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Pattern of letter substitutions in a case of acquired dysgraphia: The influence of visuospatial and stroke-feature similarity

Marie-Pierre de Partz,[a,b,*] Aliette Lochy,[a,c] and Agnesa Pillon[a,c]

[a] *Université catholique de Louvain, France*
[b] *Centre de revalidation neuropsychologique des cliniques universitaires Saint-Luc, France*
[c] *Fonds National de la Recherche Scientifique, France*

Letter substitution errors have commonly been reported in various peripheral writing disorders (Margolin & Goodman-Schulman, 1992). In particular, such errors were reported in cases of a deficit ascribed to the graphemic buffer component, a temporary memory store holding abstract grapheme representations, or to postbuffer components involved in assigning a specific letter form to grapheme representations.

Rapp and Caramazza (1997) showed that the letter substitution errors produced by two patients with a graphemic buffer deficit were not explicable in terms of stroke-feature similarity between the target letter and the error. In contrast, the letter substitution errors produced by two other dysgraphic patients whose damage was at postbuffer loci, bore a physical similarity to the intended target. Physical similarity was based on the features of the letters' component strokes rather than on the visuospatial characteristics of the letters.

We report on an additional case of a patient presenting with peripheral writing disorders, whose letter substitution errors presented a distinct pattern of target/error similarity, according to the contextual vs. noncontextual source of the error.

Case study

AD, a 67-year-old right-handed male with an University Degree in literature, suffered a left posterior parietal infarct in July 1999. He first presented with the Gerstmann syndrome, complicated by signs of apraxia and phonological dyslexia. At the time of this study, the patient presented mild difficulties in reading and writing. In contrast, there was no more evidence of spatial neglect, working memory, verbal, or visuo-spatial long-term memory deficits.

General pattern of AD's performance in writing

AD performance was midly impaired in written spelling (11% errors ; 124/1119), oral spelling (11% errors ; 124/1.119), and typing (15% errors ; 94/617). No effect of lexicality, word frequency, or imageability was noted in these tasks, but a length effect was observed in oral spelling. AD's errors were mostly single letter substitutions, deletions, additions, and transpositions. From this general pattern of performance, it was first hypothesized that the patient's writing deficit was probably located at the graphemic buffer level. However, we noted qualitative differences between the errors'distribution in written and oral spelling. In written spelling, letter substitutions were the most frequent type of errors (65.19%, among which contextual substitutions: 36.71% ; noncontextual substitutions: 28.48%) and letter deletions were only occasional (6.33%). In contrast, in oral spelling, deletions (34.09%) and contextual substitutions (26.51%) were the most frequent type of errors while noncontextual substitutions were rare (1.51%).

The differences between the errors' distribution observed in written and oral spelling suggest AD might have an additional deficit localized to a component of the spelling system specific to writing. We hypothesized that this component could be a postbuffer level component involved in computing letter forms in terms of the strokes required to produce them. On the basis of this hypothesis, we expected that stroke-feature similarity between target and error should be higher in noncontextual letter substitutions observed in written spelling than in contextual letter substitutions recorded both in written and oral spelling. This prediction was evaluated by means of an analysis of the similarity between targets and errors produced by the patient, which was based on both a stroke-feature and a visuospatial similarity metric we computed on the basis of the patient's own writing.

Stroke-feature metric

The patient was asked to write successively and in isolation the 26 letters in lowercase and script on a digitizing tablet. Then, each letter was segmented in strokes according to de Meulenbroeck and Van Galen (1990) criteria (a stroke corresponded to a written production between two direction changes). Each stroke was then classified according to five criteria (direction of lines, localization, size, starting point, curvature) adapted from Rapp and Caramazza (1997). On this basis, a stroke-feature similarity matrix was prepared for all possible letter pairs (325). The matrix displayed the number of strokes (from 0 to 4) shared by each letter pair.

Visuospatial similarity metric

The 26 lowercase script letters produced by AD were arranged by pairs (325 letter pairs) and subdivided into two sublists. The letter pairs were presented horizontally, one pair at a time, on a cardboard, to two groups of 30 subjects (one group for one sublist), who were asked to rate each pair on overall visual similarity, with '1' representing low similarity and '5' high similarity. A visuospatial similarity matrix was

* Corresponding author.
E-mail address: departz@orlo.ucl.ac.be (M.-P.de Partz).

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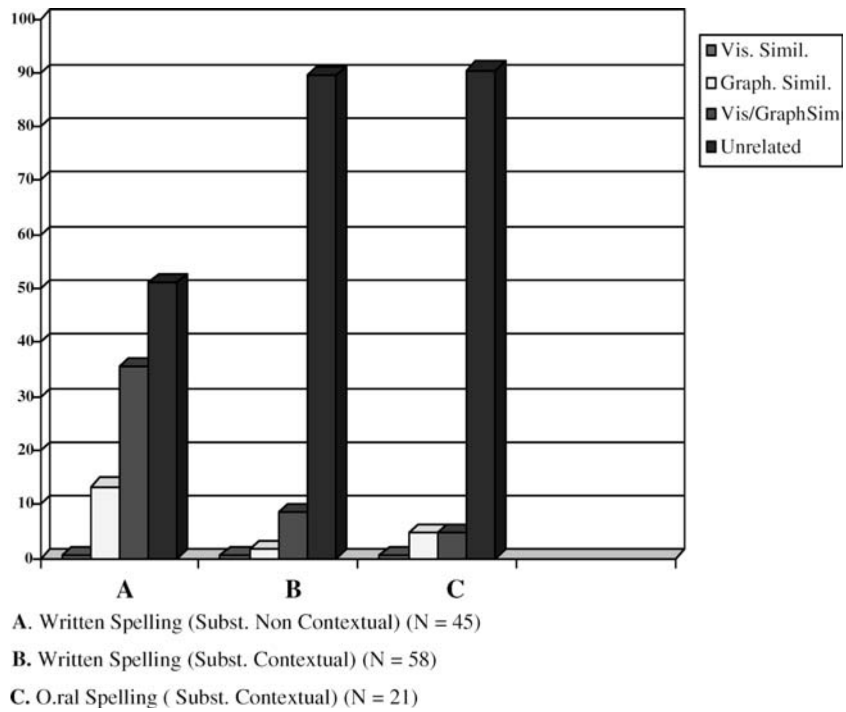

Fig. 1. Percentage of target-error type according to the criteria of visuospatial and stroke feature similarity. (A) Written spelling (subst. Non-contextual) (N = 45). (B) Written spelling (subst. contextual) (N = 58). (C) O.ral spelling (subst. contextual) (N = 21).

then prepared, which gives the mean similarity values for each letter pair.

Analysis of target/error similarity

On the basis of the above metrics, AD's noncontextual (N = 45) and contextual (N = 58) substitution errors in written spelling, and contextual substitution errors in oral spelling (N = 21) were examined in term of the target/error relation and classified into the four following categories: (a) Unrelated by either visuospatial or stroke-feature metrics; (b) Visuospatially similar only; (c) Similar in terms of stroke features only ; (d) Similar according to both visual and stroke-feature metrics. The results are displayed in Fig. 1. The errors' distribution across the categories significantly differed between the noncontextual and contextual errors produced in written spelling ($\chi^2_{(3)}$ = 19.22, p .0001), but did not significantly differ between the contextual errors observed in written spelling and the contextual errors observed in oral spelling ($\chi^2_{(3)}$ = 0.864, n.s.). In fact, only noncontextual substitution errors appeared to be physically similar to their target letters, and similarity was in term of both stroke features and visuospatial characteristics.

Conclusion

We found evidence that the noncontextual and contextual letter substitution errors produced by the patient in written spelling could be attributed to an impairment of representationally distinct cognitive components that, in spite of being superficially of the same kind. Contextual letter substitution errors did not bear any physical similarity to the intended targets, a pattern that was found in other case studies of patients presenting with a graphemic buffer deficit (Rapp & Caramazza, 1997). In contrast, noncontextual letter substitution errors had a physical similarity with the intended targets, sharing both the component strokes and their visual characteristics. We propose that these noncontextual errors were caused by an impairment of the mechanisms assigning letter form to abstract grapheme representations. AD's pattern of performance suggests that both visually and graphically based representations might be handled at that peripheral processing level of the writing system.

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