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Influence of neurodegenerative diseases on handwriting

Abstract

Handwriting, like all other behavior, is regulated by the brain. This is typically an unconscious mechanism that is closely related to brain impulses. Any mental disorder can impair the forearm's kinetic motions, as can be seen in the subject's handwriting. It's crucial to focus on how a subject write rather than what a subject write if you want to understand health and mental issues. The aim of this analysis study is to learn about the changes that occur in an individual's handwriting characteristics during psychological problems, or when the subject is in a troubled state of mind. Calligraphy The study and analysis of handwriting, especially in relation to human psychology, is known as graphology. It has been discovered that features related to motion, time, and pressure are very useful and could be used to diagnose health and mental disorders using a manual or digital handwriting analysis approach.

Keywords: handwriting, graphology, neurological disorders

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Introduction

Questioned documents is an important area of Forensic Sciences, comprehending document fraud analysis such as identity theft, forged signatures or texts, documents alterations and falsification of security documents or banknotes. While physical analysis is widely applied in questioned documents, many situations demand the chemical analysis of inks and support paper.[1] Handwriting is a neuro physiological method of expressing our feelings and speaking in a written form on a floor using a writing instrument driven by forearm movements. Handwriting has long been used to describe people's personalities and emotional states (Graphology).[1] We make a lot of spontaneous movements when writing. These movements are captured on paper and represent our ever-changing emotions. This registered movement - handwriting - is like an open window from which we can see the entire panorama of a person's personality. Handwriting, like expression, is inextricably connected to the way we think. It is also acutely conscious of emotions such as disappointment or excitement. We transfer our emotions onto paper during the writing process, and the phrases we create represent those emotions. In reality, handwriting is so sensitive that it could be used as an emotional gauge. Excitement, apprehension, anxiety, irritability, and rage are all visible emotions.[2,3] That is why knowing how to write is so important; for example, if you write while anxious, the anxiety will show up as a nearly imperceptible trembling within the strokes of positive letters. It may not be visible at first glance (though it does happen occasionally), but it will almost certainly show up under a microscope. This is because your handwriting is the written externalization of the vivid hobby you're involved in on the inside.

It's a mental representation of your internal strategies in which small short movements reflect the internal vibration of play and spherical easy moves represent your sense of rest and calm.[4] Graphology is the analysis of and evaluation of handwriting, with an emphasis on human psychology. In the clinical setting, it can be used to consult handwriting analysis as a valuable aid in the diagnosis and monitoring of mental and nervous system disorders.[1] Since the mid-twentieth century, graphology has been used to find suitable staff, determine the validity of a signature or document, and establish the country of origin of a signature or text (e.g., under the influence of alcohol or anxious). It's also been seen in courtrooms and during criminal investigations. In psychology, handwriting tests are accepted scientific equipment.[5] Regardless of style, format, spelling, or material, handwriting is typically accurate. It allows for the examination of persona traits through the strokes and styles discovered through the use of an individual's handwriting, exposing tendencies such as emotional and intellectual dysfunction, which may lead to deviant or complex behavior.[6] Following the publication of Ludwig Klages systematic theory of handwriting assessment by a 19th century German logician and psychologist, the use of graphology for various purposes, including psychological studies and evaluation, spread throughout Europe.[5] In 1942, graphologist Lewiston and psychologist Zubin created L-Z scales to objectively compare quantitative and qualitative hand-writing elements, using statistical proof to differentiate between odd and ordinary personalities' handwriting. There is an extensive list of neurological disorders that influence handwriting, including Congenital apraxia, Strephosymbasia, and others.[7–10]

Many psychological illnesses, such as depression, obsessive compulsive disorder, schizophrenia, and multiple types of psychosis, have been attributed to handwriting change in numerous studies.[11–15] The following are important handwriting roles for ailment prognosis:

i. Congestion: This is shown by letters with ovals and curls that are completely covered in ink.

ii. Fragmentation: This is illustrated by disconnected letter curves.

iii. Lines' direction

iv. Anomalies Layout

v. Torsion is an irregularity or luxuriation of a portion of a letter or the whole letter.

vi. Viscosity: It is a shaky or filthy extension of higher and lower letter components

vii. Tremors: These are mild disturbances in letter strokes.

viii. Slant: When drawing letters, a slant is an unevenly inclined right movement of the pen on the page.

ix. Transitions between stokes,

x. Changes in the length of letters as they are being written,

xi. Variations in the shape of curves for identical letters,

xii. Breeze: It's the aspect of a stroke over a sheet of paper where the pen doesn't leave any ink behind.

xiii. When writing, pressure is applied to the writing organ at the same time.

xiv. Accent Marks and Periods that represent memory issues, creativity, and attention

xv. For handwriting evaluation, graphologists use a combination of or more of the functions mentioned above. For statistical assessment and ailment prognosis, these functions are extracted and converted into numeric values.[16,17]

xvi. Changes in handwriting characteristics that occur during the course of the following disorders-

Anxiety, stress, and negative mood

Stress is triggered by two factors: psychological pressure perception and the body's reaction to it, which includes various processes ranging from metabolism to muscles to memory. Anxiety is a reaction to stressful situations that can be life threatening. People who are upset show a difference in the amount of pressure they put on their pen when writing; additionally, the strokes are odd in time and space.[18,19] Luria et al.[20] investigated the connection between handwriting and temperament. Sixty topics from the University of Haifa were covered in the study, with a median age of 24 and a range of 21 to 29 years. For function assessment, the Computerized Penmanship Evaluation Method and Program (ComPET) are used. The length, width, peak of strokes, length, and strain applied were calculated amongst a group of incredible, horrible, and unbiased people. The strokes were shorter in awful topics, although they were longer in tremendous and impartial topics. The width of the strokes narrowed in the awful topics, compared to 3.60mm in the tremendous and neutral topics, respectively. In contrast to terrible and neutral topics, the peak of strokes created in the institution of terrible topics became shorter. Between the tremendous and awful moods, the duration of on-paper strokes became shorter, respectively. In addition, strokes made with subjects in a bad mood had less tension than those made with subjects in neutral or good moods.

Depression

Werner et al.[21] investigated functional dysfunction in handwriting output among elderly people with Mild Major Depressive Disorder (MDD). Twenty elderly people with mild MDD were included in the sample, as were twenty safe subjects recruited from MDD participants' relatives who were of similar gender, age, and educational level. Four handwriting tasks were used to quantify space, time, and pressure: copying a paragraph, writing one's name and surname, writing all alphabets sequentially, and filling in a check. Depressed patients exerted substantially less pressure, which was found to be a major factor influencing writing output. In addition, the time taken to prepare and execute hand movements was longer. In-air period on a pen was used to calculate this function. Singh et al.[22] looked at the handwriting of a 3rd year mbbs student who was suffering from major depressive disorder symptoms and discovered certain inconsistencies between the samples taken before and after the illness. The new handwriting of the patient varied from the old in the following ways:

- An improvement of 85 percent in letter width Letters' heights have been increased by 10%.
- Words were often above and now below the mean, which was not followed previously.
- Used to write 5–6 words per line, but now only writes 3–4 words per line.
- Increased angulations result in decreased fluency, irregular slanting, decreased organization, and decreased connectivity of letters in words. On paper, the fluidity, speed, and force were all about the same.

Handwriting improvement has also been reported in patients with depressive disorders in the past and present[14,15] for the diagnosis of suicidal attempts[13] and extreme major depressive disorder.

Attention deficit hyperactivity disorder (ADHD)

Handwriting is a difficult task that necessitates the integration of many factors, such as behavior (inattention, hyperactivity), motor planning, adequate motor skills, and visible motor vision.[23] Bad organization of written cloth in the space available, bad spacing within and among words, bad average legibility, inconsistent letter size and form, bad alignment, common erasures, common omissions of letters or words, letter inversions, bad rhythm and waft of writing, and gradual velocity, according to Lerer et al.[24] According to Adi et al.[25] the kinematic manifestations of writing deficits in children with ADHD include a quick, inaccurate, and inefficient written product, as well as the use of excessive axial pen pressure. The authors ostensibly identified this location by using the hyperactivity-related hyperkinetic behavior and lack of reaction control that are common in ADHD,[26] which encouraged the children to complete the assignment as quickly as possible. It is confirmed by using current research, which shows that there is no significant difference between women with and without ADHD, despite the fact that women with ADHD are known to have less hyperactive/impulsive symptoms and more inattentive symptoms than men.[27] Other studies have shown that children with ADHD have a lower acceptable execution velocity and more motor difficulties than children without ADHD,[28,29] but they did not differentiate between the co morbid mastering problems in ADHD that could cause a decrease in writing velocity.[30] The handwriting of ADHD subjects in females did not change in contrast to variable findings in the control group. Ascending/descending/fluctuating strains have been found to be the most common (53.6 percent) dysgraphia predictor.[31] Handwriting assessment can correctly differentiate children with ADHD or ADHD with learning disabilities (ADHD-LD) from control topics, according to Li T sang et al.[32] by using the degree of variation in writing velocity or pen strain.

Obsessive compulsive disorder (OCD)

Divergences in the kinematic parameters of circle drawing and handwriting tasks were compared between patients with OCD and controls (sentence, signature, letter) When writing a sentence and signing their name, patients with OCD had a significantly slower top speed than healthy subjects. In addition, handwriting strokes (sentence and signature) were shorter in OCD patients compared to controls, indicating micrographic. In patients with OCD, the percentage of time spent in acceleration during the writing of a sentence and the signing of a personal signature was significantly lower than in

healthy controls. The final result reveals that patients with OCD have shortened acceleration periods in their handwriting strokes. There were no significant differences between the two companies in any other kinematic parameter or venture. Hand motor disorders in OCD patients were found to be venture dependent, according to multivariate variance analyses. When performing basic motor activities (repetitive drawing of superimposed concentric circles), patients with OCD exhibited faster and more automatic hand movements than healthy controls, but slightly slower handwriting actions (sentence and signature) and a lower degree of automatization when writing letter sequences. Micrographia in OCD sufferers became limited to handwriting (writing a sentence and personal signature).[12]

Autism

Autism or autistic disorder is a developmental disorder characterized by difficulties in social interaction and communication, as well as by repetitive, restricted interests, and behaviors. The speed, slant, and size of a child's handwriting can be used to identify him or her as having Autism.[33] Rosenblum[34] investigated how children with autism spectrum disorder write. The research included 60 children aged 9 to 12 years old from third to sixth grades from various schools. Half of the children had high-functioning autism spectrum disorder, with an Intelligence Quotient of 80 or higher, while the other 30 were average children. For each issue, the amount of pressure applied to the paper, the rhythm and pace of handwriting, in-air time, slant, and other characteristics were measured. In contrast to normal students, the letters created by children with Autism were taller and larger, and the degree of pen slant on paper was smaller. Additionally, on-paper and in-air waiting times were longer. A research by Johnson et al.[35] used digitized handwriting tasks to characterize handwriting output in children with Autism Spectrum Disorder (ASD). The participants in the study were 52 boys aged 8 to 12, 29 normally developing (TD) children from the control group, and 23 ASD patients. The MABC-2 test was used to assess the performance of motor movements. Every topic was given five writing sequences in cursive letters (1. emem, 2. elel, 3. eeem, 4. eeel, 5. eeee) with passage movements between identical (e-to-e) and different (e-to-m, e-to-l) letters with sizing and path variation. A writing sequence's unevenness, scale, writing speed, and average peak velocity were all calculated. The findings revealed that when compared to a group of TD children of similar age, ASD children had more trouble writing. ASD children have spaced the letters/words unevenly.

Alzheimer and mild cognitive impairment disease

Alzheimer's disease (AD) is a neurodegenerative disease characterized by extracellular plaques containing -amyloid (A) and intracellular neuro fibrillary tangles containing tau. Though amnestic cognitive impairment has been the most prevalent symptom of Alzheimer's disease, non-amnestic cognitive impairment can also occur. Short-term memory loss is the most frequent symptom of Alzheimer's disease, although it can also affect expressive speech, visuospatial processing, and executive (mental agility) skills. The majority of instances of Alzheimer's disease are not dominantly inherited, and many people with the disease have a complicated genetic connection. Patients with serious Alzheimer's disease have difficulty putting a pen to paper. In contrast to healthy people, Alzheimer's and MCI patients have significant differences in the kinetic and stress functions of handwriting.[36] Onet et al.[37] investigated how people with MCI and Alzheimer's disease write. The first functions of handwriting that they used were spatial, temporal, and stress measures. The spatial functions preserved the millimeter-long duration of on-paper strokes. Temporal functions protected the amount of time it took to complete the mission, as well as time spent in the air and on paper, both of which were calculated in seconds. They also worked on other crucial features, such as the average speed of the pen while it was on paper. The mean stress applied with a pen, calculated with non-scaled devices from 0 to 1024, became more stable. The findings revealed a continuous difference in in-air time between healthy people and patients. In contrast to healthy normal participants, subjects with MCI and Mild AD had significantly longer time in the air. Except for speed, all kinematic and stress measures consistently differ between Mild AD subjects and healthy people. In comparison to Mild AD and MCI subjects, healthy normal people put significantly more tension on the pen. The kinematic functions showed a 10% to 27% difference in power of relationship (ETA- Squared ratings) between ratings of MCI, Mild AD, and daily topics. Badarna et al.[38] looked at pen movement trends in patients with low and high MCI. The evaluation of handwriting was primarily focused on spatial measures such as distance, height, displacement, and curve time, as well as kinematic measures such as mean, median, and widespread variance in acceleration, in-air and on-paper duration, tension, and angles. Based entirely on the on-floor pen movement study, they obtained a group accuracy of 95.23 percent for patients with low MCI and 85.80 percent for patients with high MCI.

Parkinson disease

As the second most frequent neurodegenerative disorder, Parkinson's disease is characterized by motor symptoms, such as bradykinesia, resting tremor, muscle stiffness, and postural instability, as well as non-motor symptoms, including olfactory dysfunction, sleep disorders, constipation and dysautonomia, which are due to the loss of neurons in several brain areas and may occur before or after the loss of dopaminergic neurons.[39] Parkinson's disease is thought to be caused by a combination of ageing, as well as genetic and environmental risk factors and □5–10% of patients with Parkinson's disease have rare Mendelian variants.[40] Song et al.[41] used quantitative handwriting measurement to evaluate and distinguish in everyday handwriting activities between people with Parkinson's disease, people with psychotropic-induced Parkinsonism, and healthy people. The aim was to find any psycho-parameters that could be used to predict Parkinsonism severity. Ten participants (1 female and 9 males) met DSM-IV requirements for schizophrenia with clinically identifiable drug-induced Parkinsonism, thirteen patients (4 females and 9 males) diagnosed with idiopathic PD, and twelve (2 females and 10 males) stable control subjects participated in the study (NC). The peak velocities of vertical strokes from middle to bottom were nearly doubled in the speed study of handwriting samples, while the velocities of SZ patients were constant. NJ was also measured with normalized size and length of strokes to determine the degree of smoothness of handwriting. Both SZ and PD patients had lower velocities than normal people, particularly for stokes larger than 4cm, according to the findings. Both PD and SZ subjects had a significant reduction in VS, while SZ subjects had a lack of smoothness. Naumann et al.[42] examined the kinetic characteristics of Parkinson's disease patients' handwriting movements, including speed, stroke length, scale, and acceleration. Concerns were asked to create a combination of the letters 'll' from the German words 'helles' (bright) and 'grelles' (grelles) (glaring). For each trial, the maximum positive/

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negative absolute acceleration (slowing down) and distance of writing traces (in mm) of letter with 'll' combination were calculated in both descending and ascending strokes. For comparison, total writing time (in ms) and maximum/minimum absolute (tangential) velocities were measured. In addition, the number of inversions in the direction of acceleration and velocity profiles with a combination of 'll' letters were counted. For each subject, the analysis was administered with a mean of several measurements. When PD patients were compared to healthy normal people, the findings revealed a major difference in the kinetics of handwriting movements.

Dysgraphia

Dysgraphia is diagnosed in school-aged children. Dysgraphia affects children's ability to organize letters and express choppy, disordered handwriting types. Dysgraphia can be easily identified in children using spatial and temporal tests.[43] Mzourek et al.[44] compared the handwriting of 27 Dysgraphia children to 27 age-matched controls who had spent years writing in school. The parameters were focused on 51 capabilities grouped into three categories: non-linear dynamic capabilities, kinematic capabilities, and other capabilities. The findings were almost entirely dependent on altitude/tilt and tension. The abilities dependent on stress were discovered to be more useful for Dysgraphia research. They discovered that when children with Dysgraphia were given a 17 percent stress reduction, their stress levels improved.

Schizophrenia

Schizophrenia is a severe and debilitating neuropsychiatric illness that affects around 1% of the population.[45] One percent of the human population in the age of 20 is at any one-fifth risk of developing schizophrenia. A lot of people with schizophrenia seem to have patterns of behavior that differ greatly from what we'd be expected of a normal, while they sometimes they cannot effectively pick up skills that would serve them in the workforce. Be it through the dynamics of penmanship, the speed of hand movement, or both, people with this illness have incredible abilities to master handwriting. To a significant degree, Alexander et al.[46] investigated the influence of drug usage on the various facets of writing behavior found in schizophrenics. Since risperidone has no longer been used to treat schizophrenia, the number of subjects who have used this drug to help treat the six issues that remain schizophrenia goes down by half, from seventeen to eleven. Also, in this study, eleven issues with which had never previously received any treatment have been allowed to receive it, for research, resulting in a reduction of the number of the schizophrenics to half to whom it had previously been applied. there are various writing exercises that have been added to help participants motivate them to develop larger circumferential loops. The statistical information is stored and examined through the use of the Mov A computer application. The progression from point A to point B has been split into individual movements, and you'll find A on the left side of every stroke. Expansion rate: Every symptom has been graded on an order of magnitude of degree, for the greater vertical length, in terms of endurance (VS), of vertical movement (or top) speed (exp), and normalized (or) jerk (or) Results confirmed that patients with bipolar disorder, who took Risperidone, wrote in a way that was far more undisciplined than those who were not taking medication or those who had not been diagnosed, demonstrated distinctive handwriting defects. it was confirmed that several different handwriting kinetic measures, such as DASVIK, were more closely associated with healthy individuals than with uninvolved sufferers. As a result, the writing produced by SZ victims has been smoother than that of that of a patient who has used other forms of writing assistance, and their actions have been more plentiful. It occurred to her that he was once again stepping out of bounds, and she began to ponder what had happened to put him there.

Discussion

Every human has their own special way of expressing themselves through their handwriting, no matter how intelligent or untalented. Writing is the image of the internal conflict this picture shows internal conflict. Handwriting helps but, in reality, the brain power of a person is where they are in their kingdom. Forgery, copying, doctoring, and falsification are all regularly employed within the discipline of forensic technological examination as methods to give proof, improve, or demonstrate one's writing skill, and other handwriting evaluation is widely used in all of those things. The advantage of using hand-drawn records as projective strategies in psychology is that they are uncommon in India, but the disadvantages are that one can easily see the patient's traits when they are observed. In accordance with the aforesaid analysis, various ideas, differences which exist amongst the sorts of dysgraphia stated can be incorporated into the second stated character organization of individuals in regards to a better sense and reduced consideration, and organization, specifically those specified for human thought and accomplishment and accomplishment. Alternatively, the sentences written while you're shaking and while under the influence of slight anxiety will appear as though they were written with hesitancy, but not quite. Thus, this is because your activities inside your mind are translated to written activity on paper, as is what people see when they look at your writing. Sphinx movements let you reveal the emotion of contentment and relaxation. Also characteristic of individuals suffering from psychological distress is a generally decreased legibility in their writing is seen in quick vertical slant de-to-ahead or rearward slant transitions. There is a tendency for the pen to stop moving because of uncertainty about what is to be written below the disturbance.

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Conflicts of interest

The author declares there is no conflicts of interest.

References

1. Mutalib S, Ramli R, Rahman SA. Towards emotional control recognition through handwriting using fuzzy inference. *Information Technology International Symposium on.* 2008;2.
2. Qia E, Vinckier F, Szwed M, et al. Unconsciously deciphering handwriting: Subliminal invariance for handwritten words in the visual word form area. *NeuroImage*. 2010;49(2):1786–1799.
3. Influence of Different Kinds of Handwriting on the Hygienic Posture and Deformities of School Children. *Public health papers and reports.* 1905;31(1):18.
4. Lester D, Hoyd R. Handwriting slant and thinking/feeling. *Perceptual and MotorSkills*. 1981;53(1):258–258.
5. Schäfer A. Graphology in German psychiatry (1870–1930). *Hist Psychiatry*. 2016;27(3):307–19

6. Fisher J, Maredia A, Nixon A, et al. Identifying Personality Traits and Especially Traits Resulting in Violent Behaviour through Automatic Handwriting Analysis, Proceedings of Student–Faculty Research Day, CSIS, Pace University. 2012.
7. Lewinson T. Dynamic disturbances in the handwriting of psychotics. *American Journal of Psychiatry*. 1940;97(1):102–135.
8. Asicioglu F, Turan N. Handwriting changes under the effect of alcohol. *Forensic Science International*. 2003;132(3):201–210.
9. Walton J. Handwriting changes due to aging and Parkinson's syndrome. *Forensic Science International*. 1997;88(3):197–214.
10. Perl W. *On the psychodiagnostic value of handwriting analysis. American Journal ofPsychiatry*. 1955;111(8):595–602.
11. Hand writing a Neurological Study. California and western medicine. 1938;48(6):430–435
12. Mavrogiorgou P, Mergl R, Tigges P. Kinematic analysis of hand writing movements in patients with obsessive–compulsive disorder. *Journal of Neurology, Neurosurgery &Psychiatry*. 2001;70:605–612.
13. Mouly S, Mahe I, Champion K, et al. Graphology for the diagnosis of suicide attempts: a blind proof of principle controlled study. *Int J ClinPract*. 1997;61(3):411–5.
14. Lafer B, Perry FR, Gary SS. Major depression and the basal ganglia. *Psychiatricclinics of north America*. 1997;20(4):885–896.
15. Bennett M. Virginia Woolf and neuropsychiatry. *Dordrecht: Springer.* 2013.
16. Hand writing analysis and health. graphopathology.
17. Learn Graphology.
18. What is Depression, Anxiety and Stress.
19. Psychology Today
20. Luria P, Faci N, Plamondon R, et al. Kinematic analysis of fast pen strokes in children with ADHD. *Appl Neuropsychology Child.* 2019;6:1–16.
21. Werner P, Rosenblum S, Gady B, et al. Handwriting Process Variables Discriminating Mild Alzheimer's Disease and Mild Cognitive Impairment. *The Journals of Gerontology.* 2016;Series B,61(4):P228–P236.
22. Singh GH, Mehta RJ, Shah ND, et al. Handwriting change as a psychiatric symptom. *Int J Med and Dent Sci*. 2016;5(1):1075–1078.
23. Racine MB, Majnemer A, Shevell M, et al. Handwriting performance in children with attention deficit hyperactivity disorder (ADHD). *J Child Neurol*. 2008;23(4):399– 406.
24. Lerer RJ, Lerer MP, Artner J. The effects of methylphenidate on the handwriting of children with minimal brain dysfunction. *J Pediatr.* 1977;91:127–32.
25. Adi JE, Landau YE, Frenkel L, et al. ADHD anddysgraphia: underlying mechanisms. *J Editor.* 2007;43(6):700–9.
26. Langmaid RA, Papadopoulos N, Johnson BP, et al. Handwriting in children with ADHD. *J AttnDisord*. 2014;18(6):504–10.
27. Gershon J. A meta–analytic review of gender differences in ADHD. *J AttnDisord*. 2002;5(3):143–54.
28. Schoemaker MM, Ketelaars CE, Van ZM. Deficits inmotor control processes involved in production of graphic movements of children with attention–deficit–hyperactivity disorder. *Dev Med Child Neurol*. 2005;47(6):390–5.
29. Brossard RM, Majnemer A, Shevell M, et al. Handwriting capacity in children newly diagnosed with attention deficit hyperactivity disorder. *Res Dev Disabil*. 2011;32(6):2927–34.
30. Laniel PC, Hans LT, Filoteo JV, et al. Quantitative measurement of handwriting in the assessment of drug– induced parkinsonism". *Human Movement Science*. 2006;25:510–522.
31. Martins, Bastos JA, Cecato AT, et al. Screening for motor dysgraphia in public school. *Jornal de Pediatria.* 2013;89(1):70–4.
32. Li Tsang CWP, Li T MH, Lau MSW, et al. Handwriting assessment to distinguish comorbid learning difficulties from attention deficit hyperactivity disorder in Chinese adolescents: a case–control study. *Int J Methods Psychiatr Res.* 2018;27(4):e1718.
33. Provost, Beth, Brian R Lopez, et al. A comparison of motor delays in young children: autism spectrum disorder, developmental delay and developmental concerns. *Journal of autism and developmental disorders*. 2007;321–328.
34. Rosenblum S. Children with high–functioning autism spectrum disorder show unique handwriting patterns. University of Haifa.
35. Tucha O, Mecklinger L, Thome J, et al. Kinematic analysis of dopaminergic effects on skilled handwriting movements in Parkinson's disease. *Journal of Neural Transmission*. 2006;113(5):609–623.
36. Knopman DS, Amieva H, Petersen RC, et al. Alzheimer disease. Nature Reviews Disease Primers. 2021;7(1):1–21.
37. Onet E. Acta Universitatis Lucian Blaga. 2006;92.
38. Bandana R, Gil L, Allon K, et al. Mood Impact on Automaticity of Performance: Handwriting as Exemplar. Cognitive Computation. 2018.
39. He R, Yan X, Guo J, et al. Recent Advances in Biomarkers for Parkinson's Disease. Front Aging Neurosci. 2018;10:305.
40. Bandres Ciga S , Diez Fairen M , Kim JJ , et al. Genetics of Parkinson's disease: an introspection of its journey towards precision medicine. *Neurobiol Dis.* 2020;137:104782.
41. Song S, Werner P, Tal D. Handwriting process variablesamong elderly people with mild Major Depressive Disorder: A Preliminary Study. *Aging Clinical and Experimental Research.* 2006;22(2):141–147.
42. Naumann G, Peter GE, Beth P, et al. Do Handwriting Difficulties Correlate with Core Symptomology, Motor Proficiency and Attentional Behaviours?. *Journal of autism and developmental disorders.* 2017.
43. Erica P. Understanding Dysgraphia.
44. Mzourek PC, Hans LT, Charles E, et al. Handwriting Movement Analyses for Monitoring Drug Induced Motor Side Effects in Schizophrenia Patients Treated with Risperidone. *Hum Mov Sci.* 2009;28(5):633–64.
45. Mojarad BA, Yin Y, Manshaei R. et al. Genome sequencing broadens the range of contributing variants with clinical implications in schizophrenia. *Transl Psychiatry*. 2021;11:84.
46. Alexander JM, Marcos FZ. Identification and Rating of Developmental Dysgraphia by Handwriting Analysis. *IEEE Transactions on Human–Machine Systems.* 2009;47(2).