-RH and Rvf-LH presentations, but the ER was lower for Lvf-RH presentations than for Rvf-LH presentations at all times.

With regard to response times, HJ showed shorter RT with high-imageability nouns and verbs than with low-imageability nouns and verbs, when these were presented to the Lvf-RH, whereas no effect of imageability on Rvf-LH presentations was observed. At T1 and T2, RT to Lvf-RH presentations were as fast as those to Cv displays and shorter than those to Rvf-LH presentations. During the same period, the results on the aphasia battery showed some improvement in oral and written comprehension but no major change in oral expression. At T3, RT to Rvf-LH displays improved considerably relative to T2, and there was no longer any presentation site effect. Concurrently, the results on the aphasia battery showed some improvement in oral expression, particularly oral naming. At T3, there was also a grammatical class effect on the lexical decision task, with faster RT for nouns than verbs.

With regard to the development of attentional resources over time, the results of the Location Task of the NVST only showed a slight decline at T2 (i.e. increased Stroop effect). Finally, performance on the NVST and LDT was closely but inversely related. Thus, when the NVST resulted in the greatest Stroop effect (i.e. T2), RT with the LDT were shortest. This pattern indicates that the results obtained on the LDT cannot be accounted for by fluctuations in attentional capacities over time. Therefore, the changes in the patient's performance on the LDT through time should be interpreted in terms of changes in linguistic rather than attentional capacities.

Lexical Decision Task: We shall first discuss the error data and then move on to a discussion of RT data. Both cerebral hemispheres improved over time, but the RH's superior accuracy was maintained throughout the experiment. From T1 to T3, there was also a reduction in the ER with high- and low-imageability nouns and high-imageability verbs, but not low-imageability verbs. Since this improvement did not differ as a function of presentation site (i.e. no time x site x grammatical x imageability interaction), it appears to be a function of both hemispheres' improving their linguistic capacity.

Regarding RT on the LDT, the RH was faster with high than low-imageability targets, regardless of their grammatical class (i.e. noun or verb), whereas no such effect was found for the LH. Nieto et al. (1999) made similar observations in their study with normal subjects. Conversely, Day (1977, 1979) reported that an Lvf x high imageability effect was present only for nouns. However, while in this study, as in Nieto et al.'s, lexical frequency for high- and low-imageability targets was controlled for within each grammatical category, Day failed to control for lexical frequency across grammatical categories. Hence, Day (1977, 1979) described his stimuli as «fairly common» but did not check for the existence of word frequency differences between the nouns and verbs. This lack of control for lexical frequency in Day's studies may well account for the lack of any imageability effect with verbs presented to the RH. Finally, if the Nieto results are taken into consideration as a baseline for the normal RH effect with verbs, the RH superiority with high-imageability verbs observed in HJ is likely to reflect his pre-morbid RH capacities.

The RT with Lvf-RH targets at T1 and T2 (two and six months post-onset, respectively) suggest an RH superiority at the beginning of the experiment, which increased at T2. It should be pointed out that, at T1 and T2, there was no difference between RT with RH presentations and RT with Cv presentations. This suggests that, at those test sessions, lexical processing in central vision mainly depended on the RH. In that same period, language comprehension improved while language expression remained severely impaired. The recovery of language comprehension in the sub-acute state of the recovery from aphasia has been related to RH activity in metabolic (Demeurisse & Capon, 1987; Heiss et al., 1993) and clinical studies (Gainotti, 1993). More specifically, Cappa et al. (1997) found a positive correlation between the recovery of comprehension and the increase in metabolic activity in the RH in a group of aphasics followed-up between two weeks and six months after stroke. Interestingly, HJ showed a Lvf-RH advantage on the lexical decision task and a recovery of comprehension roughly within the same time window as that explored by Cappa et al. (1997).

The fact that our patient showed no improvement in expression tasks within the same period (i.e. T1 and T2) suggests no recovery of the LH. The literature shows that there is a close relation between recovery of the LH and improvement in oral expression tasks (Heiss et al., 1993). Furthermore, the production of semantic paralexias observed at T2 seems congruent with the assumption of RH superiority in lexical processing between two and six months after aphasia onset. Hence, it is considered that in cases of extensive LH lesions, the production of semantic paralexias during the recovery from aphasia reflects RH reading (Landis & Regard, 1983). Specifically, it is argued that the RH provides a lexical address that is unconstrained by phonology, and thus semantic paralexias are likely to occur (Landis & Regard, 1983). HJ had an extensive LH lesion and presented semantic paralexias, a Lvf-RH advantage on the LDT, and selective improvement on comprehension tasks. This pattern may be interpreted as an indication that the language recovery observed in HJ between two and six months after onset was sustained by the RH.

Schweiger and Zaidel (1989) described a similar pattern of recovery in the case of RW, an aphasic subject who showed an Lvf-RH advantage in a lexical decision task and semantic paralexias in reading tasks. The authors concluded that RW showed a shift to RH dominance for lexical decisions. However, Schweiger and Zaidel's patient was a bilingual woman. The literature shows that bilingual subjects and women may have less marked LH lateralization for language processing (Hiscock, Israelian, Inch, Jacek & Hiscock-Kalil, 1995). Therefore, in the case reported by Schweiger and Zaidel, the RH superiority may have been largely a function of an atypical pre-morbid language lateralization. In the case reported here, the RH dominance observed cannot be attributed to the pre-morbid factors of gender or bilingualism, since HJ is a unilingual male.

At T3, HJ's pattern of lateralization on the LDT changed. There was a reduction in RT with LH displays relative to T2, while RT with RH displays remained stable in the same interval. There was no presentation site effect, given that the difference between RT with lateralized and Cv presentations was no longer significant. Concurrently, an improvement was observed in oral naming at T3, while the scores on comprehension tasks remained stable relative to T2. Although semantic paralexias were still frequent, oral language gained in fluency, specifically at the word level. As discussed in the previous paragraph, an improvement in oral expression has consistently been related to the recovery of LH function during the recovery from aphasia (Demeurisse & Capon, 1987; Gainotti, 1993; Heiss et al., 1993). In line with these findings, the improvement in RT with LH presentations in the LDT, together with the improvement of oral expression observed in HJ, points to a recovery of the LH at T3.

Overall, the results of the LDT indicate a change in the pattern of hemispheric lateralization with time elapsed after aphasia. There was an RH superiority on RT at T1 and T2, and a more equivalent participation of both cerebral hemispheres in lexical processing at T3. Changes in the lateralization pattern during the recovery from aphasia have been reported in activation studies using cortical potentials (Thomas, Altenmüler, Marckmann, Kahrs & Dichgans, 1997), regional cerebral blood flow (Demeurisse & Capon, 1987; Karbe et al., 1997), and PET (Cappa et al., 1997; Karbe et al., 1998). These studies describe changes in the pattern of lateralization over time which are consistent with the observations of the present study. Thomas et al. (1997) reported that Broca's aphasics subjected to a silent search for synonyms showed an increased activation in the RH at one month post-aphasia onset, and a shift back to LH lateralization one year after aphasia onset. The fact that HJ presented with Broca's aphasia and an initial RH dominance in the LDT is in line with these findings. Moreover, the recovery of the LH observed 10 months after aphasia in HJ (i.e. T3) could indicate the beginning of greater LH participation in HJ's language recovery. Unfortunately, this study was not pursued long enough after HJ'S aphasia onset to examine this possibility. Finally, HJ showed faster RTs with nouns than with verbs at T3. These results are in line with previous reports by Micelli et al. (1988), who found that subjects with Broca's aphasia are more impaired in processing verbs than nouns.

CONCLUSION

The results of this experiment show that both cerebral hemispheres participated in HJ's recovery from aphasia. However, the pattern of lateralization with the lexical decision task indicates that the relative contribution of the two cerebral hemispheres varied during the course of recovery. The RH appeared to dominate language processing between two and six months after aphasia, and this coincided with an improvement in language comprehension, but not in language expresion. Furthermore, the RH was particularly sensitive to high-imageability words, regardless of their grammatical class. These results suggest that, in cases of severe aphasia due to extensive LH lesions, high-imageability words may be more likely to recover and thus should be particularly considered when planning language therapy. Ten months after aphasia onset, however, there was a recovery of the LH, but the contribution of the RH did not decline, and both hemispheres were at that point equivalent in terms of speed of response. However, the RH was still more efficient in terms of accuracy. At the same time, language comprehension remained stable by reference to previous test sessions, whereas there was also an improvement in oral expression. The impact of language therapy on the evolution of the latarlization pattern overtime is difficult to evaluate. It is interesting to notice that HJ continued to show language recovery throughout the two years during which he received therapy, and that his communication abilities, particularly with regards to language expresion, have continued to improve showing that recovery from aphasia is a long term process.

To conclude, the present findings suggest that even when both cerebral hemispheres participate in the recovery from aphasia, either one may contribute to the recovery of specific language abilities. The RH seems capable of sustaining the recovery of language comprehension and the processing of high-imageability nouns and verbs. Hence, the recovery of comprehension may start early after stroke and attain a functional level even in cases of severe aphasia following extensive lesions in the main LH language areas Conversely, severe damage to the LH will seriously compromise the recovery of language expression, which may take longer to begin, since it seems to depend on the recovery of LH function. The process of recovery from severe aphasia is long, and thus opens a wide window for language rehabilitation.

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 aging. *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.

Boles, D.B. (1983). Dissociated imageability, concreteness and familiarity in lateralized word recognition. *Memory and Cognition* 11, 511-519.

Broca, P. (1865). Sur la facultté du langage articulé. *Bulletin de la Societé d'anthropologie*, *6*, 337-393.

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.

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.

Cummings, J.L., Benson, D.F., Walsh, M.J., & Levine, H.L. (1977). Left-to-right transfer of language dominance. A case study. *Neurology*, 29, 1547-1550.

Day, J. (1977). Right-hemisphere language processing in normal right handers. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 518-528.

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

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

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

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.

Gainotti, G. (1993). The riddle of the right hemisphere's contribution to the recovery of language. *European Journal of Disorders of Communication*, 28, 277-246.

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

Heiss, W., Kessler, J., Karbe, H., Fink, G., & Pawlik, G. (1993). Cerebral glucose metabolism as a predictor of recovery from aphasia in ischemic stroke. *Archives of Neurology*, 50, 958-964.

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.

Hines, D. (1976). Recognition of verbs, abstract nouns and concrete nouns from the left and right visual half fields. *Neuropsychologia*, 14, 211-216.

Hiscock, M., Israelian, M., Inch, R., Jacek, C., & Hiscock-Kalil, C. (1995). Is there a sex difference in human laterality? II. An exhaustive survey of visual laterality studies from six neuropsychology journals. *Journal of Clinical and Experimental Neuropsychology*, 17, 590-610

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

Howell, J.R., & Bryden, M.P. (1987). The effects of word orientation and imageability on visual half-field presentations with a lexical decision task. *Neuropsychologia, 25*, 527-538.

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.

Kingma, A., La Heij, W., Fasotti, L., & Eling, P. (1996). Stroop interference and disorders of selective attention. *Neuropsychologia*, 34, 273-281.

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

Koening, O., Wetzel, C., & Caramazza, A. (1992). Evidence for different types of lexical representation in the cerebral hemispheres. *Cognitive Neuropsychology*, 9, 33-45.

Lambert, A.J., & Beaumont, J.G. (1983). Imageability does not interact with visual field in lateral word recognition with oral report. *Brain and Language*, 20, 115-142.

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

Levine, D.N., & Mohr, J.P. (1979). Language after bilateral cerebral infarctions: Role of the minor hemisphere in speech. *Neurology*, 29, 927-938.

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

Mannhaupt, H.R. (1983). Processing of abstract and concrete nouns in a lateralized memory search task. *Psychological Research*, 45, 91-105.

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

McLeod, B., & Walley, R. (1989). Early interference in a priming task with brief masked targets. *Canadian Journal of Psychology*, 43, 444-470.

McMullen, P.A., & Bryden, M.P. (1987). The effects of word imageability and frequency on hemispheric asymmetry in lexical decisions. *Brain and Language*, 31, 11-25.

Miceli, G.; Silveri, M.C.; Nocentini, U. & Carramaza, A. (1988). Patterns of disociation in comprehension and production of nouns and verbs. *Aphasiology*,, 2, 351-358.

Moutier, F. (1908). *L'aphasie de Broca.* Paris: Steinheil.

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.

Nielsen, J.M., & Raney, R.B. (1939). Recovery from aphasia studied in cases of lobectomy. *Archives of Neurology and Psychiatry*, 42, 189

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].

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.

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.

Von Monakow, C. (1914). Die Lokalisation im Grosshirn und der Abbau der Funktion durch kortikale Herde. Wiesbaden: Bergmann

Weiller, C., Isensee, C., Rijntjes, M., Huber, M., Müller, S., Bier, D., Duschka, K., Woods, R.P., Noth, J., & Diener, H.C. (1995) Recovery from Wernicke's aphasia: A positron emission tomographic study. *Annals of Neurology*, 37, 723-732.

Wernicke, K. (1874). The symptom complex of aphasia. *Boston Studies in the Philosophy of Science*, 6, 34-97.

Young, W., & Ellis, A. (1985). Different methods for lexical access for words presented in the left and right visual hemifields. *Brain and Language*, 24, 32-358.

Table 1

Correct Responses on Subtests of the MT Beta Protocol at Each Time of Measurement

	T1	T2	T3
Oral word comprehension	6/9	7/9	9/9
Oral sentence comprehension	6/38	12/38	14/38
Written word comprehension	4/15	8/15	10/15
Written sentence comprehension	1/8	3/8	3/8
Oral picture naming	1/31	3/31	8/31
Written picture naming	0/31	2/31	3/31
Reading words aloud	0/33	3/33	8/33

T1 = 2 months post–aphasia onset, T2 = 6 months post–aphasia onset, T3 = 10 months post–aphasia onset

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
Lvf	Average RT	1243.8	979.8	1097.7
	SD	286.8	196.7	227.4
	ER (%)	31.6	21.3	18.9
Cv	Average RT	1165.6	969.2	1025.4
	SD	277.7	220.5	213.1
	ER (%)	23.3	23.5	20.5
Rvf	Average RT	1334.4	1118	1063.6
	SD	343.8	255.0	239.9
	ER (%)	47.5	40.0	36.4
Global	Average RT	1247.9	1022.3	1062.2
	SD	84.4	83.0	36.1
	ER (%)	35.4	29.5	25.2

Table 3

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

			T1	T2	T3
Location Task	Congruent	RT	413.2	368.0	398.0
		SD	201. 0	113.0	52.4
		ER	0.1	0.0	0.6
	Incongruent	RT	611.0	591.0	596.2
		SD	158.7	94.3	70.1
		ER	0.6	0.1	0.2
Orientation Task	Congruent	RT	443.6	368.1	403.2
		SD	201.0	113.0	52.4
		ER	0.1	0.0	0.1
	Incongruent	RT	520.6	482.0	492.0
		SD	158.7	94.3	70.1
		ER	49.0	45.0	49.0
Congruency Effect		Location	197.7	223.0	198.1
		Orientation	76.9	114.0	88.8

Figure Captions

1. Figure 1

Lexical Decision Task: Imageability x Grammatical Class Interaction with Left Visual Field Displays

2. Figure 2

Lexical Decision Task: Presentation Site Effect at T1

3. Figure 3

Lexical Decision Task: Presentation Site Effect at T2

Figure 1

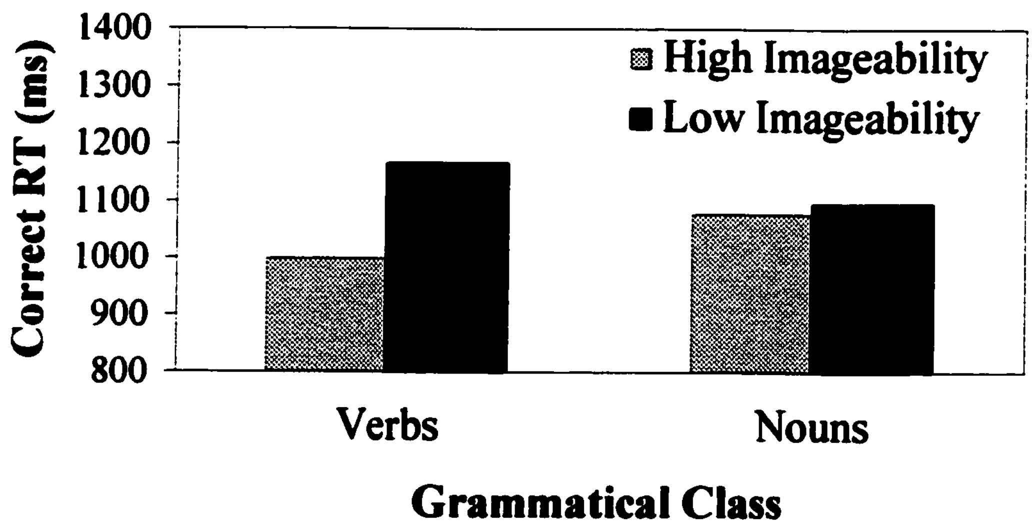

1400
1300
1200
1100
1000
900
800
Correct RT (ms)
High Imageability
Low Imageability
Verbs
Nouns
Grammatical Class

Figure 2

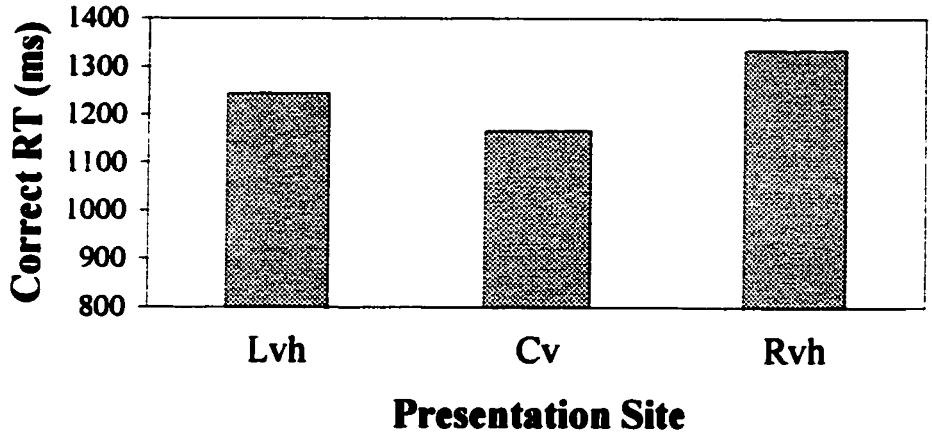
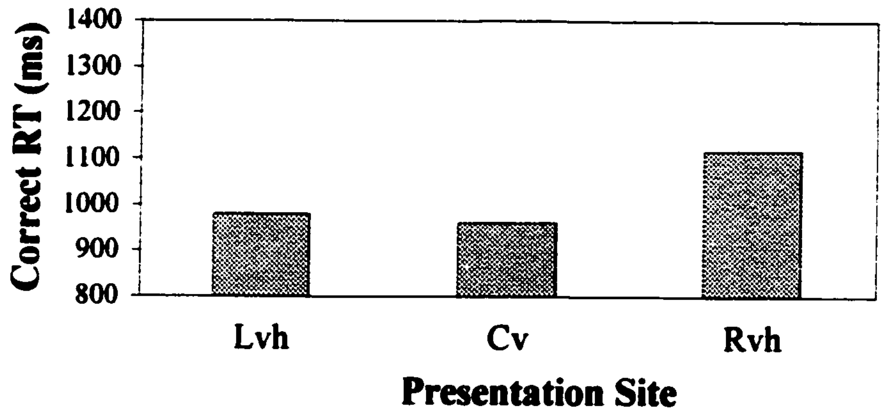

1400
1300
1200
1100
1000
900
800
Correct RT (ms)
Lvh
Cv
Rvh
Presentation Site

Figure 3


1400
1300
1200
1100
1000
900
800
Correct RT (ms)
Lvh
Cv
Rvh
Presentation Site

Acknowledgments

This work was made possible by the financial support of Consejo Nacional de Investigación en Ciencia y Tecnología de la República Argentina (A.I.A.), as well as a group grant (M.A.) and a team grant (A.R.L.) from the FCAR. Martin Arguin is a research fellow under the Fonds de la recherche en santé du Québec. This work was done in partial fulfillment of the requirements for Ana Inés Ansaldo's Ph.D. dissertation.

Chapitre 4

Article 3

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

Ana Inés ANSALDO, Martin ARGUIN & André Roch LECOURS

Soumis à Journal of Clinical and Experimental Neuropsychology, 2002.

Running Title: RECOVERY FROM APHASIA LANGUAGE, ATTENTION AND LATERALIZATION PATERNS

ABSTRACT

The hypothesis of a right-hemisphere take over of language processing as a source of recovery from aphasia has interested researchers since the last century. The question was first raised by Gowers in 1887, and despite the large body of clinical and experimental studies, the issue remains controversial. Thus, whereas metabolic studies show that long term recovery from aphasia depends upon improvement of left hemisphere function (Knopman et al, 1984; Cappa, 1997; Metter et al.1992), clinical reports (Basso, Gardelli, Grassi & Mariotti, 1989), as well as recent activation studies with neuroimaging techniques (Yamaguchi, 1980; Demeurise & Capon, 1987; Cappa et al. 1997; Karbe et al. 1998) suggest that recovery from aphasia may be sustained by the right hemisphere. Furthermore, the nature of the right hemisphere contribution is subject to debate. Divided visual field studies on non-brain damaged populations show that the RH is sensitive to specific linguistic variables (Joanette, Goulet & Hannequin 1990), and therefore suggest that the right hemisphere has a potential to provide a language specific contribution to aphasia recovery. However, it has been argued that the right hemisphere advantage on lateralized tasks results from pathological attentional mechanisms, consequence of left hemisphere lesion, and thus has no implication whatsoever on language recovery in aphasia.

This paper reports the results of a longitudinal single-case study on the patterns of lateralization for lexical semantic processing during recovery from aphasia. MJ a fifty-two-year-old, right-handed man, presented with an embolic CVA in the territory of the left middle cerebral artery and aphasia. He was followed-up during one year at a four month interval, with a protocol that included: a lateralized lexical decision task (LDT), an attentional task (NVST) and a language test (M-T Beta).

The results of this study show that recovery from aphasia was sustained by both cerebral hemispheres throughout the experiment. Both attentional factors and language factors played a role on MJ's performance on the lexical decision task. The influence of attentional factors was particularly evident five months after the stroke, concurrently

with the improvement of the comprehension of phrases as documented on language tests. However, a grammatical class by imageability interaction with Lvh displays on the lateralized lexical decision task provides evidence for a right hemisphere advantage specific to language processing. The results of this study highlight the advantage of experimental protocols that integrate lateralized tasks, non-verbal attentional tasks and language tests for the study of recovery from aphasia. In the case reported here, this cluster of experimental tools served to show the joint influence of language and attentional factors during the course of language recovery. Specifically, the results of this study suggest that attentional factors may play a role in the recovery of sentence comprehension. The interface between the recovery of language comprehension and attention as well as the lateralization patterns underlying its recovery remain to be explored.

INTRODUCTION

The hypothesis of a right-hemisphere take over of language processing as a source of recovery from aphasia has interested researchers since the last century. The question was first raised by Gowers in 1887, and despite the large body of clinical and experimental studies, the issue remains controversial. Clinical reports have shown that improved language abilities after aphasia relapsed following a new lesion in the right hemisphere (Moutier, 1908; Henschen, 1926, Nielsen & Raney, 1939; Nielsen 1946; Lecours et al. 1987; Levine & Mohr, 1979; Mazzocchi & Vignolo, 1979; Lee, Nakada, deal, Lin & Kwee, 1984; Basso, Gardelli, Grassi & Mariotti, 1989), a fact that was interpreted as evidence of right hemisphere take over of language processing after the left hemisphere lesion at the origin of aphasia. However, as focal brain damage can disturb functions on remote brain structures anatomically connected to damaged areas[3], the worsening of a previously improved aphasic syndrome after right hemisphere lesion could result from the remote effect exerted by the right hemisphere lesion on left hemisphere structures, and thus prove that recovery from aphasia depended on the left hemisphere and not on the right one.

More recently, activation studies on the recovery from aphasia with neuroimaging techniques have shown an increased metabolic activity in right hemisphere regions homologous to left hemisphere language areas during the acute state of recovery (Demeurise & Capon, 1987; Cappa et al. 1997; Karbe et al. 1998), a finding that has been interpreted as evidence of right hemisphere take over of language processing. Long-term recovery from aphasia, however, has been found to be mainly associated with greater regional cerebral blood-flow in the left temporo-parietal associative areas, whereas low metabolic activity in the left hemisphere was associated with poor language recovery (Knopman et al, 1984; Cappa, 1991; Metter et al.1992). However, the neuro-biological mechanisms that sustain cerebral activation are largely unknown. Cerebrovascular accidents affect cerebral metabolism and thus, it is possible that they

[3] This mechanism was decribed by Von Monakov in 1914, and is known as diaschisis. Diaschisis has beeen confirmed by a large number of studies (see Andrews, 1991 for review).

may disrupt activation mechanisms as well. Hence, cerebral activation patterns observed among recovering aphasic subjects during language tasks might result from non-specific cognitive processing related to the amount of resources demanded by the task. Being this as it may, and specifically concerning the role of the RH during recovery from aphasia, it is possible that the RH activation observed (Yamaguchi, 1980; Demeurise & Capon, 1987; Cappa et al. 1997; Karbe et al. 1998) reflect a non-specific language role of the RH during recovery from aphasia.

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. Using divided field presentations, researchers have shown that the performance with Lvh-RH presentations depends on the degree of imageability and the grammatical class of the target. Many studies with non-brain damaged populations have reported the attenuation, and even the absence of the habitual Rvh-LH advantage with visual presentations of high imageability words (Day, 1977, 1979; Ellis & Shepherd, 1974; Hines, 1976; Mannhaupt, 1983; Young & Ellis, 1985). Specifically, 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 (Day, 1979). Other studies, however, have reported no significant effect of these variables (e.g. Boles, 1983; Howell & Bryden, 1987; Koening, Wetzel & Caramazza, 1992; Lambert & Beaumont, 1983; McMullen & Bryden, 1987; Eviatar, Menn & Zaidel, 1990). This lack of consistency between studies can be attributed to methodological issues regarding the control over lexical frequency and grammatical class. Nieto, Santacruz, Hernandez, Camacho-Rosales and Barroso (1999) found an imageability effect with both nouns and verbs, and argued that Day (1979) failed to find an imageability effect with verbs because he did not control for lexical frequency in the verb category. Eviatar et al. (1990) failed to find a differential effect of grammatical class or imageability across the Rvf-LH and the left visual field–right hemisphere (Lvf-RH), but used a set of verbs which was actually made up of words that are both nouns and verbs.

The method of divided presentations has also been used with recovering aphasics. Early studies using auditory presentations report an advantage of the left over the right ear in recovering aphasics (Johnson, Sommers & Weidner, 1977; Petit & Noll, 1979; Castro-Caldas & Botelho, 1980; Papanicolau et al, 1988). However, Niccum et al. (1986) showed that the report of auditorily presented verbal stimuli improved with both left and right presentations in a group of recovering aphasic subjects. Given that the auditory fibres are both ipisilateral and contralateral, it is not possible to a certain a completely lateralized presentation of auditorily presented stimuli, and thus no strong conclusions can be drawn from patterns of lateralization obtained with dichotic listening studies. In this regard, the divided visual field paradigm is more suitable to examine cerebral asymmetries, given that the visual fibres are only contralateral. Schweiger & Zaidel (1989) used this paradigm to examine the role of the RH during recovery from aphasia in a patient with Broca's aphasia and deep dyslexia. The authors (Schweiger & Zaidel, 1989) reported a left hemifield-right hemisphere advantage (Lvh-RH) with isolated high imageability words. However, they failed to control for attentional factors that may have caused the Lvh-RH superiority. Hence, Kinsbourne (1970) has shown that the Lvh RH advantage displayed by LH damaged patients may result from a lesion effect causing an attentional shift to the left visual hemifield, and thus having no implications regarding the participation of the RH in language recovery from aphasia. Recently, Ansaldo et al. (in press) reported a Lvh-RH advantage in the follow-up study of a patient with Broca's aphasia, who was assessed with a lexical decision task and an attentional task. Furthermore, the authors (Ansaldo et al, in press) reported a close and inverse relation between the evolution of attention and the RH performance on the lexical decision task; thus they concluded that the RH takeover observed in their patient could not be attributed to attentional factors The present paper reports the results of a similar study. In the present case, a patient with Wernicke's aphasia was followed-up. We examined the impact of the factors time elapsed after aphasia, degree of imageability, grammatical class of the word, and attentional resources on the patient's performance, in relation to the role of the RH in the recovery from aphasia.

CASE REPORT

MJ, a fifty-two-year-old, right handed man, was admitted in February 1997 for assessment of right hemiplegia and aphasia. In January 1997 he had suffered an embolic CVA in the territory of the left middle cerebral artery. He had no previous history of cerebro-vascular disease, no history of left-handedness, he was French-speaking and had a bachelor's degree in French. A CT scan taken in January 1997 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. The lesion was mainly cortical but some sub-cortical structures, namely the putamen and the globus pallidus were damaged. In February 1997 MJ was examined with the M-T Beta Protocol for the assessment of aphasia (Béland & Lecours, 1990). He showed a Wernicke's aphasia characterized by severe auditory comprehension deficits (Oral word comprehension: 0/5; Oral sentence comprehension: 0/38), with better preserved written comprehension (Written word comprehension: 5/5; Written sentence comprehension: 1/8). MJ presented a severe anomia (Oral naming: 1/31; Written naming: 1/31); oral expression was characteried by phonologic paraphasia and neologisms. Repetition was abolished and oral reading was severely impaired (i.e.: 1/33). MJ presented no clinical signs of hemianopia or visual neglect according to the Bell Test (Gauthier et al. 1989).

MATERIALS AND METHODS

The experimental protocol consisted of three tasks:

A. A language test: the Beta -Montreal -Toulouse Protocol (Béland, & Lecours, 1990). in order to determine MJ's pattern of aphasia over time,

B. A lateralized lexical decision task (LDT), in order to compare MJ's performance with Lvh-RH, Rvh-LH and CV presentations of isolated words, and

C. An attentional task: the Non-verbal Stroop Test, (Beauchemin, Arguin & Desmarais1996), which served to follow-up attentional resources.

Repeated measures were obtained at 1, 5, 10, and 14 months post-aphasia onset (i.e. T1, T2, T3 and T4). The order of presentation of the tasks was the same at each test period. Finally, in order to examine the relation between the pattern of lateralization with the lexical decision task and the evolution of attentional abilities, correlations between the results obtained on lexical decision task and the results obtained on the attentional task were gathered.

A. THE MONTREAL-TOULOUSE-86 BETA VERSION OF THE MT APHASIA BATTERY (Béland, & Lecours, 1990): The M-T beta was devised for the clinical assessment of adult French speakers with language disorders. It includes 22 tasks for the appraisal of linguistic abilities in both encoding and decoding oral and written language. Even though the M-T Beta (Béland & Lecours, 1990) was administrated in its complete version, only the results of a subset of tasks were considered in the present study. 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 the subject a card with six drawings, and asked him to point to the picture representing the stimulus word. Stimuli were high frequency, high imageability nouns. The drawings on the card depicted the stimulus word and five distractors : a) a semantic distractor, b) a phonological distractor, c) a visual distractor, and d), e) two distractors not related 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 the subject a card with four drawings and asked him to point to the the picture corresponding to the stimulus sentence. The drawings on the card depicted the stimulus sentence and three distractors. 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, distractors depicted semantic alternatives to the target for simple sentences; for reversible sentences, distractors depicted reversible alternatives to the

target, or sentences in which the subject had been changed (i.e. 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 wrong answers.

3. Written word comprehension: fifteen cards, each containing the picture of 6 objects were presented to the subject one at a time[4].The subject was given a small card with the name of the target and had to match it with the corresponding picture. Each set of 6 drawings included the target picture, a semantic distractor, a phonological distractor, a visual distractor, and two distractors not related to the target.

4. Written sentence comprehension: on 8 trials, the subject had to match a written sentence with the corresponding drawing. The examiner gave the subject a card with a written phrase and a card with four drawings. The examiner asked the subject to match the written card with the corresponding picture. Stimuli were written sentences that varied in syntactic complexity (non-reversible short sentences, n= 3, and complex reversible long sentences, n=5). The drawings corresponded to the written phrase and three distractors. For non-reversible sentences, distractors depicted semantic alternatives to the target; for reversible sentences, distractors depicted reversible alternatives to the target or sentences which the subject had been changed (i.e. 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 wrong answers.

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.

[4] The original task includes five trials. Given that there was a ceiling effect at baseline, ten trials were added in order to examine evolution of word comprehension abilities over time.

6. Written picture naming: on 31 trials, the subject had to write down the name corresponding to a picture. Targets were 25 nouns and 6 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 phrases (n= 3). The task was stopped after three consecutive errors.

B. LEXICAL DECISION TASK: In the LDT, the subject was asked to indicate whether a letter string presented on a screen corresponded to a word in French.

B.1. Stimuli: Two hundred and forty words and two hundred and forty non-words were selected for use as experimental stimuli. Words were nouns (n =120) or verbs (n=120). Within each grammatical category, there were high imageability foils (n=60) and low imageability foils (n= 60). Word and non-word length ranged from five to eight letters. Lexical frequency was controlled using Beaudot's frequency dictionary (Beaudot, 1989). Given that lexical frequency of nouns is higher than that of verbs (Beaudot, 1989), lexical frequency was controlled with regard to high and low imageability foils, within each grammatical category. The difference between the lexical frequency of high imageability and low imageability nouns was not statistically significant (i.e. high imageability nouns: 270.38, and low imageability nouns: 295.08), and the difference between the lexical frequency of high imageability verbs and low imageability verbs was not statistically significant (i.e. high imageability verbs: 64.08, and low imageability verbs: 67.78). The degree of imageability of nouns was determined according to Hogenraad's norms of imageability (Hogenraad, 1981). As no norms of imageability for verbs in French were available, 28 judges were asked to rate 250 verbs on a 7 point scale, using a French translation of Paivio's et al. (1968) instructions for rating nouns, but modified for rating verbs. Mean imageability was 6.69 for highly imageable words, and 4.15 for low imageability words. A program that generates non-words by altering one or two letters in the selected words was used to construct 240 non-words. This program attempts to match the nonword produced to the base word as closely as possible on bigram frequency (Mayzner & Tresselt, 1965). Hence, non-words were pronounceable, and they were formally and phonologically close to French words. The resulting 480 stimuli were divided into five blocs, each of them containing 48 words -- 24 nouns and 24 verbs, 12 high imagery foils and 12 low imagery foils for each grammatical category -- and 48 non words. Twenty practice items (10 words and 10 non-words) were constructed in the same manner as the experimental items, and constituted a practice block . A black dot presented at the center of the display screen served as fixation point. The stimuli were presented in 24 point Geneva bold lower case they were oriented horizontally and shown in black on a white screen. The target items were presented either in the center of the screen or on either side of fixation, and thus were lateralized. For lateralized 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 most central letter of the word coincided with the center of the screen.

B.2. Procedure: The LDT was run on a Power Macintosh 7300/180 computer. The subject was seated in a chair at a distance of 60 cm from the screen. The subject was asked to respond by pressing with his left index finger on the « yes » or the « no » button of the keyboard connected to the computer. He was encouraged to do so as quickly and accurately as possible.

Stimuli were randomly presented either to the left or the right of the fixation point which appeared in the center of the screen at the beginning of each trial. HJ 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 online by the experimenter and it was repeated at the end of the current block. Each experimental session started with a practice bloc during which the optimal presentation time for the target stimuli was determined. The first stimulus of the practice bloc was presented during 971 ms. The next stimulus would be presented at 971-21 msec if the first answer was correct, or 971 + 21 msec, if the 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 bloc, the optimal presentation time was identified and kept constant during the experimental session. The optimal presentation time was 950 msec at T1, and 950 msec at T2, and 929 at T3 and T4 .

C. NON-VERBAL STROOP TEST (NVST): The non-verbal Stroop Test (Beauchemin, Arguin & Desmarais1996) is a visuo-spatial version of the Stroop task (Stroop, 1935). The Stroop task examines the interference effect that may be observed when two competitive pieces of information are presented simultaneously and only one of them may serve as a basis for response. In order to give the correct answer, the subject has to attend to a particular aspect of the stimuli, and ignore irrelevant information that it also comprises. However, given that the conventional Stroop task consists of a color/word interference paradigm, results are largely a function of reading abilities. The non-verbal version of the Stroop task (Beauchemin, Arguin & Desmarais1996) permits the assessment of attentional abilities within a non-verbal paradigm because it uses graphic non-verbal stimuli and requires a manual response.

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

DATA ANALYSIS

A. Montreal -Toulouse Protocol

For each experimental period (T1, T2, T3, and T4), we considered the number of correct responses on each subtest, and the type of errors (i.e. type of paraphasia, type of paralexia). Results from the Montreal-toulouse Protocol are outlined in Table 1.

Insert Table 1 here

In terms of the aphasia profile, 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 changed over time: at T1, the most frequent errors were contaminations, neologisms and phonemic paraphasia, at T2: anomia, phonemic paraphasia, semantic paraphasia, semantic paralexia and semantic paragraphia. These types of errors were also observed at T3, and at T4, but in a much smaller number. By the end of the experiment, MJ had attained a functional level of communication in everyday life. However, comprehension and production of long and syntactically complex sentences remained impaired. Anomia was still frequent, but MJ could overcome this difficulty with periphrases.

There was a big improvement on language tasks over time. The improvement was particularly evident between T1 and T2, both with regard to language comprehension and language expression (see table 1). Thus, MJ attained the maximum score on the oral word comprehension task at T2 and showed a big improvement on oral and written phrase comprehension (Oral phrase comprehension: 0/38 at T1, and 10/38 at T2; Written phrase comprehension: 0/38 at T1 and 10/38 at T2). There was also a big improvement on oral expression tasks at T2 (Oral Naming: 1/31 at T1, and 28/31 at T2; Oral Reading: 1/33 at T1 and 17/33 at T2; Repetition: 0/30 at T1 and 10/30 at T2), as well as on written naming (Written Naming task: 1/31 at T1, and 14/31 at T2). At T3 and T4, the results were quite stable by reference to T2, with the exception of written naming which continued to improve between T2 and T3, and oral comprehension of phrases which still showed some improvement at T4.

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 has been considered for analysis. There was a significant reduction of global error rates (ER) with time elapsed after aphasia (c2 = 0.34, $p < 0.05$). This reduction was verified with Lvh presentations (c2 8.71, $p < 0.05$), and with Rvh presentations (c2=14.58, $p < 0.05$), but not with Cv displays. Furthermore, ER decreased significantly over time with nouns (c2= 9.48, $p < 0.05$), and with high imageability words (c2= 27.3 $p < 0.01$). 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.

Insert Table 2 here

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 x 3 x 2 x 2 ANOVA including the factors of Time Post- Aphasia Onset (T1, T2, T3, and 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 x Imageability x Presentation Site (F (2,794) = 3.13, $p < 0.05$). Further analysis of the triple interaction revealed an interaction of Grammatical Class x Degree of Imageability with Lvh presentations (F (1,794) = 8.05, $p < 0.01$), but not with Rvh (1,749) = 0.49, $p = 0.49$), or Cv displays (F (1,749) = 0.86, $p = 0.57$). 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, $p < 0.001$). There was no effect of grammatical class with high imageability words (F (1,749) = 0.02, $p < 0.9$) (see figure 1)

Insert Figure I here

There was also a main effect of time elapsed after aphasia on RT (F (3,794) = 63.02, $p < 0.01$). 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: $r = 0.3162$, $p =$ *n.s* ; at T2: $r = 0.9487$, $p =$ *n.s*; at T3: $r = 0.6325$, $p =$ *n.s*, and at T4: $r = 0.6325$, $p =$ *n.s*). No other interactions or main effects were significant.

Insert Figure 2

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: ($d_2 = 1.00$, $p= 0.001$), and also at T3 (Spearman correlation Coefficients: ($d_2 = 1.00$, $p= 0.001$). No other correlation achieved significance.

C. NON-VERBAL STROOP TASK

Table 3 presents the results from the NVST. It should be noted that ER for the orientation task in the incongruent condition were close to chance level at every session, whereas they were very low in the congruent condition. 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 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.

Insert table 3 here

A 4 x 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 x congruence ($F(3,486) = 13.23$, $p < 0.01$). The congruence between location and orientation information affected performance at every experimental session (at T1: $F(1,486)=5.12$, $p < 0.05$); at T2: $F(1,486)=5.06$, $p < 0.05$; at T3: $F(1,486) = 5.49$, $p < 0.05$, and at T4: $F(1,486)=43.73$, $p < 0.01$). RT with the congruent condition improved at T2 and remained stable in subsequent sessions.

Insert figure 3 here

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.

D. RELATIONSHIP BETWEEN THE RESULTS ON THE LEXICAL DECISION AND THE ATTENTIONAL TASKS

It has been argued that a lesion in the left hemisphere may cause an attentional bias to the left visual hemifield and thus result in a left visual field advantage on language tasks (Kinsbourne, 1970). It has also been claimed that a Lvh advantage on language tasks may result from the superior attentional abilities of the right hemisphere, with no implications regarding its linguistic processing abilities. In order to examine the relation between the evolution of attentional resources and the evolution of lexical semantic abilities in our subject, correlations between the LDT and the NVST were gathered. The LDT/NVST correlation represented the direction and the strength of the relationship between the performance with either presentation site on the lexical decision task and the performance on the attentional task. For each site of presentation (Lvh, Cv and Rvh), the 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 Non-Verbal Stroop Task (Spearman Correlation Coefficients: $d_2 = 1.000 p > 0.001$). Correlations between the performance with lateralized presentations (Lvh and Rvh) and the performance with the Non-Verbal Stroop Task did not reach significance.

DISCUSSION

The purpose of this study was to examine the role of the right hemisphere during recovery from aphasia in MJ, a fifty-two year old man who suffered from Wernicke's aphasia resulting from an embolic CVA in the left temporal and parietal lobes. The results of this experiment showed a global recovery of language with time elapsed after aphasia. With regards to the pattern of lateralization observed on the lexical decision task, no presentation site effect was observed throughout the experiment. There was also a global main effect of time elapsed after aphasia on RT, a correlation between RT with Lvh-RH presentations, and RT with CV presentations at T2. There was also an interaction between the grammatical class and the degree of imageability of the targets with Lvh presentations, but not with CV or Rvh-LH presentations. More precisely, RT with low imageability nouns were faster than with low imageability verbs when presented to the Lvh, whereas the difference between RT with high imageability nouns and verbs was not significant.

With regard to the time effect on RT, a global analysis of the results shows that it does not correspond to a real improvement on RT over time. Thus, the time effect results from the particularly low RT obtained at T2 in comparison to the rest of the experiment. Concurrently, ER were particularly high in comparison to the rest of the experiment. Even when there was no speed accuracy trade-off, the performance on the lexical decision task at T2 suggests that MJ privileged speed over accuracy, which determined the time effect. Thus, beyond changes observed at T2, the global pattern of results on the LDT shows no improvement over time, both with regard to speed and accuracy of response. Walter (1995) examined the performance of a group of non-brain damaged subjects on a lateralized lexical decision task. The results obtained indicate that RT and ER obtained by MJ on the lexical decision task were within the values found among non-brain damaged subjects already at T1 (Walter, 1995). Thus, a ceiling effect on the lexical decision task cannot be discarded.

There was an improvement in language abilities over time, as documented by the results on the Montreal-Toulouse Protocol. More specifically, comprehension improved particularly between 1 and 5 months post aphasia onset (T1 and T2), whereas language expression improved between 10 and 14 months post aphasia onset (T3 and T4). The changes observed on the language test contrast with the stability of the pattern of lateralization displayed by MJ on the lexical decisison task. These findings show that no strong conclusions on the degree of recovery from aphasia should be made on the analysis of the pattern of lateralization on a lexical decision task alone. The combination of a lateralized task and a language test provided a more comprehensive picture of the pattern of recovery from aphasia in MJ.

The only interaction observed throughout the experiment was Presentation Site x Imageability x Grammatical Class with Lvh displays. More preciselly, RT with low imageability nouns were faster than RT with low imageability verbs, when presented to the Lvh. On the contrary, the grammatical class of the target had no effect on the persentation of high imageability words to the Lvh-RH. Day (1979) argued that the RH of normal subjects is capable of processing high imageability nouns and adjectives, whereas verbs are processed exclusively by the LH regardless of their rated imageability. In the case reported here, the noun superiority arose only with low imageability words, whereas no difference between nouns and verbs was observed when targets were rated as highly imageable. In other words, the RH performance with verbs was above the limits of Day's findings with normal subjects (Day, 1979). Given that the previously described interaction did not include the Time factor, it is unlikely that this RH advantage in comparison to the descriptions on normal populations resulted from functional reorganization during recovery from aphasia. As the RH contribution to the processing of high imageability verbs was already present one month after aphasia onset, a pre-morbid RH capacity to process high imageability verbs in MJ cannot be excluded.

There was no Presentation Site effect on the lexical decision task at any moment of measure. This suggests that the recovery of lexical semantic abilities documented with the Montreal-Toulouse Protocol was equally sustained by both cerebral hemispheres. However, the processing demands of the lateralized task concerned the word level, and thus the degree of lateralization underlying the recovery of lexical semantic abilities at the phrase level observed with time elapsed cannot be determined. The results reported here are in line with previous reports by Weidner et al. (1976) who found no difference between the performance with left and right auditory presentations of isolated words in a group of recovering aphasics submitted to a lateralized lexical decision task. It is possible that the processing demands of single word lateralized task facilitate bilateral processing, given that both the left and the right cerebral hemispheres can sustain lexical semantic processing at the word level (Joanette et al. 1990). The lexical semantic processing of phrases and discourse could result in different lateralization patterns that remain to be explored.

The joint influence of attentional and language factors seems particularly evident at T2. Specifically, on the attentional task there was a reduction of RT with the congruent condition and an increase on the congruent coefficient. These results suggest an improvement of attention at T2. Concurrently, on the lexical decision task, there was a global reduction on RT as well as an increase on ER[5]. Furthermore, even when the correlation between the RT with Lvh presentations and RT with CV presentations shows that the processing of lexical items on central vision was mainly dependent on the RH, the performance with CV displays on the lexical decision task was also correlated with the results obtained on the attentional task. Thus, it is difficult to determine whether the RH superiority resulted from language processing factors, attentional factors or both. It is possible that the recovery of attention observed at T2 may have influenced MJ's performance on the lexical decisison task. On the other hand, the results on the Montreal-Toulouse Protocol show an improvement on language comprehension of words and phrases, as well as an improvement on oral expression. It is possible that the recovery of attention contributed to a better performance on the Montreal-Toulouse Protocol, particularly on sentence comprehension tasks. In the case of language expression, however, the recovery observed at T2 is more difficult to explain in terms of attentional factors alone and indicates that an improvement on language abilities as well. Thus, altogether the results at T2 show that MJ's performance was jointly influenced by attentional and language factors, probably resulting from the improvement of both functions. At T3, the improvement on language expression continued, particularly with regards to written naming. The possible changes on the lateralization pattern underlying the recovery of oral expression documented with the M-T Protocol could not be captured

---

[5] However, there was no speed-accuracy trade-off.

by the lataralized task, given that its processing demands concerned receptive-lexical semantic abilities only. According to the literature however, the improvement of language expression following aphasia is mainly dependent on functional recovery of LH function (Heiss et al., 1999; Karbe et al., 1998).

The results obtained on the attentional task show that attentional abilities were quite stable throughout the experiment, except for some improvement observed at T2. Thus, the congruent coefficient[6] was slightly higher at T2, in comparison to the rest of the experimental sessions. As previously discussed, the only positive correlation between the results with the lexical decision task and the results with the Non-verbal Stroop task was observed at T2. Specifically, there was a positive correlation between RT with CV displays and the performance on the non-verbal Stroop Test at T2. This shows that attentional factors may modulate the performance of aphasic patients on lateralized tasks. Furthermore, these observations highlight the importance of non-verbal instruments in the assessment of attention and in the study of lateralization patterns during the recovery from aphasia.

In summary, the results of the present study indicate that the lexical semantic processing of words in this aphasic subject was sustained by both cerebral hemispheres since the beginning of the experiment. Language comprehension continued to improve over time, but the pattern of lateralization remained stable throughout the experiment. The fact that RT and ER were already within normal limits at T1, suggests that a ceiling effect on the lexical decision task may have masked any lateralization effect related to ongoing recovery of lexical semantic processing The extent to which the lateralization pattern observed on the lexical decision task resulted from attentional factors, language factors or both is difficult to determine. On the one hand, it is possible that attentional factors played a role on MJ's performance on the lexical decision task particularly at T2. On the other hand, the grammatical class x imageability interaction with Lvh displays provides evidence for a RH advantage specific to language processing, given that it

[6] The congruent coefficient corresponds to the difference between RT with the congruent and the incongruent condition of the Non-verbal Stroop Task

concerns the linguistic factor of imageability. However, the fact that the interaction did not include the time factor suggests that this RH advantage results from pre-morbid RH capacities in this specific individual, as opposed to a RH take-over during recovery from aphasia. Altogether, the results of this experiment highlight the importance of combining lateralized tasks with attentional tasks and language tests in the study of lataralization patterns underlying the recovery from aphasia and raises the question of the the joint influence of attentional and language factors during recovery. Specifically, the impact of attentional factors on the recovery of sentence comprehension and the lateralization patterns underlying its recovery remain to be explored.

REFERENCES

Ansaldo, A.I., Arguin, M., & Lecours, A.R. (in press). Initial right hemisphere take-over and subsequent bilateral participation during recovery from aphasia. *Aphasiology.*

Basso, A., Gardelli, M., Grassi M.P. & Mariotti, M. (1989). The role of the right hémisphère in recovery from aphsia. 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 des mots en français*. Montréal : Presses de l'Université de Montréal.

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

Boles, D.B. (1983). Dissociated imageability, concreteness and familiarity in lateralized word recognition. *Memory and Cognition*, 11; 511-519.

Broca, P. (1865). Sur la facultté du langage articulé. *Bulletin de la Societé d'anthropologie*, 6; 337-393.

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.

Cappa, S.F. (1997). Subcortical aphasia : Still a useful concept ? *Brain and Language*, 58; 424-426.

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

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

Day, J. (1977). Right-hemisphere language processing in normal right handers. *Journal of Experimental Psychology: Human Perception and Performance*, 3; 518-528;

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

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

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.

Gauthier, L., Dehaut, F. & Joanette, Y. (1989) The bells test : A quantitative and quantitative test for visual neglect. International Journal of Clinical Neuropsychology, 11 ; 49-54.

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

Heiss, W. D., Kessler, J., Thiel, A., Ghaemi, M., & Karbe, H. (1999). Differential capacity of left and right hemispheric areas for compensation of poststroke aphasia. *Annals of Neurology,* 45; 430-438.

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.

Hines, D. (1976). Recognition of verbs, abstract nouns and concrete nouns from the left and right visual Fields. *Neuropsychologia,* 14; 211-216

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

Howell, J.R. & Bryden, M.P. (1987). The effects of word orientation and immangeable on visual half-field présentations with a lexical decision task. *Neuropsychologia,* 25; 527-538

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

Johnson, J.P., Sommers, R.K., & Weidner, W.E. (1977). Dichotic ear preference in aphasia. *Journal of Speech and Hearing Research,* 20; 116-129.

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

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

Knopman, D. S., Rubens, A. B., Selnes, O. A., Klassen, A. C., & Meyer, M. W. (1984). Mechanisms of recovery from aphasia: evidence from serial xenon 133 cerebral blood flow studies. *Annals of Neurology*, 15; 530-536.

Koening, O., Wetzel, C., & Caramazza, A. (1992). Evidence for different types of lexical representation in the cerebral hemispheres. *Cognitive Neuropsychology*, 9; 33-45.

Lambert , A.J., Beaumont, J.G. (1983). Imageability does not interact with visual field in latéral word recognition with oral report. *Brain and Language*, 20; 115-142

Lecours, A.R., Mehler, J., Parente, M.A., Caldeira, A. Cary, L., Castro, M.J., Dehaut, F., Delgado, R., Gurd, J., Fraga Karman, D. de, Jakubovitz, R., Osorio, Z., Cabral, L.S., & Junqueira, A.M.S. (1987). Illiteracy and brain damage. 1. Aphasia testing in culturally contrasted populations (control subjects). *Neuropsychologia*, 25; 231-245.

Lee, H., Nakada, T., Deal, J.L., Lin, S., & Kwee, I.L. (1984). Transfer of language dominance. *Annals of Neurology*, 15; 304-307

Levine, D.N. & Mohr, J.P. (1979). Language after bilateral cerebral infarctions: Role of the minor hemisphere in speech. *Neurology*, 29; 927-938.

Mannhaupt, H.R. (1983). Processing of abstract and concrete nouns in a lateralized memory search task. *Psychological Research*, 45; 91-105.

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

Mazzocchi, F. & Vignolo, L.A. (1979). Localization of lesions in aphasia : Clinical-CT scan corrélations in stroke patients. *Cortex*, 15; 627-653.

McMullen, P.A. & Bryden, M.P. (1987). The effects of word immangeable and frequency on hemispheric asymmetry in lexical disorders. *Brain and Language*, 31; 11-25

Metter, E.J., Jackson, C.A., Kempler, D., & Hanson, W.R. (1992). Temporoparietal cortex. And the recovery of language comprehension in aphasia. *Aphasiology*, 6; 387-396.

Moutier, F. (1908). *L'aphasie de Broca.* Paris: Steinheil.

Niccum, N., Selnes, O.A., Speaks, C., Risse, G.L., & Rubens, A.B. (1986). Longitudinal dichotic listening patterns for aphasic patients. III. Relationship to language and memory variables. *Brain and Language*, 28; 303-317

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

Nielsen, J.M. & Raney, R.B. (1939). Recovery from aphasia studied in cases of lobectomy. *Archives of Neurology and Psychiatry*, 42; 189

Nieto, A., Santacruz, R., Hernadez, 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].

Papanicolaou, A. C., Moore, B. D., Deutsch, G., Levin, H.S., & Eisenberg, H. M. (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.

Stroop, J.R. (1935). Studies of interference in serial verbal réactions. *Journal of Experimental Psychology*, 18; 643-662

Walter, N. (1995). *Latéralisation du traitement des mots selon leur degré d'imageabilité et leur classe grammaticale, dans trois groupes de sujets*. Mémoire de DEA Neurosciences. Marseille : Université d'Aix-Marseille II.

Weidner, W.E. & Lasky, E.Z. (1976). The interaction of rate and complexity of stimulus on the performance of adult aphasic subjects. *Brain and Language*, 3; 34-40.

Young, W. & Ellis, A. (1985). Different methods for lexical access for words presented in the left and right visual hemifields. *Brain and Language*, 24; 32-358

Table 1

Correct Responses on Subtests of the MT 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

T1 = 1 months post–aphasia onset, T2 = 5 months post–aphasia onset, T3 = 10 months post–aphasia onset, T4 = 14 months post-aphasia onset

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
Rvf	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

Table 3

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

			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

Figure Captions

1 Figure 1

Lexical Decision Task: Grammatical classs x Imageability intercation with Lvh displays

2 Figure 2

Lexical Decision Task: Main effect of Time elapsed after aphasia on RT

Figure 1

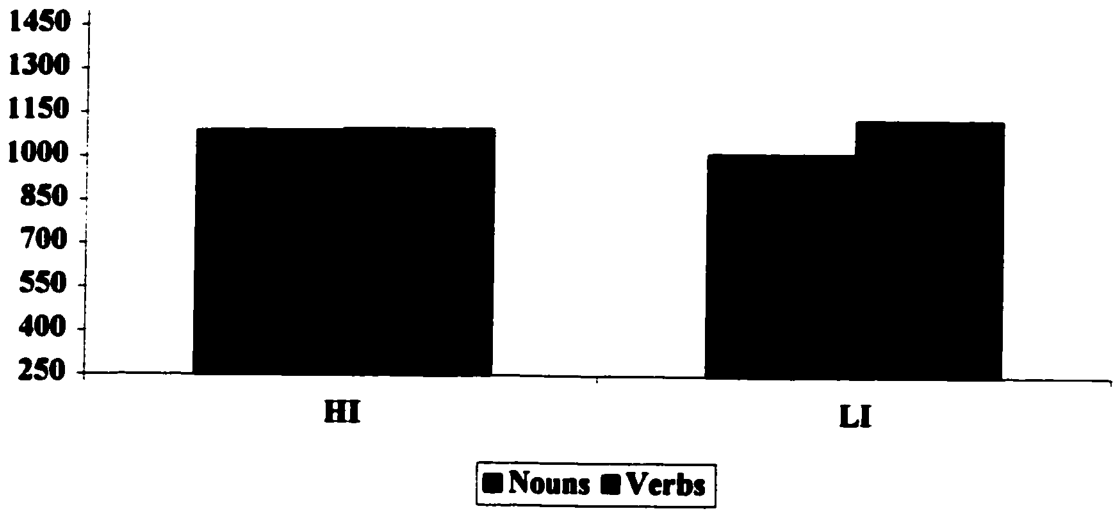
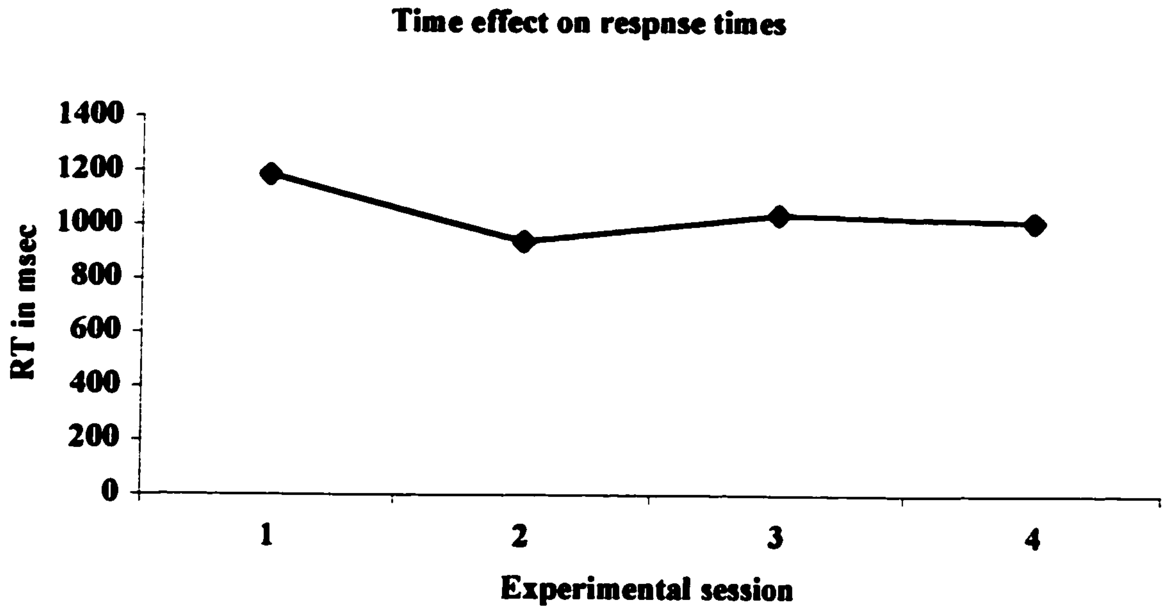


Figure 2


Time effect on respnse times
1400
1200
1000
800
600
400
200
0
RT in msec
1
2
3
4
Experimental session

Acknowledgments

This work was made possible by the financial support of Consejo Nacional de Investigación en Ciencia y Tecnología de la República Argentina (A.I.A.), as well as a group grant (M.A.) and a team grant (A.R.L.) from the FCAR. Martin Arguin is a research fellow under the Fonds de la recherche en santé du Québec. This work was done in partial fulfillment of the requirements for Ana Inés Ansaldo's Ph.D. dissertation.

Chapitre 5

Discussion générale : implications cliniques et théoriques des observations

L'objectif général de ce travail était d'examiner la contribution respective de chacun des hémisphères cérébraux dans le processus de récupération de l'aphasie. L'hypothèse générale à la base des études rapportées concernait la possibilité d'une prise en charge par l'hémisphère droit du traitement lexico-sémantique des mots au cours de la récupération de l'aphasie. Chacun des chapitres composant le cœur de ce travail rapporte les résultats d'une étude de cas à mesures répétées, réalisée durant la première année de récupération d'un individu aux prises avec une aphasie. Ces études ont été effectuées en faisant usage d'une tâche de décision lexicale en présentation visuelle, tachistoscopique et latéralisée, ainsi que d'une tâche attentionnelle de nature non verbale et d'une évaluation des habiletés langagières.

Les résultats de la première étude rapportée au chapitre 2 démontrent que les deux hémisphères cérébraux participent à la récupération de l'aphasie. Toutefois, fait à noter, la contribution de chacun des deux hémisphères cérébraux varie au cours de la récupération. C'est ainsi que la contribution de l'hémisphère droit semble prédominante pendant les huit premiers mois après le début de l'aphasie, alors que les deux hémisphères semblent contribuer de façon équivalente à partir du douzième mois. L'avantage de l'hémisphère droit est progressif en ce qui concerne les dimensions des mots : dans un premier temps, elle concerne les mots de haute imageabilité, puis avec le temps, s'étend aux mots de basse imageabilité. Ce patron de performance de l'hémisphère droit suggère sa contribution au traitement des mots pendant la récupération de l'aphasie. Plus spécifiquement, pour ce qui est des mots de basse imageabilité, la performance de l'HD est au-dela de celle qu'on retrouve chez les sujets non cérébrolésés. Ceci indique une prise en charge par l'HD au cours de la récupération de l'aphasie. Par ailleurs, les résultats démontrent également que cette prise en charge ne peut être attribuée à une amélioration de l'attention, elle apparaît plutôt spécifique au traitement du langage, et concomitante à la recupération des composantes réceptives du langage par opposition à l'expression verbale. Avec le temps, les deux hémisphères cérébraux participent au traitement lexico-sémantique de façon équivalente, comme conséquence de la récupération fonctionnelle de l'hémisphère gauche. La récupération fonctionnelle de l'hémisphère gauche n'entraîne cependant pas une retraite de participation de l'hémisphère droit, ce qui démontre que la contribution de l'HD à la récupération de l'aphasie est effective et non pas tributaire du degré d'atteinte fonctionnelle de l'hémisphère gauche. En résumé, le patron global d'évolution chez cet individu démontre que la récupération du traitement lexico-sémantique est dans un premier temps latéralisée à droite. Une prise en charge par l'HD du traitement des mots de basse imageabilité indique une réorganisation fonctionnelle après l'AVC. Puis, avec le temps écoulé, le traitement lexico-sémantique devient non latéralisé comme conséquence d'une contribution comparable des deux hémisphères. Ainsi, l'HG récupère mais pas au point de reprendre sa prédominance. La récupération de l'HG en décision lexicale coïncide avec une importante récupération de l'expression verbale.

Les résultats de la deuxième étude (chapitre 3) démontrent un patron d'ensemble similaire à celui de la première étude, bien que l'on y retrouve certaines spécificités. Ainsi, l'HD est prédominant pendant les six premiers mois de l'évolution, alors qu'une participation équivalente de deux hémisphères est observée par la suite. L'avantage de l'HD concerne exclusivement les mots de haute imageabilité, noms et verbes confondus. Cette observation ne permet pas de trancher sur la nature du rôle de l'HD dans la récupération de l'aphasie chez cet individu, c'est-à-dire, prise en charge par opposition à contribution prémorbide. Plus précisément, bien que certaines études chez des sujets non cérébrolésés prouvent que l'HD est incapable de traiter les verbes, pas même ceux de haute imageabilité, d'autres études rapportent que si la fréquence lexicale est bien contrôlée, l'HD est capable de traiter des noms et des verbes de haute imageabilité. Compte tenu du manque de convergence dans la littérature, la possibilité d'une prise en charge par l'HD dans le cas de cet individu ne peut être ni confirmée, ni écartée. La prépondérance de l'hémisphère droit coïncide encore une fois avec une amélioration de la compréhension du langage. En revanche, lorsque la performance de l'hémisphère gauche en décision lexicale s'améliore, on remarque de façon concomittante une légère amélioration de l'expression orale. L'ensemble des résultats obtenus après six mois d'évolution suggère que le traitement lexico-sémantique dépend encore de l'HD, bien que l'amélioration fonctionnelle de l'hémisphère gauche soit déjà amorcée. Tel qu'il a été observé dans l'étude précédente, le temps écoulé entraîne une participation équivalente des deux hémisphères au traitement des mots en décision lexicale comme conséquence d'une amélioration de l'HG. Comme dans le cas précédent, l'amélioration fonctionnelle de l'HG n'entraîne pas une diminution de la participation de l'hémisphère droit au traitement lexico-sémantique des mots. De plus, elle coïncide avec une légère récupération de l'expression orale.

Dans la troisième étude, les deux hémisphères participent au traitement des mots de manière équivalente à la phase subaiguë. Or, le traitement lexico-sémantique n'est pas latéralisé du début à la fin de l'étude. Cette observation démontre que dans certains cas, la récupération des aspects lexico-sémantiques au cours de la première année d'évolution peut dépendre d'une contribution comparable et soutenue des deux hémisphères depuis la phase subaiguë. Les performances de cet individu sont conjointement influencées par les facteurs d'imageabilité, de classe grammaticale et d'attention. Plus précisément, le faible degré d'imageabilité met en évidence les différences dans le traitement des noms et des verbes par chaque hémisphère. Or, lorsqu'il s'agit de présentations de mots de faible degré d'imageabilité, l'HD traite plus rapidement les noms que les verbes, alors que cet effet n'est pas observé suite aux présentations à l'HG. En d'autres mots, l'effet de la classe grammaticale est subsidiaire au degré d'imageabilité des mots. Par ailleurs, il y a une amélioration de l'attention, à quatre mois d'évolution, mais son impact dans la performance en décision lexicale est difficile à interpréter. L'amélioration de la compréhension de la syntaxe concomitante soulève la question de l'impact des troubles de l'attention dans le traitement de la syntaxe en particulier, et du langage en général. En résumé, les résultats de la troisième étude démontrent que le traitement lexico-sémantique était soutenu par les deux hémisphères tout au long de l'expérience. À quatre mois d'évolution, des facteurs attentionnels ont possiblement modulé la performance en décision lexicale, en coïncidence avec l'amélioration de la compréhension de la syntaxe.

L'ensemble des résultats des trois études démontre plusieurs similitudes et quelques différences entre les profils d'évolution des trois sujets étudiés. En ce qui concerne les patrons de latéralisation en décision lexicale, on observe que les deux hémisphères participent à la récupération de l'aphasie chez les trois cas étudiés. Leur contribution respective varie au cours de la récupération et concerne différents aspects du traitement du langage. Le patron de latéralisation évolue de façon similaire chez deux sujets, tandis que le troisième sujet démontre un profil quelque peu différent. Plus particulièrement dans la première et deuxième études, on observe que le traitement lexico-sémantique peut-être latéralisé à droite durant les premiers mois d'évolution. Ceci signifie que l'HD soutient ce type de traitement pendant les premiers mois de la récupération de l'aphasie. Avec le temps écoulé, l'amélioration fonctionnelle de l'HG masque tout effet de latéralisation pour le traitement lexico-sémantique environ une année après l'AVC. Dans la troisième étude, le traitement lexico-sémantique est non latéralisé depuis la phase subaiguë jusqu'à la fin. En résumé, dans deux cas, le traitement lexico-sémantique est latéralisé à droite pendant les premiers mois de récupération. De plus, chez les trois individus, le temps écoulé entraîne une participation comparable des deux hémisphères au traitement lexico-sémantique.

Les observations portant sur les facteurs d'imageabilité et de classe grammaticale confirment leur influence sur la performance de l'HD chez les individus aphasiques. L'impact de la classe grammaticale sur le traitement par l'HD apparaît exclusivement lorsqu'il s'agit des mots de basse imageabilité. Cette observation suggère que c'est surtout le degré d'imageabilité des mots qui module la performance de l'HD. En effet, les mots de haute imageabilité, noms et verbes, bénéficient les premiers de la prise en charge par l'HD. Comme cette prise en charge est rapide et transitoire, il est probable qu'elle exprime des habiletés pré-morbides de l'HD. En revanche, lorsque l'avantage de l'HD s'étend aux mots de basse imageabilité, la performance de l'HD est bien au-delà de celle qu'on retrouve chez le sujet non cérébrolésé suggèrent ainsi une évolution dans ses capacités quelques mois après l'apparition de la lésion à l'HG.

En résumé, les observations recueillies dans les trois études qui forment le corps de cette thèse confirment la participation de l'HD à la récupération de l'aphasie. Cette participation débute tout de suite après l'AVC et se prolonge pendant la première année d'évolution. Elle ne cède pas lorsque l'HG s'améliore et n'est pas sous-produit de l'évolution de l'attention. De plus, la contribution de l'HD peut dans certains cas, prendre une forme de prise en charge du traitement lexico-sémantique. Enfin, l'HD peut démontrer une performance supérieure à celle qu'on retrouve chez les sujets non cérébrolésés.

L'ensemble des observations fournit des pistes de réflexion sur des aspects cliniques de la récupération de l'aphasie et soulève des questions concernant les bases neurobiologiques de la récupération du langage après un AVC. Dans la section suivante, les implications cliniques et de nouvelles avenues de recherche clinique dans le domaine de l'orthophonie sont discutées. Finalement, l'ensemble des observations est situé dans l'une des perspectives théoriques qui permettent de rendre compte des résultats obtenus.

1. Implications cliniques des observations empiriques

L'ensemble des résultats des trois études démontre que les trois personnes suivies récupèrent de leur aphasie avec le temps écoulé. L'impact de la thérapie en orthophonie dans la récupération ne peut être évalué dans le cadre méthodologique choisi dans cette thèse. Par contre, certaines des observations empiriques peuvent contribuer à une prise en charge plus efficace des personnes atteintes d'aphasie. En ce qui concerne les types de mot examinés, le degré d'imageabilité des mots apparaît comme un facteur à considérer au cours de la thérapie en orthophonie. Or, les mots de haute imageabilité semblent de bons candidats pour la thérapie en orthophonie si l'on veut optimiser les chances de prise en charge par l'hémisphère droit en début d'évolution. Pour ce qui est de la classe grammaticale, les résultats sont moins tranchés. En effet, les noms et les verbes semblent d'aussi bons candidats pour la prise en charge par l'HD. Toutefois, il est probable que le traitement des verbes de basse imageabilité demande plus de ressources que celui des verbes de haute imageabilité.

En ce qui concerne la récupération du langage, la compréhension évolue mieux et plus rapidement que l'expression. Plus particulièrement, chez deux individus, il faut attendre une année après l'AVC pour que la récupération de l'expression soit évidente. Les orthophonistes qui travaillent en milieu clinique font ce constat régulièrement. Cette thèse fournit une preuve expérimentale sur l'importance du temps écoulé après la lésion dans la récupération des patients aphasiques.

Les observations rapportées soulèvent aussi des questions concernant les modalités de prise en charge des patients aphasiques. Plus précisément, une fois le diagnostic d'aphasie posé, l'équipe interdisciplinaire en soins aigus doit décider de l'orientation du patient dans le continuum de soins de santé. Cette décision détermine l'accès aux soins de réadaptation. Or, si le patient est orienté vers la réadaptation, il peut bénéficier d'une thérapie du langage intensive, pendant plusieurs mois. Par contre, s'il est orienté vers l'hébergement, les chances de bénéficier d'une thérapie diminuent de manière considérable. La décision de l'orientation est prise pendant le premier mois d'évolution après l'installation de l'aphasie, en fonction des progrès démontrés par le patient au niveau de l'aphasie et d'un ensemble de facteurs médicaux et psychosociaux. Les résultats des trois études rapportées dans cette thèse suggèrent qu'à un mois d'évolution, le portrait du potentiel de récupération est incomplet. Ainsi, la récupération de l'expression prend du temps à s'amorcer et peut très bien évoluer avec le temps écoulé, même quand le déficit est très sévère en phase subaiguë. Par conséquent, toute décision finale sur l'orientation prise en début d'évolution pourrait pénaliser des individus dont la récupération de l'expression orale n'est pas encore amorcée. La réévaluation périodique à l'externe est une alternative possible dans les cas où peu d'évolution est constatée en phase subaiguë. Cette modalité de suivi permettrait de contrôler l'évolution du patient afin d'identifier le meilleur moment pour l'intervention. De plus, cette approche semble réaliste, compte tenu des questions de coût des services que conditionnent les possibilités de choix des professionnels dans le milieu de la santé.

Les observations concernant l'évolution de l'attention rapportées dans le cadre de ce travail rappellent que les individus aphasiques peuvent présenter des troubles de l'attention. Les trois sujets étudiés démontrent des difficultés importantes dans des conditions d'interférence, soit lorsque la résolution de la tâche demande de se concentrer sur l'une des deux informations disponibles et d'inhiber l'autre. Les travaux qui traitent spécifiquement des troubles de l'attention chez les aphasiques ne sont pas très nombreux. Les études réalisées rapportent des troubles de l'attention divisée (LaPointe & Erickson, 1991; Korda & Douglas, 1997; Gloser & Goodglasss, 1990), et de l'attention sélective (Kigma et al., 1996). Toutefois, la composante verbale des tâches n'est pas toujours contrôlée dans les études rapportées ici et par conséquent l'impact du trouble du langage sur la performance des patients est difficile à évaluer. Dans les études rapportées ici dans cette thèse, le choix d'une tâche non verbale s'est avéré très utile pour contrôler le facteur du trouble du langage et détecter des troubles de l'attention sélective. Par conséquent, les observations indiquent la pertinence d'inclure l'évaluation de l'attention dans l'évaluation standard de l'aphasie, afin de voir à une prise en charge spécifique du trouble de l'attention dans les cas pertinents et de diminuer l'impact des troubles de l'attention sur les habiletés de communication.

Une autre question qui découle des observations effectuées dans le cadre de la tâche d'attention concerne les rapports probables entre l'attention et les habiletés de traitement du langage. Or, on remarque que l'amélioration de l'attention coïncide avec une récupération de la compréhension de la syntaxe chez un des individus suivis. Les rapports entre les troubles d'attention et les difficultés de compréhension de la syntaxe sont peu connus. Il est possible que l'amélioration de l'attention favorise la compréhension de la syntaxe. Il se pourrait aussi qu'un autre facteur non contrôlé dans cette étude (p. ex. la mémoire de travail), puisse interagir avec l'attention et avoir une influence sur le traitement de la syntaxe. L'influence des troubles de l'attention sur les difficultés de compréhension dans l'aphasie apparait comme un domaine de recherche pertinent. La recherche dans ce domaine pourrait contribuer à identifier des processus sous-jacents au traitement du langage, afin d'identifier des stratégies d'intervention mieux adaptées à la nature des troubles aphasiques. Dans une perspective plus théorique, ce type de recherche contribuerait à augmenter les connaissances sur les rapports entre le langage et d'autres fonctions cognitives.

En résumé, les observations recueillies dans les trois études qui forment le corps de cette thèse fournissent des pistes d'intervention en orthophonie chez des patients aphasiques. Entre autres, l'importance du temps écoulé après l'AVC dans l'appréciation des chances de récupération à long terme et l'impact du degré d'imageabilité des mots dans les capacités de l'HD à prendre en charge le traitement lexico-sémantique. Par ailleurs, les troubles de l'attention et leur rapport avec le traitement du langage apparaissent comme une question à considérer en clinique et une avenue de recherche à explorer.

2. Évolution de la latéralisation fonctionnelle

En plus des implications cliniques discutées ci-dessus, les observations empiriques recueillies dans le cadre de cette thèse fournissent des pistes de réflexion concernant les bases neurobiologiques de la récupération de l'aphasie. Plus précisément, l'analyse des performances en champ visuel divisé chez les trois sujets examinés illustre un patron de latéralisation pour le traitement lexico-sémantique différent de celui qu'on retrouve chez les sujets non cérébrolésés. L'observation d'une prédominance de l'HD et d'une participation conjointe des deux hémisphères dans le traitement lexico-sémantique pendant la première année d'évolution des trois patients indique que l'aphasie entraîne des changements au niveau de la latéralisation du traitement du langage. De plus, le fait que les patrons de latéralisation varient au cours du temps suggère que le temps écoulé après la lésion gauche joue un rôle dans le déclenchement des mécanismes sous-jacents aux modifications observées au niveau des patrons de latéralisation pour le traitement lexico-sémantique.

Plusieurs questions surgissent en ce qui concerne le rôle de l'HD dans la récupération de l'aphasie : Comment une lésion de l'hémisphère gauche peut-elle entraîner une suprématie globale de l'HD pour le traitement lexical? Pourquoi la suprématie de l'HD est-elle temporaire? Qu'est–ce qui fait que chez des aphasiques l'HD peut, dans certains cas, démontrer une performance en décision lexicale supérieure à celle qu'on retrouve chez le sujet non cérébrolésé? Dans les sections qui suivent, nous allons discuter des phénomènes qui pourraient fournir les réponses.

2.1 Levée de la diaschisis comme mécanisme de récupération

Le terme diaschisis fut introduit par Von Monakow (1914) pour décrire l'effet d'inhibition causé par une lésion focale du système nerveux sur des aires fonctionnellement connectées à celle-ci. Ses effets se manifestent par des modifications du métabolisme, au niveau des neurotransmetteurs, de la synthèse des protéines ou de l'activité bioélectrique. On distingue plusieurs types de diaschisis : la *diaschisis ipsilatérale*, qui affecte le bon fonctionnement des structures cérébrales voisines de la lésion; la *diaschisis controlatérale*, qui a un effet d'inhibition sur des régions de l'hémisphère non lésé, particulièrement sur les aires-miroir de l'aire lésée. Finalement, la *diaschisis cérébelleuse croisée, qui* affecte le cervelet controlatéral à la lésion. La durée de la diaschisis varie selon l'organisation interne du système touché et selon les autres sources d'afférence que celui-ci possède, et est permanente dans certains cas (Kempinsky, 1958). La levée de la diaschisis peut entraîner la récupération de la fonction à des degrés divers.

L'avènement de la neuroimagerie fonctionnelle a permis de documenter les phénomènes de diaschisis et de faire évoluer le concept. On sait aujourd'hui que les effets à distance ne sont pas seulement inhibiteurs, mais peuvent également être facilitateurs, selon l'étendue et la localisation de la lésion qui les provoque (Andrews, 1991). Ainsi, les lésions corticales de faible étendue entraînent des phénomènes de désinhibition; par contre, des lésions corticales plus larges ou des lésions sous-corticales provoquent l'inhibition des aires fonctionnellement reliées à l'aire lésée. L'effet facilitateur ou inhibiteur d'une lésion sur une aire donnée dépend du type de connections entre les aires en question, et aussi du temps écoulé après la lésion (Andrews, 1991). Ainsi, la mise hors-circuit d'une influence inhibitrice peut augmenter l'activation d'une autre région. Il est probable que des phénomènes de diaschisis de type inhibiteur et/ou excitateur aient un impact sur l'évolution des patrons de latéralisation et les profils de récupération du langage observés au cours de la récupération de l'aphasie.

Plusieurs des observations rapportées dans cette thèse pourraient découler des phénomènes de diaschisis. Plus précisément, un phénomène de diaschisis désinhibitrice résultante de la lésion gauche pourrait expliquer des performances de l'HD supérieures à celles qu'on a retrouvé chez les individus non cérébrolésés, tel que rapporté dans cette thèse.

Chez deux sujets, le temps écoulé apporte une amélioration de l'HG et démontre le caractère transitoire de la prise en charge par l'HD. La régression de la diaschisis d'inhibition ipsilatérale peut rendre compte de cette observation, de même qu'elle peut expliquer la récupération remarquable de l'expression orale observée chez un des sujets une année après l'installation de la lésion. D'autres études ayant utilisé des techniques d'imagerie cérébrale fonctionnelle ont rapporté des changements au niveau des activations de l'HD et l'HG en cours de récupération de l'aphasie dans le cadre du phénomène de diaschisis (Cappa et al., 1997; Bakar et al., 1996; Iglesias et al., 1996).

Le phénomène de diaschisis, tel qu'on le connaît aujourd'hui (Andrews, 1991), fournit des indices sur le fonctionnement du cerveau après la lésion. Or, si une lésion a des influences excitatrices ou inhibitrices sur d'autres aires fonctionellement connectées, il se pourrait aussi que ces influences modifient les rapports entre les hémisphères cérébraux. L'analyse de l'évolution des patrons de latéralisation au cours de la récupération de l'aphasie chez les trois sujets examinés indique que les rapports entre les hémisphères cérébraux sont dynamiques et qu'ils varient à travers le temps. Ceci entraîne des questions théoriques concernant les rapports interhémisphériques en cours de récupération de l'aphasie.

2.2 Les rapports interhémisphériques dans la récupération de l'aphasie

Dans sa revue sur la question de la diaschisis, Andrews (1991) explique comment la présence d'une lésion peut déclencher des phénomènes de désinhibition dans des aires fonctionnellement connectées à l'aire lésée. Il est donc probable que l'avènement d'une lésion de l'hémisphère gauche permette à l'HD d'exprimer un potentiel pour le traitement lexico-sémantique des mots non évident lorsque l'HG est fonctionnel. En effet, l'observation d'une prise en charge par l'HD du traitement des mots de haute et de basse imageabilité, de même que des noms et des verbes, dans un des cas rapportés dans cette thèse, suggère qu'au-delà de sa contribution effective au traitement des mots, l'HD peut avoir un potentiel pour le traitement lexico-sémantique non exprimé alors que les deux hémisphères intacts ont toute latitude pour interagir. Des études menées auprès de sujets *split brain* ou "au cerveau divisé" (Faure & Blanc-Garin, 1994), ainsi que chez des sujets normaux (Quemé et al., 2000), abondent dans ce sens. Ainsi, dans une série d'expériences de décision lexicale, Faure et ses collègues ont démontré que les performances du cvg-HD progressent lorsque la charge mnésique verbale augmente chez les sujets *split brain*. Les auteurs (Faure & Blanc-Garin, 1994; Querné et al., 2000) considèrent que la progression dans la performance de l'HD est le résultat d'une levée de l'inhibition interhémisphérique par surcharge hémisphérique gauche. En d'autres mots, la charge de traitement HG augmentant, l'HD est recruté pour maintenir un traitement efficace, parce que l'inhibition habituellement exercée depuis l'HG, dominant, sur l'HD, est levée (par la voie calleuse ou la voie sous-corticale). En accord avec les données de Faure & Blanc-Garin (1994) et de Querné (2000), l'avantage démontré par l'HD dans le traitement des mots de basse imageabilité au cours de la récupération de l'aphasie pourrait découler d'une augmentation de la charge dans le traitement verbal par l'HG comme conséquence de la lésion.

L'ensemble des résultats chez les sujets normaux, les *split-brain* et les observations rapportées dans cette thèse suggèrent une explication en termes de rapports interhémisphériques flexibles et non pas des dichotomies permanentes. La question de la levée de l'inhibition sur l'HD par lésion de l'HG a été largement discutée entre autres par Kinsbourne (1979), qui fut parmi les premiers à souligner le caractère dynamique des rapports interhémisphériques. Ceci met en évidence les limites des perspectives traditionnelles sur les bases de la récupération de l'aphasie et du fonctionnement du cerveau qui mettent l'accent sur les dichotomies fonctionnelles et non pas sur la dynamique interhémisphérique.

La plupart des études s'intéressant à la synergie interhémispérique ont été faites chez des sujets non cérébrolésés. Il est maintenant établi que chaque hémisphère assume des fonctions spécifiques et fait d'importantes contributions à des activités quotidiennes comme reconnaître des visages, percevoir de la musique ou même lire : les hémisphères se complètent et, nécessairement doivent "travailler" ensemble (Faure & Icher, 2001). Il n'existe toutefois pas de théorie générale de la spécialisation hémisphérique (*cf.* pour discussion Cohen et al., 1993; Sergent, 1994; Springer & Deutsch, 2000). Kosslyn, Gazzaniga, Galaburda et Rabin (1999) constatent que "les efforts pour caractériser les hémisphères en termes de dichotomies – le gauche est analytique, le droit holistique, le gauche est verbal, le droit perceptif, etc. – ont échoué à caractériser les différences hémisphériques" (p.1521). Comme le soutient Sergent (1994) "cette quête d'un principe explicatif de l'asymétrie fonctionnelle du cerveau nous [a] détournés de l'essentiel, à savoir comment les deux hémisphères cérébraux joignent leurs ressources et leurs compétences respectives pour produire un comportement adapté et unifié" (p.113). L'étude des bases anatomiques de la récupération de l'aphasie à été victime du même réductionisme. Les nouvelles perspectives sur le fonctionnement du cerveau normal nous amènent à privilégier une explication en termes de coopération plutôt que de compétition entre les hémisphères lors de la récupération de l'aphasie. Ainsi, si les assemblées de neurones qui sous-tendent la représentation lexicale étaient distribuées sur les hémisphères (notamment pour les mots à référent concret) et qu'une représentation serait donc plus efficacement activée quand les deux composantes hémisphériques de l'assemblée transcorticale de neurones correspondante sont "stimulées" (*cf.* Pulvermüller & Mohr, 1996; Pulvermüller, 1999, pour ce modèle Hebbien de la représentation cérébrale du lexique), il est fort probable que la récupération des aspects lexico-sémantiques soit soutenue par un réseau bilatéral et non pas par des régions circonscrites dans l'un ou l'autre hémisphère.

Des études récentes faisant appel à l'imagerie cérébrale fonctionnelle suggèrent que la récupération de l'aphasie pourrait être soutenue par un réseau bilatéral dans les deux hémisphères cérébraux (Cao et al, 1999, Weiller et al., 1995, Cappa et al., 1997). Toutefois, les méthodes d'analyse des activations utilisées actuellement ne permettent pas d'examiner les relations dynamiques entre les différents constituants du réseau, puisqu'elles ne peuvent rendre compte du caractère transitoire ou permanent ni de la force et de la direction des liens entretenus. Grâce à de récents développements dans le champ des mathématiques, les nouveaux modèles développés permettent d'examiner ces questions. L'approche connue sous le nom de connectivité fonctionnelle (Bénali, 1997) pourrait avoir des applications intéressantes à l'étude des soubassements de la récupération de l'aphasie.

3. L'étude de la connectivité fonctionnelle appliquée à l'étude des bases de la récupération de l'aphasie

La connectivité fonctionnelle est un modèle d'analyse des activations cérébrales en neuroimagerie fonctionnelle qui permet d'identifier des réseaux et de caractériser leur fonctionnement en termes de circuits cognitifs. Cette approche méthodologique apparaît comme une avenue intéressante dans l'étude des bases du traitement du langage et de la récupération de l'aphasie. Plus précisément, la connectivité fonctionnelle permettra le développement d'une méthodologie de quantification des processus neuronaux avec, pour objectif, une meilleure : a) localisation spatiale des ensembles neuronaux distribués b) caractérisation temporelle des ensembles neuronaux distribués par l'analyse conjointe des processus électromagnétiques et hémodynamiques, et c) caractérisation des circuits neuronaux des processus cognitifs ainsi que les invariants spatio-temporels de ces circuits (Bénali, 1997, Bénali et al. 1998).

De plus, la connectivité fonctionnelle permettra d'étudier les relations dynamiques et fonctionnelles entre les populations de neurones activés et d'élaborer les circuits neuronaux liés transitoirement pour exécuter une tâche sensorielle ou cognitive. Dans des études longitudinales chez un même sujet aphasique, ceci pourrait permettre l'identification des invariants spatiaux à partir des cartes statistiques d'activation ou des distributions de sources d'activité. Par ailleurs, on pourrait examiner les invariants dans les liens fonctionnels entre des ensembles de neurones. Ces invariants permettraient ainsi d'élaborer des modèles de réorganisation fonctionnelle cérébrale.

Cette nouvelle avenue dans l'étude du fonctionnement du cerveau s'avère prometteuse. Son application à l'étude de la réorganisation fonctionnelle durant la récupération de l'aphasie pourra augmenter nos connaissances sur les mécanismes mis en jeu par le cerveau pour faire face à la perte du langage.

Religions die when they are proved to be true.
Science is the record of dead religions.

Oscar Wilde (Phrases and Philosophies for the Use of the Young)

Chapitre 6

Conclusion

Les résultats des études qui constituent le corps de cette thèse démontrent que la récupération de l'aphasie est soutenue par une action intégrée du cerveau. Selon le temps écoulé après l'AVC, on retrouve une prédominance de l'HD ou alors une action conjointe des deux hémisphères pour le traitement lexico-sémantique. En effet, dans un premier temps, lorsque l'atteinte fonctionnelle de l'HG est importante, l'HD peut prendre en charge certains aspects du traitement du langage, en particulier, ceux pour lesquels il a une compétence pré-morbide. De plus, l'HD peut, dans certains cas, démontrer un potentiel pour le traitement lexico- sémantique non évident dans un cerveau intact alors que lorsque les deux hémisphères ont toute latitude pour interagir. Il est probable que la levée de l'inhibition de l'HG sur l'HD facilite l'expression du potentiel de l'HD pour le traitement des mots. Avec le temps écoulé, la levée de la diaschisis ipsilatérale permet une certaine récupération fonctionnelle de l'HG et un partage bilatéral pour le traitement lexico-sémantique.

Les propositions traditionnelles sur les bases de la récupération de l'aphasie ne permettent pas de rendre compte des résultats obtenus dans les trois études ici rapportées. En effet, à la lumière des résultats obtenus, examiner les bases de la récupération de l'aphasie à partir d'une perspective basée uniquement sur d'éventuelles modifications de la latéralisation fonctionnelle apparaît comme une approche trop réductionniste de ce sujet. Par contre, les résultats obtenus dans cette thèse s'intègrent bien dans une perspective de coopération et d'intégration des apports hémisphériques de l'organisation fonctionnelle du cerveau, proposée par Justine Sergent (1990; 1994). Les nouvelles approches méthodologiques combinant la neuroimagerie et la connectivité fonctionnelle ouvrent des perspectives novatrices et intéresantes dans la recherche de soubassements neurobiologiques de la récupération de l'aphasie.

Références générales

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.

Benali, H. (1997). Analyse des données en IRM fonctionnelle. In, J. Bittoun, M. Décorps, & D. Le Bihan, Eds, *Méthodes et application de l'imagerie neurofonctionnelle*. Le Vésinet : INSERM, 161-169

Benali,H., Anton, J.L., Pélégrini, M., Di Paila, M., Bittoun, J, Burnod, Y., & Di Paola, R. (1998). Space-time statistical model for functional MRI image sequences. In J. Duncan & D. Gindi, Eds. Information Processing in Medical Imaging. Berlin : Springer, 285-298.

Boles, D.B. (1983). Dissociated imageability, concreteness and familiarity in lateralized word recognition. *Memory and Cognition*, 11 ; 511-519.

Boller, F. (1968). Latent aphasia : Right and left "non aphasic" brain damaged patients compared. *Cortex*, 4; 245-256.

Broca, P. (1865) Sur la faculté du langage articulé. *Bulletin de la Société d'Anthropologie*, 6; 337-393.

Calvert, G.A., Brammer, M.J., Morris, R.G., Williams, S.C.R, King, N., & Matthews, P.M. (2000). Using fMRI to study recovery from acquired dysphasia. *Brain and Language*, 71; 391-399.

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

Cao, Y., Vikingstad, E.M; Paige George, K. Johnson, A.F., & Welch, K.M.A. (1999). Cortical language activation in stroke patients recovering from aphasia with functional MRI. *Stroke*, 30; 2331-2340.

Cappa, S.F., Perani, D., Grassi, F., Bressi, S., Alberoni, M., Franceschi, M., Bettinardi, V., Todde, S., & Fazio, F. (1997). A PET follow-up study of recovery after stroke in acute aphasics. *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

Cummings, J.L., Benson, D.F., Walsh, M.J., & Levine, H.L. (1977). Left-to-right transfer of language dominance. A case study. *Neurology*, 29 ; 1547-1550

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

Day, J. (1977). Right-hemisphere language processing in normal right handers. *Journal of Experimental Psychology: Human Perception and Performance*, 3 ; 518-528;

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

Dejerine, J. (1914) *Sémiologie des affections du sytème nerveux*. Paris : Masson.

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

Ellis, A.W. (1984). Reading, writing and dyslexia : A cognitive analysis. London: Lawrence Erlbaum & Associates

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

Faure, S., & Blanc-Garin, J. (1994). Right hemisphere semantic performance and competence in a case of partial interhemispheric disconnection. Brain and Language, 47(4), 557-581.

Faure, S. & Icher, A. (2001). Coopération inter-hémisphérique en décision lexicale et efficacité du transfert inter-hémisphérique chez des sujets normaux. *Journée d'hiver de la Société de Neuropsychologie de Langue Française*, 7 décembre 2001, Paris.

Finger, S. & Stein, D.G. (1982) *Brain and damage, and recovery. Research and clinical perspectives*. New York: Academic Press.

Gainotti, G. (1993). The riddle of the right hemisphere's contribution to the recovery of language. *European Journal of Disorders of Communication,* 28 ; 277-246.

Gazzaniga, M.S. & Sperry, R.W. (1967). Language after bisection of the cerebral commissures. *Brain,* 90; 131-148.

Gazzaniga, M.S. (1983) Right hemisphere following brain bisection. A 20-year perspectives. *American Psychologist,* 38; 525-537.

Gazzaniga, M.S. (1984). Right hemisphere language: Remaining problems. *American Psychologist,* 39; 1494-1496.

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

Heiss, W.D., Karbe, H., Weberluxenburger, G., Herholz, K., Kessler, J., Pietrzyk, U., & Pawlik, G. (1997). Speech-induced cerebral metabolic actiovation reflects recovery from aphasia. *Journal of the Neurological Sciences,* 145; 213-217.

Heiss, W.D., Kessler, J., Thiel, A., Ghaemi, M., & Karbe, H. (1999). Differential capacity of the left and right hemispheric areas for compensation of postroke aphasia. *Annals of Neurology,* 45; 430-438.

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.

Joanette, Y. & Ansaldo, A.I. (2000). The ineluctable and interdependent evolution of the concepts of language and aphasia. *Brain and Language,* 71, 106-109.

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

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

Kinsbourne, M. & Hicks, R.F. (1978). Functional cerebral space : a model for overflow, transfer and interference effects in human performance. In, J. Requin (Ed.). *Attention and Performance VII.* Hillsdale NJ : Lawrence Erlbaum Associates.

Koening, O., Wetzel, C., & Caramazza, A. (1992). Evidence for different types of lexical representation in the cerebral hemispheres. *Cognitive Neuropsychology,* 9, 33-45.

Kosslyn, S.M., Gazzaniga, M.S., Galaburda, A.M., & Rabin, C. (1999). Hemispheric specialization. In, M.J. Zigmond, F.E. Bloom, S.C. Landis, J.L. Roberts, & L.R. Squire (Eds.). *Fundamental Neuroscience*. Boston MA : Academic Press, 1521-1542.

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

Lecours, A.R., Mehler, J., Parente, M.A., Caldeira, A., Cary, L., Castro, M.J., Dehaut, F., Delgado, R., Gurd, J., Fraga Karman, D. de, Jakubovitz, R., Osorio, Z., Cabral, L.S., & Junqueira, A.M.S. (1987). Illiteracy and brain damage. 1. Aphasia testing in culturally contrasted populations (control subjects). *Neuropsychologia*, 25; 231-245.

Lesser, R. & Milroy, L. (1993). *Linguistics and aphasia. Psycholinguistic and pragmatic aspects of intervention*. London: Longman.

Levine, D.N. & Mohr, J.P. (1979). Language after bilateral cerebral infarctions: Role of the minor hemisphere in speech. *Neurology,* 29 ; 927-938.

Mannhaupt, H.R. (1983). Processing of abstract and concrete nouns in a lateralized memory search task. *Psychological Research,* 45 ; 91-105.

Moutier, F. (1908). *L'aphasie de Broca.* Paris: Steinheil.

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.

Nielsen, J.M. & Raney, R.B. (1939). Recovery from aphasia studied in cases of lobectomy. *Archives of Neurology and Psychiatry,* 42 ; 189

Paradis, M. Ed. (1983) *Readings on aphasia in bilinguals and polyglots.* Montréal: Didier.

Pulvermüller, F. (1999) Words in the brain's language. Behavioural and Brain Sciences 22; 253-279

Petersen, P.M., Jorgensen, H.S., Nakayama, H., Raaschou, H.O., & Olsen, T.S. (1995). Aphasia in acute stroke: incidence, determinants and recovery. *Annals of Neurology,* 38; 659-666.

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

Querné, L., Eustache, F. & Faure, S. (2000). Interhemispheric inhibition, intrahemispheric activation, and lexical capacities of the right hemisphere : a tachistoscopic, divided visual-field study in normal subjects. *Brain and Language,* 74; 171-190.

Samson, Y. Belin, P., Zilbovicius, M, Remy, P., Van Eeckhout, P., & Rancurrel, G. (1999). Mécanismes de la récupération de l'aphasie et imagerie cérébrale. *Revue Neurologique,* 155; 725-730.

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

Sergent, J. (1990) Les dilemmes de la gauche et de la droite. Opposition, cohabitation ou coopération ? In, X. Seron & M. Jeannerod (Eds.). Psychologie du cerveau. Paris : Presses universitaires de France, 121-151.

Sergent, J. (1994). Spécialisation fonctionnelle et coopération des hémisphères cérébraux. In, X. Seron & M. Jeannerod (Eds.). *Neuropsychologie humaine.* Bruxelles : Mardaga, 106-125.

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

Spinger, S.P. & Deutsch, G. (2000). Cerveau gauche, cerveau droit. Paris : DeBoeck .

Von Monakow, C. (1914). *Die Lokalisation im Grosshirn und der Abbau der Funktion durch kortikale Herde*. Wiesbaden: Bergmann.

Wade, D.T., Wood, V.A., & Hewer, R.L. (1985) Recovery after stroke: the first three months. *Journal of Neurology, Neurosurgery and Psychiatry*, 48; 7-18.

Warburton, E., Price, C., Swinburn, K., & Wise, R. (1999). Mechanisms of recoevry from aphasia: evidence from positron emisssion tomography studies. *Journal of Neurology, Neurosurgery and Psychiatry*, 66; 155-161.

Young, W. & Ellis, A. (1985). Different methods for lexical access for words presented in the left and right visual hemifields. *Brain and Language*, 24 ; 32-358

Weiller, et al., 1995. Recovery from Wernicke'aphasia. A positron emission tomography study. *Annals of neurology*, 37 ; 732-732

Zaidel, E. (1976). Auditory vocabulary of the right-hemisphere following brain bisection or hemidecortication. *Cortex*, 12; 191-211.

Zaidel, E. (1978). Lexical organization in the right hemisphere. In P.A. Buser & A. Rougel-Buser (Eds), *Cerebral correlates of conscious experience*. Amsterdam: Elsevier; 177-197.