Original Research Article

The Tree Drawing Test in Evolution: An Explorative Longitudinal Study in Alzheimer's Disease

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Abstract

Objective: To study the evolution of the Tree Drawing Test (TDT) in a group of Alzheimer's disease (AD) patients.

Methods: A total of 33 AD patients were consecutively evaluated by Mini Mental State Evaluation (MMSE) and TDT. The evolution of the TDT parameters, trunk-to-crown (TC) and space occupation (SO) index, were analyzed.

Results: The median age at first visit was 79 years. Globally, trees drawn by patients showed an evolution characterized by a progressive reduction of the crown compared to the trunk. TC index showed a significant linear growth change (2.52 points per year) while SO index did not significantly increase. No significant associations were found examining the relations between MMSE and TC and SO index.

Conclusions: TDT could represent a complementary technique to the main neuropsychological screening tests for orienting cognitive impairment diagnosis and an aid in following the evolution of cognitive impairment over time in AD patients.

Keywords

Alzheimer's disease, dementia, tree drawing test, personality, projective techniques

Introduction

Alzheimer's disease (AD) is a neurologic disorder that affects cognition, behavior, and social skills leading to a progressive inability to function independently. In the western world it is the most common cause of dementia accounting for 50-75% and doubling in prevalence every 5 years after age 65, thus most patients are 75 years old and older.[1]

Neuropsychological assessment is essential to diagnose AD together with neuroradiological exams. Since neuropsychological evaluation is generally complex, screening tests are important to guide an effective and efficient examination. They are usually easy to administer, representing a first useful approach to cognitively impaired patients.[2]

In the last few years a complementary way to the traditional conception of screening cognitively impaired patients has been proposed.[3-6] It has been shown in fact that projective techniques currently used in the study of personality can be useful in the evaluation of the cognitive functioning of patients suffering from Alzheimer's disease.

These types of techniques for the study of personality and affectivity are instruments of simple administration with the

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potential to involve unconscious psychic dynamics along the whole lifespan. Lindzey proposed the following definition: "a projective technique is an instrument that is considered especially sensitive to covert or unconscious aspects of behavior, it permits or encourages a wide variety of subject responses, is highly multidimensional, and it evokes unusually rich and profuse response data with a minimum of subject awareness concerning the purpose of the test". He adds further that "the stimulus material presented by the projective test is ambiguous, interpreters of the test depend upon holistic analysis, the test evokes fantasy responses, and there are no correct or incorrect responses to the test".[7] Projective techniques are thus methodologies of global investigation of the personality which is considered as an evolving totality with the main constituent elements in interaction, a distinctive structure of thoughts and behaviors that constitutes a permanent set of adaptation to the surrounding world by an individual.

The significance that personality has in relation to cognition and in determination and conditioning of neurocognitive disorders is an open problem.

Populations studied are mainly represented by subjects suffering from minor or major neurocognitive disorder caused by Alzheimer's disease. The majority of the scientific works in recent decades refer to the use of questionnaire tests, hetero- or self-administered, as instruments of personality investigation in such type of patients.

Among questionnaire tests for the study of personality in cognitively impaired patients the Big 5 Factors Questionnaire based on the five-traits personality model is the most used.[8,9] This test allows identifying the coexistence and prevalence in subjects examined of 5 personality traits (neuroticism, extraversion, openness to experience, agreeableness, conscientiousness) that make an exhaustive and operationally effective image of the basic personal traits of each individual.

It is well known that across the adult lifespan openness is positively associated with general cognitive ability, reasoning, language, and memory, followed by neuroticism being negatively linked to general cognitive ability and reasoning.[10] Moreover, higher neuroticism is clearly associated with greater cognitive decline in older adults.[10,11] It has been supposed that individuals with higher neuroticism experience more "mental noise" due to higher levels of anxiety and stress that could impair attention and cognitive performance.[12,13]

Studies on AD show that when personality is evaluated by informant-rated measures, AD patients have significantly higher levels of neuroticism, lower levels of openness, agreeableness, conscientiousness, and extraversion than healthy subjects. When personality is evaluated by self-rated measures, the results obtained from informants are confirmed for neuroticism, openness, and extraversion but not for agreeableness and conscientiousness where AD patients and healthy subjects have similar scores. Thus high neuroticism and low openness and extraversion are distinctive personality traits significantly associated with a diagnosis of AD.[14] Furthermore, the presence of the alteration of these 2 personality traits, neuroticism and conscientiousness, correlates with Alzheimer's disease and is a risk factor for the development of behavioral disorders associated with the disease.[11,15,16]

Whether these personality characteristics are related to the pathology in itself or actually represent a patient adaptation to the environmental and relational changes implied by the disease remains an open question. In this regard it is important to consider that minor neurocognitive disorder patients due to AD are also characterized by greater neuroticism and less conscientiousness and mental openness if compared with healthy subjects[16-19] and this pattern is confirmed in patients with subjective cognitive decline evolving in minor neurocognitive disorder.[20,21] In summary, neuroticism is the main modified personality trait both in minor and in major cognitive disturbance due to Alzheimer's disease, both as a personological characteristic during illness and as a premorbid quality.

Due to its structural characteristics, personality is therefore not a simple element that contributes to the determination and conditioning of neurocognitive and behavioral disorders but constitutes the very background on which all organized behaviors and individual cognitive functioning develop.

As part of the totality of one's own self, cognitive functioning leaves an imprint on this background, a trace, and therefore our operative hypothesis is that a patient suffering from Alzheimer's disease shows a different trace in the background compared to a normal subject comparable for age and education because of the difference and alteration of his/her cognitive functioning. The problem is how to detect such a trace.

The main way to evaluate individual cognitive functioning consists in measuring the cognitive deficit through neuropsychological tests, which are a direct exploration of cognitive functions carried out through tools that require the active awareness of both the patient and the examiner. This awareness of the subject examined is the same that is involved in completing questionnaire tests for the assessment of personality. These types of tests would therefore capture the trace left by the altered cognitive functions on the background of the personality starting from and in the coexistence of the same cognition, that is of the direct functioning of cognition. In a subject characterized by a primary alteration of cognitive functions as in Alzheimer's disease, questionnaire tests would then have a lower ability to detect such a trace.

On a complementary side, projective personality tests have also been studied in old age but not in large numbers of subjects.[22-24] Most of these tests can be classified as verbal as their execution mainly involves linguistic expression (Rorschach test, Thematic Apperception Test, Sentence Completion Techniques etc.). In this regard, literature data about differences between patients with Alzheimer's disease and normal subjects or compared to other types of dementia show results that are not always consistent even if alterations in cognitive functions can also be highlighted with this type of tests.[25-28]

Finally, projective personality tests that mainly use non-verbal praxic functions (e.g. drawings) in patients with Alzheimer's disease have been little studied.[3,4,6,29-32] It is these types of tests that, being based on a projective psychic mechanism that uses unconscious mental dynamics, might be better suited to access the evaluation of the trace left by the cognitive functions on the background of the personality in an indirect way that does not directly imply verbal cognitive functions. In fact, these types of tests are generally easier to perform by cognitively impaired patients facilitating the unconscious expression of affection and personality.

Thus, since personality and affectivity are the background of every behavior, our operative hypothesis is that cognition can be indirectly studied through projective techniques, mainly of the non-verbal type, pointing out different degrees of cognitive impairment.[3-6,32]

Among these, Tree Drawing Test (TDT) is used for assessing personality both in the developmental age and in adult life. First described by Karl Koch in 1949,[33] its easiness of administration makes it a rapid and useful tool to express self-image with relatively little resistance. Within this global representation of self-image, the different parts of the tree have their own meaning. In particular, from a psychological point of view, the trunk would represent the supporting structure of the ego, the temperament, while the crown would indicate the space in contact with the external reality of the subject.[33]

Although mainly developed for the study of pediatric age, TDT has been also widely studied in adult psychiatric patients, both schizophrenics and depressed.[34-40]

Trees drawn by schizophrenic patients are generally of small size, the trunk is a single line or narrow and is open at the base, and the branches are single lines or open at the end reflecting the fact that these patients tend to be socially withdrawn with a reduced ability in reality testing.[35] Furthermore, in schizophrenics the involvement of the left middle frontal region, bilateral inferior frontal and parietal regions, and the left superior temporal region while drawing an imagined tree has been shown by means of near-infrared cerebral spectroscopy thus supposing attention, working memory and executive functions as the main cognitive functions involved.[36]

When patients are depressed trees are generally smaller with small crowns and trunks with small width and TDT can be an aid in differentiating this type of patients from normal subjects.[37-40]

Finally, it has been also demonstrated that TDT can be used in the study of cognitively impaired patients in an attempt to discriminate patients suffering from AD from those with mild cognitive impairment (MCI) and healthy subjects.[3,32] In general, cognitively impaired patients draw smaller trees compared to healthy subjects. Trees drawn by AD patients in particular are significantly smaller compared to those drawn by MCI and by healthy subjects and they are poorly detailed with a smaller crown while MCI patients draw trees intermediate in size between AD patients and healthy subjects suggesting a sort of progression from mild to greater degrees of cognitive impairment. Patients affected by frontotemporal dementia draw trees with a wider space occupation than AD and MCI patients but smaller than healthy subjects as well as patients affected by vascular dementia.[3]

To our knowledge, there are no data available in the literature describing the evolution of trees drawn by AD patients along the course of cognitive impairment. In order to evaluate the evolution of TDT along the worsening of cognitive impairment, we longitudinally studied a group of AD patients analyzing the development of the main test parameters.

Materials and Methods

We evaluated 33 consecutive AD patients referred by their relatives and physicians to the Cognitive Disorders Centers of IRCCS Istituto delle Scienze Neurologiche of Bologna and of the General Hospital of Imola, Italy. All patients were evaluated 4 times (T1-T2-T3-T4) and 72.7% of them had a fifth evaluation (T5). The average interval between evaluations was of 8.2 ± 1.8 months (mean observation interval per subject: 30.5 ± 5.3 months).

Inclusion and Exclusion Criteria

Patient inclusion criteria were as follows: (a) major neurocognitive disorder according to DSM-5 criteria[41]; (b) diagnosis of AD based on the international criteria.[42]

Patient exclusion criteria were: (a) current or previous neurological, psychiatric (e.g. major depressive disorder) and systemic diseases; (b) alcoholism or other substance abuse; (c) use of neuroleptics or other antipsychotics and tricyclic antidepressants considering their possible negative effects on cognition; (d) history of diseases with a significant impact on visual acuity (e.g., severe glaucoma, progressive cone dystrophy, severe cataract or macular degeneration)

All patients were taking acetylcholinesterase inhibitors at therapeutic doses. Serotoninergic antidepressants, Trazodone, and low doses of benzodiazepines were allowed.

All participants gave consent to personal data processing for research purposes and the protocol was approved by the Local Ethical Committee (CE AVEC 17066, 21/09/2017). All participants gave their informed consent to the study according to the Declaration of Helsinki. If the patient was not cognitively able to be adequately informed, consent was given by the participant's legal representative. Data were collected according to the General Data Protection Regulation (GDPR) (Regulation (EU) 2016/679 - Directive (EU) 2016/680).

Procedures

All patients underwent a general cognitive screening with the Mini Mental State Examination (MMSE)[43] and TDT.

MMSE: the MMSE was administered to patients by an examiner blind to TDT results. The MMSE score was corrected for age and education according to Italian standardizations (MMSEc).[44]

TDT: All patients were requested to draw a tree on an A4-sized white paper sheet with a pencil. Instructions were as follows: "Draw a tree, as you like." No limits of time were given. On the basis of the results of our previous study,[3] we analyzed for all patients the TDT parameters that discriminate cognitively impaired patients from normal subjects. In particular, the trunk-to-crown (TC) index [(trunk height/crown height) × 10] and the space occupation (SO) index [(tree height × tree width)/(paper sheet height × paper sheet width)]. Then we correlated TDT parameters with MMSEc.

Statistical Analysis

In the descriptive analysis, categorical variables were reported as absolute number (n) and frequencies (%). Continuous variables were presented as mean ± standard deviation (SD) or median and interquartile range (IQR) depending on the data distribution. Linear mixed models (LMM) were employed to examine the longitudinal changes of MMSEc, TC index and SO index (dependent variables), following the strategy described by Shek et al.[45]

The strategy is based on Individually Growth Curve (IGC) model, a technique for modelling within-person systematic change and between-person differences in developmental outcomes across different measurement waves over time. This technique does not require balanced data across the different time points.

To develop this strategy, the first step was to estimate an unconditional model including random intercepts and random slope for the time. In a second step, to account for possible non-linearity in the data, a quadratic term and a cubic term for the time were inserted. The last step was to estimate a final IGC model to evaluate the longitudinal association between MMSEc value and TC and SO index, using MMSEc as dependent variable and adding, in addition to time, TC and SO index (as covariates separately in 2 different models).

For each outcome, Intraclass Correlation Coefficients (ICC) from the unstructured mean model were estimated for the evaluation of interindividual variability. Generally, LMM required ICC equal to .25 or above. Estimation of parameters was based on the maximum likelihood method and unstructured covariance structure. To select the best model, likelihood ratio test (LR test) was used ($P < .05$).

The trajectories of MMSEc, TC index and SO index over the time were evaluated stratifying by age classes (≤80 vs > 80 years) and education classes (≤5 vs > 5 years).

Results are presented as ß coefficients, 95% confidence intervals (95% CI) and P-values.

Statistical analysis was performed using Stata SE version 14.2.

Results

Baseline characteristics of the 33 AD cases are described in Table 1. The median age at first visit was 79 years (IQR 77-84) and 29 patients (87.9%) were female. Mean disease duration was 3 ± .7 years.

Median and IQR for MMSEc, TC and SO index over the time are reported in Table 2. The median (IQR) at baseline was 19.2 (16-21) for the MMSEc, 10.8 (8.8-15.3) for the TC index and 4.1 (2.7-8.8) for the SO index.

MMSEc Longitudinal Evaluation

The ICC for MMSEc total scores was .51. There was a significant linear monthly decrease in the MMSEc indicator scores ($\beta = -.15$, CI 95% = −.18 to −.11, $P < .001$). The mean estimated initial status (the intercept of the model) was 19.46.

Patient MMSEc change was non-linear over time. Based on the results of the LR test the model that fit better the data was the quadratic 1 (quadratic model vs linear model P = .003; quadratic model vs cubic model P = .117).

The quadratic effect was significant ($\beta = -.003$, CI 95% = −.005 to −.002, P<.001) and suggested an accelerated decline in MMSEc over time (Figure 1).

Stratifying the MMSEc trajectories by education and age, there were no differences in trends between the groups.

TC Index Longitudinal Evaluation

The ICC for TC index was .33. There was a significant linear monthly increase in the TC index scores ($\beta = .21$, CI 95% = .08 to .32, P = .001). The mean estimated initial status (the intercept of the model) was 12.

Based on the results of the LR test, the model that fit better the data was the linear 1 (linear model vs quadratic model P = .517; linear model vs cubic model P = .998). Individual trajectories are shown in Figure 1. Examples of trees drawn longitudinally are shown in Figure 2.

Stratifying the TC index trajectories by education, there were no differences in trends between the groups. Stratifying the TC index trajectories by age classes (≤80 vs > 80 years) we observed a linear monthly increase only in the >80 years group

Table 1. Demographic and clinical data of patients.

	AD n = 33 Mean ± st.dev.; Median [IQR]
Age (years)	79.1 ± 6.1; 79 [77-84]
Sex (N (%) female)	29 (87.9)
Education (years)	5.9 ± 3.6; 5 [3-8]
MMSE (baseline)	18.6 ± 3.4; 18 [16-21]
MMSEc (baseline)	18.9 ± 3.3; 19.2 [16.4-20.4]
TC index (baseline)	12.1 ± 4.9; 10.8 [8.8-15.3]
SO index (baseline, %)	7.7 ± 7.1; 4.1 [2.7-8.8]
n (%) of evaluations	4 out of 5: 9 (27.3) 5 out of 5: 24 (72.7)

Table 2. MMSE, TC and SO index evolution.

	T1	T2	T3	T4	T5
MMSEc median [IQR]	19.2 [16.4-20.4]	19.5 [16.5-21.4]	17.2 [15.4-19.5]	15.3 [14.2-17.5]	14 [12.2-16.9]
TC index median [IQR]	10.8 [8.8-15.3]	11.5 [8.6-16.5]	10.9 [8.5-15.2]	15 [10.8-19.4]	14.7 [11.2-19.3]
SO index % median [IQR]	7.7 ± 7.1 4.1 [2.7-8.8]	10.6 ± 11.5 6.7 [2.3-12.2]	9.8 ± 15.7 3.6 [2.3-8.5]	7.2 ± 9.4 4.1 [2.2-7.1]	7.9 ± 10.4 4.2 [1.6-7.5]

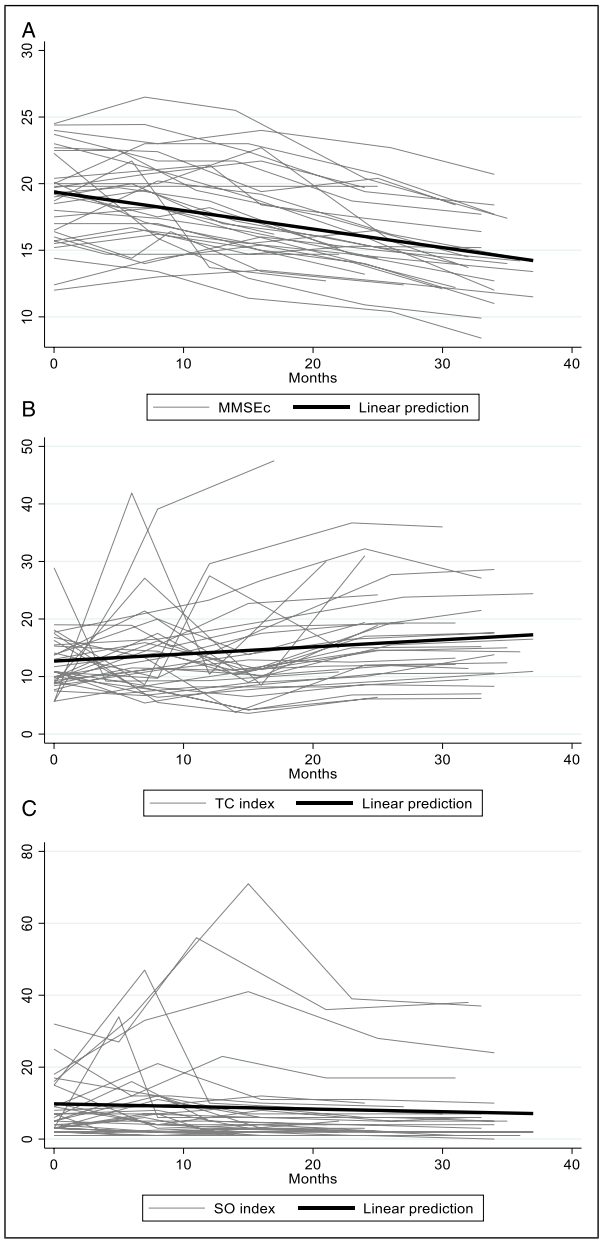

Figure 1. Spaghetti plot of individual trajectories over the time (gray) and their linear prediction (black) for MMSEc, TC and SO index. N = 33.

(β = .22, 95% CI = .06 to .38, P = .008) while in the ≤80 years group we did not observe a significant increase over time (β = .07, 95% CI = −.08 to .22, P = .367).

SO Index Longitudinal Evaluation

The ICC for SO index was .67. There was a non-significant linear monthly increase in the SO index scores (β = −.001, CI 95% = −.002 to .0002, P = .135). Since the effect of linear growth is not statistically significant, there is no need to perform further growth curve modeling analysis. Individual trajectories are shown in Figure 1.

Stratifying the SO index trajectories by education and age, there were no differences in trends between the groups.

Overall Longitudinal Evaluation

No significant associations were found examining the relations between MMSEc and TC and SO index over the time. The beta coefficients between MMSEc, and TC and SO index was non-significant both in the unconditional model and in the higher-order polynomial model (Supplementary Table).

Discussion

TDT is a projective technique to assess personality both in younger and older age by generating a drawing following open-ended instructions. In projective drawings, the subject's psychomotor activities are caught on paper so that global cognitive functioning is also implied. Personality as the background of every behavior includes cognition so that cognitively impaired patients more frequently draw different trees compared to normal subjects. Globally, in our AD patients sample, trees drawn by patients showed a tendential evolution characterized by a progressive reduction of the crown compared to the trunk. Thus TC index would be confirmed as a measure representative of changes in global cognitive status since it progressively increases along with the worsening of cognitive deterioration, possibly allowing us to consider TDT in the follow-up of cognitively impaired patients.

The TC index is a dimensional relationship within the tree drawing calculated by relating the height of the trunk to the

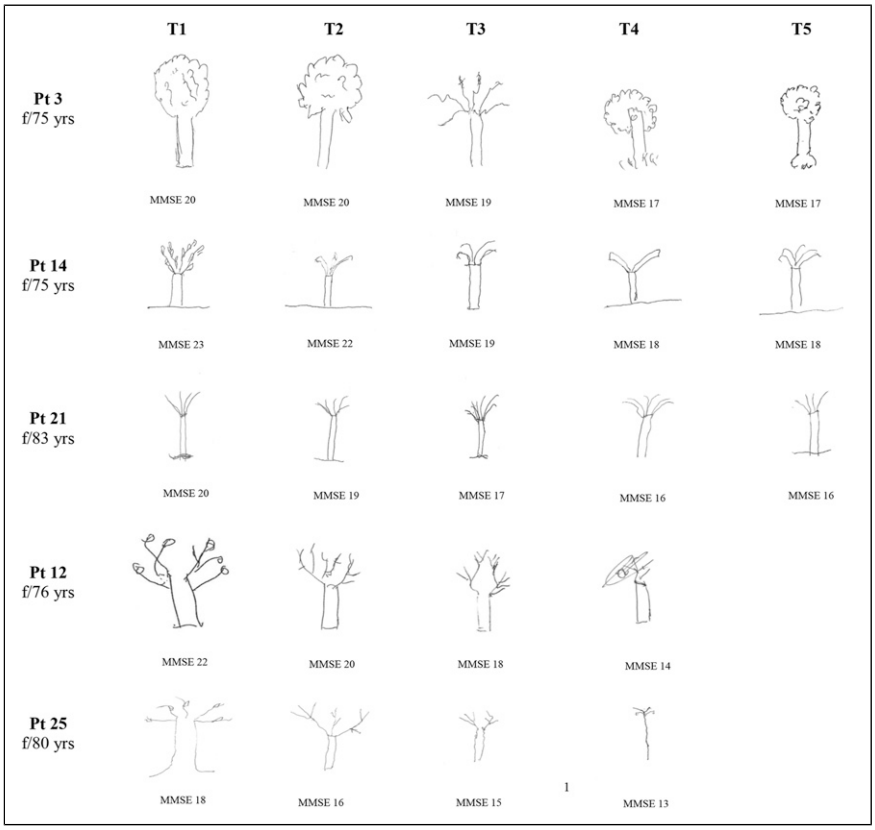

Figure 2. Examples of trees drawn longitudinally.

height of the crown. It has been shown that it can discriminate AD patients from normal subjects and it could be considered as a predictor of cognitive impairment.[3,32] In AD patients the TC index is significantly greater compared to controls because of a smaller crown compared to the trunk, and it tends to increase from patients suffering from a minor neurocognitive disorder to demented ones. In the developmental age the TC index has a specular trend compared to older age since it is known to be inversely correlated to the development of linguistic abilities and abstract thinking, thus confirming itself as a possible indicator of global cognitive change.[33,46,47] In psychiatric patients, schizophrenic and depressed, data are not homogeneous since a larger TC index compared to normal subjects has not been always reported.[34,35,37,38,40]

In our group of patients, even they do not reach a significant correlation, both MMSEc score and TC index showed a significant change during the study period. In particular, the TC index progressively tends to increase over time (mean annual increase of 2.52 points) and MMSEc score tends to decrease, indicating the worsening of the mental deterioration (mean annual decrease of MMSE is of 1.8 points).This is quite in line with the literature with a mean MMSE annual decrease between 2 and 3 points for AD patients.[48,49] In our sample the slower decrease of MMSE compared to that of literature could be influenced by the effect of a small number of patients although a possible effect of acetylcholinesterase inhibitors should be considered. Furthermore, with respect to the not-linear decrease in individual MMSEc curves, this could be consequent to the age and level of disease severity of the patients at the time of referral to the Cognitive Disorders Center. In fact, in our sample, many patients were from suburban agricultural areas where the social and family organization favors the management of the patient at home for a longer period than in urban areas. As a result, after a few years of follow-up a prevalent proportion of patients may be in a more advanced stage of the disease than a similar urban population with comparable follow-up, with a possible more rapid deterioration of their cognitive status due to the more advanced stage of the disease.

Another TDT parameter that allows us to distinguish AD patients from healthy subjects is the SO index, i.e. the ratio between the total area of the tree drawn and the area of the paper sheet.[3,32] In fact, trees drawn by AD patients are in general significantly smaller than those drawn by patients with minor neurocognitive disorder that are smaller compared to those of healthy controls. In our study group the SO index remains stable over the observation period along the worsening of mental deterioration. In this case it could be argued that the short period of observation does not allow the detection of a significant variation of this parameter and this hypothesis should be confirmed by further experimentation.

Finally, with regard to the qualitative characteristics of trees drawn by patients, it is confirmed that the they are poorly

detailed and tendentially drawings have a progressive lower formal quality with the worsening of cognitive deterioration.

In general, referring to our operative hypothesis, since trees drawn by AD patients are generally different from those of healthy subjects, the global trend difference of trees drawn by our patients and a global evolution over time of the main psychically significant parameters of the figure (i.e. the trunk and the crown) could represent the trace left by their altered individual cognitive functioning on the background that is personality. In this perspective, as a general indication, drawing a tree could be an indirect way to access to global cognitive functioning.

Some limitations of this study should be noted. First, a larger sample of patients is needed with the inclusion of patients of a younger age. Second, although all patients underwent a general cognitive assessment with the MMSE, a fully comprehensive neuropsychological battery would help to better define the cognitive evolution of patients. Third, a longer follow-up is desirable as a greater cognitive decline would allow us to identify significant differences in the evolution of the TDT. Moreover, further follow-up studies are needed to better study changes in the TDT over time along with the progression of the disease in correlation with other projective techniques and to explore the neuroanatomical association of the TDT changes, using also a cerebral magnetic resonance follow-up.

In conclusion, TDT is confirmed to be an easy test to administer and it could represent a complementary, not alternative, technique to neuropsychological screening tests for orienting cognitive impairment assessment. As a complementary technique, TDT could be an aid for the clinician in those cases where neuropsychological screening evaluation is not clearly unambiguous. In this perspective, projective techniques could in the future represent an interesting and useful way to complement the study of cognitively impaired patients in clinical practice.

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Author's contribution

Conceptualization, M.S.M., S.C. and C.M.; Methodology, M.S.M. and C.Z.; Formal Analysis, F.B. and C.Z.; Investigation, M.M. and C.M.; Data Curation, M.S.M. and M.M.; Writing – Original Draft Preparation, M.S.M.; Writing – Review and Editing, R.G., S.C. and C.M.; Supervision, R.G., S.C.

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Author's Note

All original material can be requested to the corresponding author providing an adequate motivation.

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Supplemental Material

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