

PAPER

QUESTIONED DOCUMENTS

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Altered Handwriting Suggests Cognitive Impairment and May Be Relevant to Posthumous Evaluation

ABSTRACT: Judging the validity of a disputed will is complex; however, one of the main issues is what the mental status of the testator was at the time of the will. If the will is handwritten, a handwriting analysis can provide information on the mental status of the testator. We tested how two writing parameters (the “writing score,” a novel evaluation scale that we previously described, and the percentage of spelling mistakes) are capable to identify cognitively impaired persons. These parameters are especially helpful because they can be used to evaluate the mental status of a deceased person. We found a significant correlation between either parameter and established scales of neuropsychological evaluation (Mini Mental State Examination and Milan Overall Dementia Assessment scale). Specifically, a poor score on either parameter reliably identified a compromised cognitive status. These may represent helpful additions to existing techniques in posthumously identifying persons with severe cognitive impairment.

KEYWORDS: forensic science, will challenge, handwriting analysis, cognitive impairment, dementia, posthumous

The posthumous challenge of a last will based on a claim of mental incapacity of the testator (1) is a growing problem, which is becoming increasingly painful from the social point of view. It is often claimed that somebody took advantage of the declining cognitive status of an elderly person to have the elderly person write a will in his/her favor (2,3). Judiciary trials on this matter are considerably difficult because they must rely solely on the retrospective evaluation of medical records and of witnesses' statements, which are often incomplete or even discordant. Some of us have previously suggested that if the last will was handwritten, its analysis may help understand the mental status of the testator at the time of writing and suggested a method to carry out such analysis in a quantitative way (4). Upon analyzing the verbal and lexical skills exhibited in the handwritten text, as well as the spatial orientation and disposition of the rows, a numerical value (called “writing score”) was obtained that was found to correlate in a statistically significant way with the mental status of the writer as gauged by formal neuropsychological tests. Specifically, a writing score of 5 or less was found to be attended by a severely compromised mental status (4). In the present paper, we tried not only to further confirm those findings but also to investigate the usefulness of another possible index of mental deterioration, namely the percentage of text words that have spelling mistakes. The rationale for the latter index is previously published research (5) showing that normal subjects made a mistake in writing 42 out of 1380 words (3%), patients with mild Alzheimer's disease made a mistake in 250 out of 1012 words (25%), and patients with severe Alzheimer's disease made a mistake in 267 out of 322 words (83%). This clear

asymmetry in distribution is statistically highly significant ($p < 0.0001$, chi-square), and in that series comparing mild (25%) versus severe (83%) Alzheimer's disease patients also yields a very significant difference ($p < 0.0001$, Fisher's exact test). Thus, we sought to see whether the percentage of writing errors in the text could be another indicator of mental status.

Methods

We studied a total of 30 patients, including 22 consecutive patients who had been referred to our Neuropsychology Service for the clinical suspicion of mental deterioration and six patients who had been referred to the general outpatient service of our department for conditions other than suspected dementia and who did not have lesions of the central nervous system.

Informed consent was obtained from all patients or from their legal guardians. The procedures followed were in accordance with the ethical standards of the responsible institutional committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 1983.

The Milan Overall Dementia Assessment scale (MODA) (6) and the Mini Mental State Examination (MMSE) (7) were administered to all patients. For both tests, a correction for age and education was applied according to published correction values for the Italian population (6,8). Each test provides a numerical score that, when it is lower than a cut-off value (24 for the MMSE, 85.5 for the MODA), indicates an impaired cognitive status.

In addition, we asked these patients to write:

- A spontaneous text of their choice, about six to seven lines' length, written on a blank sheet.
- A text dictated by the examiner, which the patient was requested to write on a blank sheet. The text to be dictated

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TABLE 1—The writing score.*

Examiner's evaluation	Score
Verbal and lexical skills	
No mistakes	5
Some mistakes (for example, missing or wrong letters, words written in a wrong way), however the text can be easily understood.	4
Some mistakes (as above), however the text can be understood with some effort.	3
Some mistakes (as above), the text can be understood only with considerable effort.	2
Text not understandable	1
Spatial orientation	
Normally oriented rows. In each row, beginning and end correspond to the page margins.	5
Rows slightly distorted or with beginning and end bearing little correspondence to the page margins.	4
Rows clearly distorted or with beginning and end not corresponding to the page margins.	3
Words or letters inserted where they do not belong in the text.	2
Chaotic orientation of the rows.	1

As described in our laboratory (4).

was selected from the Italian version of the Rivermead's test of behavioral memory (9).

- The same text, dictated by the examiner, that the patient was requested to write on a boxed sheet.

We excluded patients who had a severe motor deficit in the dominant hand or aphasia so severe as to make conversation difficult.

Each writing was evaluated in two ways, as follows:

- It was independently scored by three of us (PF, MI, and SV) using the semi-quantitative grading system that our laboratory has previously published (4). Detailed scoring criteria are reported in Table 1. As this table shows, a score was assigned to verbal and lexical skills, and a separate one to spatial orientation. For each mode of writing, summing these two scores yielded what was called "writing score." This score was subjected to the following statistical analysis. First, inter-rater agreement of this writing score was evaluated using Kendall's coefficient of concordance. Subsequently, the median score of the three separate evaluations was computed for each patient. Figures 1, 2, and 3 provide examples of handwriting that were assigned a writing score of, respectively, very low (Fig. 1), medium (Fig. 2), and normal (Fig. 3).
- For each text, the percentage of words containing spelling mistakes was computed.

Each of the two previously described variables (writing score and percentage of spelling mistakes) was then correlated with age, education (total years of school attendance), MMSE score, and MODA score using the statistical program GRAPHPAD PRISM version 4.03 for Windows (GraphPad Software, San Diego, CA, <http://www.graphpad.com>). Scores of 24 and 85 were used as cut-off between normal and abnormal results for MMSE and MODA, respectively.

Results

General Results

Thirty patients were included. The final diagnosis of the 22 consecutive patients sent to our Neuropsychology Service for a suspicion of cognitive decline was Alzheimer's disease (N = 15), mild cognitive impairment (N = 3), vascular dementia (N = 1), normotensive hydrocephalus (N = 1), frontotemporal dementia (N = 1),

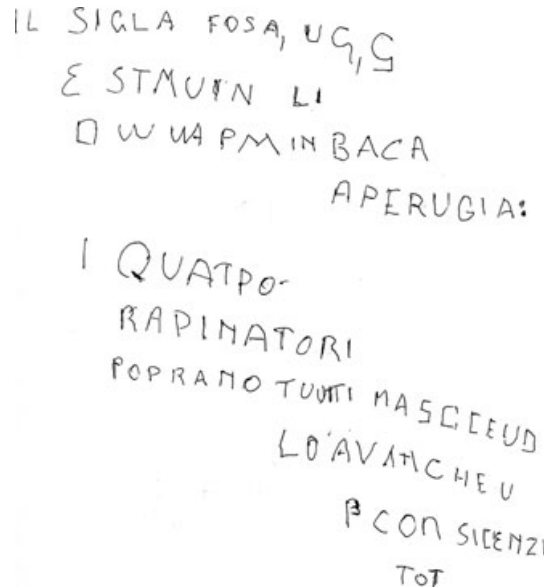


FIG. 1—An example of handwriting with a very low writing score. Dictated text, blank sheet. This text is totally unintelligible and spatially chaotic, and was given a writing score of 2 (1 for verbal and lexical skills + 1 for spatial orientation), as explained in Table 1. In this and all other cases, the text to be dictated was selected from the Italian version of the Rivermead's test of behavioral memory (see, e.g., [9]). The text reads, in Italian: "Il Signor Alberto Fossati, una guardia giurata, è stato ucciso lunedì durante una rapina in banca a Perugia. I quattro rapinatori portavano tutti una maschera e uno di loro aveva anche una pistola con silenziatore. Ieri notte la polizia ha raccolto le testimonianze oculari. Un signore presente ha detto: "E' stato davvero molto coraggioso. Ha rincorso i rapinatori armati e ha iniziato una furibonda sparatoria" ("Mr. Alberto Fossati, a security guard, was killed on Monday during a bank robbery in Perugia. The four robbers were all wearing masks and one also had a hand-gun with a silencer. Last night the police obtained the eyewitnesses' accounts. One man who was there said: "He was really very brave. He chased the armed robbers and sparked a fierce gun battle")."

and depressive episode (N = 1). The eight patients, matched for age and sex to the former ones, who were sent to our clinic for reasons other than suspected cognitive decline, had polyneuropathy (N = 4), muscular dystrophy (N = 1), ataxia (N = 1), transient ischemic attack (N = 1), and depressive episode (N = 1).

Table 2 summarizes the main demographic data of our patients, as well as mean and standard deviation of writing score and of percentage of spelling mistakes in all three writing modes (spontaneous; dictated, blank sheet; dictated, boxed sheet). As it can be seen, no differences were found between the three writing modes (spontaneous; dictated, blank sheet; dictated, boxed sheet) that we examined. In 23 cases (77%) writing scores were identical in all three writing modes. In six cases (20%) the writing scores in two modes were identical and that of the third mode differed by one measurement unit. In only one case (3%) all three writing scores were different from each other (scores 7, 8, and 6, respectively). As expected, we found a very good correlation between the MMSE and the MODA scores (6) ($r^2 = 0.76$, $df = 28$, $p < 0.0001$).

Writing Score

Results for writing score confirmed previous research from our laboratory (4). Table 3 reports the results of Kendall's coefficient of concordance, showing good interrater agreement in all cases. Figure 4 illustrates that in each writing mode, the writing score correlated positively and significantly with both MMSE and MODA.

Il signor Alberto Fossati, guardie,
 e sta ucciso lunedì durante una
 rapina in banca a Perugia.
 I quattro rapinatori portavano
 tutti una maschera e uno
 di loro aveva anche una pistola
 con silenziatore. Ieri notte la
 polizia ha raccolto le testimonianze
 oculari. Un signore presente ha
 detto: "E' stato davvero molto
 coraggioso. Ha rincorso i rapinatori
 armati e ha iniziato una furibonda
 sparatoria".

FIG. 2—An example of handwriting with a medium writing score. Dictated text, blank sheet. This text can be understood only with considerable effort and its spatial arrangement is slightly distorted, so it was given a writing score of 6 (2 for verbal and lexical skills + 4 for spatial orientation), as explained in Table 1. In this and all other cases, the text to be dictated was selected from the Italian version of the Rivermead's test of behavioral memory (see, e.g., [9]). The text reads, in Italian: "Il Signor Alberto Fossati, una guardia giurata, è stato ucciso lunedì durante una rapina in banca a Perugia. I quattro rapinatori portavano tutti una maschera e uno di loro aveva anche una pistola con silenziatore. Ieri notte la polizia ha raccolto le testimonianze oculari. Un signore presente ha detto: 'E' stato davvero molto coraggioso. Ha rincorso i rapinatori armati e ha iniziato una furibonda sparatoria'" ("Mr. Alberto Fossati, a security guard, was killed on Monday during a bank robbery in Perugia. The four robbers were all wearing masks and one also had a hand-gun with a silencer. Last night the police obtained the eye-witnesses' accounts. One man who was there said: 'He was really very brave. He chased the armed robbers and sparked a fierce gun battle'").

By contrast, in no case a statistically significant correlation was found with either age or education (Fig. 5). All patients who had a writing score of 6 or less had both an MMSE score and a MODA score below normal range (<24 and <85, respectively), and this was true no matter what writing mode was considered. On the other end of the range, in all modes several patients having the highest writing scores did have MMSE or MODA below normal levels (<24 or <85, respectively). Fifty percent of the patients with a writing score of 9 had an MMSE <24 in spontaneous and dictated (boxed sheet) mode, and the same was true for 77% of patients with a writing score of 9 in the dictated (blank sheet) mode. Considering MODA, in each of the three writing modes 50% of the patients with a writing score of 9 had a MODA below normal level (<85). In each writing mode, one of the two patients (50%) with a writing score of 10 (the highest possible) had an MMSE below normal limits (<24), while neither (0%) had a MODA level below normality (<85).

Percentage of Spelling Mistakes

Results for spelling mistakes, too, correlated positively and significantly with both MMSE and MODA (Fig. 6). As it had happened for writing score, no correlation was found with age (Fig. 7, upper row). However, at variance with the writing score, a statistically significant inverse correlation with years of education was found (Fig. 7, bottom row). A significant linear correlation was found between percentage of spelling mistakes and writing score (Fig. 8). All patients who had 60% or more of spelling mistakes had both an MMSE score and a MODA score below normal range

Il signor Alberto Fossati,
 una guardia giurata, è stato
 ucciso lunedì durante una
 rapina in banca a Perugia.
 I quattro rapinatori portavano
 tutti una maschera e uno
 di loro aveva anche una pistola
 con silenziatore.
 Ieri notte la polizia ha raccolto
 le testimonianze oculari.
 Un signore presente ha detto:
 "E' stato davvero molto coraggioso.
 Ha rincorso i rapinatori armati
 e ha iniziato una furibonda
 sparatoria".

FIG. 3—An example of handwriting with a maximal writing score. Dictated text, blank sheet. This text can be understood easily and it is normally arranged from the spatial point of view, so it was given a writing score of 10 (5 for verbal and lexical skills + 5 for spatial orientation), as explained in Table 1. In this and all other cases, the text to be dictated was selected from the Italian version of the Rivermead's test of behavioral memory (see, e.g., [9]). The text reads, in Italian: "Il Signor Alberto Fossati, una guardia giurata, è stato ucciso lunedì durante una rapina in banca a Perugia. I quattro rapinatori portavano tutti una maschera e uno di loro aveva anche una pistola con silenziatore. Ieri notte la polizia ha raccolto le testimonianze oculari. Un signore presente ha detto: 'E' stato davvero molto coraggioso. Ha rincorso i rapinatori armati e ha iniziato una furibonda sparatoria'" ("Mr. Alberto Fossati, a security guard, was killed on Monday during a bank robbery in Perugia. The four robbers were all wearing masks and one also had a hand-gun with a silencer. Last night the police obtained the eye-witnesses' accounts. One man who was there said: 'He was really very brave. He chased the armed robbers and sparked a fierce gun battle'").

(<24 and <85, respectively), and this was true no matter what writing mode was considered. On the other end of the range, in all modes several patients having the lowest percentages of spelling mistakes had MMSE and/or MODA below normal levels (<24 or <85, respectively). Fifty-seven percent of the patients with 0–20% spelling mistakes had an MMSE <24 in spontaneous mode, and the same was true for 53% such patients in both dictated modes. Considering MODA, in each of the three writing modes 62% of the patients with 0–20% spelling mistakes in the spontaneous mode had a MODA below normal level (<85), and the same was true for 58% of similar patients in both dictated modes. In all modes, even some patients having no wrongly written word had MMSE and/or MODA below normal level.

Discussion

Effects of Compromised Cognitive Status on Handwriting

Our findings confirm previous literature reports showing that handwriting is compromised in cognitive impairment and that the degree of writing impairment is related to the severity of cognitive impairment. Silveri et al. (5) found a correlation between the degree of cognitive impairment and spelling mistakes (see Table 3 of their paper). Luzzatti et al. (10) were mainly concerned with the type of dysgraphia ("surface" vs. "phonological") rather than with its degree; nevertheless, it is clear from their Table 7 that an overall worsening in dysgraphia (any type) was found in the nine patients

TABLE 2—The main demographic data and neuropsychological results of our patients. Results are mean ± standard deviation.*

Sex (M/F)	Age	Years of Education	MMSE	MODA	Spontaneous Text		Dictated Text, Blank Sheet		Dictated Text, Boxed Sheet	
					Writing index	Wrong words (%)	Writing index	Wrong words (%)	Writing index	Wrong words (%)
12/18	79 ± 6	9 ± 5	23 ± 4	76 ± 14	8 ± 2	19 ± 24	8 ± 2	19 ± 22	8 ± 2	19 ± 23

*MMSE, Mini Mental State Examination (7); MODA, Milan Overall Dementia Assessment (6).

TABLE 3—Kendall's coefficients of concordance between the three examiners.

Writing Mode	Parameter Examined	Kendall's			
		W	χ^2	df	p
Spontaneous text, blank sheet	Verbal and lexical skills	0.842	76.27	29	0.000004
	Spatial orientation	0.640	55.67	29	0.002068
Dictated text, blank sheet	Verbal and lexical skills	0.820	71.31	29	0.000020
	Spatial orientation	0.736	63.99	29	0.000192
Dictated text, boxed sheet	Verbal and lexical skills	0.834	72.53	29	0.000014
	Spatial orientation	0.738	64.19	29	0.000181

that they followed up 6–12 months after the first tests (total score, mean ± SD: first assessment 82.6 ± 11.4, second assessment 70.2 ± 24.8, N = 9, p = 0.037, t-test). Despite being unable to identify specific variables useful for evaluation, Shenkin et al. (11) were able to successfully estimate the mental status of patients upon

reading a transcript of the sentence they wrote during an MMSE administration. Furthermore, they briefly discussed previous literature reports underlining both the association of dementia with altered handwriting and the worsening of handwriting with the progression of dementia.

Besides confirming previous reports of a compromised handwriting in cognitive impairment, our findings clearly show a correlation between the degree of cognitive impairment and the worsening of handwriting (Fig 1 and 3).

It should be stressed that our research does not mainly concern the movement of writing, as other studies do (see, e.g., [12]), it rather concerns the cognitive aspects of handwriting, namely the intelligent use of verbal symbols and their spatial orientation.

Neither of the two scoring criteria we used was affected by age (Figs 2 and 4). The writing score was not affected in a statistically significant way by education either (Fig. 5), while the percentage of spelling mistakes showed a significant inverse correlation with the degree of education (Fig. 7, bottom row). We believe that this discrepancy implies that the writing score evaluates some

WRITING SCORE: CORRELATION WITH MMSE AND MODA

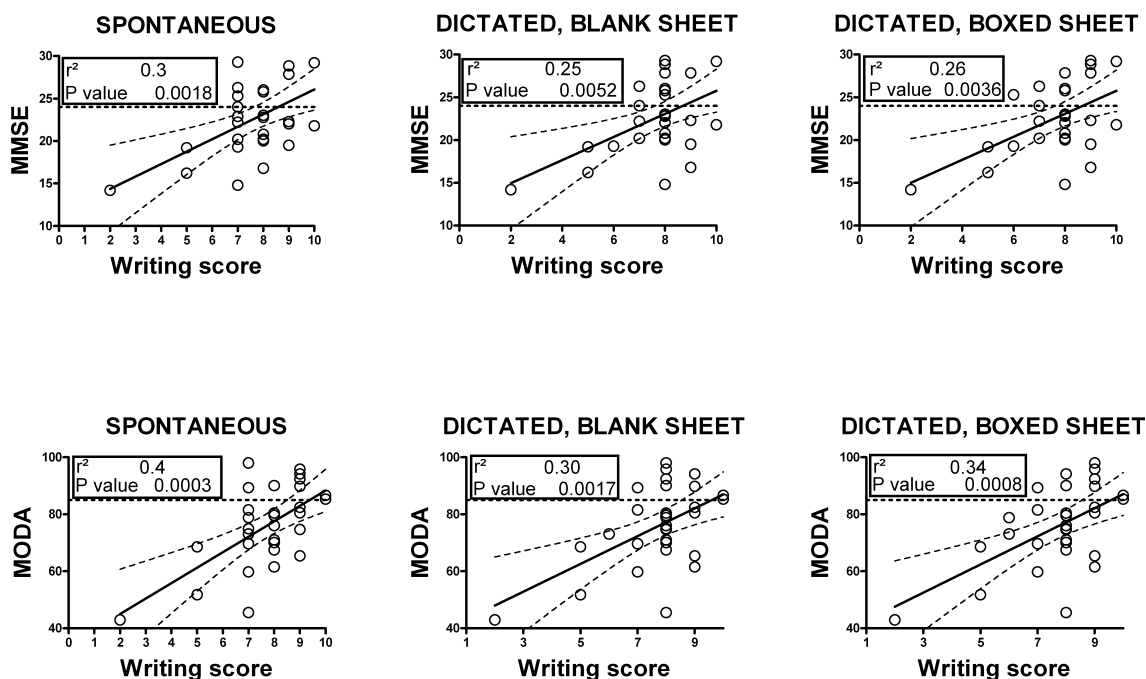


FIG. 4—This figure shows that the writing score correlates significantly with the score that the patient obtained at Mini Mental State Examination (MMSE) or Milan Overall Dementia Assessment (MODA) scales. Each graph shows the correlation between the writing score and either the MMSE or the MODA score, as indicated. On top of each graph the writing mode is specified. Inset, in each graph, the correlation coefficient and the probability value of linear regression analysis are shown.

WRITING SCORE: NO CORRELATION WITH AGE AND EDUCATION

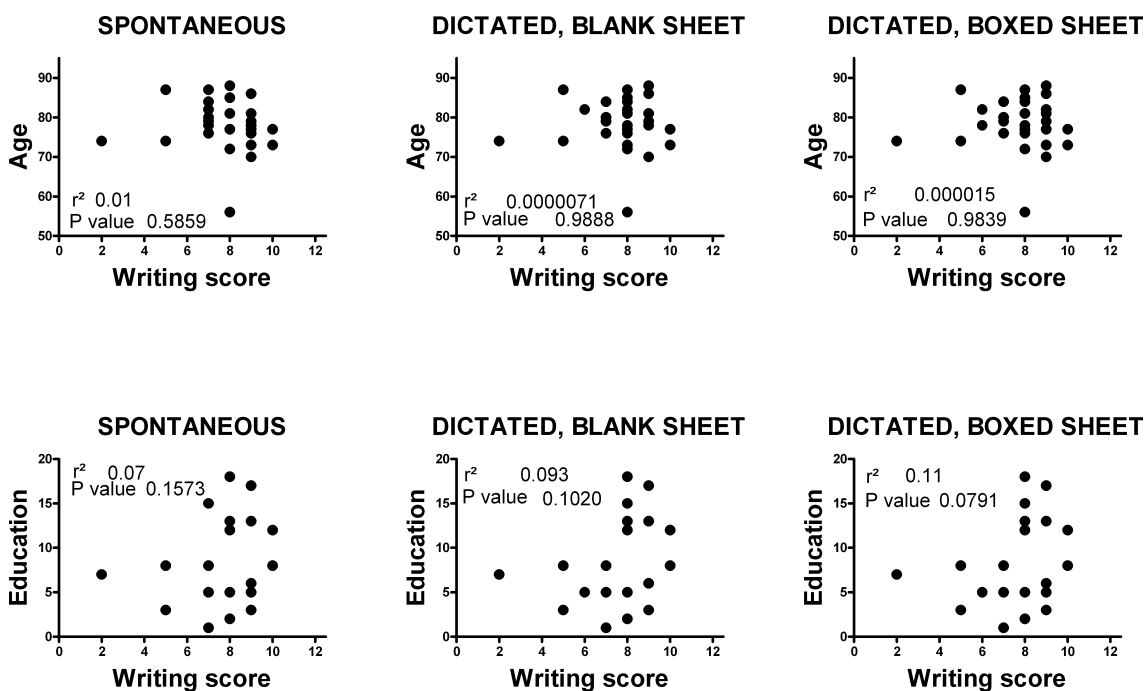


FIG. 5—This figure shows that the writing score does not correlate with neither age nor school education of the subject. Each graph shows the correlation between the writing score and either age or school education, as indicated. On top of each graph the writing mode is specified. Inset, in each graph, the correlation coefficient and the probability value of linear regression analysis are shown.

characteristics of handwriting that are more concerned with basic cognitive processes (ability to use graphic symbols, visuospatial ability); thus it is more sensitive to changes in cognitive status than to degree of literacy. By contrast, the percentage of spelling mistakes more heavily reflects to what degree the writer has learnt writing rules; thus this parameter is protected in a more robust way by a high degree of instruction.

Relevance for Forensic Psychiatry

Our ultimate goal is to craft an instrument that may be used to evaluate the mental status of a testator at the time of writing his/her will. So far, our data allow some inference about the cognitive status of the testator only when the text is severely compromised. In fact, both the writing score and the percentage of spelling mistakes were never associated with normal MMSE and MODA when they were severely compromised. As we reported in the Results section, a writing score of 6 or less was always associated with abnormal MMSE and MODA, a finding that confirms our previous results (4). In a similar way, a percentage of spelling mistakes $> 60\%$ was always attended by abnormal MMSE and MODA. As it could have been expected, there was a strong correlation between writing score and the percentage of spelling mistakes (Fig. 8); nevertheless, it should be noted that all patients with spelling mistakes $\geq 60\%$ also had a writing score ≤ 6 , while the opposite was not always true. This suggests that the writing score may have a better predictive value than the percentage of spelling mistakes.

While it seems from our data that a poor performance on either of the two analysis paradigms is a useful indicator of a compromised

cognitive status, at the other end of the range and very good performance at handwriting does not always indicate a preserved cognitive status. In fact, as we reported in the Results section, even some subjects with a very high performance at one or both handwriting analysis turned out to have an abnormal MMSE and/or MODA.

We used three different writing modes because we initially considered that the perpetrator of an abuse could either dictate the will or incite the testator to write the will in his/her own words, and believed that there could be a difference in these two situations. Moreover, we thought that handwriting could be easier or more difficult according to the type of sheet (blank or boxed) it is written on. However, it was clearly apparent that no difference exists between the three writing modes we used, so these differences should not be a concern either in analyzing a text or in future research on this subject.

Summing up, from our data so far it seems that handwriting analysis may be very useful in detecting poor cognitive status, a bit less in detecting cognitive normality. Although a high percentage ($\geq 60\%$) of spelling mistakes is a robust indicator of mental deterioration, the writing score seems to be a more sensitive indicator of cognitive impairment. As far as their practical use goes, these findings should be regarded as preliminary, needing confirmation in a larger sample. In any case and especially at this early stage of its development, handwriting analysis in a single case should be used judiciously, using it within the frame of all available evidence.

Future Developments

These data confirm previous results from our laboratory (4) and further suggest that handwriting analysis may be useful in the

SPELLING MISTAKES: CORRELATION WITH MMSE AND MODA

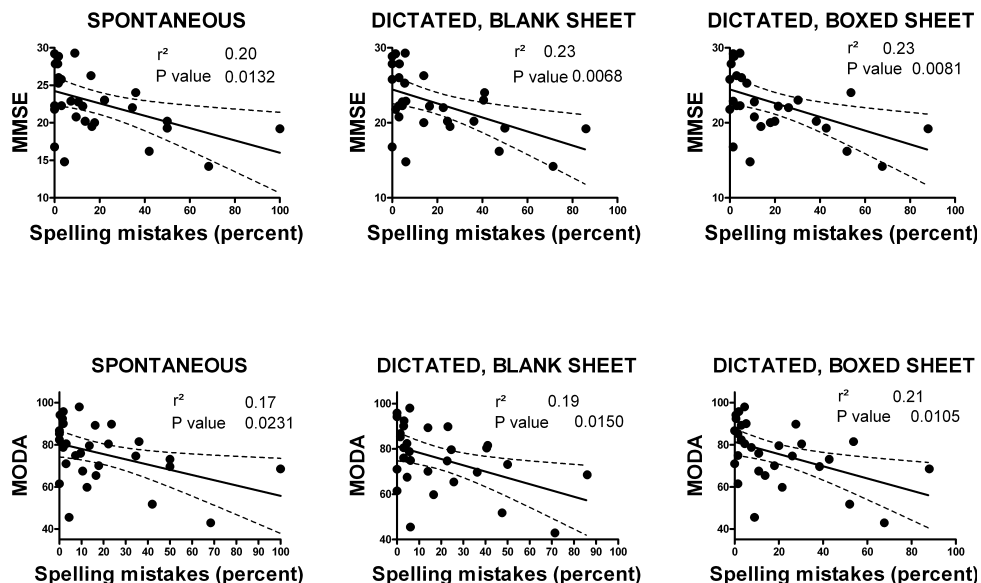


FIG. 6—This figure shows that the percentage of spelling mistakes in the text correlates significantly with the score that the patient obtained at Mini Mental State Examination (MMSE) or Milan Overall Dementia Assessment (MODA) scales. Each graph shows the correlation between the writing score and either the MMSE or the MODA score, as indicated. On top of each graph the writing mode is specified. Inset, in each graph, the correlation coefficient and the probability value of linear regression analysis are shown.

SPELLING MISTAKES: CORRELATION WITH AGE AND EDUCATION

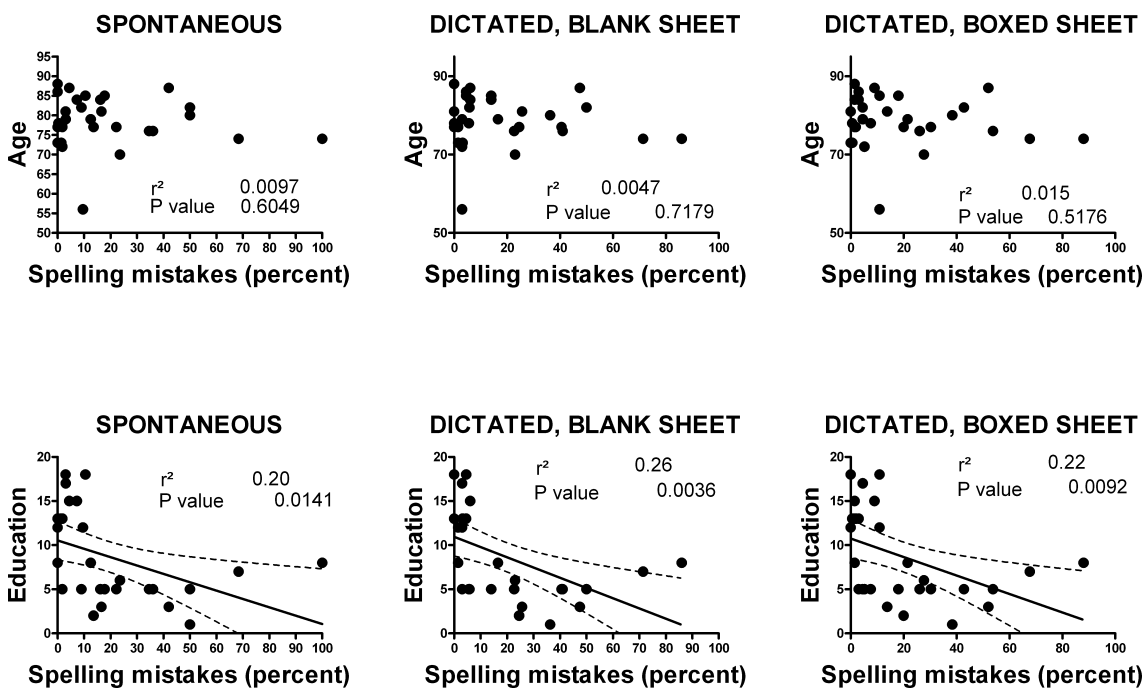


FIG. 7—This figure shows that the percentage of spelling mistakes in the text does not correlate with subject's age but correlates significantly with his/her school education. Each graph shows the correlation between the writing score and either age or school education, as indicated. On top of each graph the writing mode is specified. Inset, in each graph, the correlation coefficient and the probability value of linear regression analysis are shown.

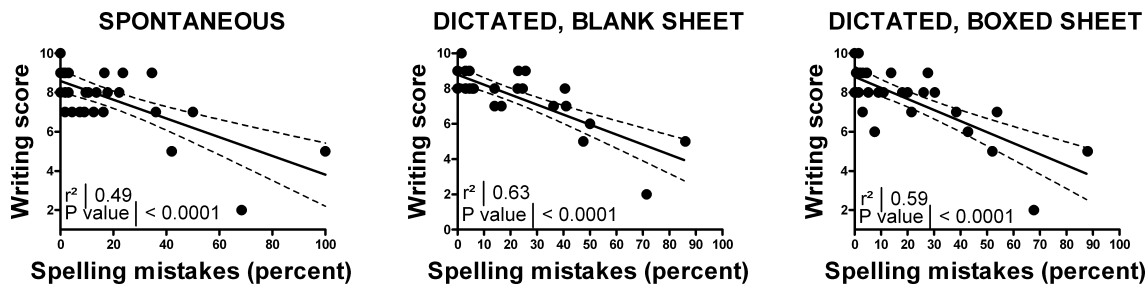


FIG. 8—This figure shows that writing score and percentage of spelling mistakes in the text correlate significantly with each other. Each graph shows the correlation between writing score and percentage of spelling mistakes in each of the three writing modes we used. Inset, in each graph, the correlation coefficient and the probability value of linear regression analysis are shown.

evaluation of a controversial last will. Further research is needed before it may be hopefully used in a routine way, especially validation of these results in a larger sample is needed. Although our research was conceived in the framework of forensic psychiatry, we would like to suggest that a reliable tool for handwriting analysis could in principle be exploited also as an inexpensive and easy way to carry out a screening for cognitive impairment. As an example, elderly people could write once a year or so a short letter to a screening center, without having to leave their homes at all, and only those with a poor handwriting performance could be invited for further tests. Not having to travel to a medical center could be an advantage especially in regions where distances are long and severe weather conditions could jeopardize the health of frail, old people.

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