JGG 2019;67:239-243

Handwriting as a possible marker of progression of cognitive impairment in dementia? A pilot study

S. Bortolotto[1], E. Ara[2], M. Devita[1], G. Bruno[2], A. Girardi[1], E. Manzato[1], G. Sergi[1], A. Coin[1]

[1] Geriatrics Division, Department of Medicine – DIMED, University of Padua, Italy; [2] Department of General Psychology, University of Padua, Italy

Background & objectives. An increasing number of studies have investigated the role of handwriting in describing different stages of dementia evolution. It has been showed that handwriting allows to distinguish among mild cognitive impairment (MCI), early stages of Alzheimer's disease (AD) and its latest stages. However, to our knowledge there are no rigorous studies on this issue, and there is no scientifically based application of handwriting analysis in clinical practice. The aim of this qualitative pilot study is to provide a description of handwriting peculiarities in the different stages of dementia, from MCI to AD, and to suggest that graphological analysis may be a clinical support in diagnosing dementia.
Methods. Four patients were evaluated every six months and assessed with MMSE, the Clock test, and a complete neurological evaluation. The "Morettian graphemic system" was then used to analyze handwriting.
Results. Handwriting changes over time might reflect variations not only in global cognitive functioning itself, but also in different stages of the disease. Further and more methodologically rigorous investigations are required to explore handwriting as a clinical marker of dementia evolution.

Key words: Handwriting, Dementia clinical marker, Morettian graphemic system

INTRODUCTION

Handwriting is a complex human activity involving cognitive, kinesthetic, and perceptual-motor components and is considered an important source of information when dealing with neurological diseases [1]. An increasing number of studies have focused on the peripheral and motor handwriting impairments following a diagnosis of neurological disease, such as Parkinson's [2] or, more recently, Alzheimer's disease (AD) [3]. Several studies have showed that handwriting might be sensitive to age-related impairments. It is considered during the diagnostic process of neurodegenerative disorders [4], to the extent that it is also included in MMSE, one of the most common screening tests. According to the existing literature, the lower the handwriting abilities, the lower the cognitive functioning [5]. The analysis of handwriting processes may be useful not just in the differentiation of cognitively impaired groups, but also in discriminating between "patients" and "healthy" persons [6].
Schröter (2003) found that graphemic movements of AD patients were significantly less regular than those of healthy controls [7]. It has been shown that individuals with AD show damage in both the central and peripheral components of writing [8]. Central deficits refer to a linguistic problem affecting the phonological or semantic spelling system, while peripheral deficits derive from damage to the allographic (i.e. case and style assignment) or grapho-motor level. AD patients produce a specific altered pattern of handwriting. Spatially disordered sentences, poor movement control, micrographia, dysgraphia (i.e. difficulty in creating letters and graphemes), jerk (which can be measured in terms of changes in acceleration) and insufficient fine-motor control typically characterize the handwriting of AD patients

Received: March 12, 2019 - Accepted: July 8, 2019
Correspondence: Maria Devita, Geriatrics Division, Department of Medicine – DIMED, University of Padua, Via Giustiniani 2, 35128 Padua, Italy. E-mail: maria.devita@unipd.it

[9]. In addition, also the semantic component of written language is impaired, so much so that these patients' handwriting is marked by indefinite terms, poor narrative organization, semantic and graphemic substitution errors, word omissions and intrusions [3 10-11].
Some studies have investigated in depth the clinical significance of these technical errors with the goal of observing the onset and evolution of neurodegenerative diseases.
For example, surface dysgraphia was identified as an important predictor of mild AD [6]. Although without a doubt handwriting cannot (and should not) be considered a diagnostic tool, it has been showed that it is characterized by completely different specific aspects during early and/or late stages of the disease [6].
The present paper describes four clinical cases in order to explore the contribution that a qualitative handwriting analysis may have in investigating the evolution of cognitive impairments in dementia.

MATERIALS AND METHODS

Four patients (two men and two women, age range: 81-88 years old) were selected from the Geriatric Clinic (University of Padua) and followed up every six months, for a period of 4 to 9 years. Demographic data, family and social history, proximal and remote pathological anamneses were extracted from patients' medical records with the patients' consent. It has been decided to consider only those patients that, for clinical reasons, were not eligible for AChEI (i.e. because of bradycardia, low compliance, other factors) in order to "purely" and naturally study the progression of handwriting along the progression of cognitive impairments.
Participants were assessed with the following tools:

- **Mini Mental State Examination (MMSE)**: a screening test investigating spatial and temporal orientation, short-term retention of simple information (immediate and delayed versions), comprehension, and executive functioning;
- **The Clock Test** [12]: a tool used to evaluate, among others, cognitive abilities such as executive functions [13];
- **A complete neurological examination**: this evaluates vigilance, temporal and spatial orientation, comprehension and the way in which patients express themselves, patients' motility, sensitivity to exogenous stimuli (such as pain), reflexes, upright position and walking;
- **Comprehensive graphological assessment**: this is based on the "Morettian graphemic system" [14]. For a description, see Table I.

RESULTS

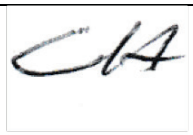
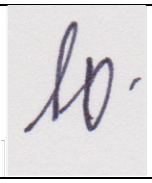
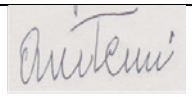
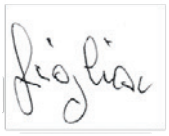
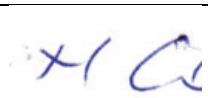
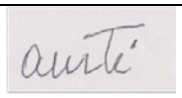
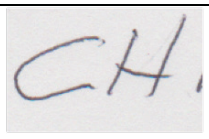
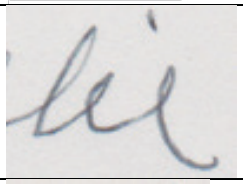
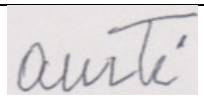
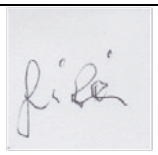
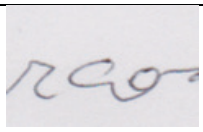
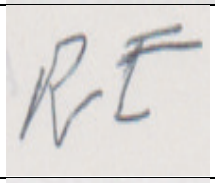
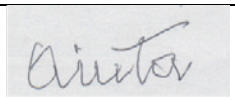
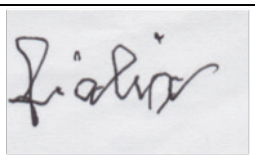
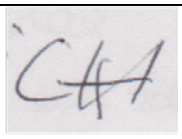
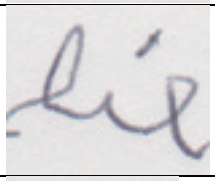
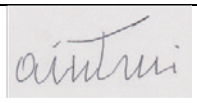
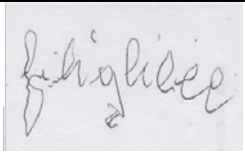
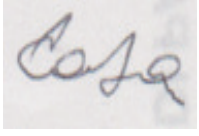
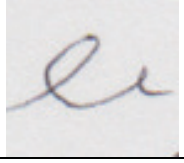
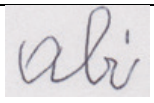
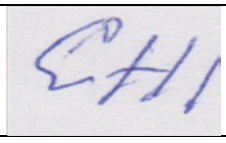
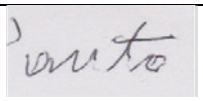
Clinical Case 1 – Paula, 81 years old, 5 years of education

Paula has suffered from short-term memory impairments for two years.
Evaluation 1. MMSE score is 24.4. The graphological layout is characterized by flowing movement and the global organization is well maintained.
Evaluation 2. MMSE score is 25.4. Her caregivers report that Paula is still autonomous and lives alone. The graphological layout highlights a sharp-cornered, less tonic mark.
Evaluation 3. MMSE score is 24.4. Her handwriting shows a general worsening: less gesture control, the written words are more rigid and more emphasized.
Evaluation 4. MMSE score is 16.4. The graphological layout reveals worsening of fine-motor control with reduced thickness and with some letters less flowing than others. Her gestural coordination is problematic: evaluation of inter-letter distance and hand movements is very difficult. There are a number of grammatical errors, of which Paula is not aware.
Evaluation 5. MMSE score is 12.4. Her caregivers report Paula is worsening: she is disoriented in her own house and does not recognize her relatives. Her handwriting shows notable deterioration and orthographic errors as well. Also her drawing confirms lack of trait continuity and organizational difficulty. Grammatical errors have increased, with single letters added and/or omitted. Pen pressure is wiry and unstable; the line is very rigid, suggesting loss of graphic-flexibility.

Table I. Grapho-pathology indices associated with the presumed Alzheimer's disease.

DIRECTION – DIMENSION– SPACE – FORM - MOVEMENT	Difficulty in precisely delineating literal profiles (dark); imprecision of the graphic structures (Disordered). Difficulty in making the connections between letters (no homogeneity in the width of letters, width between words and wide of letters), easy tendency to descending (descending), slow motion, hesitant, flickering (stented, arthritic), lack of stability, omissions of parts of letters and loss of movement sequences and spatial coordinates.
RITMO – ORGANIZATION – ENERGY	Rhythm compromised and stunted, disorganized spelling, de-structured and confused (no graphic homogeneity), the graphic maturity loses the personalization, the energy is reduced, the modulated variability of the graphical indices is absent and tends to non-homogeneity (non-presence of unequal method).

Table II. Longitudinal evaluation of patients' handwriting performance compared with their MMSE scores.

Evaluation Time (T)	Clinical Case (C.C.)			
	C.C. 1	C.C. 2	C.C. 3	C.C. 3
T1				
T2				
T3				
T4				
T5				
T6				
T7				

Evaluation 6. MMSE score is 16.4. Her caregivers report that she has now become aggressive and insufficiently independent and that she is now living with a formal caregiver. The handwriting was dilated on the horizontal dimension. Letters appear de-structured and deformed (bent).

Evaluation 7. MMSE score is 11.4. The handwriting is clearly impaired: the letters are not related to one another, with a large number of perseverations. The graphic layout is characterized by tremors and pen pressure is irregular and feeble.

Clinical Case 2 – Albert, 73 years old, 13 years of education

Albert has suffered from memory impairment for one year, but he is not aware of it.

Evaluation 1. MMSE score is 23.7. The graphological layout is characterized as follows: the space organization is well balanced, the line is maintained, but grammatical mistakes are present. The graphic gesture is tonic and appropriate.

Evaluation 2. MMSE score is 22.7. Memory deficits seem to be stable; psychomotor agitation can be detected. The graphological layout appears less rapid and not so thick as in the first evaluation. Despite the aggravation of the illness, his handwriting generally appears still stable and well controlled.
Evaluation 3. MMSE score is 16.3. As his wife died a few months ago, his relatives are looking for a formal caregiver. Albert's handwriting is generally preserved, but a variable pen pressure persists between ascending and descending traits.
Evaluation 4. MMSE score is 17.3. He now has to live with a formal caregiver. During the evaluation he often appears disoriented. Albert writes in italics rather than printing and the graphological structure is inaccurate and unstable (it is difficult to recognize the single letters). The worsening of the illness is evident both in his handwriting and at the clock test (where Albert finds it difficult to correctly insert the numbers).
Evaluation 5. MMSE score is 15.3. He is disoriented and he is no longer autonomous. His handwriting is characterized by both space disorganization and inconsistent graphic movements. The use of print prevails over italics and pen pressure is irregular.
Evaluation 6. MMSE score is 16.3. He shows difficulties in coordinating the movements of his upper limbs.
His handwriting is characterized by uncertain graphic movement, unstructured space, descending graphic orientation. Trait caliber is medium-small. The graphic gesture is obviously strained.
Evaluation 7. MMSE score is 13.3. Presence of praxis disorders. His handwriting reveals a qualitative worsening of graphic gesture: the writing is damaged and the letters have become unclear.

Clinical Case 3 – Liam, 87 years old, 5 years of education

Liam has suffered from memory impairments for 6 months, after undergoing surgery for abdominal aortic aneurysm, and has motor difficulties, and he shows a profile compatible with vascular dementia.
Evaluation 1. MMSE score is 17.4. The graphological layout is characterized as follows: he uses italics, his letters are small and not well defined. The handwriting appears tangled up and an ascending line is evident.
Evaluation 2. MMSE score is 18.4. Asthenia episodes associated with tremor of the lower limbs. There is a clear deterioration of his handwriting: words are barely identifiable and the space is carelessly organized. However, motor and graphological impairments are improved.
Evaluation 3. MMSE score is 20.4. He is still well oriented; he is now attending an adult day care center.
The graphological examination finds increased graphic caliber and stronger pen pressure. The handwriting has regained legibility.
Evaluation 4. MMSE score is 16.4. He is still well oriented; he is now attending an adult day care center six/seven days a week.
Graphological examination finds a switching between print and italics, and his handwriting is now trembling, chaotic and difficult to read.
Evaluation 5. MMSE score of 17.4. He is not well oriented in time and space.
Graphological structures are inaccurate and pen pressure is unstable. There are a lot of perseverations and omissions; letters are not clearly recognizable.
Evaluation 6. MMSE score is 14.4. His handwriting is readable, although the layout is rigid and less adaptable.
Evaluation 7. MMSE score is 15.4. The worsening of his handwriting is now evident: it is characterized by insufficient space organization, tangled-up letters, perseverations and omissions.

Clinical Case 4 – Ornella, 88 years old, 3 years of education

Ornella suffers from memory and praxis deficits, and agnosia.
Evaluation 1. MMSE score is 24.2. The graphological layout is characterized as follows: space is almost totally pervaded by big letters and indistinct words. The quality of her handwriting and the failed auto-corrections are coherent with her low education level.
Evaluation 2. MMSE score is 25.2. Despite reporting worsening of her memory, her handwriting remains unchanged and still satisfactory.
Evaluation 3. MMSE score is 22.2. The worsening of her memory continues.
Despite the presence of more grammatical errors, the handwriting is clear. Pen pressure loses tone.
Evaluation 4. MMSE score is 17.2.
The graphological layout is characterized as follows: spatial organization is appropriate, pen pressure is less vivid and graphic trait is rigid because of reduced movement flexibility.
Evaluation 5. MMSE score is 20.2. Her graphic trait is stable.
Evaluation 6. MMSE score is 21.2. Graphic trait is undirected and pen pressure is irregular.
Evaluation 7. MMSE score is 13.
The graphological layout is deteriorated: there are a lot of omissions and perseverations. The graphic trait is rigid and characterized by interruptions, dragging of the final letters and difficulty in keeping a straight line.
Evaluation 8. MMSE score is 17.
Her handwriting is stable and worsened clarity and fluidity of graphic layout are confirmed.

DISCUSSION

The four clinical cases described above, although not homogeneous and easily comparable to each other, allowed to trace notable congruence between MMSE scores and changes in handwriting. In particular, a clear handwriting impairment occurs when the MMSE scores are below the cut-off point (i.e. MMSE = 24/30). Based on MMSE scores from 21 to 23/30, it is possible to observe an increased number of errors and a decline of graphic trait which lead to a lack of continuity and organizational difficulties. According to the Morettian graphemic system analysis, the graphic structure becomes very inaccurate and unstable and there is a careless organization of the space (not only of the page but also of the inter-letter interval – ILI) and a decreased pen pressure. All these variations can be considered as consequences of fine-motor control impairment, and the lack of auto-correction may be an effect of self-control decline. Based on MMSE scores from 11 to 20, the handwriting impairment is more evident: micrographia makes writing less readable, letters are overlapped and tangled up. Pen pressure is weak and graphic layout is very thin and lacking cohesion. The description of our clinical cases, even if qualitative and very few, seems to be in line with the findings reported in the literature. For example, Afonso et al. [6], Forbes et al. [8] and Cuetos et al. [15] studied surface dysgraphia (i.e. difficulty in producing letters and graphemes) as an important predictor of "minimal AD". Afonso et al. [6] have found significant differences between MCI patients and AD patients: pen pressure and ILI decreased only in AD patients but not in MCI patients, thus confirming the later impairment of handwriting peripheral aspects [8 15]. The combination of MMSE and kinematic measures (especially pen pressure and written latency) are important predictors in classifying MCI and AD patients [4].

This study has several limitations that must be acknowledged. This is a pilot, qualitative description and it cannot definitely be considered representative of the clinical population studied. Furthermore, our small sample is largely heterogeneous and it was not possible to compare patients for age, gender and/or MMSE scores. Finally, we acknowledge the lack of a control group of healthy, non demented participants.

The contribution provided by this descriptive paper and all the results discussed above encourage further and more rigorous investigations on larger samples of patients.

Conflict of interest

The Author declare to have no conflict of interest.

References

1 Reisman JE. *Development and reliability of the research version of the Minnesota handwriting test*. Phys Occupational Ther Pediatrics 1993;13:41-55.

2 Serratrice G, Habit M. *L'écriture et le cerveau*, Amsterdam: Masson 1993.

3 Vigliotti A. *La memoria grafologica, demenza vascolare e degenerativa in grafologia medica peritale*, 2015 (http://www.neuroscienze.net).

4 Werner P, Rosenblum S, Bar-On G, et al. *Handwriting process variables discriminating mild Alzheimer's disease and mild cognitive impairment*. J Gerontology series B: Psychological Sciences and Social Sciences 2006;61:228-36.

5 Rosenblum S, Werner P. *Assessing the handwriting process in healthy elderly persons using a computerized system*. Aging Clin Exp Res 2006;18:433-9.

6 Afonso O, Álvarez CG, Martínez C, et al. *Writing difficulties in Alzheimer's disease and mild cognitive impairment*. Reading Writing 2019;32:217-33.

7 Schröter A, Mergl R, Bürger K, et al. *Kinematic analysis of handwriting movements in patients with Alzheimer's disease, mild cognitive impairment, depression and healthy subjects.* Dem Geriatr Cogn Disord 2003;15:132-42.

8 Forbes KE, Shanks MF, Venneri A. *The evolution of dysgraphia in Alzheimer's disease.* Brain Res Bull 2004;63:19-24.

9 De Stefano C, Fontanella F, Impedovo D, et al. *Handwriting analysis to support neurodegenerative diseases diagnosis: a review.* Patt Recogn Lett 2019;121:37-45.

10 Fernandes C, Lopes Lima JM. *Alzheimer's disease and signature execution*. J Forensic Doc Examination 2017;27:23-30.

11 Müller S, Preische O, Heymann P, et al. *Diagnostic value of a tablet-based drawing task for discrimination of patients in the early course of Alzheimer's disease from healthy individuals*. J Alzheimer's Dis 2016;55:1463-9.

12 Tuokko H, Hadjistavropoulos T, Miller JA, et al. *The Clock test: a sensitive measure to differentiate normal elderly from those with Alzheimer disease*. J Am Geriatr Soc 1992;40:579-84.

13 Shulman IK. *Clock-drawing: is it the ideal cognitive screening test?* Int J Geriatr Psychiatr 2000;15:548-61.

14 Moretti G. *Trattato di grafologia. Intelligenza-sentimento.* Padova: Messaggero 2002.

15 Cuentos F, Samartino T, Ellis AW. *Age acquisition norms from elderly Spanish people: characteristics and the prediction of word recognition performance in Alzheimer's disease*. Int J Methodol Experim Psychol 2012;33:59-76.

How to cite this article: Bortolotto S, Ara E, Devita M, et al. *Handwriting as a possible marker of progression of cognitive impairment in dementia? A pilot study.* Journal of Gerontology and Geriatrics 2019;67:239-43.