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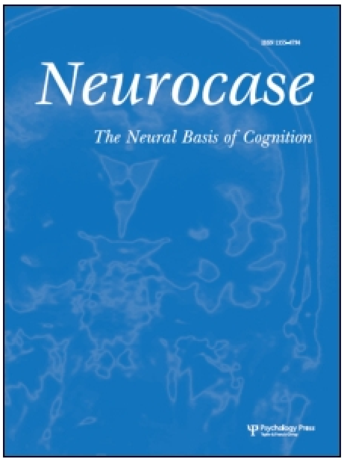

Neurocase
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713658146

Naming performance in two bilinguals with frontal vs. temporal glioma

Peggy Gatignol [ab]; Hugues Duffau [bc]; Laurent Capelle [d]; Monique Plaza [b]
[a] ENT and Otoneurosurgy Department, Hôpital de la Salpêtrière, Paris, France [b] Laboratoire de Psychologie et Neurosciences Cognitives, UMR CNRS 8189, Université Paris Descartes, Boulogne Billancourt, France [c] Department of Neurosurgery, CHU de Montpellier, Hôpital Gui de Chauliac, Montpellier, France [d] Department of Neurosurgery, Hôpital de la Salpêtrière, Paris, France

First Published on: 18 June 2009

To cite this Article Gatignol, Peggy, Duffau, Hugues, Capelle, Laurent and Plaza, Monique(2009)'Naming performance in two bilinguals with frontal vs. temporal glioma',Neurocase,99999:1,

To link to this Article: DOI: 10.1080/13554790902950434

URL: http://dx.doi.org/10.1080/13554790902950434

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NEUROCASE
2009, i*First*, 1–12

Psychology Press
Taylor & Francis Group

Naming performance in two bilinguals with frontal vs. temporal glioma

Peggy Gatignol,[1,2] Hugues Duffau,[2,4] Laurent Capelle,[3] and Monique Plaza[2]

[1]ENT and Otoneurosurgy Department, Hôpital de la Salpêtrière, Paris, Cedex 13, France
[2]Laboratoire de Psychologie et Neurosciences Cognitives, UMR CNRS 8189, Université Paris Descartes, Boulogne Billancourt, France
[3]Department of Neurosurgery, Hôpital de la Salpêtrière, Paris, Cedex 13, France
[4]Department of Neurosurgery, CHU de Montpellier, Hôpital Gui de Chauliac, Montpellier, France

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Two bilingual patients had World Health Organization Grade II Gliomas removed from a language area, one in the left mesiofronto-cingular region and one in the left postero-temporal region. They performed a picture naming task in their two languages before their surgery and afterwards. Both patients showed slowness in naming in their first language but different patterns of naming performance across their first and second language. Their patterns depended upon the site of their lesion and their language experience. These data, from brain-damaged, bilingual adult patients, contribute to the neuropsychological literature on brain organization and plasticity, and highlight the importance of assessing naming speed to obtain a better understanding of impairment and recovery mechanisms.

Keywords: Bilingualism; Picture naming; Low-grade glioma; Frontal area; Temporal area; Recovery.

INTRODUCTION

Recent studies using event-related functional MRI (fMRI) and event-related brain potentials (ERP) showed that the bilingual's brain is specifically organized. In bilingual children, the two languages are processed by non-identical brain systems according to hemisphere dominance and vocabulary size (Abutelabi et al., 2008; Conboy & Thal, 2006; Khateb et al., 2007). The relations between lexicons and semantics in bilingualism depend on variables such as age of acquisition and proficiency level of each language (Kroll & Stewart, 1994). The earlier and more precisely the second language develops, the more similarly both languages activate the brain (Paradis, 2000).

In bilingual patients suffering from brain pathologies, changes in both languages may occur as deficits are acquired or during recovery after surgery; the changes may be parallel, differential, successive, selective, or of mixed or antagonist patterns (Paradis, 2000). The reasons for changes in language are complex, and understanding them is made even more difficult because they are affected by the location of the tumor, the age when the second language is acquired, and how frequently the patient uses each language in their environment. In addition, bilingualism studies are methodologically difficult because the tests used to assess each language are not standardized across languages.

However, picture naming tasks allow analyzing relevant aspects of lexical, phonological, and morphological skills in bilinguals after damage of brain areas that subserve language. Their results are reproducible across languages and performance is easily timed. Thus, naming tasks are frequently

We thank Sylvain Mottet for the computer-program implementation and Anthony de Casper for the English revision of the manuscript.
Address correspondence to Peggy Gatignol, (E-mail: peggy.gatignol@psl.aphp.fr).

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http://www.psypress.com/neurocase
DOI: 10.1080/13554790902950434

used for comparing failure and recovery patterns in bilingual patients.

Here we report the naming profiles of two bilingual patients (S1 and S2) operated on for left World Health Organization Grade II Gliomas (WHO-GRADE II) affecting, respectively, the mesiofronto-cingular (S1) and postero-temporal regions (S2).

According to the lesion sites, we expected more severe impairments in S2 than in S1.

S1, with a left mesiofronto-cingular glioma, could present articulatory disorders, spontaneous speech reduction, initiation and programming difficulties, which could generate 'speech arrest' or phonetic paraphasia (Duffau et al., 2002; Naeser, Palumbo, Helm-Estabrooks, Stiassny-Eder, & Albert, 1989; Gil Robles, Gatignol, Capelle, Mitchell, & Duffau, 2005).

S2, with a left postero-temporal tumor, could present hearing and language reception disorders, visual perception and identification impairments, memory deficits, verbal working memory deficits, and semantic error production (Catani, Jones, & Fytche, 2005; Duffau et al. 2005; Teixidor et al. 2007).

In the present paper, we assessed the subjects the day before surgery and then 1 week and 6 months afterwards. We focused on speed and accuracy of naming pictures in their first (L1) and second (L2) languages, while being especially attentive to site of their lesion and their language experience. The tip of the tongue phenomena are the most frequent lexical disturbance in the brain damaged patients. We aimed at analyzing the preoperative contrasted profiles and the post-surgical recovery patterns in bilingual individuals with aphasia.

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METHODS

Subjects

S1 was a 27-year-old English speaking (L1) Welsh woman. She was right handed. She began learning French (L2) at school when she was 11 years old. She married a Frenchman in 1999 and worked in France as an English teacher for a Human Resources company.

S2 was a 36-year-old Spanish (L1) woman. She was right-handed. She learned French (L2) in a daily context after marrying a Frenchman at age 25. She had two children and worked in France as a telephone operator for a removal firm (Table 1).

Each patient harbored a left WHO Grade II Glioma that was revealed by partial seizures. Preoperative anatomical MRIs showed that the tumors were located in the left mesio-fronto cingular (S1) and in the left temporal posterior (S2) regions. The control MRI performed 3 months after surgery showed the quality of glioma removal (Figures 1–4).

Pre- and post operative language assessment

The patients were administered a computer-program based on the picture naming DO 80 (Metz-Lutz et al., 1991) before and after surgery. This standardized test is most used in France. It consists of 80 black and white substantive pictures presented on a screen (see, e.g., Figure 5). The subject looks at each picture and names it into a microphone. The latency and production time are automatically measured for each picture and then summed. L1 was first assessed, by two fluent English- and Spanish-speaking examiners. L2 was assessed by the same French-speaking examiner. In order to compare the patients' performances to normative data, using *z*-scores, we administered the DO 80 to a control group of 8 English and 8 Spanish speakers, matched on age (mean age: 25 years for the 'English' group and 34 years for the 'Spanish' one), socio-cultural level, and manner of learning (i.e., in early schooling for the 'English' controls and late after coming in France for the 'Spanish' subjects) (Table 2).

RESULTS

Control group

The control subjects homogeneously performed at the quantitative level (means and standard deviation: 78.6/80 (0.89) for the English group and 78.4/80 (0.56) for the Spanish one. The 'Spanish' were slower (140.4 s (12.4)) than the 'English' subjects (115.4 s (13.5)), due to word length effects. The patients' results were average for French (L2), English (L1 in S1) and Spanish (L1 for S2).

TABLE 1
Results of questionnaires used to evaluate language history and use patterns

Section 1: Family History Questionnaire	*S1*	*S2*
What is the family's country of origin?	Welsh	Spain
Age you were first exposed to French?	11	25
What languages does your mother speak?	Welsh	Spanish
What languages does your father speak?	English	Spanish
What was the age of immigration to France?	23	26
Are you right or left handed?	Right handed	Right handed
Do you speak other languages than English or French?	Few words in Italian	Few words in Italian
Part II : Education background (check all that apply)		
Elementary?	Welsh	Spanish
High school?	Welsh	Spanish
College?	Welsh	Spanish
Graduate school?	English	Spanish
For the following questions, say the language you generally use…		
During childhood, did you speak		
At home, to your parents?	50/50 English Welsh	Spanish
At home to your brothers or sisters?	50/50 English Welsh	Spanish
At home, to your grandparents?	Welsh	Spanish
At home, to other relatives?	50/50 English Welsh	Spanish
To your friends	50/50 English Welsh	Spanish
When you were a child, how did the following people speak to you?		
At home, to your parents?	50/50 English Welsh	Spanish
At home to your brothers or sisters?	50/50 English Welsh	Spanish
At home, to your grandparents?	Welsh only	Spanish
At home, to other relatives?	50/50 English Welsh	Spanish
To your friends	50/50 English Welsh	Spanish
When you were a teenager, what language did the following people speak to you?		
At home, your parents?	50/50 English Welsh	Spanish
At home, your brothers or sisters?	50/50 English Welsh	Spanish
At home, your grandparents?	Welsh	Spanish
At home, other relatives?	50/50 English Welsh	Spanish
your friends	50/50 English Welsh	Spanish
Now what language do you use?		
At home, to your spouse, living companion?	Only French	French more than Spanish
At home to your children?	English	So-So
At home, to your colleagues at work?	English	French
At home, to other relatives?	French	French
To your friends	French	French
Now how do the following people speak to you?		
At home, to your spouse, living companion?	Only French	French more than Spanish
At home to your children?	English /French	French more than Spanish
At home, to your colleagues at work?	English	French more than Spanish
At home, to other relatives?	French	French more than Spanish
To your friends	French	French only
How would you rate your speaking ability in L1/ L2?		
Rate yourself according to the following categories		
L1: very good, somewhat good, somewhat poor, very poor	Very good	Very good
L2: very good, somewhat good, somewhat poor, very poor	Very good	Somewhat so
How would you rate your reading ability in L1/L2?		
L1: very good, somewhat good, somewhat poor, very poor	Very good	Very good
L2: very good, somewhat good, somewhat poor, very poor	Very good	Somewhat so
How would you rate your writing ability in L1/L2?		
L1: very good, somewhat good, somewhat poor very poor	Very good	Very good
L2: very good, somewhat good, somewhat poor, very poor	Very good	Somewhat poor
How would you rate your comprehension ability in L1/L2?		
L1: very good, somewhat good, somewhat poor, very poor	Very good	Very good
L2: very good, somewhat good, somewhat poor, very poor	Very good	Somewhat so

(*Continued*)

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TABLE 1
(*Continued*)

Section 1: Family History Questionnaire	*S1*	*S2*
Do you sound like a monolingual speaker when you phone somebody who doesn't know you?		
L1: always, almost always, sometimes, almost never, never	Always	Almost always
L2: always, almost always sometimes, almost never, never	Almost never	Almost always
Do you sound like a monolingual speaker in a face to face conversation with a stranger?		
L1: always, almost always, sometimes, almost never, never	Always	Almost always
L2: always, almost always, sometimes, almost never	Always	Almost always
Which language do you feel more comfortable speaking?	English	Spanish
Which language do you speak when you're really tired?	French (with my husband)	Spanish
When you are angry?	French (with my husband) English (with my children)	Spanish
When you're incredibly happy?	It depends	50/ 50 French Spanish
Which language do you use in simple arithmetic (counting, adding, multiplying, etc?)	English	Spanish
Do you hear any voice when you read?		
In L1? in L2?	NO	NO
When reading a letter, have you ever experienced the sensation of hearing the voice of the person who wrote it as you read the words?		
In L1? in L2?	Yes in L1, Yes in L2	NO
If you were asked to remember twelve items, without being able to write theme down, which technique do you think would work better for you? Check only ONE		
1. Visualizing the objects	**1**	
3. Visualizing the words for the objects in L1		
4. Visualizing the words for the objects in L2		
5. Visualizing the words for each object either in L1 or L2, depending on the object type?		**5**
According to surgery, you were informed by your doctor that one consequence of surgery would be complete loss of one of your two languages, maintaining your other language intact. The doctor adds that you may choose which language to keep.	English	Spanish

Both subjects were administered the questionnaire in French. (A) Self rating on a 5-point scale (1–5: very good–very poor)

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Patient S1

We considered as pathological all scores below 2 *SD*. For each language, we calculated the *z*-scores by establishing a ratio raw average score/standard deviation.

Pre-operative language assessment

S1 accurately performed the picture naming task in English (80/80, $z = +1.57$, $p < .001$) and in French (79/80, $z = 0$, *ns*), producing only one semantic paraphasia (chain/wire netting) (Figure 6). However, naming speed was significantly slower than the control groups for both languages, 208 s in English, $z = -6.85$ $p < .001$, and 200 s in French, $z = -8.41$, $p < .001$.

Post operative assessment

One week after surgery, naming accuracy was more impaired in L1, 76/80, $z = -2.92$, $p < .001$, than L2, 79/80, $z = 0$, *ns*. Her naming speed was impaired, but faster in L2, 244 s, $z = -12.13$, $p < .001$, than L1, 373 s, $z = -19.08$, $p < .001$. Lexical retrieval was more difficult in L1. Three switch errors occurred in both languages. The patient used the French terms 'coq' for 'rooster', 'bureau' for 'desk' and 'ombrelle' for 'parapluie' (confusion between 'ombrelle' and 'umbrella'). We also noted one semantic paraphasia (squirrel/dog) and one phonemic paraphasia (watering pan/watering can).

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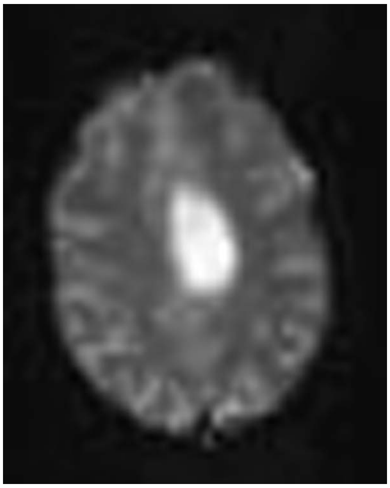


Figure 1. S1 Preoperative MRI.

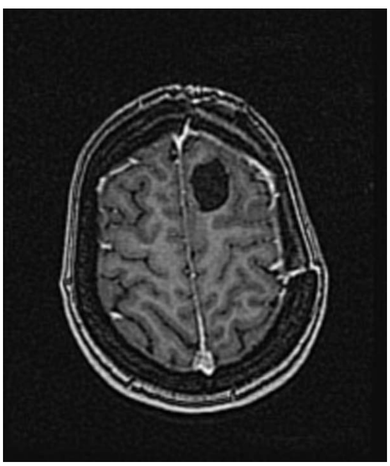


Figure 2. S1 Post operative MRI.

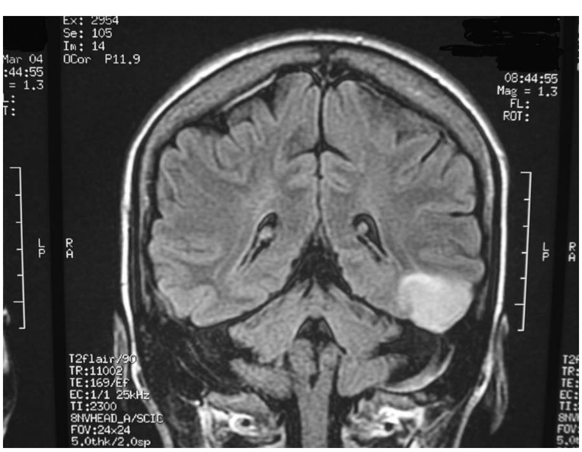


Figure 3. S2 Preoperative MRI.

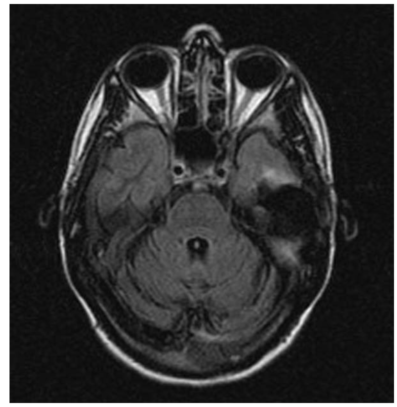
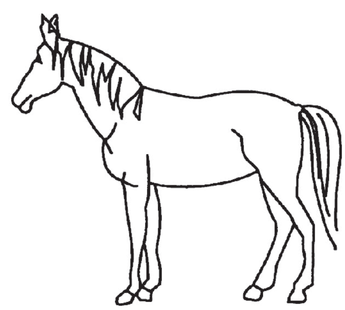


Figure 4. S2 Postoperative MRI.



cheval (horse)

Figure 5. Example of an item from the test DO 80.

Six months later, S1, who did not benefit from reeducation, obtained similar naming speed scores for both languages, 152 s for L1, $z = -2.71$, $p < .001$ and 150 s for L2, $z = -2.24$, $p < .001$.

Patient S2

Pre operative assessment

The assessment was difficult because the patient displayed significant tip-of-the-tongue (TOT) phenomena, in both languages and when she spoke in constrained and in spontaneous situations. There were long latencies, perseverations, semantic paraphasia and lack of response. We observed four speech arrests during the L1 naming task.

For Spanish (L1), her accuracy score was 58/80, $z = -36.42$, $p < .001$ and naming time 682 s, $z = -33.30$, $p < .001$. She produced many paraphasias,

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TABLE 2
Results from the different languages assessments

S1 *Oral naming picture (DO 80)*	*L1*	*L2*
Preoperative assessment	***English***	***French***
Fence (grillage)	+	Chain (chaîne)
Total	**80/80**	**79/80**
Standard deviation	*+1.57*	*0*
Naming time	**208s**	**200s**
Standard deviation	*–6.85*	*–8.41*
One week after		
Dog (chien)	Squirrel (écureuil)	+
Watering can (arrosoir)	watering **p**an (jerrican)	+
Umbrella (parapluie)	+	**ombrelle*** (sunshade)
Rooster (coq)	**coq***	+
Desk (bureau)	**Bureau*** (french term)	+
Total	**76/80**	**79/80**
Standard deviation	*–2.92*	*0*
Naming time	**373s**	**244s**
Standard deviation	*– 19.08*	*– 12.13*
6 months later		
Fence (grillage)	+	Net (filet)
Total	**80/80**	**79/80**
Standard deviation	*+1.57*	*0*
Naming time	**152s**	**150s**
Standard deviation	*–2.71*	*– 4.18*
S2 Oral naming picture (DO 80)	L1	L2
Preoperative assessment	***Spanish production***	***French production***
Dog (chien)	+	Cat (chat)
Fir tree (sapin)	***Arbre**** (tree)	Tree (arbre)
Wheelbarrows (Brouette)	***Escabeau**** (Stepladder)	+
Rhinoceros (rhinoceros)	***Hippopotame**** (Hippopotamus)	Hippopotamus (hippopotame)
Drum	–	+
Peacock (paon)	–	–
Comb (peigne)	Brush (brosse)	+
Pan (casserole)	***Poêle**** frying pan	frying pan (poêle)
Clog (botte)	+	Shoe (chaussure)
Hairbrush (Brosse à cheveux)	Comb (peigne)	Comb (peigne)
Scissors (ciseaux)	*Blocking*	+
Kangaroo (kangourou)	*Blocking*	+
Grating (grillage)	*Blocking*	+
Watering can (arrosoir)	*Blocking*	+
Broom (balai)	Comb (peigne)	Floorcloth (serpillère)
Armchair (fauteuil)	Chair (chaise)	Chair (chaise)
Ladle (louche)	Spoon (cuiller)	Spoon (cuiller)
Zebra (zèbre)	Horse (cheval)	Horse (cheval)
Padlock (cadenas)	–	Key (clé)
bucket (seau)	–	+
Chest of drawers (commode)	–	Furniture (meuble)
Umbrella (parapluie)	–	+
Stool (tabouret)	Chair (chaise)	+
Rocks	+	Seesaw (Brosse à cheveux)
Boots (botte)	+	Shoes (chaussures)
Snail (escargot)	+	Tortoise (tortue)
Hatchet (hache)	–	–
Desk (bureau)	+	Furniture (meuble)
Total	**58/80**	**62/80**
Standard deviation	*–36.4*	*–17.0*
Naming time	**682s**	**554s**
Standard deviation	*– 33.30*	*–33.36*

(*Continued*)

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TABLE 2
(*Continued*)

S1 Oral naming picture (DO 80)	*L1*	*L2*
One week after		
Flag (drapeau)	+	Scarf (écharpe)
Fir tree (sapin)	Tree (arbre)	Tree (arbre)
Cannon (canon)	+	–
Wheelbarrows (Brouette)	Towing (remorque)	Canddle (bougie)
Rhinoceros (rhinoceros)	Hippopotamus (hoppopotame)	+
Drum (tambour)	–	+
Peacock (paon)	–	–
Bear (ours)	Cow (vache)	+
Comb (peigne)	Brush (brosse)	Brush (brosse)
Pan (casserole)	***poêle**** Frying pan	+
Clog (botte)	Shoe (chaussure)	Shoe (chaussure)
Brushe (brosse)	Comb (peigne)	+
Butterfly (papillon)	–	–
Scissors (ciseaux)	–	+
Kangaroo (kangourou)	***Ecureuil**** (squirrel)	+
Grating (grillage)	–	+
Watering can (arrosoir)	–	+
Broom (balai)	Comb (peigne)	Floorcloth (serpillère)
Armchair (fauteuil)	Chair (chaise)	Chair (chaise)
Ladle (louche)	Spoon (cuiller)	Spoon (cuiller)
Zebra (zebra)	Horse (cheval)	–
Padlock (cadenas)	–	–
Bucket (seau)	–	+
Masks (masque)	–	+
Bench (banc)	–	+
Chest of drawers (commode)	–	+
Umbrella (parapluie)	–	+
Stool (tabouret)	Chair (chaise)	+
Hatchet (hache)	–	–
Tortoise (tortue)	Snail (escargot)	+
Cork (fourchette)	Knife (couteau)	+
Total	**51/80**	**66/80**
Standard deviation	*–48.92*	*–13*
Naming time	**389s**	**384s**
Standard deviation	*–15.28*	*–20.84*
6 months after		
Fir tree (sapin)	Tree (arbre)	Tree (arbre)
Wheelbarrows (Brouette)	***Escabeau**** stepladder	+
Rhinoceros (rhinoceros)	Hippopotamus (hippopotame)	+
Peacock (paon)	–	–
Comb (peigne)	Brush (brosse)	Brush (brosse)
Pan (casserole)	***Poêle**** Frying pan	+
Clog (botte)	+	Shoe (chaussure)
Brush (brosse)	Comb (peigne)	+
Butterfly (papillon)	+	–
Kangaroo (kangourou)	***Écureuil**** (squirrel)	+
Grating (grillage)	–	+
Broom (balai)	Comb (peigne)	Floorcloth (serpillère)
Armchair (fauteuil)	Chair (chaise)	Chair (chaise)
Ladle (louche)	Spoon (cuiller)	Spoon (cuiller)
Padlock (cadenas)	–	–
Chest of drawers (commode)	–	+
Stool (tabouret)	Chair (chaise)	+
Desk (bureau)	Furniture Meuble)	+
Total	**64/80**	**71/80**
Standard deviation	*–25.7*	*–8*
Naming time	**346s**	**300s**
Standard deviation	*–12.6*	*–11.05*

+, Good answer; –, No answer; *Item produced in the second tested language; *Blocking,* the patient was enable to articulate a word; ( ) French production.

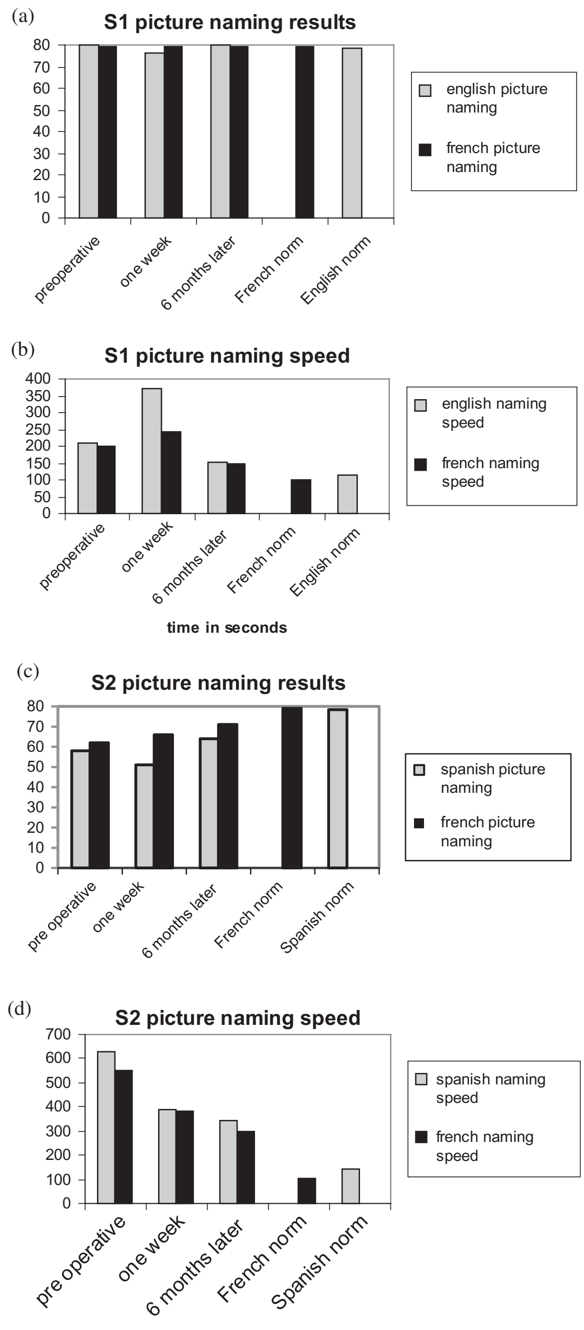

Figure 6. (a) S1 picture naming results; (b) S1 picture naming speed; (c) S2 picture naming results; and (d) S2 picture naming speed.

perseverations (such as 'Silla' for 'armchair', 'stool') and TOT phenomena (she said: 'I know but I do not find'). For French (L2), her accuracy score was 62/80, $z = -17.00$, $p < .001$, and naming time was 554 s, $z = -33.36$, $p < .001$.

Post operative assessment

During the 3 days following surgery, S2 used only L1, but with much difficulty (anomia and TOT) in spontaneous speech or when speaking on the phone.

One week after surgery, picture naming was more difficult in L1, 51/80, $z = -48.92$, $p < .001$, than L2, 66/80, $z = -13$, $p < .001$. Naming speed was similarly slow in both languages, i.e., L1, 389 s, $z = -15.28$, $p < .001$ and L2, 384 s, $z = -20.84$, $p < .001$.

Six months after surgery, L2 had improved. The patient, who benefited from speech therapy in both languages, complained of a lack in her mother tongue, notably when interacting with her children. The children used French during the week and Spanish on Saturday. They corrected her errors. S2 was more accurate in L2, 71/80, $z = -7.63$, than L1, 64/80, $z = -25.7$, $p < .001$. She remained faster in L2, 300 s, $z = -11.05$, $p < .001$, than L1, 346 s, $z = -12.6$, $p < .001$. All language scores improved (Table 2, Figure 5).

DISCUSSION

The question addressed in this paper concerned the language recovery patterns of two bilingual patients operated on for a glioma involving left mesiofronto-cingular (S1) and left postero-temporal regions (S2), respectively. We focused on the speed and accuracy of picture naming in L1 and L2 before and after surgery. We were attentive to the sites of the lesion and the patient's language experiences.

L1 and L2 evolution patterns

Preoperatively, S1 had average accuracy and slow performances in L1 and L2. S2's accuracy was more impaired in L1 and she was slow in both languages. In the immediate post-operative session, the two patients were more impaired in L1 than L2, and S1's naming speed remained particularly affected in L1. Six months later, S1 accurately and slowly processed L1 and L2, whereas S2 remained more impaired and slower in L1 than L2. Thus, in both patients, L1 was the most vulnerable language, but their recovery patterns were different.

Paradis (2000) described nine recovery patterns in bilingual subjects. In the 'parallel type', the

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languages present a similar deficit and recover at the same rate. This was the case for S1, who similarly recovered both languages, with naming being accurate and slow. By contrast, S2 presented a 'successive pattern', using only L1 in spontaneous speech immediately after surgery, and later developed a 'mixed pattern', combining L1 and L2 with semantic errors. With the 'successive pattern', language representations are relatively intact but the mechanism controlling access to them is affected in each language (Gollan & Kroll, 2001).

Why is L1 more affected?

Our findings highlighted selective deficits of the first language relative to the second language. Both patients presented isolated L1 impairment in naming tasks. Several hypotheses can account for the differential deficits between L1 and L2.

According to the order hypothesis, the order of language recovery follows the order of language acquisition (Emmorey & McCullough, 2009; Galloway, 1978). This was not the case in our patients.

According to the temporal hypothesis, when languages are learned at different ages or periods of development, they could be represented in the same or different cerebral zones (Grosjean, 1989). Thus, brain damage can affect a language acquired earlier that differently than it affects a language acquired later. The fact that S1 learned L2 earlier than S2 can explain the different recovery patterns.

According to the frequency hypothesis, when a native language is not practiced on a regular basis, it becomes difficult to access. Conversely, in case of brain damage, the language that is practiced more before illness and that is more stimulated afterwards will be better preserved and recover better. Our results are consistent with this hypothesis. Our patients were in the same hospital and tended by the same staff members who spoke only in French: This could explain the better L2 score during the immediate post-surgery evaluation. During this time, S2 presented L2 difficulties in spontaneous speech and was more efficient in L2 than L1 one week later. She benefited from a specific language therapy with a bilingual speech therapist (French–Spanish), who provided therapy twice a week in 30-min sessions. After 6 months of reeducation, neither positive nor negative effects were observed in L1. In general, the quantitative and qualitative differences observed in the secondary and late phase were correlated with aphasia severity. French was initially, and remained, less severely affected than Spanish.

A fourth, cognitive, explanation refers to the specific memory correlates of L1 and L2 naming skills. Kroll and Stewart (1994) proposed a hierarchical model conceptualizing bi-directional relations between L1/L2 lexicons, and the semantic system. Picture naming involves various stages of processing; from visual, semantic, phonological representation to articulation, which lasts about 600–1200 ms. Although no model clearly accounts for the altered control of passing from one language to another, some authors showed that bilinguals committed more TOTs, were slower than monolinguals during specific naming tasks, and performed like monolinguals only in the fifth picture presentation (Gollan & Kroll, 2001; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Gollan & Brown, 2006). More recently, they argued that bilinguals' ability to name pictures reflects their experience with word forms in both languages (Gollan, Montoya, & Bonanni, 2007). Picture naming revealed extensive differences related to manipulation, impact of semantic reference on brain activation, episodic memory, and word class. 'L2 better than L1' could be due to the fact that L2 words are represented in episodic memory (Gollan & Kroll, 2001), whereas L1 requires implicit memory (Moretti et al., 2001). L1 impairment depended on the learning context during which language is represented in the brain (Ivanova & Costa, 2008; Kim, Relkin, & Lee, 1997). The acquisition of the mother tongue is based on procedural memory, becomes automatic and controlled by sub-cortical structures (Moretti et al., 2001). In contrast, the control of L2 is conscious, voluntary, and based on declarative memory, which is managed by cortical structures. This can explain the L1 impairment in our two patients.

Finally, as observed in direct electrical stimulation studies (e.g., Bello et al., 2006; Giussani, Roux, Lubrano, Gaini, & Bello, 2007; Kho et al., 2007; Roux & Trémoulet, 2002; Serafini, Gururangan, Friedman, & Haglund, 2008), some stimulations specifically perturbed patients' mother tongue, confirming that the first and second language are located in different sites, at cortical and sub-cortical levels. When comparing 25 bilinguals and 117 monolinguals Lucas, McKhann, and Ojemann (2004) showed that two specific modules (areas 21/22) were activated for L1 and L2 and those temporal and parietal sites but not frontal sites were involved in L2.

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Naming speed in L1 and L2

According to Abutalebi (2008), language control depends on cognitive processes, memory and attention. Our findings showed that naming speed is an important marker, for the cognitive cost (in S1) and the linguistic deficit (in S2), Green (1998).

Three switch errors were observed in S1, e.g., one phonemic paraphasia (watering pan/watering can) and one semantic paraphasia (squirrel/dog). The concept of 'switch', proposed by Leischner (1948), defines the mechanism sustaining the passage between two languages. Switch recruits different areas, notably the left caudate nucleus, which assures specific word selection, (Crinion et al., 2006; Kho et al., 2007). When the subjects start speaking L1 or L2, semantic processing that is shared by both languages (Kroll & Stewart, 1994) starts in parallel. When this mechanism is affected, either the patient uses only one language or alternates between the two languages without control. Thomas and Allport (2000) showed that language switching imposes a heavy load on linguistic performance. S1, who switched from L1 to L2, was inhibited and reacted slowly. She did not produce any aphasic errors, but only one switch between L2 and L1. She was slower in L1, which was not due to slowness in accessing internal lexicon, but rather in articulating the target word, because of the competition/inhibition cost between languages. S2 who was aphasic in both languages, had difficultly activating the naming process whatever the target word. These difficulties explain the TOT phenomena, long latencies and slow naming times. One week after surgery, she was more accurate and faster in both languages than preoperatively, as she did not present the blockings observed preoperatively.

Location implications in recovery

Recovery was different in the two patients. S1, operated on for a glioma affecting left mesiofronto-cingular, was slightly but significantly disturbed in both languages probably due to implication of SMA structure. S2, with a left postero-temporal tumor, was very impaired and already aphasic *before* surgery, with real speech difficulties in both languages, especially the mother tongue. As expected, the temporal location was more disturbed for language than its frontal counterpart.

The SMA plays a role in verbal initiation and programming, which accounts for S1 production slowness (Alario, Chainay, Lehericy, & Cohen, 2006). Broca's area is an executive site implicated in working memory, verbal selection and inhibition, and in phonological, lexical-semantic and syntactical processing. Using the naming task across three different contexts with bilingual subjects, Abutelabi et al. (2008) showed that the left caudate nucleus and anterior cingulate cortex participated in language selection processes, especially when the subjects have a weak L2, which was observed long naming times in L2, for S1 and S2.

The temporal lobe is recruited in various processes, such as concatenation and phonological perception (left posterior of T1), lexical and semantic memory access, and plays an associative role between the auditory representation of a word and its motor realization. Specific disturbances in semantic classes are found in cases of lesion, which was observed in the semantic paraphasias of S2.

Leischner (1948) suggested that damage on the supramarginal gyrus leads to loss of one language, or a mixture of both. Ojemann and Whitaker (1978) administered direct electrical stimulation to a polyglot patient during a naming task. They observed that stimulations either spare naming or perturb it in one or both languages. Using this technique, Roux and Trémoulet (2002) administered reading, counting, and naming tasks to 12 'multilingual' subjects with different language proficiencies and lesions. They observed errors (speech arrest) and evidenced different eloquent sites in frontal, temporal, and parietal areas.

CONCLUSION

Usually, when naming latencies are observed, especially during cortical mapping (e.g., Ojemann & Whitaker, 1978), they are not considered as errors. In our study, time measures allowed differentiating patients' aphasic disorders, concept loss in S2 and access difficulties due to initiation impairment in S1. Thus, we could refine diagnosis criteria, confirm the level of linguistic impairment and recommend remediation. In S2, we diagnosed an aphasia requiring a specific rehabilitation and in S1, an access impairment that spontaneously recovered.

Original manuscript received 9 July 2008
Revised manuscript accepted 26 February 2009
First published online

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