Journal: Aphasiology
Date Submitted by the Author: 19-Dec-2008

Title: Recovery in reading, a treatment study of acquired deep dyslexia in Spanish

Complete List of Authors:
- Davies, Robert; University of Oxford Brookes, Psychology
- Cuetos, Fernando; University of Oviedo, Faculty of Psychology
- Rodríguez-Ferreiro, Javier; University of Oviedo, Faculty of

Keywords:
deep dyslexia, acquired dyslexia, phonological dyslexia, treatment, reading, Spanish

Acknowledgements

We are grateful, above all, to MJ. This investigation was funded by grant MEC-06-SEJ2006-6712 from the Spanish government. Robert Davies and Fernando Cuetos are members of the Marie Curie Research and Training Network: Language and Brain (RTN: LAB) funded by the European Commission (MRTN-CT-2004-512141) as part of its Sixth Framework Program. Javier Rodríguez-Ferreiro was supported by a grant from the Gobierno del Principado de Asturias (Plan de Ciencia, Tecnología e Innovación de Asturias 2006-2009).

Introduction

In a small number of cases, deep dyslexia has resolved into phonological dyslexia over time (Glosser & Friedman, 1990; Job & Sartori, 1984; Klein, Behrmann, & Doctor, 1992; Laine, Niemi, & Marttila, 1990; Southwood & Chatterjee, 2001). Deep dyslexia is characterized by a profound deficit in non-word reading and the production of semantic substitutions in partially preserved word reading (Coltheart, 1984). Phonological dyslexia is characterized by a non-word reading impairment and an absence of semantic substitutions (Patterson, 1982). The pattern of change is consistent with the idea that deep dyslexia and phonological dyslexia represent different points on the same continuum (Friedman, 1996). In a longitudinal investigation, we addressed the way that therapy can be shown to contribute to the recovery of reading function. We add to a small evidence base concerning the effect of therapy on deep dyslexic reading (dePartz, 1986; Mitchum & Berndt, 1991; Nickels, 1992, 1995).

Our investigation was conducted in Spanish, a language with a transparent orthography. Observations of deep or phonological dyslexia in Spanish are impressive because of the way reading in transparent orthographies has been assumed to occur (e.g. Ziegler & Goswami, 2005). The inconsistency of the English orthography means that reading aloud in that language is assumed to depend normally on sub-lexical information - knowledge about spelling-sound mappings at the level of grapheme-phoneme correspondences - as well as lexical (Coltheart, 1984; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) or semantic (Plaut, McClelland, Patterson, & Seidenberg, 1996) information, especially for low frequency words with exceptional pronunciations. The contrast between this inconsistency and the consistency of the Spanish orthography is argued to mean that (Ardila, 1991, p. 444): “Reading in

English and reading in Spanish are undoubtedly two different cognitive tasks. Reading in Spanish is always mediated through phonology …" Here 'phonological reading' means that letter strings are encoded phonologically, through the assembly of the outputs of grapheme-phoneme correspondences (Coltheart, 1984), or perhaps syllable-level mappings (Ardila, 1998), to yield access to the lexicon.

It follows that if reading is done primarily or solely through a sub-lexical reading system then one should not see superior preservation of word compared to non-word reading. Thus, in transparent orthographies, one would not expect cases of phonological or deep dyslexia. This expectation is partially supported by the evidence from surveys of reading in samples of tens of aphasic patients speaking Spanish (Ardila, 1991) or Italian (Toraldo, Cattini, Zonca, Saletta, & Luzzatti, 2006). Ardila (1991) reported that no semantic paralexias were recorded in the outputs of 41 patients. However, the information in Ardila's (1991) report does not allow one to evaluate whether any individual patient presented with better preserved word compared to non-word reading. Toraldo et al. (2006) reported that, of 90 aphasic patients, 54% were able to name some words successfully but were more impaired on reading non-words, fitting a phonological dyslexia profile; of these, however, only one made semantic paralexias and so could be said to have been deep dyslexic.

One would not expect a difference between word and non-word reading performance if reading was purely sub-lexical so the group evidence in Italian, at least, suggests that reading in transparent orthographies might be done through lexical as well as sub-lexical mappings. Indeed, the evidence from studies of reading in healthy adults indicates that lexical spelling-sound mappings are employed in healthy adult reading in transparent orthographies (Spanish - Cuetos & Barbón, 2006; Italian - Pagliuca, Arduino, Barca, & Burani, 2008). Moreover, a number of single case studies

have been reported where Spanish-speaking patients demonstrated better preserved word than non-word reading, and, critically, produced semantic paralexias in word reading (Cuetos, 2002; Cuetos & Labos, 2001; Davies & Cuetos, 2005; Ferreres & Miravalles, 1995; Iribarren, Jarema, & Roch Lecours, 1999; Ruiz, Ansaldo, & Roch Lecours, 1994). Extrapolating from accounts explaining the occurrence of semantic paraphasias in dyslexic reading in English, these semantic reading errors indicate the use of a lexical-semantic reading route (Caramazza & Hillis, 1990; Morton & Patterson, 1980; Newcombe & Marshall, 1980; Shallice & Warrington, 1980; Southwood & Chatterjee, 2001). The question then follows: do we see, in the Spanish semantic paralexias, evidence for a preserved lexical-semantic reading route?

Our task in the present article is to apply patient data to an evaluation of answers to this question. We will focus on the possibility that, where a Spanish-speaking patient produces semantic paralexias, it is because they are reading using a lexical-semantic strategy, not available for premorbid reading, but made available as a consequence of therapy. This is because, in a review of cases where Spanish-speaking aphasic patients, Ardila (1998) argued that semantic reading errors occur, essentially, only under exceptional circumstances: as a result of therapy; in association with a high level of education; or in association with multilingualism. Our data speak most directly to the role of therapy because the patient we shall discuss was not a multilingual reader, nor did she benefit from a high level of education. However, in our investigation, the patient, MJ, was given therapy to improve her reading.

Possible effects of therapy on aphasic reading in transparent orthographies

The claim under examination, here, is that (Ardila, 1998; p. 894): "… semantic paralexias are more likely to occur after speech therapy; the probability of developing

new reading strategies, non-existing during the premorbid period, may be raised …" This claim could be read to mean that: (1.) semantic paralexias are more likely, having never occurred previously; or (2.) more likely, occurring more often than previously; in either case, where a lexical-semantic reading strategy is established through therapy, having been unavailable to premorbid reading. Either possibility implies that the occurrence of semantic paralexias in aphasic reading should rise as the amount of therapy received increases over time. This is because no or few semantic errors would occur, except by chance, without a lexical-semantic reading route. The establishment of such a route would make semantic errors possible where they had not been possible before. Therefore, the occurrence of such errors should rise as the lexical-semantic route became established, as a result of therapy, and was then more often applied to reading.

Contrasting expectations about the effect of therapy can be formed, however, if one assumes that a lexical reading route was available to the patient before injury (e.g. Cuetos & Barbón, 2006; Pagliuca et al., 2008). A number of possible pathways to recovery from acquired dyslexia have been envisaged. Friedman (1996; Glosser & Friedman, 1990) argued that the likelihood of semantic paralexias is principally determined by the severity of the impairment of lexical-semantic reading. This is because, in Friedman's (1996) account, lexical oral reading (in English) can be achieved either through an orthography-to-semantics-to-phonology route or through an orthography-to-phonology route that also supports non-word reading. In such a system, impairment of the orthography-to-phonology route would cause a deficit in non-word reading but spare word reading, which could be completed through the semantic route. However, dependence upon the semantic route would mean that an impairment of the semantic reading route would predict the occurrence of semantic

substitutions. Friedman (1996) suggested that the likelihood of such errors occurring decreases as a result of the recovery of reading by the semantic route. If therapy successfully treats lexical-semantic reading then one should see an improvement in word reading, and a decrement in the occurrence of semantic substitutions, independent of any improvement in non-word reading (Friedman, 1996).

A related possibility is that a patient produces semantic reading errors because, though she is capable of accessing the meaning of a word after decoding print, and though the transmission of information from the semantic level to the output phonological level is correct, she is unable, then, to select the appropriate word. That is, semantic errors may arise from response blocking (Morton & Patterson, 1980). In this situation, the patient would be expected to make semantic errors not just in reading but also in other tasks dependent upon the mapping between semantics and phonology, for example, the picture naming task. Improvement in both naming and reading performance, including a decrement in semantic errors, would imply that therapy had successfully improved the mapping between semantics and phonology, or the processing involved in phonological output.

The production of semantic paralexias might be seen to decrease also in association with the recovery of the orthography-to-phonology reading route. As Newcombe and Marshall (1980) noted, phonological information about a letter string can be used to exclude semantic errors from output (compare, for similar outcomes but differing perspectives, Caramazza & Hillis, 1990; Southwood & Chatterjee, 2001). Indeed, Friedman (1996) proposed that partial phonological information output from partially preserved, or recovered, spelling-sound mappings may be sufficient to prevent semantic paralexias but insufficient to support non-word reading. If therapy successfully treats the orthography-to-phonology route, then one should see both an

improvement in word reading (including a decrement in semantic substitutions) and an improvement in non-word reading.

The present study

We hypothesized that training in grapheme-phoneme correspondences would promote improvement in oral reading irrespective of whether target letter strings were words or non-words. This is because Spanish is a transparent orthography where lexical exceptions to letter-level spelling-sound correspondences do not occur. We hypothesized that training in lexical orthography-to-semantics-to-phonology and semantics-to-phonology mappings would yield improvement in both word reading and picture naming. This is because we assume that reading in Spanish can be done through a lexical-semantic route that includes semantics-to-phonology mappings that can be used for both reading and naming. We hypothesized that the effect of improvement in lexical reading would combine with the effect of improvement in non-lexical reading to ensure a reduction in the frequency of semantic reading errors over time. This contrasts with the expectation that "…semantic paralexias are more likely to occur after speech therapy …" (Ardila, 1998), because, we suppose, therapy can drive the establishment of a lexical-semantic reading strategy not available to premorbid reading. The main contribution of the present study is to examine the effect of therapy in a longitudinal investigation in which the same reading tests were administered repeatedly in a systematic comparison of performance over time.

Clinical description

MJ was reported by family members to have been a competent reader before injury and to have learnt to read without problems at school. Following high school,

she attended a secretarial college before going to work as an administrator in a small company. MJ enjoyed reading as a major aspect of her premorbid leisure time activity.

MJ was 37 years old when she was first admitted to hospital in Oviedo, in late November 2003. Admission occurred following a week of headaches and vomiting in which she had shown changes in superior cognitive functioning. She had had no neurological illnesses prior to admission.

A Computed Tomography (CT) scan on the day of admission indicated a hypodense mass in the left basal ganglia, suggesting a low grade glioma. A structural magnetic resonance imaging scan, conducted the day after admission, showed the lesion to be an astrocytic tumor situated in the left cerebral hemisphere. Seven days after admission, a stereotactic biopsy was carried out that resulted in a haemorrhage. In order to evacuate the hematoma, a decompressive craniotomy with no reposition of the bone-flap was conducted. A further CT scan, conducted 20 days later, indicated the presence of two lesions: a deep lesion that encompassed the thalamus and basal ganglia, corresponding to the astrocytic tumor; and another lesion, that encompassed both the left striate body and the capsula externa and extende to the cortical surface of the temporal lobe, that was caused by the biopsy. The lesions were the results, in sum, of the original lesion plus the damage caused as a result of the biopsy. The location and extent of the lesions are shown in Figure 1.

(Figure 1, about here)

At the first behavioural assessment, conducted by the hospital rehabilitation unit, in January 2004, MJ was initially found to be paralyzed in her right arm and her

right leg. We note she had recovered movement, with some slight difficulties, by the time we began testing her, 18 months later. Also at the first hospital assessment, some buccal motor difficulties were observed, shown in difficulties of verbal expression. Only some hesitancy and dysfluency remained at the time of our testing.

In January, 2004, MJ was reported to show a mixed aphasia with, predominantly, production problems and some comprehension difficulties. At that time, MJ failed to name objects (20% correct), was 20% correct in naming body parts, 4/6 correct in naming most letters, and 5/6 in naming numbers. The names she could produce were phonologically well-formed. She made no responses to tests of verbal fluency, for example, to category "animals" or letter "p". There was, also, marked use of stereotyped phrases and the use, on occasion, of jargon expressions. MJ correctly repeated spoken words. She was unable to read words aloud, except for one or two, isolated, correct responses. Writing with her left hand, owing to the paralysis of her premorbidly preferred right hand, she showed spelling and written word production difficulties, but she was able to copy and produce letters, with some graphomotor difficulties. In sum, MJ's language capacities at the first survey, completed by the admitting hospital's rehabilitation unit, indicated severe anomia, practically complete dyslexia, and dysgraphia. As only summary records were kept of MJ's behavioural testing in 2004, we will not discuss those results further.

Our neuropsychological cognitive testing began in the summer of 2005, 18 months after MJ's biopsy in December 2003. In the period from late 2003 to summer 2005, MJ received speech therapy at the hospital rehabilitation unit, for up to one hour a session, three days a week. This therapy was exclusively concerned with improving MJ's speech production, owing to the severity of her anomia, alongside the apparent preservation of her semantic knowledge. MJ did not receive reading therapy before

our investigation, nor did she engage in re-training herself.

Observations on reading-related skills

As described by Davies and Cuetos (2005; where further details can be found), at the beginning of our investigation, we tested MJ's cognitive abilities over a range of domains. We discuss word and non-word reading, as well as picture naming in following sections. We set the scene by describing the results of tests of reading-related skills, conducted at the start of our investigation. Most tests were drawn from the Spanish version of the PALPA battery (Kay, Lesser & Coltheart, 1992), the EPLA (Valle & Cuetos, 1995), and the results are summarized in Table 1. The EPLA normative scores are based on the responses of a group of 22 healthy adults (45-65 years old).

We examined the phonological, orthographic and semantic components of the system of skills hypothesized to support reading (Plaut et al., 1996). To probe orthographic processing, we tested MJ's visual word recognition. She appeared able to distinguish between words and non-words in a visual lexical decision task (no comparison to controls is available). To probe her preservation of semantics, we tested her ability to match words to pictures or to distinguish synonyms. MJ evidenced preserved semantic knowledge, indicated by a capacity for verbal auditory comprehension within normal limits in both a word-picture matching and a synonym judgment task drawn from the EPLA. However, she demonstrated impaired access to semantics from printed words, evident in her performance in written word-picture matching and written synonym judgment tasks. A numeric trend in which MJ responded more accurately to high imageability items in the semantic tests did not prove significant (spoken synonyms, chi-sq. = 2.59, q d.f., p = 0.11; printed

synonyms, chi-sq. = 0.7). MJ was impaired in her ability to name pictured objects in the Spanish version (Kaplan, Goodglass, & Weintraub, 1996) of the Revised Boston Naming test (Goodglass, Kaplan, & Weintraub, 1983). She named only about 25% of target pictures correctly. Semantic cuing using word associates did not help naming accuracy. Cuing with the initial phoneme of picture names elicited correct responses on 70% of the remaining pictures.

In relation to phonological processing skills, MJ showed impairments of short-term memory (digit span, EPLA) and phonological awareness (word or non-word initial or final phoneme discrimination, EPLA) in comparison to healthy adults. In addition, whereas she was entirely accurate in a 24-item test of letter-sound matching (EPLA) she correctly named or said the sound of only 20 out of 26 letters of the Spanish alphabet. Finally, we observed that MJ showed problems in comparison to controls in word and non-word repetition (EPLA).

(Table 1, about here)

Therapy

Our initial observations indicated a reliance on lexico-semantic reading, shown by the occurrence of semantic reading errors (Davies & Cuetos, 2005). MJ's performance in letter-sound matching suggested her knowledge of correspondences may have been substantially preserved but her impaired letter naming suggested she had difficulty producing the outputs of such correspondences. Our observations motivated a therapy regime focused, firstly, on retraining in the completion to spoken output of grapheme-phoneme correspondences, and, secondly, on retraining in the association of concepts and written or spoken concept names, to improve spoken

word production. Therapy was administered by a speech and language therapist in MJ's local hospital, half an hour per day, three days a week.

As noted, prior to our investigation, training focused exclusively on the naming of pictures of objects, for the rehabilitation of MJ's anomia. MJ was asked to name pictured objects using pictures taken from the standardized Snodgrass and Vanderwart (1980) set. (These were not the object pictures that were used in the longitudinal testing, reported later.) MJ was given the initial phonemes of object names if she struggled to produce the correct response. Further, using the same item set, she was given exercises in the association of object concepts and names. In one set of exercises, MJ was presented with arrays of three pictures and a word (the name of one of the pictured objects), and she was asked to point out the picture of the object named by the word. In another set of exercises, MJ was presented with arrays of three words, and a picture of an object named by the words, and she was asked to point out the word that named the object. In each exercise, one non-target alternative was a picture or the name of an object from the same semantic category as the target, the other alternative was semantically unrelated.

The training in the association of concepts and names continued as our investigation proceded but, from the start of our investigation onwards, the training was augmented to include exercises designed to rehabilitate reading. The training in oral reading was based on the syllable-based literacy teaching methods used in primary schools in Spain in the 1970s. This is because the Spanish syllabary consists largely, in type and token frequency terms, of simple consonant-vowel, vowel and consonant-vowel-consonant syllables (Alameda & Cuetos, 1995). In this approach, students are taught to pronounce consonants associated with vowels in simple consonant-vowel syllables. For example, initially, MJ was shown the printed vowels

“a,e,i,o,u” and was asked to build consonant vowel syllables using the phoneme corresponding to the letter “m”, to read aloud: “ma, me, mi, mo, mu”. Training then consisted of repetition exercises leading to rote learning of the syllables. Grapheme-phoneme correspondences were included in training exercises incrementally. That is to say, at first, the syllables encountered in training consisted of just the vowels and a small number of consonants until these were trained to a high level of performance. These lessons were then extended to wider sets of syllables by the association of different consonants with the same vowels, for example, “pa, pe, pi, po, pu”. Teaching built on the pronunciations of the simple syllables by asking MJ to combine the syllables to construct words, for example, “mama”. Further teaching extended to more complex syllables, for example, “cos” (a consonant-vowel-consonant syllable) and the construction of words from the latter.

The rote learning of orthography-to-phonology mappings was supported with exercises designed to develop phonological processing skills, including phonological awareness for those phonemes whose correspondences were being taught in the reading training. The exercises were adapted from those recommended by García (1979). They were designed to develop the different aspects of phonological processing assumed to underlie the encoding of print in reading aloud, namely, phoneme production, phoneme awareness, and the combination of the outputs of grapheme-phoneme correspondences into spoken words.

In one combination of exercises, MJ was asked, firstly, to produce individual phonemes and to show, when doing so, the place and mode of articulation. She was then asked to distinguish between similar phonemes spoken by the speech therapist that differed by one distinctive feature, for example, to distinguish /polo-bolo/. In another set of exercises, aimed at training her phoneme awareness, MJ was asked to

read aloud words differing by a single phoneme, for example, “fijo-dijo”, and she was asked to classify as same or different spoken words that are distinguished by only a single phoneme, for example, /perro-pelo/ (note that “rr” is the hard /r/, spoken as a single phoneme, in Spanish). Further exercises were designed to train MJ in the capacity to distinguish graphemes and to produce phonemes in a given order. Thus, she was asked to read aloud words that differed only in the order in which letters were printed, for example, “lu-ul”. And she was asked to read sequences of words in which the same phoneme appeared in all possible positions, for example, to read words beginning with the grapheme “p” as in “pato, pata, apto, topo” and so on.

Finally, in a combination of exercises aimed at developing her capacity to concatenate the products of grapheme-phoneme correspondences, MJ was asked to form word sounds, building the words from a choice of letters whose correspondences were being trained in the session. She was then asked to separate the words she had formed into syllables, and then to count the number of syllables in each word. As new correspondences were introduced in the reading exercises, MJ was encouraged to include them in the words she formed in the word production exercise.

Further exercises were administered with the aim of developing MJ’s language and reading skills at the level of mappings involving semantics. The principle was to build on preserved semantic knowledge through the use of pictures as a basis for training in associations between pictured concepts and printed and spoken concept names. In one exercise, MJ was presented with pictured concepts (objects or actions) together with the picture names printed with some letters missing. She was asked to produce the missing letters (saying the phonemes), to produce the whole picture names, and then to indicate the number of syllables in each name. In another exercise, MJ was asked to name pictured objects or actions and to match printed words to the

pictures she had named. Training in concept-name associations was done, as noted, using different pictures from those used by us in testing MJ's abilities.

Reading tests: performance at the start of the longitudinal investigation

At the start of our investigation, we conducted an extensive battery of reading tests in which we asked MJ to read words aloud, including reading tests previously reported by Davies and Cuetos (2005) plus additional tests, not previously reported, yielding a total data-set on word reading of 356 responses. We report the accuracy of MJ's reading across all tests administered at the outset of the longitudinal investigation in Table 2.

(Table 2, about here)

We classified MJ's responses as correct, null response, word error, non-word error or circumlocution. The frequency of errors are reported in Table 3. It can be seen that MJ's errors consisted largely of word substitutions or null responses though she also produced a number of non-word errors.

(Table 3, about here)

We classified MJ's word substitutions as semantic, morphological, visual, visual+semantic, visual then semantic, functor substitution or unrelated errors. The frequency of word substitutions of each type are also reported in Table 3. Semantic errors were categorically or associatively related to target words, for example, "ventana" (window) → /puerta/ (door). Morphological errors were related by

inflection or derivation to targets, for example, “nuestro” → “nuestra/, where both words mean “ours” but the forms differ at the word final phoneme according to grammatical gender. Visual errors shared over 50% of letters with the target but were semantically or morphologically unrelated. Visual+semantic errors bore both a semantic and a visual relation, for example, “piña” (pineapple) → /pera/ (pear). Visual then semantic errors were rare, there were only two recorded, but these were “crecer” (to grow) → /dios/ (god) which we think arose through “creer” (to believe) and “momento” (moment) → /iglesias/ (church) which we think arose through “monumento” (monument). Functor substitutions involved the production of one function word instead of another, for example, “debajo” (underneath) → /delante/ (in front). Unrelated errors bore no relation according to defined categories with the target word, for example, “camión” (lorry) → /chaqueta/ (jacket). It is worth noting that a substantial number of semantic errors were recorded, and that these errors constituted about 40% of word substitutions or 10% of total responses recorded.

We note that MJ was sometimes able to distinguish her semantic reading errors, sometimes saying, for example, “puerta” (door) → /ventana [window], no/. MJ’s behaviour resembles that observed in so-called output dyslexics such as VJ (Laine et al., 1990) or DE and PW (Patterson, 1978). Following Morton & Patterson (1980), we could argue that MJ made semantic paralexias because of an impairment of the transmission of information from semantics to phonology, or because of response blocking at the level of output phonology.

Longitudinal study of MJ’s reading aloud

We followed MJ over a two year period from the summer of 2005 onwards. At four points, at approximately six monthly intervals, we tested her reading of words

and non-words. Two of the reading tests summarized in Table 2 were administered at every time point in our longitudinal investigation. In one test, we presented words and non-words intermixed in a single block of items (EPLA 26). The words in this test had been selected to vary factorially on both imageability and frequency. In the second test, administered in the same sessions, we presented words alone. These words consisted of nouns, verbs, adjectives and function words matched, as far as possible, on frequency and length in letters or syllables (EPLA 30). We report MJ's performance in reading aloud the items of the EPLA 26 and EPLA 30 tests in Table 4.

(Table 4, about here)

We hypothesized that the administration of reading therapy would be associated with an increase in reading accuracy irrespective of target lexicality. It is clear from our results (Table 4) that MJ's word and non-word reading accuracy did improve through the period of testing (non-word reading, Cochran's test of the significance of differences between k related samples, $Q = 138.64$, 3 d.f., $p < .001$; word reading, $Q = 245.28$, 3 d.f., $p < .001$), reaching an apparent plateau in performance in both tasks at around 90% accuracy in word reading and around 75% in non-word reading.

We hypothesized that if the administration of therapy were associated with the establishment of a lexical reading strategy and if such a lexical reading strategy were associated with the production of semantic reading errors then we should observe the increasing production of semantic substitutions over time. The frequencies of word substitutions of different types are summarized in Table 5. It can be seen that the proportion of semantic paralexias decreased over time (Cochran's test of the

significance of differences between k related samples, Q = 9.0, 3 d.f., p = 0.029).

(Table 5, about here)

We note that as MJ's non-word reading accuracy improved, the number of non-word errors she made to non-word targets increased over time (Cochran's Q = 17.12, 3 d.f., p = .001). This can be seen in the response type frequencies in relation to non-word reading summarized in Table 6.

(Table 6, about here)

Discussion

We conducted an investigation of the effect of therapy on word and non-word reading over two years. The therapy regime included exercises designed to retrain MJ's capacity to complete spelling-sound mappings at the level of grapheme-phoneme correspondences, to concatenate the outputs of such correspondences to produce whole words, and to associate concepts with word labels. The therapy appeared to be successful because we found that MJ's word and non-word reading improved at every time point at which she was tested.

As MJ's reading accuracy improved, her production of semantic substitutions decreased. This clearly disconfirms the hypothesis that the likelihood of semantic paralexias would be raised, following therapy, because therapy drove the establishment of a new (in our interpretation, lexical-semantic) reading strategy (Ardila, 1998). Non-word reading did not improve as steeply as word reading. MJ continued to present a non-word-reading deficit by the end of our investigation. At

that stage, MJ's word reading accuracy was superior (at 90-98%) to her non-word reading (73%). This means that MJ can be characterized as having evolved from deep to mild phonological dyslexia during our investigation.

It seems that MJ's reading skills improved as a result of the training of both orthography-to-phonology (OP) and orthography-to-semantics-to-phonology (OSP) mappings. She continued to produce word errors at all four times at which we tested her reading but the occurrence of word substitutions declined. In comparison, MJ's production of non-word errors in non-word reading tended to increase over time. We ascribe the improvement of non-word reading to the augmentation of OP mappings but explain the increase in the number of non-word errors to a residual imprecision in the application of those mappings (cf. Southwood & Chatterjee, 2001). We think it likely that MJ's word reading performance depended upon both her OP and OSP mappings and that as these were improved through training her word reading improved faster than her non-word reading because word reading is informed by the outputs of both OP and OSP mappings whereas non-word reading is informed by the outputs of OP mappings alone.

Our account is congruent with the accounts of phonological dyslexia put forward by Friedman (1996), and Southwood and Chatterjee (2001), among others. Our version of the explanation is that word reading depends upon two routes, the OP and OSP mappings, which interact, combining to inform the production of oral reading responses. The disappearance of semantic paralexias over time can be explained by the increase in information supplied to phonological output coding by improved OP and OSP mapping. Such increase is clearly sufficient to edit semantic errors from output or to raise the likelihood of the correct word being output in the first place (Caramazza & Hillis, 1990; Friedman, 1996; Newcombe & Marshall, 1980;

Southwood & Chatterjee). Tellingly, in reading, MJ was sometimes aware that she had produced a semantic substitution. We believe the evidence indicates that MJ's production of semantic errors was substantially caused by a difficulty in selecting the correct response for output (Morton and Patterson, 1980).

We note that the appearance of an imageability effect on reading accuracy, at the first test points, early in the investigation (Tables 2 and 4), can be explained by the greater strength and specificity argued to characterize transmission of information from the semantic to the phonological levels for high compared to low imageability words (Barry & Gerhand, 1997). Words that are more strongly activated from semantics ought to be easier to select for production (Roelofs, 1992). Over time, MJ's improved capacity to complete OP and OSP mappings supported an improved capacity to, activate, select and then output the right response, rather than a semantic relative, in her word reading.

In sum, our view is that the data show that the therapy MJ received helped her to recover the use of a pre-existing orthography-to-semantics-to-phonology reading route. Granted that transparent orthographies like Spanish are entirely consistent in spelling-sound mappings, why should any Spanish-speaking reader develop orthography-to-semantics-to-phonology mappings? Non-lexical spelling-sound mappings are sufficient to read any word correctly in any transparent orthography. However, a substantial body of evidence suggests that a key variable in raising individual differences in how reading is done (Chateau & Jared, 2000) is reading experience or print exposure (Stanovich, 1986). It is well established that children with more reading experience, where experience is operationalized as print exposure, evidence more skilled orthographic processing (Cunningham, Perry, & Stanovich, 2001) even after relative phonological processing skill has been taken into account.

Moreover, it has been shown that differences relating to print exposure persist into adulthood (Chateau & Jared, 2000). We think that one reason a reader might develop OSP mappings is that the need to rapidly access meaning from print drives the establishment of direct orthography-to-semantics (OS) mappings (Harm & Seidenberg, 2004). Further investigation is necessary to probe directly the hypothesis that people who read more are more likely to establish direct orthography-to-semantics mappings.

We suspect that orthographic transparency limits the extent to which variation in the quantity of literacy practice can precipitate a reading system architecture in which lexical-semantic knowledge is involved in reading. Ardila (1998) reported that Spanish-speaking patients who produced semantic reading errors tended to have been highly literate before presenting with symptoms of brain injury whereas English-speaking patients who also made such errors appeared to have had much more varied premorbid levels of reading skill. We speculate that patients speaking languages with relatively opaque orthographies will be found to produce semantic paralexias irrespective of quite wide variation in premorbid literacy whereas patients speaking languages with relatively transparent orthographies will be found to produce semantic paralexias only where premorbid literacy had been high. This would account for the preponderance of cases in which aphasic patients speaking languages with transparent orthographies do not produce semantic substitutions when asked to read words aloud (Ardila, 1991, 1998; Miceli, Capasso, & Caramazza, 1994; Toraldo et al., 2006), while also accounting for those cases, such as that presented by MJ, where semantic reading errors are recorded.

Our investigation shows that, after her injury, MJ was reading using OSP mappings. While we propose that her premorbid reading also depended upon OSP

mappings, it may be that MJ adapted to post-injury impairments by using mapping structures well established for tasks other than oral reading. We presume that MJ had established SP mappings prior to injury, since such mappings would underlie semantically-driven speech production. What invites further investigation, in future case studies, is whether a reader with an average education, like MJ, would have used orthography-to-semantics mappings in her premorbid reading. We contend she may have done because computational simulations indicate that direct orthography-to-semantics mappings tend to be established where efficient access to semantics is rewarded (Harm & Seidenberg, 2004), because work by Stanovich and colleagues suggest that how much people read may vary considerably (Stanovich, 1986) and that this has an impact on the quality of orthographic processing skill (Cunningham et al., 2001), and because we know that MJ read as a major leisure activity. Together, orthography-to-semantics mappings and semantics-to-phonology mappings could have afforded a means of translating spelling to sound via semantics. Further investigation will tell us if reading in healthy Spanish-speaking adults can be found to show the normal use of lexical semantic knowledge.

Reference List

Alameda, J. R. & Cuetos, F. (1995). *Diccionario de frecuencias de las unidades lingüísticas del Castellano [Frequency dictionary of the linguistic units of Castellano]*. Oviedo: Servicio de Publicaciones de la Universidad de Oviedo.

Ardila, A. (1991). Errors resembling semantic paralexias in Spanish-speaking aphasics. *Brain and Language, 41,* 437-445.

Ardila, A. (1998). Semantic paralexias in the Spanish language. *Aphasiology, 12*, 885-900.

Barry, C. & Gerhand, S. (1997). Both concreteness and age-of-acquisition affect reading accuracy but only concreteness affects comprehension in a deep dyslexic patient. *Brain and Language, 84*, 84-104.

Caramazza, A. & Hillis, A. E. (1990). Where do semantic errors come from? *Cortex, 26,* 95-122.

Chateau, D. & Jared, D. (2000). Exposure to print and word recognition processes. *Memory and Cognition, 28,* 143-153.

Coltheart, M. (1984). Acquired dyslexias and normal reading. In R.Malatesha & H. Whitaker (Eds.), *Dyslexia: A global issue* (pp. 357-373). The Hague: Martinus Nijhoff Publishers.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108,* 204-256.

Crawford, J. R. & Howell, D. C. (1998). Comparing an individual's test score against norms derived from small samples. *The Clinical Neuropsychologist, 12*, 482-486.

Cuetos, F. (2002). Sistemas de lectura en ortografias transparentes: evolución de la dislexia profunda en español. *Cognitiva, 14,* 133-149.

Cuetos, F. & Barbón, A. (2006). Word naming in Spanish. *European Journal of Cognitive Psychology, 18,* 415-436.

Cuetos, F. & Labos, E. (2001). The autonomy of the orthographic pathway in a shallow language: Data from an aphasic patient. *Aphasiology, 15,* 333-342.

Cunningham, A. E., Perry, K. E., & Stanovich, K. E. (2001). Converging evidence for the concept of orthographic processing. *Reading and Writing: An Interdisciplinary Journal, 14,* 549-568.

Davies, R. & Cuetos, F. (2005). Acquired dyslexia in Spanish: A review and some observations on a new case of deep dyslexia. *Behavioural Neurology, 16,* 85-101.

dePartz, M.-P. (1986). Re-education of a deep dyslexic patient: rationale of the method and results. *Cognitive Neuropsychology, 3,* 149-177.

Ferreres, A. R. & Miravalles, G. (1995). The production of semantic paralexias in a Spanish-speaking aphasic. *Brain and Language, 49,* 153-172.

Friedman, R. B. (1996). Recovery from deep alexia to phonological alexia: Points on a continuum. *Brain and Language, 52,* 114-128.

García, P. (1979). *La dislalia [Dyslalia]*. Madrid: Cepe.

Glosser, G. & Friedman, R. B. (1990). The continuum of deep/phonological alexia. *Cortex, 26,* 343-359.

Goodglass, H., Kaplan, E., & Weintraub, S. (1983). The Revised Boston Naming Test. Philadephia,PA: Lea and Febiger.

Harm, M. W. & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. *Psychological Review, 111,* 662-720.

Iribarren, I. C., Jarema, G., & Roch Lecours, A. (1999). Lexical reading in Spanish: Two cases of phonological dyslexia. *Applied Psycholinguistics, 20,* 407-428.

Job, R. & Sartori, G. (1984). Morphological decomposition: evidence from crossed phonological dyslexia. *The Quarterly Journal Of Experimental Psychology, 36,* 435-458.

Kaplan, E., Goodglass, H., & Weintraub, S. (1996). Test de Vocabulario de Boston [Boston Vocabulary Test]. Madrid: Editorial Medica Panamerica S.A.

Kay, J., Lesser, R., & Coltheart, M. (1992). *Psycholinguistic Assessment of Language Processing in aphasia*. Hove: Psychology Press.

Klein, D., Behrmann, M., & Doctor, E. (1994). Spontaneous evolution of deep dyslexia: phonological or semantic recovery? *Cognitive Neuropsychology, 11,* 579-611.

Laine, M., Niemi, P., & Marttila, R. (1990). Changing error patterns during reading recovery: a case study. *Journal of Neurolinguistics, 5,* 75-81.

Miceli, G., Capasso, R., & Caramazza, A. (1994). The interaction of lexical and sublexical processes in reading, writing and repetition. *Neuropsychologia, 32,* 317-333.

Mitchum, C. C. & Berndt, R. (1991). Diagnosis and treatment of the non-lexical route in acquired dyslexia: An illustration of the cognitive neuropsychological approach. *Journal of Neurolinguistics, 6,* 103-137.

Morton, J. & Patterson, K. (1980). A new attempt at an interpretation, or, an attempt at a new interpretation. In M.Coltheart, K. E. Patterson, & J. C. Marshall

(Eds.), *Deep Dyslexia* (pp. 91-118). London: Routledge & Kegan Paul.

Newcombe, F. & Marshall, J. (1980). Transcoding and lexical stabilization in deep dyslexia. In M.Coltheart, K. E. Patterson, & J. C. Marshall (Eds.), *Deep Dyslexia* (pp. 176-188). London: Routledge & Kegan Paul.

Nickels, L. A. (1992). The autocue? Self-generated phonemic cues in the treatment of a disorder of reading and naming. *Cognitive Neuropschology, 9,* 155-182.

Nickels, L. A. (1995). Reading too little into reading? Strategies in the rehabilitation of acquired dyslexia. *European Journal of Disorders of Communication, 30,* 37-50.

Pagliuca, G., Arduino, L. S., Barca, L., & Burani, C. (2008). Fully transparent, yet lexical reading aloud: The lexicality effect in Italian. *Language and Cognitive Processes, 23,* 422-433.

Patterson, K. E. (1978). Phonemic dyslexia: Errors of meaning and the meaning of errors. *The Quarterly Journal of Experimental Psychology, 30,* 587-601.

Patterson, K. E. (1982). The relation between reading and phonological coding: Further neurological observations. In A.W.Ellis (Ed.), *Normality and pathology in cognitive functions* London: Academic press.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. E. (1996). Understanding normal and impaired reading: Computational principles in quasi-regular domains. *Psychological Review, 103,* 56-115.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. Cognition, 42, 107-142.

Ruiz, A., Ansaldo, A. I., & Roch Lecours, A. (1994). Two cases of deep dyslexia in unilingual hispanophone aphasics. *Brain and Language, 46,* 245-256.

Shallice, T. & Warrington, E. (1980). Single and multiple component central dyslexic syndromes. In M.Coltheart, K. E. Patterson, & J. C. Marshall (Eds.), *Deep Dyslexia* (pp. 22-47). London: Routledge & Kegan Paul.

Southwood, M. H. & Chatterjee, A. (2001). The Simultaneous Activation Hypothesis: Explaining recovery from deep to phonological dyslexia. *Brain and Language, 76,* 18-34.

Stanovich, K. E. (1986). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21,* 360-407.

Toraldo, A., Cattani, B., Zonca, G., Saletta, P., & Luzzatti, C. (2006). Reading disorders in a language with shallow orthography: A multiple single-case study in Italian. *Aphasiology, 20,* 823-850.

Valle, F. & Cuetos, F. (1995). *EPLA: Evaluación del procesamiento lingüístico en la afasia [EPLA: Evaluation of Language Processing in Aphasia]*. Hove: Erlbaum (UK) Taylor & Francis.

Ziegler, J. C. & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin,* 131, 3-29.