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Regular and irregular morphology and its relationship with agrammatism: Evidence from two Spanish–Catalan bilinguals

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Abstract

We report the performance of two aphasic patients in a morphological transformation task. Both patients are Spanish–Catalan bilingual speakers who were diagnosed with agrammatic Broca's aphasia. In the morphological transformation task, the two patients were asked to produce regular and irregular verb forms. The patients showed poorer performance with irregular than regular morphological transformations in both of their languages. These results are at odds with the proposal that agrammatic speech is always or even preponderantly associated with poorer performance in processing regular versus irregular verb form. Instead, these results support the view that a major component of agrammatic production is a deficit in morphosyntactic processing, independently of whether this processing ultimately involves regular or irregular forms.

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1. Introduction

Damage to the left inferior frontal lobe frequently results in a pattern of performance characterized by agrammatic production and asyntactic comprehension so-called Broca's aphasia. Agrammatic speech is characterized by the omission or misuse of free and bound grammatical morphemes and the tendency to omit or nominalise verbs, resulting in incomplete, fragmented sentences. These patients' comprehension is frequently impaired, revealing difficulties in assigning the correct thematic roles to nouns. Although different explanations have been proposed for these patterns of deficits (Berndt & Caramazza, 1999; Caplan, 1991; Grodzinsky, 2000; Herron & Bates, 1997), there is general agreement that a morphosyntactic processing deficit is one of the major components implicated in the complex disorder clinically classified as Broca's aphasia. This view is based on the assumption that one of the functions of the left inerations in sentence processing. Recently this view has been challenged. Ullman (2001), Ullman et al. (1997), have proposed a role for the left inferior frontal cortex that is both broader and narrower than that typically assumed to explain the patterns of aphasic performance in patients with damage to this area of the brain. The proposal is broader because it assumes that the left inferior frontal cortex (along with the basal ganglia) is involved in all sorts of rule-based computations; it is narrower because it limits its involvement in relation to language to those processes that are rule-based. For example, a lesion to this region of the left hemisphere would result in impairment of only regular morphological processes, while sparing the ability to produce irregular morphology. Ullman et al. (1997) recently tested the hypothesis

ferior frontal lobe is to carry out morphosyntactic op-

Ullman et al. (1997) recently tested the hypothesis that damage to the left inferior frontal cortex results in a deficit restricted to rule-based morphological processing. They assessed the performance of aphasic patients with left anterior and posterior lesions in a morphological transformation task with regular and irregular verbs.

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Ullman et al.'s, 1997 patients had broad lesions although the left inferior frontal lobe was only compromised in the case of the so called "anterior" patients. In their framework, regularly inflected words are computed from a stored stem plus the application of a morphological affixation rule—a procedural knowledge. It relies on the ability to apply combinatorial abstract rules. These rules apply in the same manner independently of the lexical form as long as it is identified as a verb. By contrast, when the morphological transformation is carried out on irregular forms, procedural knowledge would not be useful, and such forms have to be retrieved from the lexicon. For example, it is assumed that when the speaker produces the past tense form of the verb "to walk" she retrieves from the lexicon the lexical node corresponding to the uninflected form of the verb and then a rule-based morphological transformation is triggered, having as a result the attachment of the regular past-tense ending "-ed" to the base word. However, when the speaker wants to produce the past-tense form of the verb "to run," she retrieves the irregular past-tense form, "ran," directly from the lexicon—a declarative knowledge operation.

Ullman et al. (1997) tested the performance of four types of patients: Parkinson's, Alzheimer's, anterior aphasics, and posterior aphasics. The patients were asked to perform a sentence completion task requiring the production of a verb in the past tense. For example, they would be given the stimulus "Every day I dig a hole. Just like every day, yesterday I ____ a hole" and would be required to complete the sentence. The results revealed that anterior aphasics (and Parkinson patients) performed worse with regular than irregular verbs, while the opposite was found for posterior aphasics (and Alzheimer patients). These results were interpreted as evidence supporting the notion that the left frontal cortex (along with the basal ganglia) is involved in rulebased language processing but not in the processing of irregular morphology, and that temporal lobe areas are implicated in the storage of lexical forms.

However, there are also reports of agrammatic patients who perform worse on irregular than regular morphological transformations (patient RC: Shapiro & Caramazza, 2003; patient MR: Laiacona & Caramazza, 2004; Penke, Janssen, & Kraus, 1999; Faroqi-Shah & Thompson, 2003), who were classified as Broca's aphasics, but who performed more poorly in producing the irregular than the regular forms of verbs. These results are consistent with the classical view that left inferior frontal cortex is involved in morphosyntactic processing and not just in rule-based transformations. Here we explore this issue further by considering the performance of two agrammatic Spanish/Catalan bilingual patients.

Consider the past-tense formation in Spanish. The production of regular and irregular verbs mirrors that of

English. Regular verbs, such as mirar (to look), are generated by "adding" to the verb root (mir-) the inflectional ending corresponding to the past tense (-aba, resulting in *miraba*, looked). As in English, irregular forms in Spanish differ from the base word. Usually, an irregular verb (salir [to exit]) has two stems: the regular stem that corresponds to the infinitive form (sal-es [you exit]) and the irregular stem (salg-o [to exit, I exit]).² Importantly, the verbs forms for which an irregular stem is required are not always the same for all irregular verbs. In other words, whether a given form of an irregular verb requires the irregular stem is not predictable. For example, consider the case of the irregular verb "pedir" [to ask] and "salir" [to exit]. Both verbs have some forms that are irregular in the present. However, the cases in which the irregular stem is required are not the same. While for the verb "pedir" all the singular forms plus the third person plural form take the irregular stem [pid-], for the verb salir, only the first person singular takes the irregular stem [salg-]. Thus, the fact that a verb is irregular does not predict in which contexts the irregular stem is necessary.

Nevertheless, it is important to note that irregular forms in Spanish also have regular inflections attached to them. That is, the person and number inflections that are attached to irregular stems correspond to the regular inflections that are also attached to regular stems. In this scenario, it would seem reasonable to assume that irregular forms are produced by means of two mechanisms: (a) a mechanism that retrieves the irregular stem from the lexicon, and (b) a rule-based mechanism that retrieves the regular inflection that is attached to the irregular stem.

However, there are reasons to believe that the retrieval of irregular forms in Spanish does not involve the application of morphological rule-based procedures. This is because the retrieval of the irregular stem is guided by all the grammatical features of the intended verbal form. That is, it is not the case that an irregular stem can be selected solely on the basis of, say, tense, and that afterwards a morphological-rule translates the number and person grammatical features in the corre-

¹ Note, however, that there are many past tense suffixes in Spanish. The verb system in Spanish has three conjugation classes and the corresponding suffix of a verb will depend on the conjugation it belongs to (e.g., -ía, -ías, -íamos, etc., for 2nd and 3rd conjugations, and -aba, -abas, -abamos, etc., for 1st conjugation verbs). Furthermore, the past-tense suffix agrees with the subject's person [yo mir-aba (I looked), tú mir-abas (you looked), and nosotros mir-abamos (we looked)]. Thus, more than one suffix form is present in the morphology of Spanish, leading to a more complex system for regular verbs.

² The past tense or present tense of a verb can be irregular only for some forms and not others: for example, for the verb 'salir' an irregular stem is used for the first person singular [salg-o (I exit)] but a regular stem appears [sal-es (you exit)] for second person singular in the present. Thus, to say that a verb is irregular in Spanish is just to say that some forms of the verb are irregular.

sponding inflections. Instead, all grammatical features are needed in order to decide whether a regular or an irregular stem needs to be produced. For example, the selection of the irregular stem PID- [from pedir (to demand)], is determined by the combination of tense, aspect, person and number of the intended form. None of these features alone is sufficient for the selection of the irregular stem. For example, for present tense, indicative aspect, first person plural the correct stem is the regular form PED- [ped-imos (We ask)]. However, if only one grammatical feature was changed, say number, then the correct stem would be the irregular form PID- [yo pido, (I ask)]. Note that this is not only true for number, but also for, say, tense. If the tense feature were "past," then the first person singular would not take the irregular stem (*yo pidía) but the regular one ("yo pedía," I asked).

Given that the selection of the irregular stem depends on the person and number features of the intended form, these features do not function independently of the other verbs features in selecting the verb form. Instead, it would seem that irregular forms as a whole are retrieved from the lexicon. In this scenario, the retrieval of irregular verbal forms in Spanish would work in the same way as in English and, on the hypothesis proposed by Ullman et al.'s (1997), agrammatic patients should find the regular forms harder than the irregular forms. Catalan is a language with the same characteristics as Spanish for the issues described before. Hence, the same predictions follow for both languages. Given the properties of Spanish and Catalan the predictions that one can derive from a theory such as that of Ullman (2001), Ullman et al. (1997) for the performance of agrammatic patients in processing regular and irregular verbs in these languages are similar to English. Regular verbs could, in principle, be retrieved as in English. That is, lexical access would be necessary to retrieve the regular stem [mir-] and then a rule-based inflectional process would be triggered in order to retrieve the regular inflection (say, mir-aba [looked]). On this view, patients with damage to rule-based morphophonological processes should have problems with this type of verbs. The production of irregular forms in these two languages would be achieved in a similar way as in English. That is, information about tense, person, aspect, and number would be combined to access the proper irregular form from the lexicon. Thus, damage to the left inferior frontal cortex should result in worse performance for regular than irregular verb production in both Spanish and Catalan.

We tested these predictions by analyzing the performance of two agrammatic Spanish-Catalan bilingual aphasic patients (MP and JM), with lesions comparable to those reported for the anterior aphasic patients studied by Ullman et al. (1997). In addition to the specific hypothesis concerning the relationship between

agrammatic production and the regular/irregular contrast, the bilingual status of the patients allows us to explore the extent to which the performance of the patients is comparable across their two languages.

Despite the similarity between the morphological systems of Spanish and Catalan, there are also several important differences between them that are worth exploring. For example, a given verb can be regular in one language but not in the other, revealing that this property may vary across the two languages. This is even more interesting when we consider cognate verbs (translations that are phonologically similar across languages). For example, the verb "sentir" [to sleep] is regular in Catalan ("sent-o") and irregular in Spanish ("sient-o"). There are also cases in which irregular verbs in the two languages undergo different transformations (e.g., "veng-o" in Spanish, "vin-c" in Catalan, from "venir" [to come] in both Catalan and Spanish). Finally, although Catalan and Spanish have similar verbal suffixes (e.g. -o: first person, present tense), Catalan also has suffixes that do not exist in Spanish (-c, for the same tense and person as -o).

Thus, in principle, the morphological systems of the two languages are different enough to allow us to detect a dissociation in the production of verbal morphology across languages, if such difference existed in our patients. However, if the morphophonological processes engaged in verb production in the two languages share a common neural substrate, then we should observe similar levels of performance across languages.

2. Patient JM

2.1. Neurological profile

JM is a right-handed, 50-year-old college educated male who suffered a hemorrhagic stroke 9 years before testing for this study. He was first diagnosed with global aphasia, which evolved into an anterior aphasia as diagnosed by means of the Test Barcelona (Peña-Casanova, 1991). A recent SPECT (January 2002; see Fig. 1) shows severe frontal hypoperfusion, moderate in parietal lobe, and mild in the temporal. The MRI scan (January 2002; see Fig. 2) also showed abnormalities in the left frontotemporal subcortical area and periventricular right hemisphere.

2.2. Neuropsychological profile

Premorbidly, JM was a balanced Spanish–Catalan bilingual. His L1 was Spanish. His education in school and at the university was primarily in Spanish. However, he spoke in Catalan with his wife and sons, and Catalan is the language he prefers to use currently. After the stroke, both languages seemed similarly affected.

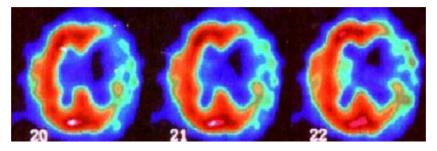


Fig. 1. Sagittal slice obtained with SPECT showing severe hypoperfusion in the left hemisphere of patient JM. Following radiological convention left is plotted on the right side.

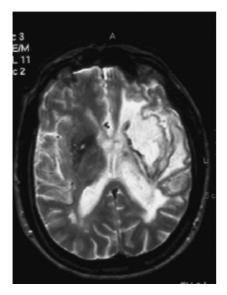


Fig. 2. Sagittal slice obtained with MRI showing JM's lesion. Following radiological convention left is plotted on the right side.

Language therapy was carried out in both languages with special emphasis on Catalan, the language of current use.

At the time of the investigation reported here, JM showed right hemiplegia and hemianopsia. His spontaneous speech in both languages was characterized by very short sentences (3–5 words) with many hesitations, omission and substitution of function words (especially prepositions) and verbs (see Appendix A). He also

produced subject-verb agreement errors. Occasionally, he produced semantically related substitutions of target verbs and intrusions from his other language. Word finding difficulties were present in his spontaneous speech in Spanish and Catalan. JM also showed articulatory problems, which sometimes made his speech difficult to understand.

JM's picture-naming ability was impaired (Spanish: 73% (48/66); Catalan: 78% (98/126)). Overall, he was worse at naming verbs than nouns [verbs: 51/76 (67%); nouns: 95/116 (82%); $\chi^2 = 14.143$, p < .001], although this difference did not reach significant values when Spanish and Catalan were analyzed separately (Spanish: verbs 25/38 (66%); nouns 23/28 (83%), $\chi^2 = 1.480$, n.s.; Catalan: verbs 26/38 (68.4%); nouns 72/88 (82%), $\chi^2 = 2.755$; n.s.). His naming errors were similar in the two languages—consisting mostly of circumlocutions, non-responses or morphological errors.

JM was severely impaired in word and non-word repetition both in Spanish [words: 14/37 (37%), non-words: 1/5 (20%)] and in Catalan [words: 6/17 (35%), non-words: 2/5 (40%)]. His errors were mostly articulatory deformations of the target. In addition to articulatory errors, his sentence repetition performance was characterized by the omission or substitution of function words. He performed relatively well in visual and aural lexical decision tasks (Spanish: visual [98% 39/40]; aural [98%, 39/40]; Catalan: visual [95% 38/40]; aural [92.5%, 37/40]). JM's reading performance was characterized by many articulatory errors. He was able to read 74% (14/

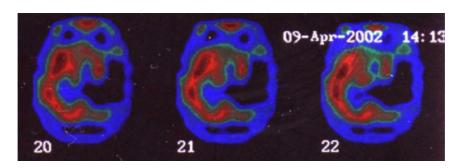


Fig. 3. Sagittal slice obtained with SPECT showing severe hypoperfusion in the left hemisphere of patient MP. Following radiological convention left is plotted on the right side.

19) of the words presented in Spanish, and 86.6% (13/15) of the words presented in Catalan. His ability to read nonwords was also impaired [40% (4/10) for nonwords derived from Spanish words; and 70% (7/10) for nonwords derived from Catalan words]. However, JM's ability to comprehend single words was good. In a task in which he had to point to the picture (among two semantically related pictures) corresponding to an aurally presented word, JM was 100% correct in both languages (20/20). He was also perfect in both languages (100%, 20/20) when asked to identify the correct written word corresponding to a picture, among a semantic, a phonological, and an unrelated foils. He also performed flawlessly when he had to point to the written word in response to an aurally presented name (100%, 12/12 in both languages).

JM performed well in a task in which he had to judge whether or not aurally presented sentences were grammatically well formed (95% 19/20). In a sentence/picturematching task, he presented with comprehension difficulties in understanding reversible active and passive sentences (62%, 5/8, in both Spanish and Catalan) but made no errors on non-reversible sentences (8/8, in both Spanish and Catalan). In a task in which he had to orally describe pictures depicting a scene by using the leading NP provided by the experimenter (e.g., The cat is..., for a scene in which a cat is bitten by a dog) he produced agrammatic responses. He was able to produce correctly only 3/15 (20%) sentences in Spanish and 7/15 (47%) sentences in Catalan. He was able to perform the task correctly only when the lead fragment could be completed with an active sentence. When the fragment forced the use of a passive sentence, he produced role reversal errors, verb and preposition omissions.

In summary, JM's performance and lesion site are consistent with the classical agrammatic profile. Ac-

cording to the procedural/declarative hypothesis, the patient is expected to perform better in the production of irregular than regular morphology.

2.3. Morphological task: Regular versus irregular verb production in Spanish and Catalan

To explore JM's ability to use regular and irregular inflectional morphology, we designed a test in which he was required to complete aurally presented sentence frames using the appropriate spoken forms. For example, given the sentence frame "Ayer yo comía, Hoy yo..." (Yesterday I ate, today I ...), JM was required to produce the verb form "como" (eat). In half of the test the past tense was given in the leading sentence and the patient had to retrieve the present tense. In the other half, the leading sentence contained the present tense and the patient had to retrieve the past-tense (see Tables 1 and 2 for Spanish and Catalan examples). Regular and irregular verbs were presented randomly in the same testing session.

Spanish materials. We selected 34 regular and 30 irregular verbs from the three conjugations (22 verbs of the 1st conjugation (-ar), 23 verbs of the 2nd conjugation (-er), and 19 verbs of the 3rd conjugation (-ir)). Some of the verbs were presented more than once in different sessions, resulting in 43 observations for regular verbs and 87 for irregular verbs. The selected verbs were not matched for concreteness or imageability. The irregular verbs were more frequent than the regular verbs (see Table 3). Regular and irregular verbs were presented equally often in the past and in the present tense.

Catalan materials. We selected 34 regular and 39 irregular verbs from the three conjugations (25 verbs of the 1st conjugation (-ar), 35 verbs of the 2nd conjugation

Examples of the different types of the required morphological transformations for regular and irregular verbs in Spanish	
Regular Verbs (a) hoy yo bebo, ayer yo (bebía; from the verb beber -to drink-); today I drink; yesterday I (drank), (b) ayer yo miraba, hoy yo (miro from the verb mirar -to look-); yesterday I looked; today I (look)	
Irregular Verbs (c) hoy yo voy, ayer yo (iba; from the verb ir -to go-); today I go; yesterday I (went), (d) ayer yo daba, hoy yo (doy; from the verb dar -to give-); yesterday I gave; today I (give)	
Table 2 Examples of the different types of verbal the required morphological transformations for regular and irregular verbs in Catalan	
Regular Verbs (a) Aquest matí jo temia, Ara jo (temo; from the verb témer -to fear-) (This morning I feared, Now I (fear)) (b) Ara jo menjo, Aquest matí jo (menjava; from the verb menjar -to eat-) (Now I eat, Yesterday I (ate))	
Irregular Verbs (a) Aquest matí jo feia, Ara jo (faig; from the verb fer -to make-); (This morning I made; now I (make)) (c) Ara jo vaig Aquest matí jo (apaya from the verb apar -to go-); (Now I go this morning I (went))	

Table 3 Mean frequency, concreteness and imageability (SD in parentheses) of the materials used in the morphological production task in Spanish (L1) and in Catalan (L2) for JM

	Frequency	Concreteness	Imageability
L1			_
Regular verbs	302 (282)	4.2 (0.93)	4.7 (0.94)
Irregular verbs	1744 (3091)	3.6 (0.81)	4 (0.91)
T value	$2.54 \ (p < .016)$	$2.52 \ (p < .015)$	$2.99 \ (p < .004)$
L2			
Regular verbs	155 (187)	4.3 (0.82)	5 (0.91)
Irregular verbs	1543 (3708)	3.93 (1.14)	4.23 (1.05)
T value	$2.33 \ (p < .025)$	1.32 (p < .2)	$3.30 \ (p < .002)$

tion (-er/-re), and 13 verbs of the 3rd conjugation (-ir)). Some of the verbs were presented more than once in different sessions, resulting in 45 observations for regular verbs and 132 for irregular verbs. The selected verbs were not matched for concreteness or imageability, but concreteness did not differ statistically. The irregular verbs were more frequent than the regular verbs (see Table 3). Regular and irregular verbs were presented an equal number of times in the past and in the present tense.

2.3.1. Data scoring

Incorrect responses were scored as lexical, morphological, mixed or other errors. Lexical errors included phonologically related, semantically related, or unrelated word responses. Morphological errors were wrong subject—verb agreement and tense errors, regularizations, or the production of the infinitive forms. Mixed errors consisted of more than one of these errors in the same item. 'Other' errors included perseverations, language switch, and no responses.

2.3.2. Data analysis

Since not all the verbs were presented the same number of times, the number of repetitions for each item was taken into account in the statistical analysis. Thus, in the analysis we do not consider each observation as one independent data point. Instead, the score for a given verb was calculated by considering the number of correct responses to an item divided by the number of repetitions of the item. In this way, all items were given the same weight in the statistical analysis regardless of how many times they were presented.

2.3.3. Results

The general pattern of results for JM reveals that he had more difficulty in producing morphological transformations with irregular than with regular verbs. He correctly produced 92.2% of regular verbs (59/68) versus 59.3% of the irregular verbs ((40.9/69), $\chi^2 = 13.11$, p < .001). Most of the errors produced by JM were "no

responses" followed by morphological errors and lexical substitutions. In the following section we discuss the data broken down by language (see Table 4).

Spanish. JM was much better at producing regular verbs (82.4%, 28/34) than irregular verbs (43.7%, 13.1/30; $\chi^2 = 10.38$, p < .01). However, before interpreting these results in terms of differences between regular versus irregular morphological processing, we need to consider the possible effects of correlated variables.

The items included in the overall analyses were not matched for several variables. For example, regular and irregular items differed statistically is frequency: irregular verbs were more frequent than regular verbs. Although it is unlikely that this difference is responsible for the poorer performance with irregular verbs—note that for this to be the case we would have to assume a reverse frequency effect—we decided to carry out an analysis with a subset of the verbs matched for frequency, concreteness, and imageability. The sample resulted in 34 regular verbs that produced a total of 43 observations, and 20 irregular verbs that produced a total of 47 observations. Verb conjugations were distributed as follows: 20 verbs from the first conjugation (-ar; 23 observations), 17 from the second conjugation (-er; 30 observations), and 17 from the third conjugation (-ir; 36 observations). With this subset of items, JM was still much better at producing

Table 4
Distribution of the errors produced by JM in the morphological production task in L1 and L2

	L1		L2	
	Regular	Irregular	Regular	Irregular
Lexical errors				
Unrelated verb	1 (14)	2 (4)	1 (25)	3 (10)
Semantically related	_	_	_	_
Phonologically related	1 (14)	4 (8)	1 (25)	7 (24)
Morphological error	S			
Regularization	_	2 (4)	_	3 (10)
Infinitive form	_	_	_	_
Person agreement	_	3 (6)	1 (25)	6 (21)
Tense agreement	_	2 (4)	_	_
Wrong	_	2 (4)	_	_
irregularization				
Mixed errors				
Phonol and semant	_	2 (4)	_	_
Tense and person	_	5 (10)	_	_
Phonol and tense	_	_ ` `	_	_
Unrelated and tense	_	_	_	_
Other errors				
Perseveration	2 (29)	_	_	_
Language switch	_ `	_	_	2 (7)
No response	3 (43)	28 (56)	1 (25)	8 (28)
Total	7 (100)	50 (100)	4 (100)	29 (100)

Numbers in parentheses represent the percentage of errors.

regular verbs (82.3%, 28/34) than irregular verbs (53%, 10.6/20), $\chi^2 = 5.354$; p < .025.

Catalan (L2). JM was better at producing regular verbs than irregular verbs (91.2%, 31/34 correct versus 71.3%, 27.8/39 correct, respectively, $\chi^2 = 4.588$, p < .05). When considering a subset of the items matched for frequency, concreteness and imageability [30 regular verbs that produced a total of 41 observations, and 30 irregular verbs that produced a total of 92 observations: 19 verbs from the first conjugation (-ar), 30 from the second conjugation (-er) and 11 from the third conjugation (-ir)], JM was still much better in the production of regular verbs (95%, 28.5/30) than irregular verbs (74%, 22.2/30; $\chi^2 = 5.050$, p < .025).

2.4. Comment

It is clear that the results obtained with JM—worse performance with irregular than regular verb morphology—are problematic for the procedural/declarative model, which predicts better performance with irregular than regular verbs in patients with agrammatic aphasia. Since JM's greater difficulty with irregular verb morphology persisted even when regular and irregular verbs were matched on variables such as frequency, concreteness, and imageability, it seems reasonable to attribute the observed difference to the "regularity" of the morphological transformation of the verbs.

3. Patient MP

3.1. Neurological profile

MP is a right-handed 42-year-old college educated woman who suffered a left temporal hematoma, seen in the first CT scan, 7 years before testing. The arteriography showed an aneurism at the trifurcation of the left middle cerebral artery, as described in the radiological report. She underwent a craniotomy to clip the aneurism and drain the hematoma. One month after the intervention, her diagnose was Mixed Aphasia and the control CT scan showed that the hematoma was reabsorbed. A recent SPECT scan (January 2002; see Fig. 3) shows marked hypoactivity in the whole left hemisphere.

3.2. Neuropsychological profile

MP's first language was Catalan but her education at school was exclusively in Spanish. She was highly fluent both in Spanish and Catalan before brain damage. Language therapy was carried out both for Catalan and Spanish. She speaks in Catalan at home. In August 2002, she was tested on the Spanish version (García-Albea, Sánchez Bernardos, & Del Viso, 1996) of the

Boston Diagnostic Aphasia Evaluation (Goodglass & Kaplan, 1983) and was classified as having Broca's Aphasia. At the time of testing she still suffered severe right hemiplegia and a reduced visual field due to right hemianopsia.

MP's spontaneous speech in both languages is characterized by very short sentences (2–4 words), word finding difficulties, frequent use of idioms, and unfinished sentences, leading sometimes to isolated words or incorrectly ordered constituents. Agreement violations (for auxiliary–verb and subject–verb agreement, especially for person and tense) were also present. She often omitted verbs, and she substituted or omitted function words (especially prepositions) (see Appendix A). She occasionally produced phonologically or semantically related verb or noun substitutions. She sometimes produced verbs in the infinitive instead of the inflected form, and had occasional intrusions from her other language.

In a picture-naming task, MP showed naming problems both in Catalan [105/134 (78.4%)] and Spanish [96/ 134 (71.6%)]. She performed roughly equally poorly for nouns and verbs in the two languages (Catalan: verbs 26/36 (72.2%), nouns 79/98 (80.6%), $\chi^2 = 1.093$, p < 1; Spanish: verbs 25/36 (69.4%), nouns: 71/98 (72.4%), $\chi^2 = 0.116$; p < 1). The errors in both languages were mostly circumlocutions and no responses. MP performed very well in word and non-word repetition [Catalan: words 91/93 (97.8%), non-words 28/28 (100%); Spanish: words 117/117 (100%), non-words 35/37 (94.6%)]. Her performance in reading words [Catalan: 68/83 (82%); Spanish: 10/12 (83.3%)] was better than in reading non-words [Catalan: 14/23 (60.9%); Spanish: 8/ 12 (66.7%)]. The errors in reading non-words were mostly phonological errors. MP performed very well in visual and auditory lexical decision tasks [Catalan: visual: 56/60 (93%); auditory: 38/40 (95%); Spanish: visual: 45/50 (90%); auditory: 49/50 (98%)]. In a picture– word matching task, she had no problems in matching an aurally presented word to one of the three pictures presented simultaneously [Catalan: 18/19 (95%) correct; Spanish: 10/10 (100%)]. She was also able to decide which one of the three printed words corresponded to a given picture [Catalan: 18/19 (95%) correct; she was not given this task in Spanish], or to a given aurally presented word [Catalan: 11/11(100%) correct; Spanish: 10/ 12 (83%)].

MP's grammaticality judgment performance was relatively good, [9/10 (90%) correct, both in Catalan and Spanish] but her performance in a sentence–picture matching task was impaired [Catalan: 39/52 (75%); Spanish: 44/52 (85%)]. Almost all of her errors involved semantically reversible sentences, for which she was correct only in 33% of the trials. Overall, her performance was similar for passive (Catalan: 71%; Spanish: 88%) and active (Catalan: 79%; Spanish: 95%) sentences (Catalan: $\chi^2 = 0.334$, n.s.; Spanish: $\chi^2 = 0.496$, n.s.).

MP also showed problems when asked to describe pictures of simple scenes. Her output was agrammatic, characterized by subject/verb agreement errors, verb omissions, and omission or incorrect use of prepositions. She produced only 2/15 correct sentences in Catalan and 1/15 in Spanish. Her difficulties were even more severe when she was required to start the sentence with a given NP. None of the sentences were produced without error in this condition.

In summary, MP presents with a classic agrammatic profile. According to the procedural/declarative hypothesis, the patient is expected to perform better in the production of irregular than regular morphology.

3.3. Morphological task: Regular versus irregular verb production in Catalan and Spanish

MP was asked to perform the same morphological task (but with slightly different items) as was given to JM (see examples in Tables 1 and 2). She was tested both in Catalan and Spanish.

Catalan materials. We used 53 verbs (35 regular and 18 irregular), some of which were repeated across different sessions. The verbs were from different conjugations (21 1st conjugation verbs used in 51 test items, 16 2nd conjugation verbs used in 57 test items, and 16 3rd conjugation verbs used in 48 test items). The selected verbs were not matched for concreteness or imageability. The irregular verbs were more frequent than the regular verbs (see Table 5).

Spanish materials. We used 53 verbs (28 regular and 25 irregular), some of which were repeated across different sessions, for a total of 40 regular trials and 81 irregular trials. The verbs were from different conjugations (17 1st conjugation, 17 2nd conjugation, and 19 3rd conjugation verbs). The selected verbs were not matched for concreteness or imageability. The irregular verbs were more frequent than the regular verbs (see Table 5).

In both languages, the present or past tense forms were used. Regular and irregular verbs were intermixed and presented randomly in a given session. In one half

Table 5 Mean frequency, concreteness, and imageability (SD in parentheses) of the materials used in the morphological production task in Spanish (L1) and in Catalan (L2) for MP

	Frequency	Concreteness	Imageability
L1			_
Regular	166 (181)	4.4 (0.82)	5.07 (0.87)
Irregular	3278 (4841)	3.65 (1.07)	4 (1.11)
T value	$2.65 \ (p < .017)$	$2.62 \ (p < .012)$	$3.54 \ (p < .001)$
L2			
Regular	309 (272)	4.46 (0.84)	5.01 (0.83)
Irregular	2133 (3274)	3.64 (0.86)	4.04 (0.92)
T value	$2.78 \ (p < .010)$	$3.36 \ (p < .002)$	$3.83 \ (p < .001)$

of the test trials the past tense was given in the leading sentence and the patient had to retrieve the present tense. In the other half of the trials, the leading sentence contained the present tense and the patient had to retrieve the past tense.

3.3.1. Data scoring and data analysis

As in the case of JM, the number of repetitions of a given verb was taken into account in the statistical analysis so that the score for a given verb was calculated by considering the number of correct responses to an item divided by the number of repetitions of that item. Errors were scored as described for JM.

3.3.2. Results

The general pattern of results for MP reveals that she had more problems when asked to produce a morphological transformation with irregular than with regular verbs. She correctly produced 84.3% (53.1/63) of the regular verbs versus 47.9% (20.6/43) of the irregular verbs, $\chi^2=15.96$; p<.001. As in the case of JM, most of MP's errors were "no responses" followed by morphological errors and lexical substitutions (see Table 6). In the following section we discuss the data broken by language.

Catalan. Overall, MP was much better in the production of regular verbs (79.7%, 27.9/35) than in the production of irregular verbs (41.7%, 7.5/18). This dif-

Table 6
Distribution of the errors produced by MP in the morphological production task in L1 and L2

	L1		L2	
	Regular	Irregular	Regular	Irregular
Lexical Errors				
Unrelated verb	_	5 (12)	_	9 (24)
Semantically related	_	1 (2)	_	3 (8)
Phonologically related	1 (7)	9 (21)	4 (67)	10 (27)
Morphological Error	S			
Regularization	_	2 (5)	_	1 (3)
Infinitive form	_	3 (7)	_	_
Person agreement	_	1 (2)	_	7 (19)
Tense agreement	1 (7)	_	_	1 (3)
Wrong	_	2 (5)	_	_
irregularization				
Mixed errors				
Phonol and semant	2 (13)	1 (2)	_	1 (3)
Tense and person	_ `	_	_	
Phonol and tense	1 (7)	2 (5)	_	_
Unrelated and tense	_	1 (2)	_	_
Other errors				
Perseveration	2 (13)	_	2 (33)	_
Language switch	_	1 (2)	_	_
No response	8 (53)	14 (33)	_	5 (14)
Total	15 (100)	42 (100)	6 (100)	37 (100)

Numbers in parentheses represent the percentage of errors.

ference was significant ($\chi^2 = 7.758$; p < .01). Analyses on a subset of verbs: 11 irregular verbs (44 observations) and 14 regular verbs (30 observations), matched for frequency, concreteness, and imageability revealed a similar pattern of results, although the advantage for regular over irregular verbs did not reach significance because of the small number of items (85.1% versus 49.8%, respectively, $\chi^2 = 2.46$; p < .2).

Spanish. Overall, MP was much better in the production of regular verbs (90%, 25.2/28) than in the production of irregular verbs (52.4%, 13.1/25, $\chi^2 = 9.316$; p < .01). Analyses on a subset of verbs: 18 irregular verbs (55 observations) and 18 regular verbs (27 observations) matched for frequency, concreteness, and imageability showed an advantage for regular over irregular verbs although the difference here did not reach significance (89.8% versus 62.9%, respectively, $\chi^2 = 3.697$; p < .1).

The two languages showed the same pattern of results. Taking the results of the two matched sets together, to overcome the limited number of observations, the difference between regular and irregular performance leads to significance (87.7% versus 57.9%, respectively, $\chi^2 = 6.819$; p < .01).

3.4. Comment

MP, an agrammatic Broca's aphasic, was more accurate with regular than irregular verb morphology in a sentence completion task in both Catalan and Spanish. This pattern of performance is inconsistent with predictions derived from the procedural/declarative model proposed by Ullman et al., which predicts poorer performance on regular than irregular morphology in agrammatic patients.

4. General discussion

We have reported the performance of two aphasic patients in a morphological transformation task. Both patients are bilingual speakers who were diagnosed with agrammatic Broca's aphasia. The patients showed poorer performance with irregular than regular morphological transformations in both of their languages. Our pattern of results adds to the increasing number of data in a variety of languages with similar results (Shapiro & Caramazza, 2003; Faroqi-Shah & Thompson, 2003, with English; Laiacona & Caramazza, 2004, with Italian; Penke et al., 1999, with German; Tsapkini, Jarema, & Kehayia, 2001, with Greek agrammatic aphasics) (Fig. 4).

In Section 1, we discussed a model of language production that assumes that different brain areas are involved in processing regular and irregular morphology (Ullman, 2001; Ullman et al., 1997). According to this proposal, the left inferior frontal cortex (and basal

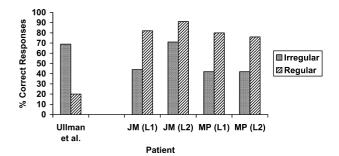


Fig. 4. The results in the morphological production task observed by Ullman et al. (1997), along with the results of JM and MP.

ganglia) is involved in those morphological processes that are rule-based, and therefore damage to this brain area is expected to result in specific difficulty when applying regular morphological transformations but not when generating irregular forms.

This hypothesis is based on three assumptions. First, agrammatic speech is a consequence of impairment in the ability to carry out rule-based processes. Second, morphological transformations on regular verbs are rule-based. Third, damage to the neural structures involved in rule-based processing (which include the left inferior frontal cortex) will result in impairment of all types of linguistic behavior that depend on the application of rule-based processes.

Despite the fact that our patients had lesions that included the left inferior frontal cortex and that they were clinically classified as agrammatic, they did not perform worse with regular than with irregular morphology. Thus, it appears that neither of these two factors correctly predicts the inflectional performance of our two patients. Thus, Ullman et al.'s (1997) characterization of the relationship among left inferior frontal cortex, agrammatism, and morphophonological transformations does not appear to be accurate. Our results show that agrammatic aphasics with damage that includes the left inferior frontal cortex can be impaired in carrying out morphological transformations of both regular and irregular verbs. This fact suggests the possibility that the left inferior frontal cortex is involved in morphological processing, independently of whether this processing eventually involves regular or irregular morphophonological transformations (Faroqi-Shah & Thompson, 2003; Laiacona & Caramazza, 2004; Shapiro & Caramazza, 2003). Furthermore, our results are consistent with the hypothesis that agrammatic production is the result of damage to various processes including those responsible for the retrieval, interpretation, and integration of grammatical features (such as tense, person, and number of verbs).

That is, we think that the existence of patients such as MP and JM, as well as patients RC (Shapiro & Caramazza, 2003), MR (Laiacona & Caramazza, 2004) and others (Faroqi-Shah & Thompson, 2003; Penke

et al., 1999; Tsapkini et al., 2001), suggests that agrammatic patients have a deficit at the level of morphosyntactic processing—the level where the grammatical features of a word are used to determine its ultimate phonological form, independently of whether it can be classified as a regular or irregular form. Grammatical information is crucial in determining the function of a lexical item in a sentence, and consequently the type of morphological process it can undergo. For example, in English, nouns but not adjectives are marked for number. Thus, words' grammatical category information—noun, verb, etc.—and the various grammatical features associated with them in specific contexts (e.g., number, tense, etc.) determine, through the application of a morphological process, the final form of a word. Our assumption is that some aspects of agrammatic production result from damage to these morphosyntactic processes (see also Faroqi-Shah & Thompson, 2003; Laiacona & Caramazza, 2004; Shapiro & Caramazza, 2003; Tsapkini et al., 2001). Actually, even the frontal patients studied by Ullman et al. (1997), although presenting with more severe difficulties in the production of regular verbs, did not performed flawlessly with irregular verbs. This latter deficit is not explained by Ullman's model but can be accommodated in a framework that locates the cause of the verb production deficit in a mechanism responsible for morphosyntactic processing independently of the regularity of the verb's morphology. While it seems difficult that Ullman's proposal could explain MP and JM performance, the framework adopted here can accommodate not only Ullman et al. (1997) results but a number of recent reports of agrammatic patients that are also inconsistent with Ullman's predictions (Farogi-Shah & Thompson, 2003; Laiacona & Caramazza, 2004; Penke et al., 1999; Shapiro & Caramazza, 2003; Tsapkini et al., 2001).

This is not to say, however, that specifically morphophonological processes are not affected in agrammatic production. It may very well be the case that such processes can be damaged independently of other syntactic and lexical processes. However, if they are, they do not seem to lead consistently (or even preponderantly) to a selective deficit of regular morphophonological transformations.

Having argued that agrammatic Broca's aphasics are not typically more impaired in processing regular than irregular morphological forms there remains the issue of why they may frequently be more impaired in processing irregular than regular forms. The fact that regular forms are produced better than irregular forms can have various causes other than the regularity/irregularity dimension. First, the morphological transformation applied to regular forms is more frequent than that applied to irregular forms. Thus, it is conceivable that patients with morphosyntactic and,

presumably, morphophonological deficits would tend to have more difficulty with less frequent than with more frequent morphological operations. Note, that this does not mean that the deficit affects specifically those morphological transformations that are not rule-based. Instead, the morphophonological deficit affects across the board all morphophonological transformations. However, since regular transformations are more frequent than irregular transformations, the former are better preserved. Second, regular forms tend to have larger morphological families (and also more dense word neighborhoods). Given that, both the size of morphological families and neighbor density seem to correlate positively (Bertram, Baayen, & Schreuder, 2000; Grainger, 1990) with the ease with which lexical access is achieved, one could tentatively hypothesized that brain damaged individuals would show better performance with regular than irregular verbal forms.

Our results are also relevant to issues about bilingual language processing in aphasia. The fact that the patients' performance was similar in their two languages suggests that the neural tissue (or nearby tissue) dedicated to a particular process in one language is also recruited to represent the analogous process in the other language. Catalan and Spanish are very similar languages with respect to the type of morphological processes: they are both morphologically complex languages, they both use suffixation to inflect verbs, they have person, number, and tense agreement suffixes, they each have three conjugation classes, etc. It would be interesting to see whether similar results would be obtained across languages with very different morphology—say English and Spanish, for example—or whether in such cases language specific deficits emerge.

To conclude, the proposal that agrammatic speech is always or even preponderantly associated with poorer performance in processing regular versus irregular verb forms needs to be reconsidered. Our results, as others in a variety of languages, are incompatible with that proposal and instead support the view that a major component of agrammatic production is a deficit in morphosyntactic processing, independently of whether this processing ultimately involves regular or irregular forms.

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Appendix A. Transcription of samples of patients' speech (nonwords in quotation marks, translation in parenthesis, and correct word in brackets)

A.1. JM—Spanish L1

Campamento de...b...de...Boy..Escaus. [...] (Camp of...b...of.. Boy Scouts)

Un chico mirant...mm...mirant..."prismatos," subido-en-un, en-un- "cabuo" (A boy looking...ll...looking...binoculars [prismáticos], climbed-in-a, in-a- tree [árbol])

"Uto" chico...mm...re-co-ge "ra" fruta... (A-nother [otro] boy picks-up the [la] fruit).

"O-cho"...o-tro chico..."pirán" "magbas" (A-nother [otro]...a-nother boy...looking [mirando] maps [mapas])

O-tro chi-co...mm...en-ciendo el fue-go [...] (Another bo-y...mm...m...li-ght the fire)

El...el...toro per-sigo a una...un... chi-co [...] (The ...the bull chase a –feminine-... a –masculine-...boy)

A.2. JM—Catalan L2

Estàs...es..mm...estàs en la cuina... mm...ella.., la dona...mm.. l'aixeta... mm...mm..escapa l'aigua... mm...mm...a xorro (You are...you are in the kitchen ...mm...she..., the woman...mm...the tab...scapes the water...mm...in a spout).

Nnn...N'hi ha una finestra...mm (There it is a window).

Una dona...mm...la dona...mm...ne-teja el-plat (A woman...mm...the woman...mm..cleans the plate).

El nen...c...casi "cagut"...mm..del tam-buret (The boy...almost fallen [caigut].. mm...of the stool).

A.3. MP—Catalan L1

És a la a la cuina... està.. a frega els plats.. bueno, per aixugar.. e...i de sobte.. què amb el pensament caía l'aigua, l'aigua! i de sobte, e.. xurreijava...e.. fins a.. a terra i....

(She is in the kitchen...she is...in cleans the diches ...well, to dry...and suddently...that with the thought, dropped the water, the water! And suddenly, spouted until the floor and...).

¿I el nen? Bueno, el nen i la nena...ee.. ee com que és molt alt, no puc i.. e.. una.. agafa un...un caballet...ee.. per posar galletes...i de sobte, mm, ee.. dona'm!, mm, mm, dona'm!...amm, el, el, la nena... ¡dona'm les galletes! [...] And the boy? Well, the boy and the girl..ee..ee as it is very high, I can't and.. e ..a...takes a...an easel [taburete]..ee.. to put the cookies... and suddenly,mm, ee, give it to me! mm,mm, give it to me!...amm, themasculine- the-masculine-, the-femenine- girl...give me the cookies! [...]

A.4. MP—Spanish L2

Estamos en agosto..ee..hace ee. mucho calor (We are in August..ee..it's...very hot)

En el colegio...se va...bueno, no em surt les paraules... en el campamento, de colonias, en un camping (In the school... one goes... well, words don't come... in the camp, summer camp, in a camping) Y todos, una tienda, eran, son, somos cuatro (And all, in a tent, they were, they are, we are four) Muchos para los compañeros, para... bueno.. para amigos..bueno, de repente un grupo de amigos (A lot for the schoolmates, for...web...for friends...web, suddenly a grup of friends) Un otro en el río, aquello... en el sombrero, y en los pies se refresca en el río [...] (The other one in the river, that... in the hat, and in the feet he cools down in the river [...]).

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