El-La: The impact of degraded semantic representations on knowledge of grammatical gender in semantic dementia

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Abstract

Previous research on semantic dementia (SD) has demonstrated a necessary link between conceptual representations and ability on a range of 'non-semantic' tasks, both verbal and nonverbal. In all cases, SD patients exhibit good performance on items that conform to the underlying statistical 'surface' structure of the domain in question but poor performance on items that are atypical with respect to these statistics. For such items, there is a strong tendency for the patients' errorful responses to reflect the more typical pattern. To date, most research on this topic has been conducted with English-speaking patients and where it has been extended to non-English languages, directly comparable aspects of each language have been probed. In this study we tested the generalisation of this theory by probing performance on an aspect of Spanish for which there is no analogue in English (grammatical gender). As predicted, Spanish SD patients were able to provide the correct gender to high frequency words or where the phonology of the noun strongly predicted the grammatical gender. For low frequency, atypical nouns, however, the patients made a much greater rate of errors (preferring the statistically typical gender). As expected, performance on nouns with atypical grammatical gender was strongly correlated with the degree of semantic impairment across the case-series of SD patients. The results not only provide another example of the critical relationship between semantic memory and 'non-semantic' cognition, but also indicate that this theoretical framework generalises to novel aspects of non-English languages – suggesting that the phenomenon is based on brain-general mechanisms.

Introduction

Many aspects of both linguistic and non-linguistic ability which do not, on the face of it, require access to semantic knowledge are adversely affected when semantic memory deteriorates. This phenomenon, or rather set of phenomena, has mainly been demonstrated in the degenerative brain condition known as semantic dementia (SD), in which anterior, inferior temporal lobe atrophy produces a relatively selective degradation of semantic memory or conceptual knowledge (Hodges et al., 2010; Hodges & Patterson, 2007; Snowden et al., 1989). Of course, SD patients perform poorly on cognitive tasks which *do* obviously depend on conceptual knowledge, such as understanding or defining words or naming objects; any theoretical position on the role of conceptual knowledge would predict and account for such transparent semantic deficits. The impact of SD on less-obviously semantic abilities, however, is predicted by only a subset of theories, mainly those in which 'surface'-level representations necessarily interact with the semantic system when the human brain is processing stimuli and producing responses. Parallel-distributed processing or connectionist models, like those developed by Plaut et al (1996, 2002) and Rogers et al (2004), are examples of such theories. Figure 1 presents a general representation of this kind of model. This is often referred to as a 'triangle' model (Patterson & Lambon Ralph, 1999).

What sorts of abilities do we mean when we speak of non- or less-obviously semantic tasks which have been shown to suffer in SD? Although evidence for these is by no means restricted either to verbal tasks or to English-speaking patients, that combination does cover most demonstrations of this phenomenon, and we shall therefore summarise them first. In the verbal domain, English SD patients are impaired at (1) reading written words aloud (Patterson & Hodges, 1992; Snowden et al., 1989; Woollams et al., 2007); (2) spelling words dictated to them (Graham et al., 2000); (3) generating the past tense form of a verb when given the verb's stem or present tense (Cortese et al., 2006; Patterson et al., 2001); and (4) deciding which of two written words is the real one in a two-alternative forced choice version of lexical decision, e.g. *fruit* vs. *froot* (Rogers et al., 2004a).

There are several vital things to note about this set of phenomena. First, all of the tasks involve domains that can be called quasi-regular, in which the stimuli (or the relationship between stimuli and responses) mainly follow a typical pattern but admit exceptions (Plaut et al., 1996). For example, most English verbs form the past tense by adding –ed, whereas a small but not negligible percentage have atypical past-tense forms (e.g., *buy-bought*). Secondly, SD patients demonstrate deficits on these tasks which are all characterised by a familiarity-by-typicality interaction. If the stimulus materials are designed in a 2×2 manner, crossing frequency or familiarity (high or low) of each exemplar with typicality of that exemplar in its domain (high or low), the patients score well in every task when both variables are high; at a moderately impaired level when one variable is high and the other low; and very poorly when both are low. SD is a degenerative condition and success at all of

these tasks unsurprisingly declines with disease progression; but as long as a patient is able to perform the task at all, scores usually display this familiarity-by-typicality interaction. Finally, what makes an exemplar typical or atypical in its domain is domain-specific. In the case of reading aloud, the dimension on which typicality varies is the relationship between spelling and pronunciation, measured by the proportion of words with similar spelling patterns that have similar vs. discrepant pronunciation. In English, for example, this relationship is typical for a word like *few*, because the pronunciation of *few* rhymes with almost all of its orthographic neighbours such as *new, pew, stew, chew,* etc. One member of this *–ew* family, however, has an atypical spelling-sound correspondence: *sew* rhymes with *go,* not with *new*. In the case of lexical decision, it is orthographic typicality that matters, measured by bigram and trigram frequencies. Here, *sew* is typical but *fruit* is not. And *sew*, which is a verb, also takes a typical –ed past tense. Despite this non-uniformity across domains for classifying a stimulus as typical or atypical, the results of the various tests with SD patients are highly uniform: scores are significantly worse on the items that are atypical in that domain, especially those of lower familiarity.

In brief, the account of this pattern offered by the connectionist, triangle models (Plaut et al., 1996; Rogers et al., 2004; Woollams et al., 2007; Woollams et al., 2009) is (a) that item-specific semantic representations are activated whenever people perceive meaningful words or objects and are asked to respond to them; but (b) that a lifetime of experience with each of these domains gives rise to implicit knowledge of its typicality structure, which prompts or facilitates responses typical for the domain. Atypical responses require an extra boost to rescue them from the gang of typical items and enable the correct item-specific responses (e.g., *buy→bought*, not *buy→buyed*). According to this theoretical framework, that extra boost comes from activation input to the domain from item-specific knowledge of the item's meaning. In SD, typical responses come to dominate because there is a reduction of this additional input because the underlying meaning has deteriorated. Even for a semantically-impaired patient, these responses will of course be correct when the stimulus is typical; so the patients will correctly read a word like *few* and correctly inflect a regular verb like *talk*. Responses guided solely by typicality will, on the other hand, be wrong for an atypical stimulus like *sew* for reading aloud or *buy* for past-tense inflection. That is, the response will be wrong unless the stimulus is so familiar that its meaning is somewhat more resistant to semantic deterioration. All of this results in the frequency-by-typicality interaction that describes performance by SD patients.

Semantic memory, of course, is not just for language but operates in a vast array of non-verbal domains. If this is a theory about the interaction of surface representations with conceptual knowledge, then we would expect to observe the same familiarity-by-typicality interaction in non-verbal tasks that likewise do not obviously require semantic knowledge. This is the case. For example, SD patients are poor at deciding which of two drawings of an object is the real one (e.g., a camel with or without the hump: Rogers et al., 2004) and at reproducing a drawing of an object ~10 seconds after

it has been withdrawn from view, even though they have no difficulty copying it when it is present (Bozeat et al., 2003; Lambon Ralph & Howard, 2000). Once again, the basis for classifying items on the typicality dimension is domain specific. In these two picture-based tasks of object decision and delayed drawing, a camel is atypical (because no other animals have that hump), although the word *camel* has quite a typical orthographic pattern and a typical relationship to its pronunciation. In other words, SD patients usually respond correctly to *camel* when asked to read the word aloud because its pronunciation is predictable from its orthography. They no longer know what a camel is, however, only that it is some sort of animal. Therefore, when presented with two pictures (a real humped camel and a non-real, doctored, humpless camel), they are prone to choose the unreal but more typical humpless drawing (Patterson et al., 2006; Rogers et al., 2004) and, when asked to produce a delayed copy of a picture of a camel, frequently omit the hump (Patterson & Erzinclioglu, 2008).

Not only does the theory predict the pattern of performance for English SD patients in non-verbal as well as verbal tasks: it also predicts the same pattern in SD patients from any language or culture. Although the majority of published studies are of English-speaking patients, there are some pertinent studies in other languages. For example, Japanese kanji words constitute another quasi-regular domain with respect to the relationship between orthography and phonology. As predicted, reading aloud of kanji words by Japanese SD patients reveals precisely the same frequency-by-typicality interaction as observed in their English counterparts (Fushimi et al., 2009). The general applicability of this principle would, however, be even more compellingly supported if one could demonstrate it in another language containing a feature that does not exist in English, which brings us to grammatical gender in Spanish: a prime example of a quasi-regular domain.

English nouns lack gender, but nouns in Spanish – like many other European languages (French, Italian) – must be either masculine or feminine. As the title of this paper mentions rather obliquely, a Spanish noun requires *el* if it is masculine and *la* if it is feminine. With the exception of nouns that have 'natural' gender (e.g., la monja [nun]), there is no semantic basis for a noun's gender. The domain is nonetheless quasi-regular because the correct gender is, in most cases, strongly predicted by the phoneme (or sometimes combination of a few phonemes) at the end of the word. For example, virtually all nouns ending in the sound /o/ take masculine gender and the great majority of those ending in /a/ are feminine. Table 2, in the Methods section, shows the statistics for this domain (derived from LEXESP - Léxico informatizado del Español: Sebastián et al., 2000), where it can be seen that most endings (such as o, a, r, d) have a very high probability of being one or the other gender, though a few (such as e, s and z) exhibit a somewhat weaker bias. This is precisely the sort of domain and 'non'-semantic task for which our theoretical framework makes a strong prediction regarding the performance of SD patients. A Spanish speaker implicitly learns an approximation of the statistical distributions relating word endings to noun gender. If given a new (nonce) noun without the gender being specified, such a speaker will certainly assign the masculine article if the new word

ends in –o and the feminine article if it ends in –a (Heim, 2008). It should be noted, perhaps, that there were etymological influences on the gender assignment (e.g., scientific terms ending in –a, derived from Greek, often take the masculine gender) but these historical facts are not commonly known by everyday Spanish speakers. Although, as we have already stated, grammatical gender has no semantic basis, the theory nevertheless states that semantic knowledge can provide an additional source of activation in order to retrieve the correct gender and that this will be critical in cases where the noun's phonology would mis-predict its gender. It follows, then, that as semantic knowledge declines in SD, thereby diminishing the additional activation of word-specific information, processing of nouns in a task of gender assignment will come to depend more and more on distributional knowledge. Spanish SD patients' performance in such a task should, therefore, be characterised by a frequency-by-typicality interaction.

Method

Patients

Six native Spanish-speaking patients were recruited to this study: two from Malaga (Spain) and four from Buenos Aires (Argentina). All six presented with the stereotypical neuropsychological and neuroimaging features of semantic dementia (Gorno-Tempini et al., in press; Hodges et al., 1992). All had a history of progressive deterioration of expressive and receptive vocabulary and a selective semantic impairment in the context of relative preservation of other aspects of cognition and memory. Neuroimaging confirmed the typical pattern of atrophy focussed on the anterior, inferolateral temporal lobes.

Table 1 about here

Basic demographic data and neuropsychological test results are shown in Table 1. The patients in the Table and subsequent Figures are ordered by the severity of their semantic impairment, as measured by the word-picture matching test. The background neuropsychological results mirror the typical pattern for semantic dementia. On the test of general executive function, Raven's Coloured Progressive Matrices (Raven, 1962), the patients performed well although RM's score was a little weak. Their ability to copy the complex Rey figure was also generally good, indicating preserved visuospatial and construction/planning skills. In contrast, the patients demonstrated multimodal semantic impairments, as measured by a Spanish translation (Green Heredia et al., 2009) of the Cambridge 64-item semantic battery (Adlam et al., 2010; Bozeat et al., 2000). As expected all patients exhibited moderate to severe anomia (on the fluency tasks and confrontational naming test), reduced word-picture matching performance and poor ability on both the verbal and nonverbal versions of the

Camel and Cactus semantic association judgement test. Given our aim to relate the degree of semantic impairment to performance on the new grammatical gender judgement test, it is important to note that these six SD patients covered a wide range of semantic impairment, with RM and MB at the milder end and CUB at the more severe end.

<u>Materials and procedure</u>

Psycholinguistic analysis of the relationship between grammatical gender and phonology

As noted in the Introduction, our previous explorations of and theory about the relationship between semantic representation and domain-specific processing (verbal or nonverbal) is based on the following premises: (a) that there is a direct input → output translation, the efficiency/performance of which is governed by the statistics of the domain as well as item familiarity; (b) that all meaningful stimuli automatically activate associated conceptual knowledge; (c) that this additional semantic input to the computation of a response is critical when the correct response is atypical with respect to the domain-specific statistics, especially for less familiar items; and (d) that when semantic support is reduced – as it is in semantic dementia – then patients will not only make errors on these atypical items but will render them more typical. As a result, whenever a new domain is considered in these terms, the essential first step is to quantify the underlying statistical structure of that domain. Once these statistics are available, the aim is always the same: to manipulate domain-specific typicality/consistency and item frequency/familiarity, with the prediction that SD patients' performance should be especially poor for the low frequency, atypical/inconsistent items.

A consideration of the relationship between semantics and Spanish grammatical gender, therefore, required us to assess the nature and strength of the association between the phonological offset of nouns and their grammatical gender. We achieved this via a psycholinguistic analysis of the LEXESP Spanish database (LEXESP - Léxico informatizado del español: Sebastián et al., 2000). This database contains 5 million words from various written sources (including narratives, scientific papers, essays, press, seminars, sporting press, etc.) and so provides a rich source of word types and a good estimate of their frequency of occurrence. From this database we selected only the nouns (around 20,000 types). Like any other large lexical corpus, the coverage of the database is considerable and so it contains many unusual and archaic words which are unfamiliar to the majority of the population. Accordingly, we set a minimum token frequency of one per million, leaving us with a set of 10,014 nouns to analyse. These were divided into word-ending categories and the ratio of feminine to masculine gender was computed for each category. The results are summarised in Table 2.

Table 2 – about here

Various features of these results are important for the current study. First, unlike some other verbal domains such as English reading and past tense, there is no strong bias in the language overall: across the whole set of Spanish nouns, the two genders occur in almost equal proportions, though (as in so many aspects of life) masculine slightly dominates: 52.2% M, 47.8% F. Second, the majority of noun endings are characterised by a strong bias in favour of one gender. In most cases, the ratio is greater than 80%:20% and the three endings with a lower bias only account for 182/10014 nouns. Third, for most noun endings, there are items that take the opposite gender to that predicted by the ending – i.e., their grammatical gender is atypical. These atypical items (and a set of matched typical nouns) formed the basis of our test materials.

Table 3 – about here

Test materials

We selected items from the 10014 noun corpus in order to manipulate word frequency and gender typicality, orthogonally. We included only nouns which had at least 100 exemplars of that ending in the corpus, namely from the top 10 rows in Table 2, so as to avoid endings where the language user has less experience. Within these ending types, we selected quartets of nouns, each quartet consisting of one high frequency noun with typical gender, one high frequency noun with atypical gender, one low frequency item with typical gender and one low frequency noun with atypical gender. Within each quartet, all four words were matched for syllable and phoneme length, and the typical- and atypical-gender nouns were matched for frequency. Sixty quartets of this form were selected (i.e., a total of 240 test items). We attempted to manipulate frequency as much as possible such that the high frequency items had to be above 50 per million (and on average were around 300 per million) and the low frequency below 45 per million (and on average were 11 per million). The summary psycholinguistic properties of the selected items are shown in Table 3. We checked and confirmed that the gender assignment for these selected nouns was the same in Spain and Argentina.

Test procedure

The task requirements were first introduced to each patient with reference to a non-language, card-sorting task and then by using a practice set of nouns (N=72). In the practice and main assessment, each noun was presented in written form to the patient and also read aloud by the examiner. For each item, the patient was asked whether the item took the masculine (el) or feminine (la) definite article. If the patients were uncertain about any items, we asked them to indicate which article they thought was most likely to be correct.

Results

The average performance of the SD group on the lexical gender judgement task is shown in Figure 2a. As predicted, the patients demonstrated a classic frequency × typicality interaction with poorest performance for the low frequency, atypical items (mean=64% correct; 95% confidence interval for the mean: 48%-80%; chance = 50%). The individual patient results for the test are displayed in Figure 2b. As can be seen, whilst overall levels of performance varied (in line with the patients' semantic severity, see below), each patient demonstrated a frequency × typicality pattern. In fact, the group were consistent enough that, even with only six cases, the ANOVA yielded not only main effects of frequency and typicality [$F(1,5)=15.9$, $p=0.01$; $F(1,5)=8.4$, $p=0.03$, respectively] but also a significant interaction [$F(1,5)=8.3$, $p=0.04$]. These individual data are also interesting in one additional aspect: as semantic severity increased, performance on the low-frequency atypical items not only dropped to chance level but, in the most severe case, fell well below chance. This pattern has been observed before, in two-alternative forced choice lexical decision by English SD patients at more severe levels of semantic decline (Rogers et al., 2004). Importantly, on these forced-choice tasks, below chance performance indicates that the participant's responses are actively biased towards the domain-specific statistical tendency and away from the word-specific knowledge.

A third key hypothesis was supported by the data from this study. Figure 3 shows the relationship between semantic severity (as measured by word-picture matching success; see Table 1) and gender decision accuracy for the atypical vs. typical items (collapsed across frequency). As found previously in studies of English domains such as reading words aloud (Woollams et al., 2007), there was a principled increase in the correlation between semantic severity and word type in the expected order (HF-typical – Spearman's $r = 0.70$, $p = 0.12$; LF-typical – $r = 0.71$, $p = 0.11$; HF-atypical – $r = 0.9$, $p=0.01$; LF-atypical – $r = 0.94$, $p = 0.004$). In order to explore this further, we fitted linear regressions to the results for the typical and atypical items (collapsed across frequency; see Figure 3). As expected, this revealed a strong relationship between semantic severity and performance on the atypical items (B=0.1; 95% confidence interval: 0.007 to 0.016) and a much weaker, minimal relationship for the typical items (B=0.003; confidence interval: 0.002 to 0.005; note that the confidence intervals for the two regression lines do not overlap).

In closing the Results section, it should be mentioned that, although we have not provided comparable data for a matched group of healthy controls, our test was administered informally to a number of native Spanish-speaking participants with no known neurological abnormality, and their performance was essentially at ceiling in all four conditions. As in any other language requiring

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grammatical gender, it seems that knowledge of correct gender is well- or even over-learned by Spanish speakers, even though they generally cannot explain why a particular noun has a particular gender or how they know what it is.

Discussion

The results of the gender-assignment task in six Spanish SD patients reveal a clear fit to the predictions of the 'triangle' model (Figure 1). The pattern obtained corresponds precisely to that observed for all the other 'non-semantic' abilities involving quasi-regular domains on which SD patients have been assessed: that is, the Spanish SD patients' success in assigning grammatical gender to Spanish nouns followed a frequency-by-typicality interaction, with poorest performance on low-frequency nouns with gender that is atypical for their endings. Further, this pattern became more pronounced as a function of the individual patients' severity of semantic deficit, as measured by a completely unrelated test of word-picture matching. For the most severe patient, the score in the low-frequency atypical condition was well below chance, indicating an actual preference for the incorrect but more typical grammatical gender.

SD patients do not have phonological deficits (Jefferies et al., 2005). Their receptive and expressive vocabulary is markedly and progressively restricted to higher-frequency words (Bird et al., 2000); but – at least at the single-word level – they have no trouble processing phonological patterns, either as input or output (Hodges et al., 2008; Meteyard & Patterson, 2009). Their deficit instead centres on meaning. The patients in this study would not have known the meanings of many of the nouns for which they were asked to select the correct gender. Their behaviour, however, does not reflect a random selection between the two choices in Spanish grammatical gender, *el* and *la*. On the contrary: all of the patients, even the most impaired (CUB), had much better than chance performance so long as the correct choice for the target was also the more typical choice for its ending. This was especially true for the higher-frequency nouns (group mean = 95% correct) but even the lower-frequency nouns with typical gender received an average of 88% correct responses. High-frequency stimuli with an atypical gender mainly avoided the 'pull' of typicality and averaged 84% correct responses. Low-frequency atypical words, on the other hand, engendered only 64% correct responses.

All theoretical positions regarding knowledge of grammatical gender in languages like Spanish and Italian apparently agree that speakers must have two types of information regarding the gender of a noun: the statistically likely gender, determined by the word's phonological ending, and the correct gender, determined by the whole specific word (e.g., Heim, 2008). As indicated in Table 2, the majority of endings on Spanish nouns are strongly associated with one or other gender, which means that the statistically most probable and the correct gender are usually one and the same; but of

the ten most common endings, with type counts over 100 in the corpus from which our stimulus items were selected, all permit exceptions. The results of our study establish that patients with semantic dementia have well preserved (though not perfect) knowledge of the statistical regularities of the gender distribution. Their knowledge of word-specific gender, however, is disrupted in a fashion that is sensitive to both word frequency and the patient's degree of semantic degradation.

As usual in cognitive science/neuroscience, there is debate regarding the precise nature of both types of information concerning grammatical gender, as well as whether these constitute two completely different and independent routes (see for example Gollan & Frost, 2001; Heim, 2008). From the perspective of traditional two-stage models of lexical retrieval (e.g. Dell & O'Seaghdha, 1992; Garrett, 1982; Levelt, 1989), one of the debates is whether the word-specific knowledge of a noun's gender is represented at the lemma or the lexeme level. In these models, the lemma level is posited as the interface between a semantic representation, which does not have a linguistic form, and a lexical representation, which takes a very specific linguistic form: phonology in the case of spoken words. Because the primary deficit in SD is semantic rather than lexical, our results might seem to argue for a lemma-level of representation of word-specific gender knowledge. We would not, however, draw this conclusion nor indeed its opposite, choosing instead to hide behind the words of an early 20th-century government minister in India: when he was asked a difficult question in Parliament, he apparently used to answer "That question is not cast in the mode of my thinking". This is true for us where lemmas and lexemes are concerned. We will settle for the more evidence-driven conclusion clearly supported by the results of this study, which is as follows. Knowledge of word meaning is undeniably vital in speech production. Except for words carrying natural gender (such as 'la monja', nun), the grammatical gender of a noun is not one of its semantic features. Nevertheless, when semantic knowledge deteriorates, as it does in SD, one of the 'downstream' victims is the word-specific knowledge that supports correct production of grammatical gender. When this type of knowledge is removed from the equation, the result is a necessary over-reliance on the other type of gender knowledge: statistical regularities.

There are, of course, a number of neuropsychological studies concerning grammatical gender in the literature, mostly of Italian patients. Several of these studies suggest that a version of the pattern obtained here – over-reliance on statistical typicalities for gender assignment – can arise from a very different sort of impairment: agrammatism in post-stroke aphasia (Luzzatti & De Bleser, 1996; Mondini, Luzzatti & Semenza, 1999). There is a very different clinical profile, however, that seems most pertinent here. This was observed in a single-case study of an Italian patient, labelled Dante by the researchers who studied him (Badecker et al., 1995; Sartori et al., 1993), who had a probable aetiology of meningoencephalitis. CT scanning (1990) revealed hypodensity in fronto-temporo-parietal regions. At the time of the investigations of the patient's knowledge of grammatical gender

(by Badecker et al., 1995), which was two years post onset, Dante's main cognitive deficits were amnesia and anomia, the latter in both spoken and written object naming. His semantic memory was assessed as unimpaired. The most important characteristic of Dante's anomia was that, when he failed to produce a target word, he apparently had no knowledge about its phonological form. Not only was he unable to produce any such information spontaneously when queried; he was also at chance on a number of two-alternative forced choice tasks regarding the target item's length, first letter, last letter or a rhyming word. Despite this apparently complete absence of information regarding the target word's surface form, Dante was consistently near perfect (95-98% correct) in choosing between masculine and feminine gender for nouns that he was unable to retrieve in tests of picture naming and/or sentence completion. In all of these studies, the stimulus materials contained a small but significant proportion of Italian nouns with atypical gender (such as "il problema" [problem]: as in Spanish, Italian nouns ending in –a are typically feminine). Dante was equally successful in identifying the correct gender of typical and atypical nouns whose surface forms he could not activate. Vigliocco et al. (1997) adopted a similar style of investigation of this issue by analysing knowledge of noun gender and phonological characteristics of target words for which normal Italian speakers were in a tip-of-the-tongue state. Although correct gender assignment for such unretrievable TOT (tip-of-the-tongue) words by the normal speakers in this study was not quite as high as by Dante, it was very good (84% correct over all) and equally good for nouns with typical and atypical gender.

The success of Dante, and to some extent of normal speakers, in knowing the gender of a word that they cannot produce stands in stark contrast to the pattern established here for Spanish SD patients. For Dante, knowing the word's phonological form was *unnecessary* for assigning its correct gender, typical or otherwise. For SD patients, knowing the word's phonological form (because we gave it to them) was *inadequate* for assigning its correct gender when that gender was atypical. Dante apparently had no deficit of the semantic system, which is the very cognitive system that is impaired in SD. Whether one's theoretical bent runs to lemmas or not, this contrast seems to establish that activation derived from a word's meaning – either directly to phonology or via a lemma level – is what provides knowledge of word-specific gender.

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Table 1: Background demographic and neuropsychological data

	Max score	RM	MB	BM	CG	FMPV	CUB
Demographic data							
Age		88	68	59	72	59	53
Gender		Female	Female	Male	Female	Male	Female
Occupation		English teacher (retired)	Housewife	Chemical engineer	Public notary	Driver	Government official
Education level (years)		16	12	18	18	8	16
Test results	Max score						
MMSE	30	23	26	26	26	26	24
Raven Matrices	36	16	25	26	22	25	28
Rey Figure (copy)	36	27.5	36	34	36	21.5	36
Rey Figure (delayed copy)	36	3.5	5	7	8	3	10
Letter fluency (FAS)	-	26	28	12	7	14	11
Semantic fluency (animals)	-	7	15	4	n/a	13	3
CCT (pictures)	64	47	52	26	35	30	22
CCT (words)	64	42	53	15	26	31	18
Naming Test	64	29	53	17	26	11	6
Spoken word to picture matching	64	53	51	50	44	39	8
Reading aloud	64	64	64	53	59	62	60
Writing to dictation	64	64	61	10	45	48	32

Footnote: patients are ordered by their semantic severity (as measured by word-picture matching). n/a = "not available"; CCT = "Camel and Cactus Test"

Table 2: The distribution of grammatical gender across different word endings.

Ending	Type count	Gender	
		Feminine	Masculine
o	3206	0.2%	99.8%
a	3157	95.3%	4.7%
ión	1017	98.3%	1.7%
e	674	16.6%	83.4%
r	488	1.2%	98.8%
d	488	97.1%	2.9%
n	335	3.9%	96.1%
l	220	8.2%	91.8%
s	176	35.8%	64.2%
z	102	75.5%	24.5%
t	25	0.0%	100.0%
y	20	20.0%	80.0%
é	15	6.7%	93.3%
í	13	0.0%	100.0%
c	12	0.0%	100.0%
i	11	9.1%	90.9%
g	11	0.0%	100.0%
m	10	0.0%	100.0%
x	8	0.0%	100.0%
k	5	0.0%	100.0%
á	3	33.3%	66.7%
p	3	0.0%	100.0%
j	3	33.3%	66.7%
h	2	0.0%	100.0%
f	2	0.0%	100.0%
ú	2	0.0%	100.0%
ó	2	0.0%	100.0%
b	2	0.0%	100.0%
w	1	0.0%	100.0%
u	1	0.0%	100.0%
All nouns	10014	47.8%	52.2%

Table 3: Item psycholinguistic properties of the test materials

Frequency Group	Gender Typicality	Example	Gender	Frequency (Lexesp)				Syllable length				Phoneme length			
				Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
High	Atypical	*foto*	*feminine*	313.83	405.82	50	2127	2.40	0.69	1	5	5.60	1.62	2	12
High	Typical	*lujo*	*masculine*	312.03	386.99	52	1956	2.45	0.67	1	4	5.75	1.62	3	10
Low	Atypical	*ratio*	*feminine*	10.92	10.14	1	42	2.57	0.68	2	5	6.03	1.51	4	12
Low	Typical	*jipío*	*masculine*	10.98	11.11	1	45	2.57	0.67	2	5	5.97	1.51	4	12

Fig.1: A generic framework for the interaction of
semantic representations with domain-specific computations

Semantics

1. Orthography
2. Verb stem
3. Picture
4. Kanji
5. Spanish noun

Input

Output

1. Phonology
2. Past tense
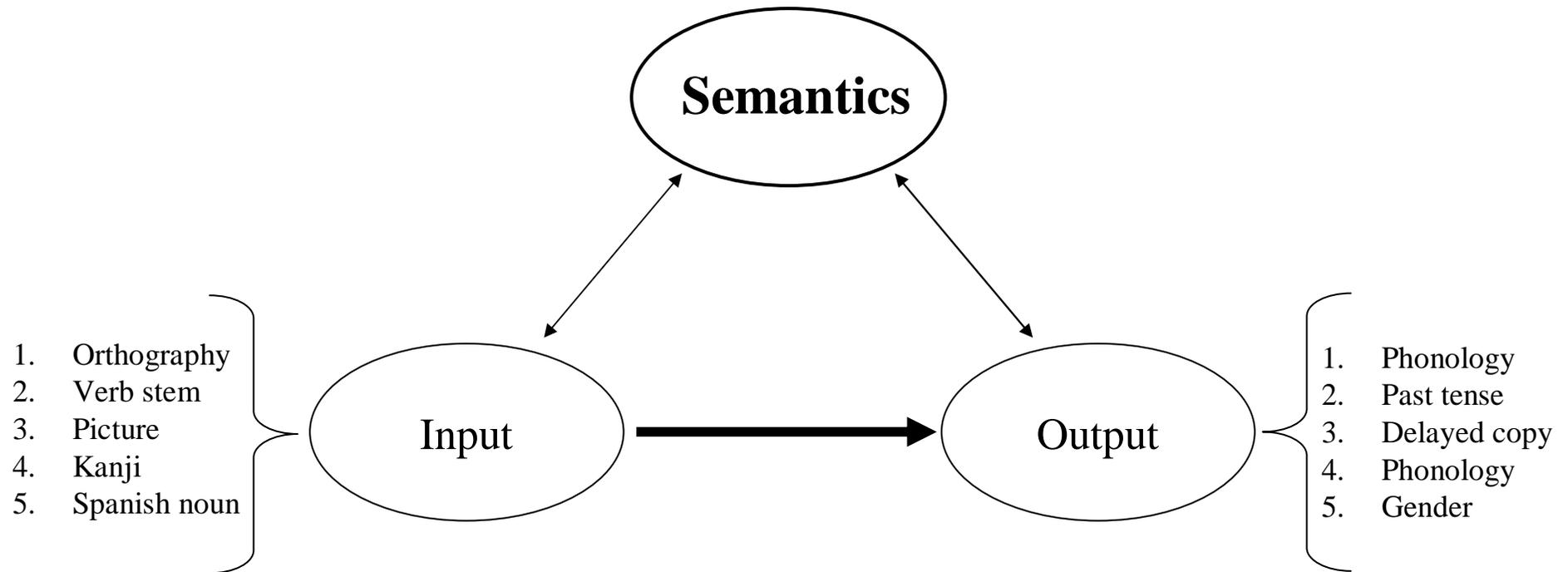3. Delayed copy
4. Phonology
5. Gender
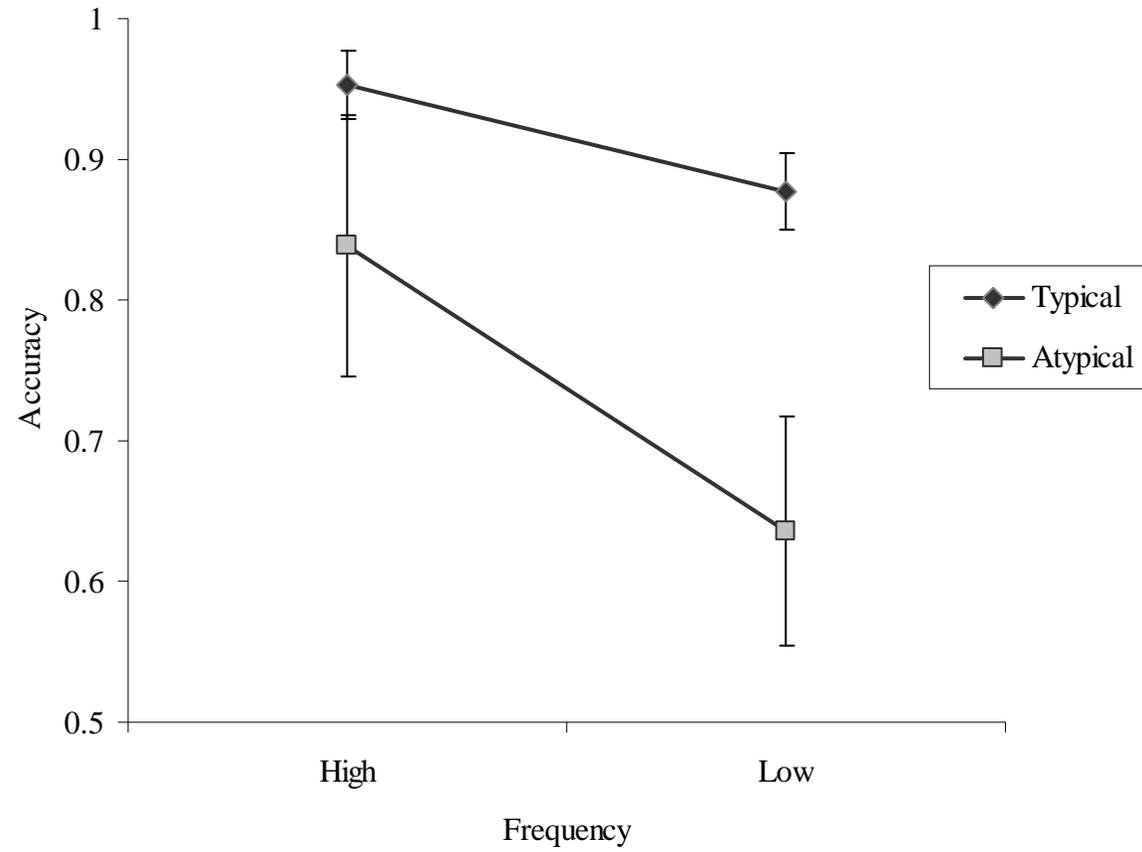
Fig.2a: Group average performance
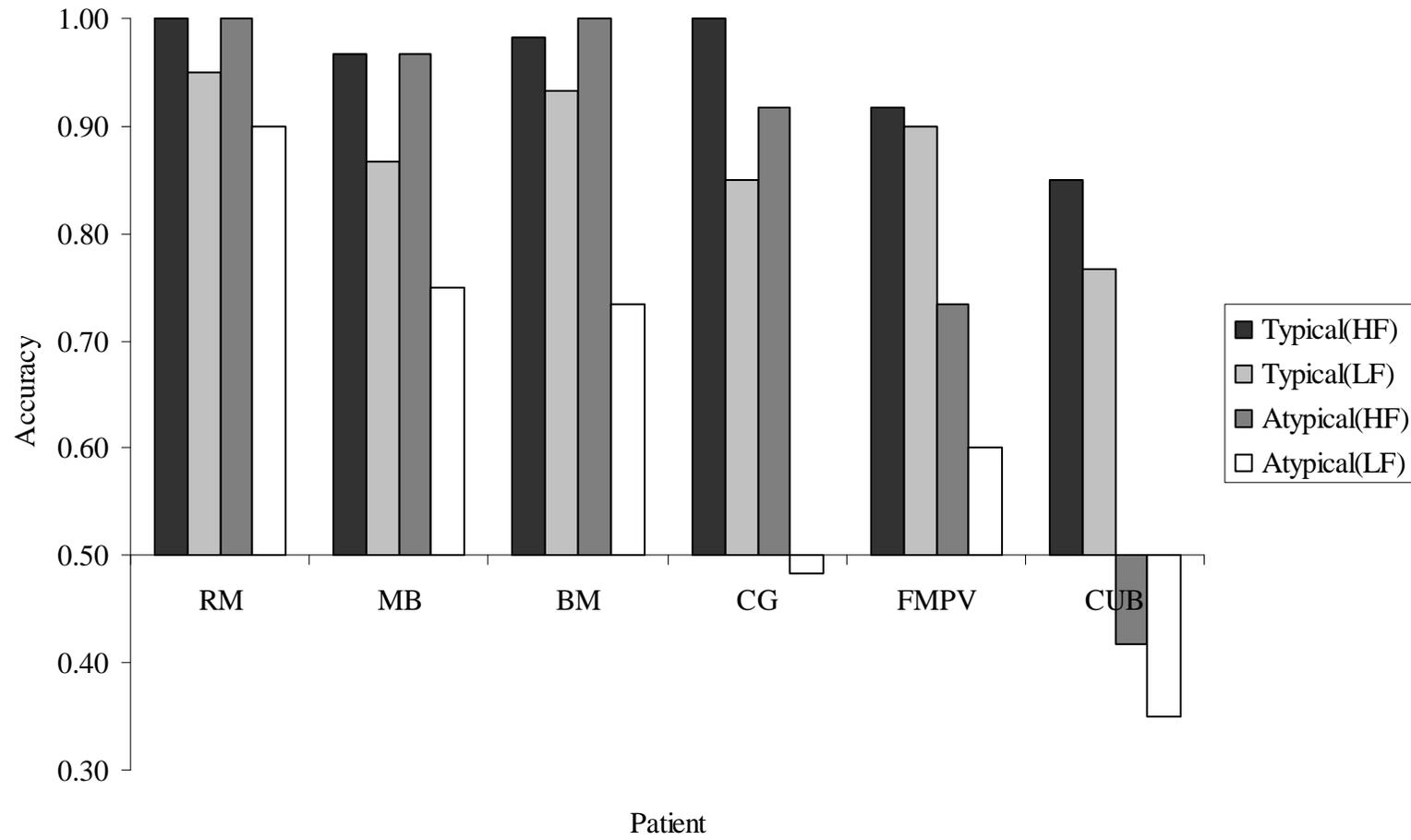
Fig.2b: Individual patient results

Fig.3: Relationship between semantic severity and lexical gender accuracy