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Allographic agraphia: A case study

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ABSTRACT

We report the case of patient MN, diagnosed with frontotemporal dementia, who exhibited a severe impairment in writing letters and words in upper-case print in the face of accurate production of the same stimuli in lower-case cursive. In contrast to her written production difficulties, MN was unimpaired in recognizing visually presented letters and words in upper-case print. We find a modest benefit of visual form cueing in the written production of upper-case letters, despite an inability to describe or report visual features of letters in any case or font. This case increases our understanding of the allographic level of letter-shape representation in written language production. It provides strong support for previous reports indicating the neural independence of different types of case and font-specific letter-shape information; it provides evidence that letter-shape production does not require explicit access to information about the visual attributes of letter shapes and, finally, it reveals the possibility of interaction between processes involved in letter-shape production and perception.

1. Introduction

Producing written letters requires at least 3 successive planning stages: activation of the abstract graphemic representation of the letter to be written, selection of the appropriate font and case (allograph), and graphic-motor planning which involves developing motor plans specific to a particular limb and writing environment (see Ellis, 1982; Margolin, 1984 and Rapp and Caramazza, 1997 for a review). In this report we describe a study of an individual with acquired agraphia that affects the stage of allographic selection.

Allographs represent the multiple variants that graphemic representations can take (e.g., case: upper *vs* lower or the font: cursive *vs* print) and, as just indicated, allographic form must be specified before graphic-motor patterns are activated. The psychological and neural reality of the allographic stage has received support from neuropsychological reports of acquired agraphias in which neural injury seems to have selectively affected this stage of written language processing. The hallmark characteristic of damage to the allographic stage is the ability of an individual to spell in some modalities, fonts or case but not in others. These reports have been valuable in that they revealed a fine-grained organization of the allographic stage and provided insight into the nature of information represented at this stage.

Some individuals have exhibited a disturbance in their ability to control the case of words, manifested in their writing in mIXeD CasES (De Bastiani and Barry, 1989; Forbes and

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Venneri, 2003; Semenza et al., 1998). In addition to revealing that the abstract identity of letters can be specified independently of allographic selection, these results indicate that there is a specific allographic selection mechanism that can be disrupted by neural injury. Other patients have been described who seem to be selectively unable to write in one specific font or case (Patterson and Wing, 1989; Kartsounis, 1992; Trojano and Chiacchio, 1994; Venneri et al., 2002; Weekes, 1994; Hanley and Peters, 1996). These findings indicate that the various fonts and case representations are functionally organized and neurally instantiated with sufficient independence from one another that they may be selectively affected by neural injury. Other studies have analyzed the errors generated at this level in order to reveal characteristics of the allographic representations themselves. For example, Rapp and Caramazza (1997) described individuals who produced letter substitution errors attributed to a deficit at the allographic level, and an analysis of target-error characteristics revealed that they shared abstract motor features rather than visuo-spatial characteristics (see also Black et al., 1989; Lambert et al., 1994; Weekes, 1994; Zesiger et al., 1994). The conclusion was that abstract motor features are represented in the course of written letter production.

The present article documents the case of an individual with a selective deficit in producing upper-case print with intact production of lower-case cursive, replicating the findings of Venneri et al. (2002) concerning case EZ. In addition, we examine the relationship between allograph production and recognition and the role of explicit/implicit access to upper-case visual form information in producing written letters.

2. Case report

MN is an 81-year-old housewife, with 5 years of formal education, who was diagnosed with frontotemporal dementia. CT scanning and MRI document a diffused cortical atrophy, more marked in the frontal regions. On the MMSE (Folstein et al., 1975) she scored 19/30 (her age and education adjusted score was 21/30) which places her in the mild dementia range. Her spontaneous language production, free of phonemic errors, was mildly anomic. On a picture naming task, she produced semantic paraphasias (e.g., helicopter → airplane) and circumlocutions. Word fluency was impaired, both in a phonological and in a semantic task, and she produced perseverations. Her verbal comprehension was essentially preserved (her Token Test age and education adjusted score was 28/36). Her forward digit span was within the normal range for her age and educational level (adjusted score: 4.5, cut off score: 3.5). MN's long-term memory learning functions (tested with the Spinnler and Tognoni battery, 1987) were below the inferential cutoff scores derived from a reference sample representative of the Italian population. Attentional problems were evident in several tests including Trail Making Test (Form A adjusted score: 358 sec, cut off score: 94 sec; Form B = unable to perform the task), attentional matrixes (adjusted score: 26.25, cut off score: 31), backward digit span (span = 2).

With regard to motor production, there was no sign of ideational or ideomotor apraxia (DeRenzi et al., 1968, 1980). Her scores were within the normal range for a test assessing constructional apraxia (copy of figures from the MDB battery; Carlesimo et al., 1996) and her spontaneous drawing was fairly good.

Informal examination of written spelling showed that the patient was unable to write in upper-case print, while she could easily write in lower-case cursive. This finding was especially surprising since she read upper-case print with no hesitation whatsoever. Moreover, MN could write most letters in upper-case cursive, a rather unfamiliar and currently virtually obsolete format (it is nowadays common to use print for upper-case even in the context of cursive writing-Italy), making it more difficult to write than upper-case print.

It was important to determine whether MN's problem could be due to premorbid unfamiliarity with upper-case print writing. While the family could not produce any sample of the patient's writing prior to her disease, they were confident that the patient had used upper-case print in shopping lists and other occasional notes. In order to further evaluate the likelihood that MN would have been proficient in upper-case print, a control group was asked to produce: the 21 letters of the alphabet, 10 words and 5 non-words in upper-case print and lower-case cursive. The group consisted of 15 individuals (10 female, 5 male) matched to MN in age (mean age = 79.8, SD = 2.8, range: 76–85) and education (mean education = 5.1, SD = 1.4, range: 3–7). The results revealed no difference between ability to produce upper-case print and lower-case cursive. For writing single letters to dictation, accuracy in lower-case cursive across the 15 subjects was 96% (301/315) while accuracy in upper-case print was 97% (306/315). In word spelling, only errors involving producing an ill-formed letter or a letter produced in the incorrect case were considered errors; actual spelling errors (e.g., attore [actor] → atore) were excluded as they are not relevant to the question of whether MN was likely to have known how to produce upper-case print. It is worth noting, however, that most spelling errors (115/159 errors, 72.5%) were phonologically plausible spellings. For words and non-words total letter accuracy across subjects in upper-case print was 98.5% (1597/1620) and for lower-case cursive it was 99% (1603/1620). These results indicate quite clearly that, in all likelihood MN was premorbidly proficient in upper-case print writing.

3. Experimental investigation

3.1. *Analysis 1: evaluating the dysgraphic deficits*

3.1.1. *Task 1: writing words and non-words to dictation*

Writing words and non-words in upper-case print and lower-case cursive was tested in order to evaluate the full extent of MN's dysgraphia. She was asked to write to dictation 48 words (24 high and 24 low frequency, 4–6 letters) and 30 non-words (4–6 letters). On separate testing sessions she was instructed to write the stimuli in upper-case print and in lower-case cursive.

She could not write in upper-case print (0%) and when required to do so she reverted to lower cursive, despite clear understanding of the request. She claimed she had forgotten how to write in upper-case print.

Her accuracy in lower-case cursive writing for words and non-words was 73% (35/48) and 60% (18/30), respectively (Pearson $X^2 = 1.41$, df = 1, p = n.s.). In addition to the absence of a lexicality effect, there was no significant effect of frequency (high frequency words 18/24, low frequency words 17/24; Pearson $X^2 = .1$, df = 1, p = n.s). There was, however, a significant effect of the length of the stimuli (accuracy was calculated as the probability of making an error on a letter given the total number of letters attempted at that length) with error rates increasing with letter length: 4 letters (1.9%), 5 letters (9.2%) and 6 letters (10.9%) (Pearson $X^2 = 7.3$, df = 2, $N = 390$, $p < .05$). She produced 29 spelling errors including letter omissions (27.6%), especially in geminate clusters (e.g., valle [valley] → vale), additions (13.8%; e.g., gente [people] → giente; ravilo → travilo), perseverations (6.9%; scuola [school] → scuolala), substitutions (48.3%; e.g., gola [throat] → gala; zova → zoba) respecting the consonant/vowel status of the target, and 1 transposition error (e.g., permo → premo). Some of the errors (e.g., igiene → igene) seem to suggest damage to (or insufficient development of) the lexical system, surface dysgraphia, while others clearly do not, we return to this in the summary.

3.1.2. *Task 2: spelling words and non-words with mobile letters*

In order to determine the extent to which MN's spelling difficulties in the previous task were due to difficulties in written production per se, she was asked to spell a similar list of words using sets of letter cards, one set contained the letters of the alphabet printed in lower-case cursive letters and one in upper-case print.

For this task MN was orally presented with a list of 18 words (9 high frequency and 9 low frequency) and 18 non-words, balanced for length (from 4 to 6 letters). She was asked to spell each stimulus, using the letter card set provided. In the first session she had to use the set in upper-case print, in the second one she had to use the set in lower-case cursive.

MN's performance on this task was similar regardless of the case or font of letters (upper-case print: 63.9% (23/36); lower-case cursive: 66.7% (24/36); Pearson $X^2 = .25$, df = 1, p = n.s.). As in Task 1, no effect of frequency was observed in either set (high and low frequency words were both 12/18 correct). Likewise, no lexicality effect observed when considering performance on words (23/36) and non-words (25/36) in upper print and in lower cursive (Pearson $X^2 = .25$, df = 1, p = n.s.). A length effect emerged (error rates calculated as the number of incorrect letters/total number of letters) with 4-letter stimuli resulting in fewer errors (3.1%) than 5-letter (9.2%) and 6-letter (9%) stimuli (Pearson $X^2 = 3.9$, df = 1, $N = 216$, $p < .05$), although there was no difference between 5-and 6-letter stimuli. MN made 28 spelling errors, distributed quite similarly to those produced in lower-case cursive reported just above: 46.4% deletions involving a geminate cluster, 25% single letter omissions, 21.4% letter substitutions, and 7.2% letter additions.

3.1.3. *Task 3: oral spelling to dictation*

In order to assess the extent to which MN's spelling difficulties were confined to written production, she was presented with a set of 16 proper names (8 city names and 8 person names), controlled for length (4–7 letters long). She was instructed to orally spell the word before writing it down. MN could orally spell only 3/16 stimuli, although she correctly wrote 14/16. She used lower-case cursive for her written response, including the initial letter of proper names. Despite repeated instructions regarding oral spelling, she almost always attempted to report the syllables of the word instead of its letters (e.g., "Elena" → /e/ /le/ /na/). The few times she attempted letter naming, she made some letter omissions leading to implausible spellings. However, rather than concluding that MN suffered an additional deficit to oral spelling, these results should be judged given the cultural context in which they were acquired. Unlike for speakers of English, oral spelling is not a familiar task for speakers of Italian who are taught in school this form of "syllable spelling", which, indeed, was performed perfectly by MN.

3.1.4. *Task 4: direct copy of words and non-words*

In order to assess whether MN's problem in writing in upper-case involved the actual motor execution of letters (thus indicating a problem at the grapho-motor level or beyond), she was asked to perform direct copy of a set of 24 words (12 high frequency, 12 low frequency) and 24 non-words, matched for length. Half stimuli were presented in upper-case print and the other half in lower-case cursive (Fig. 1).

Direct copy of words and non-words was good in both cases (upper-case print 23/24, lower-case cursive 19/24; McNemar test, binomial distribution, 2-tailed, $N = 24$, p = n.s.). In lower-case cursive, errors were letter substitutions respecting the consonant/vowel status of the target; in upper-case print she made one omission in a geminate cluster. With upper-case print, although all letters were well-formed, MN's copy was slavish and was performed very slowly, segment by segment, as one would do with a complex, unfamiliar

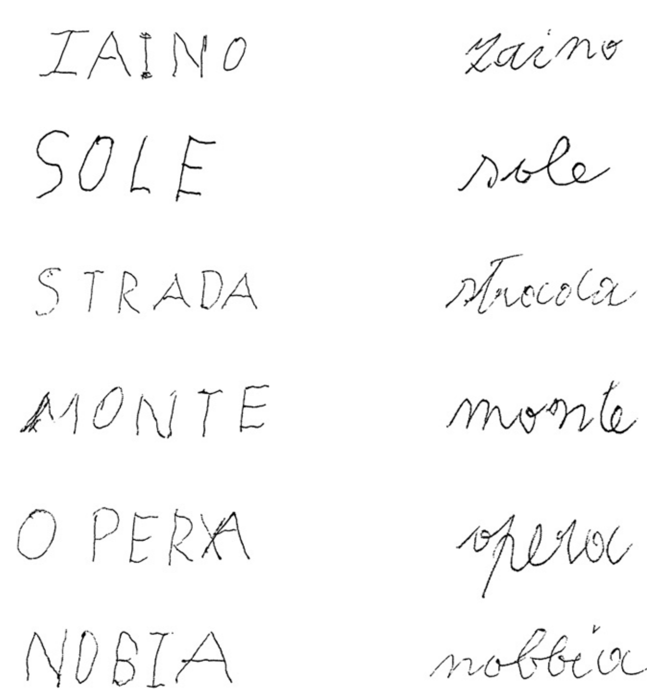

Fig. 1 – Direct copy of the words "zaino (rucksack), sole (sun), strada (road), monte (mountain), opera (opera)" and non-words " nobbia".

configuration. This behavior contrasted with the ability to read the target quickly and without problems.

3.2. Summary of analysis 1

The results of Tasks 1–4 reveal the following, with regard to the integrity of MN's spelling system: (1) MN's errors in lower-case cursive as well as in spelling with mobile letters indicate that she suffers from damage at levels prior to the stages involved in the written production of letter shapes. Possible loci of impairment include the lexical processes such as recognition of the auditorily presented stimuli or retrieval of the spellings of familiar words from long-term memory (typically referred to as the orthographic lexicon) or the buffering of the letters once they have been retrieved from long-term memory and while they await allographic selection. Evidence of a graphemic buffering deficit is the fact that performance in these spelling tasks was influenced by the length of the stimuli, that there was no difference in her accuracy for words and non-words and that she produced letter substitutions, additions, and deletions that resulted in phonologically implausible responses. Also generally consistent with this deficit locus is the fact that all the substitution errors showed preservation of CV status. In addition, to the buffering deficit there is a possibility that she suffered also from a lexical deficit. This is suggested by the fact that she produced a considerable number of phonologically plausible responses (30/57 errors, 52.6%). However, she did not exhibit a frequency effect which is the hallmark of a lexical deficit, and it is worth noting – as reported earlier – that phonological plausible responses were the predominant error type for control subjects of her age and education (although not tested on the same items). Therefore, it is difficult to be certain if MN suffered a lexical deficit in addition to a graphemic buffering deficit or if her phonologically plausible spellings resulted from lack of familiarity with certain items due to her relatively low educational level. (2) In addition to the buffering (and possibly lexical deficits) suffered by MN, the difference in MN's accuracy for lower-case cursive and mobile letters compared to upper-case print indicates a clear and specific difficulty with upper-case print. The fact the direct copy of upper-case print is intact further indicates that the difficulty with upper-case print is not a motoric one per se. These results localize her difficulties in upper-case letter production to the allographic stage. A more extensive examination of this difficulty in producing upper-case print will be carried out in the subsequent set of analyses.

3.3. Analysis 2: a selective deficit in producing upper print case

The results reported thus far indicate that MN had a very striking difficulty in producing letters in upper-case print; essentially, she was unable to produce any letters in upper-case print in the course of attempting to write 48 words and 30 non-words to dictation, while her accuracy in lower-case cursive for the same items was 68% (53/78). The following 2 tasks further document this dissociation, with the advantage these are tasks that do not require access to the lexical system and they are not necessarily taxing of the graphemic buffer.

3.3.1. *Task 5: writing single letters to dictation*

MN was asked to produce to dictation, in 2 separate occasions, the 21 letters of the Italian alphabet presented in random order, across 3 conditions: upper-case print, upper-case cursive and lower-case cursive. Since writing in lower-case print is not a familiar task in the patient's culture this was not tested. In neither administration was MN able to produce a single letter in upper-case print (0/42). However, her accuracy with lower-case cursive was 93% (39/42) and 71% correct (30/42) in upper-case cursive.

3.3.2. *Task 6: copy transcoding words and non-words*

MN was asked to transcribe 34 common words (half high frequency and half low frequency) and 12 non-words, balanced for length (4–6 letters), from upper-case print to lower-case cursive and vice versa.

She simply could not perform the task of converting lower-case cursive to upper-case print, despite several demonstrations by the examiner. In contrast, she had few difficulties with transcribing from upper-case print to lower-case cursive, performing with 83% accuracy (38/46) (28/34 words and 10/12 non-words; Pearson $X^2 = .006$, $df = 1$, $p = $ n.s.). Her errors consisted of letter substitutions, omissions and insertions. The fact that she made any errors at all on this task is, in all likelihood, a consequence of the fact that, rather than carefully attending to the stimuli, she seemed to perform the task by quickly reading the stimuli and then attempting to generate their spellings based on her available lexical and sublexical knowledge.

3.4. Summary of analysis 2

These tasks serve to clearly document the striking dissociation between MN's largely intact performance with lower-case cursive and extreme difficulty with upper-case print. The following tasks evaluate her ability to recognize visually presented letters ad words presented in different cases and fonts.

3.5. Analysis 3: letter form recognition

The fact that in direct copy and in copy transcoding MN seemed to easily identify the visual stimuli, regardless of case, suggested that she probably did not suffer from difficulties in visual letter recognition. In order to more carefully examine whether MN could recognize the upper-case print allographs that she could not write, she was administered the following sets of tasks.

3.5.1. *Task 7: categorization of letters*

Visual letter categorization was tested in 3 different ways: (1) MN was visually presented with a list of 80 pairs of letter: half of them were different allographs of the same letter (e.g., B and b, or B and b) and half were different letters (e.g., A and b). She was asked to judge whether or not the letters were the same. (2) She was asked to classify 160 letters into the 4 categories of upper- and lower-case print and upper- and lower-case cursive and (3) she was visually presented with a random sequence of 15 words and 15 non-words, written in upper- and lower-case print and in lower-case cursive, and asked to name which case and font they were written in.

MN's performance in these tasks was flawless.

3.5.2. *Task 8: single letter naming*

MN was asked to read 4 sets of 21 letters presented in upper- and lower-case print and cursive. Her overall single letter naming was relatively intact, and, most importantly, her performance was comparable across case and font (upper-case print 20/21, lower-case print 19/21, upper-case cursive 18/21, lower-case cursive 18/21; Cochran's test, $Q_{(3)} = 2.53$, $df = 3$, $p = $ n.s.).

3.5.3. *Task 9: word and non-word reading*

MN was presented with a list of 96 words (half high and half low frequency) and 30 pronounceable non-words, balanced for length (from 4 to 6 letters), presented once in upper-case print and once in lower-case cursive. The list of words contained 30 concrete and 30 abstract words, 12 function words, 12 adjectives and 12 verbs.

Neither the case nor the font of the stimuli affected performance (upper-case words and non-words 88/126, lower-case cursive words and non-words 85/126; McNemar test, $N = 126$, $p = $ n.s.).

In word reading, effects of frequency (high frequency words 79/96, low frequency words 61/96; Pearson $X^2 = 7.03$, $df = 1$, $p < .01$) and lexicality (words: 73% (140/192), non-words: 55% (33/60); Pearson $X^2 = 6.82$, $df = 1$, $p < .01$) were found. No effects of length (4-letter: 61/84, 5-letter: 53/84, 6-letter: 59/84; Cochran's test $Q_{(2)} = 1.93$, $df = 2$, $p = $ n.s.) or concreteness (concrete nouns 46/60, abstract nouns 46/60) were observed. Furthermore, her performance was not affected by the grammatical categories of the stimuli (nouns: 92/120, function words: 17/24, verbs: 17/24, adjectives: 14/24; Kruskal Wallis test: $X^2 = 3.53$, $df = 3$, $p = $ n.s.). Errors were omissions, substitutions and transpositions of single phonemes. The consonant/vowel status of the target was respected in substitutions.

MN's performance on this task (e.g., lexical and frequency effects) indicates that she probably had mild deficits affecting both lexical and phonological routes of reading. More importantly, however, her performance clearly indicates that the dissociation between upper-case print and lower-case cursive observed in written production was absent in her recognition and identification of written forms.

3.6. *Analysis 4: evaluating the accessibility of upper-case print representations*

In this section we report the results of a number of tasks directed at determining if information regarding the forms of upper-case print could be accessed under conditions that serve to facilitate access by priming or cueing that information.

3.6.1. *Task 10: delayed copy of letters and words: lower-case cursive versus upper-case print*

MN was asked to perform delayed copy of the same stimulus sets presented in lower-case cursive and upper-case print. Stimuli consisted of each of the 21 letters of the Italian alphabet as well as the same word and non-word stimuli presented for direct copy in Task 4. Each stimulus was presented for 5 sec and then removed from view and she was asked to reproduce it (Figs. 2 and 3).

3.6.1.1. Letters. MN correctly produced 21/21 stimuli in lower-case cursive and 10/21 stimuli in upper-case print (McNemar test, binomial distribution, 2-tailed, $N = 21$, $p < .01$). With upper-case print, she made 5 format errors (where she produced the target letters in upper-case cursive), 1 letter omission, 2 letter substitutions and 3 ill-formed letters.

3.6.1.2. Words and non-words. MN's accuracy with lower-case cursive stimuli was 11/24 correct and she made the same types of errors as in writing to dictation: letter omissions, substitutions, omissions in geminate clusters. These errors suggest that she was often attempting to generate the spellings based on her available lexical and sublexical knowledge. With upper-case print, MN was unable to produce any fully correct responses. However, out of the 120 letters attempted in the 24 word and non-word stimuli, she produced 10 upper-case print letters correctly (8%); 5 were in the first position of the target, 3 in the second and 2 in the third position.

3.6.2. *Task 11: form cueing in written word completion*

MN was visually presented with a list of 24 words (half high and half low frequency, balanced for length) in either upper-case print and in lower-case cursive (the same words were used for both formats) lacking a letter in final position; her task was to complete the word stimulus in the case in which it was presented (e.g., CAS_ → CAS**A** [home]) and she was not told what the target word was.

MN correctly completed most of the words in lower-case cursive (16/24 correct), and she was able to produce at least some upper-case forms (8/24 correct). It is worth noting, however, that 5/8 of these were letters which occurred elsewhere in the word (e.g., ACQU_ → ACQU**A**) and 3/8 were the letter O (similar in upper-case print and lower-case cursive). All other errors involved producing letters in lower- or upper-case cursive (Fig. 4).

3.6.3. *Task 12: form cueing-written letter completion*

MN was asked to complete a letter lacking one or more segments in upper-case print when the name of the target letter was presented orally. MN correctly completed 38% (10/26). In most cases the letters lacked only one stroke to be complete.

The fact that form cueing was modestly effective (38%) for upper-case print letters compared to uncued writing letters to dictation (Task 5: 0%) indicates that allographic information may be available but inaccessible under non-cueing conditions. In fact, MN's performance in the last 3 "priming/cueing"

Fig. 2 – Examples of delayed copy of upper print letters E, V, O, L, B, A, G, T, Z, S, P and R. E, O, L, B were correctly written in upper print; T, S, P were written in upper cursive; G was written as a C and R was written as a P; V, A, Z were ill-formed.

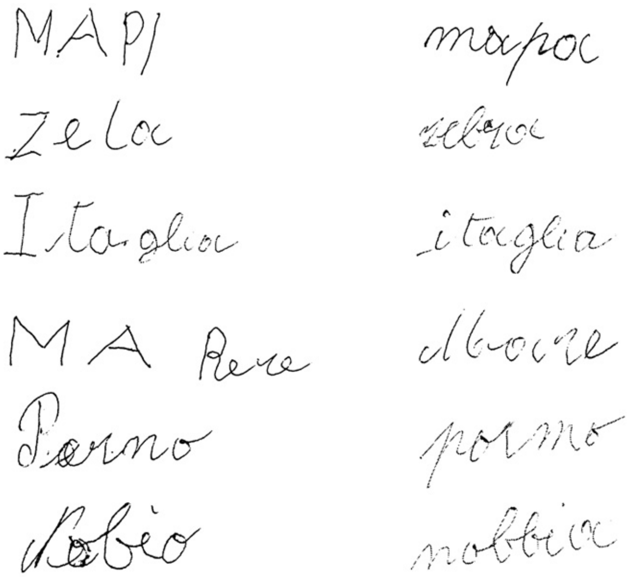

Fig. 3 – Delayed copy of words "mappa (map), zebra (zebra), Italia (Italy), mare (sea)" and non-words "permo, nobbia".

tasks shows that on some occasions she could produce the upper-case print letters that she was never able to produce in other tasks. This suggests that the allographic information specific for upper-case forms may be difficult to access, but not entirely absent (Fig. 5).

3.6.4. *Task 13: explicit access to letter form: form imagery judgment tasks*

The modest cueing and priming results suggest at least some preservation of implicit access to upper-case print letter forms. In the following tasks MN's ability to explicitly generate and inspect mental images of allographic forms was examined.

Fig. 4 – Written word completion.

Fig. 5 – Written letter completion of A, E, M, H, E, M, L and H.

MN was asked, as in Venneri et al. (2002), to judge which one of 3 letters, orally provided by the examiner (e.g., U,V,P or *n*,*m*,*f*) was visually dissimilar to the other two. She could not carry out this task *in any format*. She seemed to understand the task perfectly: indeed, when given the same task with visual presentation, as a demonstration, she was perfectly accurate in all formats. In order to check for the possibility that MN's difficulties in this task were due to a general impairment in visual imagery, she was asked to report whether or not 2 named objects were visually similar (10 pairs of objects, e.g., knife *vs* pen, or ball *vs* wheel). MN was unable to perform this task either, although she could draw the same objects fairly well. Eight subjects (mean age: 81.75) without a neurological history and with 5 years of formal education (comparable to MN) served as control group for the form judgment tasks with letters and objects. All subjects performed these tasks accurately.

MN was also requested to verbally describe upper-case print and lower-case cursive letter shapes (20 items). She was unable to perform this task. In order to make sure that the patient understood this task, she was explicitly and repeatedly demonstrated, in writing, what was meant for "vertical segment", "horizontal segment", "oblique segment" or "curve". MN was able to give these descriptions easily in presence of printed letters. But she remained unable to perform the task when required to describe an orally named letter without its visual model.

Although one cannot be certain, it seemed quite apparent that MN understood what was requested of her in this set of tasks. The results, therefore, suggest either a general impairment in generating visual imagery or in the ability to explicitly inspect it.

4. Discussion

In reporting the case of a woman suffering from frontotemporal dementia we have documented: (1) a virtually complete inability to produce upper-case printed letters in the face of intact production of lower-case cursive case letters and adequate production of upper-case cursive letters; (2) a dissociation between impaired production of upper-case print and intact recognition; (3) modest effects of cueing/priming in facilitating access to the affected letter forms; and (4) an inability to explicitly evaluate imagery regarding letters and objects.

4.1. *Implications for our understanding of letter-shape production*

The pattern of intact motor execution accompanied by a case and font-specific deficit in written letter production, places MN's primary deficit at the allographic level of letter-shape representation and processing. The findings, therefore, provide a window into some of the properties of this component of the system for written language production. Specifically, the results provide strong support for previous reports of the neural independence of different types of case and font-specific letter-shape information; they also provide evidence that letter-shape production does not require explicit access to information about the visual attributes of letter shapes and, additionally, MN's performance reveals interactions between processes involved in letter-shape production and perception. We discuss each of these conclusions briefly.

The selective difficulty in producing upper-case print letters replicates one of the patterns reported by Venneri et al (2002) and adds to the relatively small number of reports of selective impairments to the ability to produce written letters in a specific case and/or font. These cases indicate that either the information regarding the forms of letters in different fonts and cases or the procedures responsible for accessing them are represented with sufficient neural and/or functional independence that brain injury can selectively affect one case/font while leaving the others intact.

MN was unable to generate or report on imagery of letters (and objects) despite the fact that she appeared to understand the demands of the task. Interestingly, this difficulty extended to the letter types that she was able to produce easily – lower-case cursive. The generality of MN's imagery judgment difficulties contrasted with the performance of the cases reported by Venneri et al. (2002), whose difficulties were restricted to the font-case forms that they were unable to produce. Nonetheless, other cases have also been reported who, like MN, exhibited generalized imagery deficits affecting letter forms they were able to produce (e.g., Del Grosso Destreri et al., 2000; Shuren et al., 1996; see also Grossman et al., 2001). These results indicate that *explicit* access to visual images of letters is not necessary for accurate letter production. It is important to note, however, that the separate question of whether even *implicit* access to the visual attributes of letters is necessary for written letter production remains unanswered.

We have also shown that the severe impairment in producing upper-case print occurs in the face of apparently fully intact recognition and reading of letters and words in this format (see also Venneri et al., 2002). This dissociation between production and recognition cannot be unambiguously interpreted (for discussion, see Rapp and Caramazza, 1997). It may indicate that distinct representations are involved in written language comprehension and production and that the latter, but not the former, have been affected in this case. Alternatively, there may be shared representations with the deficit affecting only access to them in written production. Adjudicating between these possibilities is a challenge that has not yet been met. However, potentially relevant to this question is our finding that production of upper-case print letters could occasionally be achieved through visual priming of the letter forms. This was observed in the task of delayed copy and, perhaps more clearly, in a task in which a subset of the features of the letters were presented and MN had to complete the letter. These findings suggest that visual information could be used by the written production system and indicates some form of interaction between processes and/or representations involved letter-shape recognition and production. Certainly, additional work will be required to understand the mechanism that supports this interaction and to determine whether or not the facilitation occurs via the priming of a common representation or by some other means.

4.2. The role of ''switching'' mechanisms in written language

The most striking aspect of this case study is the marked dissociation between the virtual inability to produce upper-case print and the relatively intact and easy production of both lower- and upper-case cursive. MN's difficulties in upper-case print only rarely involved incorrect productions, rather she was typically unable to produce any form whatsoever. This pattern was also displayed by the cases reported in Venneri et al. (2002) and is different from the pattern displayed by some other individuals such as the case reported by Del Grosso Destreri et al. (2000) whose disproportionate difficulty in producing upper-case letters manifested itself largely in letter substitutions. The type of difficulty exhibited by MN suggests a difficulty in ''switching'' from one letter format to another. However, it is important to note that MN was not generally incapable of switching writing formats, as she was able to readily switch from lower-case cursive to the quite low frequency upper-case cursive format (see Task 5). The switching difficulty – if that is what it was – was specific to a particular case and font. Interestingly, switching deficits have also been invoked to account for certain patterns of bilingual aphasia, where the availability of a language fluctuates, or the individual cannot control the language he/she is speaking and there is uncontrolled switching between languages (e.g., Paradis, 1989; Fabbro et al., 2000). It is not clear whether these difficulties of this type are specific to the affected language systems or form a part of an executive control system.

In this context, one can also consider questions of neuroanatomical substrates (and etiology). Studies of bilingual aphasia as well as neuroimaging studies of language switching in neurologically intact bilinguals (Price et al., 1999; Crinion, et al., 2006) have strongly implicated left Broca's areas, the left supramarginal gyrus and/or the left caudate. Interestingly, in MN's case, as well as in a number of the other similar cases, left frontal areas have also been implicated. It is, of course, not at all clear whether MN's difficulties are ''switching'' difficulties, nor if difficulties in switching between multiple written fonts and switching between multiple languages have any neural or functional relationship. This is yet another issue regarding the relationship between written and spoken language, and the relationship between language and executive functions that will be important to clarify in the future.

5. Conclusions

This case study adds to our understanding of the cognitive mechanisms of written letter production. It reveals a system in which there is considerable cognitive and neural independence in the representation of letter shape information for different cases and fonts, a system in which letter-shape information does not need to be explicitly accessed for accurate production, and a system which supports some form of interaction with processes involved in the visual letter recognition.

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Appendix

Table 1. Summary of performance (% correct) with upper-case print versus lower-case cursive

Tasks	Print (%)	Cursive (%)
Writing single letters to dictation	0	93
Writing words and non-words to dictation	0	67.9
Copy transcoding words and non-words (*a* → A; A → *a*)	0	82.6
Delayed copy of letters	47.6	100
Direct copy of words and non-words	95.8	79.2
Delayed copy of words and non-words	0	45.8
Single letter naming	95.2	85.7
Word and non-word reading	69.8	67.5
Spelling with mobile letters	63.9	66.7

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