

# A Comparative Analysis of Handwriting Characteristics Using Different Writing Instruments: A Statistical and AI-Based Analysis

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**Abstract: Background:** Handwriting is a complicated motor skill that is influenced by physiological and instrumental variables. The variations generated through the application of various writing tools may have a significant impact on the forensic examination and comparison of handwriting. The aim of the study is to comparatively analyze the specifics of handwriting drawn with the help of various writing tools, both with the help of statistical and AI-supported methods to identify the features, which are similar or different depending on the writing tool. **Materials and Methods:** A total of 180 handwriting samples were collected out of 60 individuals by using three different writing instruments i.e., ballpoint pens, gel pens, and fountain pens, while keeping a standardized writing position and surface constant. The handwriting features that were examined in this study included slant, alignment, letter size, fluency, spacing, and pen pressure. One-way ANOVA was done ( $p < 0.05$ ) to statistically analyze the data, and analysis of handwriting with AI was conducted to validate the data. **Results:** The one-way ANOVA test showed that there was no significant difference in the slant and alignment ( $p > 0.05$ ), it implies that both of these are habitual traits and they do not vary depending on writing instrument. Significant variations ( $p < 0.05$ ) were observed in letter size, fluency, spacing, and pen pressure. The results showed that gel pens have the most consistent handwriting, ballpoint pens have variations based on pressure-dependent ink flow, and fountain pens have moderate variations based on nib sensitivity. **Conclusion:** The combined statistical and AI analysis of handwriting confirms that writing instruments can significantly affect the handwriting characteristics, but some intrinsic properties remain consistent.

**Keywords:** Handwriting, Writing Instruments, Handwriting Characteristics, Handwriting Analysis, Statistical Analysis, Artificial Intelligence,

## Introduction

The term handwriting is usually used to denote a person writing using a pen or a pencil. The comparisons of hand writing are based on the principles that all the writers are not completely same and that not two writers write in the same style though there are features that recur in all the work of a writer. Document examiners compare this set of features, which are individual to each person. [1,8] Handwriting is an acquired skill that is certainly a difficult perceptual motor activity, sometimes known as a neuromuscular task.[2] In order to communicate with another person, handwriting is the construction of letters, characters, or symbols with a writing instrument in a recognized pattern.[3] Handwriting is a complex procedure that takes most people many years to master. Only with time can one achieve the synchronization of arm-to-hand-to-finger movements required for what is roughly referred to be literate handwriting.[4] There are several things that can influence how well someone's handwriting develops. Once handwriting is established, elements in the writing process can influence and create changes in an adult's handwriting. Under unstable situations, a variety of factors can have an impact on handwriting. Writing with unconventional writing implements on unusual surfaces like walls, windows, mirrors, and furniture These circumstances can cause variances in handwriting.[5]

Forensic studies of handwriting found on weird surfaces are rarely straightforward for investigators. This is mostly because an individual's handwriting pattern varies with the surface. Furthermore, criminals often modify handwriting evidence in attempt to avoid detection.[6] Various short factors, in addition to education level, affect handwriting. These factors can be both physical, such as writing surfaces and writing instruments, as well as psychological or emotional ones. Changes due to psychological conditions are very different from those caused by physical factors, such as surfaces, pens, and paper. [7,9]

## background of the study

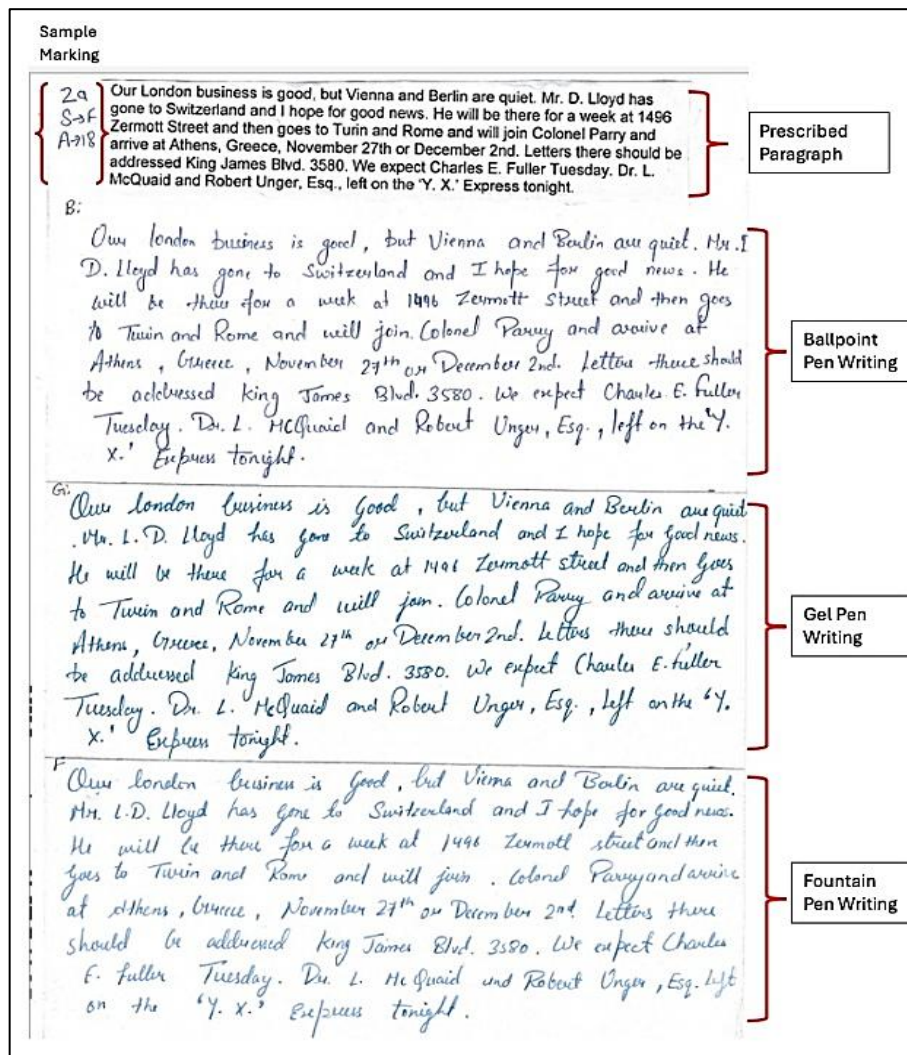
Kaur A. (2022) investigated the impact of unconventional surfaces and unorthodox writing devices on handwriting. Even though these influenced stroke patterns, line quality and consistency, they did not affect variables, simple features like shape and size of letters were maintained. The study indicates the importance of consideration of surface, writing position, and instruments, and position in forensic handwriting examination to achieve valid findings relating to authorship and document validity.<sup>[10]</sup> Threja et al. (2019) observed the influence of different writing surfaces and writing tools on handwriting. An analysis of samples comprising 30 participants showed that the production of strokes, the quality of lines, and legibility were largely influenced. The study underlines the necessity of them being considered by forensic investigators when assessing the validity and origin of handwriting on non-standard surfaces. <sup>[11]</sup> Pandey et al. (2018) examined the influence on handwriting produced by different writing instruments. They found that ball pens were used to get uniform lines, gel pens offered a comfortable writing experience and were inconsistent in the flow of the ink, and fountain pens influenced the line thickness and the speed of writing. The study shows that consideration of writing instruments is important in improving handwriting skills and quality of writing experience in learning institutions.<sup>[12]</sup> The study of the effect of writing tools using pens, pencils, markers, and digital styluses on the quality of handwriting was conducted by Ambasana and Bhatti (2014). They have found that gel and ballpoint pen improve handwriting more than fountain pens but not any of the tools improve handwriting significantly among boys. The study is essential in highlighting the need to select an appropriate writing tool to enhance learning and handwriting.<sup>[13]</sup> Van Drempt et al. (2011) discovered that neurological and orthopaedic disorders influence handwriting among healthy adults above 65 years of age. They underscored that handwriting tests and retraining should be done to compensate for the handwriting variation, particularly for tasks prevalent among elderly people. The authors recommended increased research using an expanded, more representative population to further solidify these observations.<sup>[14]</sup> Summers and Catarro (2003) learned that brief duration handwriting speed tests fail to correlate with examination performance in university students. They described that variables such as pencil grip, pain, and academic proficiency influence writing output and speed. The research proposed that employing a dynamic pencil grip would enhance writing speed and suggested further investigation on dysfunctional groups in both timed and untimed tests.<sup>[15]</sup>

There are several approaches made to correlate certain writing characteristics with the writing instruments, skills of writing, age of the writer and impact on writing characteristics, however, more research is needed when it comes in the context of forensic works where numerous writing instruments have been used to create a disputed document and other writing instrument is being used while providing the admitted or the specimen writing.<sup>[16,17]</sup> Therefore, this study was conducted with an objective to study and evaluate the impact of different writing instruments on an individual's handwriting. An attempt has also been made to study the changed and unchanged features in the handwriting while changing the three most commonly used writing instruments i.e. Ballpoint pen, Gel-pen, and Fountain pen.

## materials and methods

For the study a total of 180 handwriting samples in English language (format of "London Letter") were collected from 60 individual with three different writing instruments viz. Reynolds Ballpoint pen, Reynolds Gel pen, and Reynolds Fountain pen. The samples were collected in the same comfortable sitting position. The samples were collected on plain A4 size paper as shown in Figure. 1.

Figure 1: A Sample collected from an individual with three different writing instruments (Ball point pen, Gel pen, and Fountain pen) in comfortable sitting position.



The samples were analyzed for similarities and differences in handwriting characteristics using a Magnifying glass, Digital Microscope (100x – 1000x), 310 HP Printer scanner, PC System (LAPTOP-8T4219P6 Windows 11) and Visible light source.

For the statistical component, a single-factor ANOVA was employed to determine whether there were any significant differences in the handwriting characteristics based on the type of pens used. The null hypothesis (H0) was that there was no significant difference in a particular characteristic based on the type of pen, while the alternative hypothesis (H1) was that at least one type of pen was responsible for the significant difference. The significance level was set at  $p < 0.05$ . The calculations of the F-values, p-values, and critical values were carried out using Microsoft Excel.

In addition to manual and statistical analysis, the use of AI-based handwriting analysis was conducted using ChatGPT and Meta AI Vision. The software analyzed the scanned images to determine

the smoothness of strokes, ink density, spacing, and consistency of the base line. This analysis was conducted to verify the results of the statistical analysis and to support the observations made by the examiners. The use of both statistical and AI analysis improved the accuracy of the results.

#### RESULTS

The samples were examined for different class characteristics like writing slant, writing alignment, letter size, fluency, relative spacing between letters, pen pressure, and other specific individual characteristics that are may or may not be subconsciously altered while using different writing instruments.

After a detailed study of all the handwriting samples collected from different writing instruments, the statistical result was obtained for checking the significance or otherwise between the similarities and dissimilarities in the writing characteristics as mentioned above in the analysis by using “ANOVA Single Factor” shown in Tables 1, 2, 3, 4, 5 and 6. ChatGPT and Meta AI was also used to help recognize patterns in order to perform objective comparisons between handwriting characteristics under different conditions.

#### Statistical Analysis (ANOVA)

Table 1 reveals that the calculated p-value of slant due to writing instruments is greater than 0.05, so accepting the null hypothesis concludes that there is no significant variation due to the different writing instruments. Hence, changing writing instrument have no impact on writing slant

**Table 1: Anova result of writing slant variations due to different writing instruments**

Source of Variation	SS	d f	MS	F	P-value	F crit
Between Groups	0.07 7778	2	0.03 8889	0.07 3619	0.92 9054	3.04 7012
Within Groups	93.5	1 77	0.52 8249			
Total	93.5 7778	1 79				

Table 2 reveals that the calculated p-value of alignment due to writing instruments is greater than 0.05, so accepting the null hypothesis concludes that there is no significant variation due to the writing instruments. Hence, changing writing instrument have no impact on writing alignment

**Table 2: Anova result of writing alignment variations due to different writing instruments**

Source of Variation	SS	d f	MS	F	P-value	F crit
Between Groups	3.43 3333	2	1.71 6667	2.35 9695	0.09 7414	3.04 7012
Within Groups	128. 7667	1 77	0.72 7495			
Total	132. 2	1 79				

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Table 3 reveals that the calculated p-value of letter size due to writing instruments is less than 0.05, so rejecting the null hypothesis concludes that there is significant variation due to the writing instruments. Hence, changing writing instrument have impact on writing letter size

**Table 3: Anova result of writing letter size variations due to different writing instruments**

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.63 3333	2	1.81 6667	6.02 5297	0.00 2941	3.04 7012
Within Groups	53.3 6667	77	0.30 1507			
Total	57	79				

Table 4 reveals that the calculated p-value of fluency due to writing instruments is less than 0.05, so rejecting the null hypothesis concludes that there is significant variation due to the writing instruments. Hence, changing writing instrument have impact on writing fluency

**Table 4: Anova result of writing fluency variations due to different writing instruments**

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	85.3 4444	2	42.6 7222	320. 4943	1.47 E-59	3.04 7012
Within Groups	23.5 6667	77	0.13 3145			
Total	108. 9111	79				

Table 5 reveals that the calculated p-value of spacing between letters due to writing instruments is less than 0.05, so rejecting the null hypothesis concludes that there is significant variation due to the writing instruments. Hence, changing writing instrument have impact on writing spacing between letters

**Table 5: Anova result of writing spacing between letters variations due to different writing instruments**

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11.0 7778	2	5.53 8889	18.6 9177	4.32 E-08	3.04 7012
Within Groups	52.4 5	77	0.29 6328			
Total						

Total	63.5 2778	1 79				
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Table 6 reveals that the calculated p-value of pen pressure due to writing instruments is greater than 0.05, so rejecting the null hypothesis concludes that there is significant variation due to the writing instruments. Hence, changing writing instrument have impact on writing pen pressure

**Table 6: Anova result of writing pen pressure variations due to different writing instruments**

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.033 333333	2	0.016 666667	1.011 428571	0.365 791185	3.047 012139
Within Groups	2.916 666667	1 77	0.016 478343			
Total	2.95	1 79				

#### AI- Assisted Analysis

**Slant:** All three writing instruments had a right slant, typical in normal handwriting. The gel pen had the most stable slant, showing stable wrist control. The ballpoint pen had instabilities, perhaps because additional pressure was needed for the ink to flow. The fountain pen had random slant fluctuation, perhaps from readjusting the position of the hand to accommodate the sensitivity of the nib.

**Alignment:** Handwriting with gel pen exhibited best baseline alignment with least wavering, reflecting smooth hand movement and good control. Handwriting with ballpoint pen resembled to a certain degree drift, particularly towards the end of lines, possibly due to the difference in pressure or fatigue. Fountain pen writing had worst stability of alignment with moderate fluctuation along the baseline, which could be due to variation of grip or writing angle.

**Letter Size:** The most stable was the letter size in the case of gel pen samples, which implied high motor control. Ballpoint pen samples qualified as relatively consistent and in some cases sizes varied meaning that they were controlled moderately. The samples of fountain pens were bigger and more unstable in size, perhaps because the fountain pen has free flowing ink and low pen resistance to the paper.

**Fluency:** The gel pen produced the most natural flow of writing strokes that were smoothest. Writings involving a ball point pen were slower and with interruptions or pauses occasionally, as this writing used mechanical pressure to dispense the ink. The fountain pen provided generally fluid lines, although disrupted occasionally, possibly by interrupted flow of ink or the necessity to keep at an ideal writing position.

**Spacing Between Letters:** The writing of gel pens was spaced and evenly spaced to facilitate readability. The script written with a ballpoint pen was nearly close but readable, maybe due to the necessity of some movement in order to keep the ink flowing. The spacing of samples of fountain pens

was most uneven, and the wide and narrow spacing alternated, possibly owing to the sensitivity of the pen to hand pressure and movement.

Pen pressure: The ball pens needed and had moderate and constant pressure with minimal variation. Gel pens were moderate and steady pressure, and the lines were easy to make and rich. The fountain pens had light and erratic pressure—some spots darker as a result of concentrated ink, and others less dark because of slight contact of the nib or change of position.

## Discussion

The study highlighted the impact of certain writing tools—ballpoint, gel, and fountain pens—on handwriting characteristics and the results were based on statistical (ANOVA) and AI-based analysis. Statistical analysis showed no significant variation of slant and alignment according to pen type, i.e., such characteristics inherent in the motor memory of the writer and does not depend on the writing instruments. This suggests that regardless of whether individuals use a ballpoint pen, gel pen, or fountain pen, their writing tends to maintain a consistent slant as an unaffected characteristic feature.<sup>[18]</sup> This may be due to the subconscious writing habit deeply embedded in the brain that commands the movement of hand in a particular fashion while holding the writing instrument using the same fingers and positions.<sup>[19]</sup> This implies that individuals maintain consistent alignment in their handwriting regardless of the type of pen they use. The handwriting tends to flow in the same direction of the alignment in respect to the baseline on the writing medium.<sup>[20]</sup> Likewise, AI-based examination also supported this finding and revealed that for all the pens inspected, alignment and slant were quite invariant. Computer-based verification established strokes' inclinations and alignment with the baseline were quite insensitive to the instrument change and, as such, agreed closely with the findings from statistics.

But regarding the letter size, fluency, letter spacing and pressure, the ANOVA test and the AI inspection showed that there was a significant difference according to the pen type. Statistically, all these factors achieved p-values lower than 0.05 which implies that pen type provided an explanation to the differences in writing of these features by people in their handwriting. The ballpoint pen was extremely pressure-sensitive when it came to the flow of ink and therefore prone to variation in fluency and pressure, which was confirmed by AI inspection, which mentioned inconsistent line quality and inconsistent pressure distribution. High consistency in the size, fluency and spacing of lettering was very evident in the gel pen, which in any case had a smooth delivery and low friction of the ink. These characteristics were confirmed through AI inspection, and easy transfers of ink, uniform spacing and strokes, and no hard work were needed, which is in line with the statistical results of high performance. The fountain pen exhibited average variation. While it produced visually smooth and bold writing, the AI inspection reported sporadic variation in spacing and letter size, most likely due to pen angle and grip sensitivity. Statistically, this was verified by notable differences in these categories, though less extreme than for ballpoint pens.

With respect to letter size, the research shows that it is possible to control the size of letters produced by a change in the writing instrument. Point load as a directional factor can be responsible for letter size and letter shading.<sup>[21]</sup> Smoothness of the friction between paper and pen subconsciously directed an individual towards the flow and hence allowed an individual to unusual variation in the letter size without changing the nature of the letter.<sup>[22]</sup> Further, tip size of the pen can also be another

probable reason for this phenomenon. This result points towards the fact that individuals subconsciously adjust the size of the letter depending upon the type of pen. For instance, a big tip on the marker will lead to further expansion of the letter size.<sup>[23]</sup> Similarly, variations in letter spacing were

also observed, indicating that such handwriting features are founded on the nature of the writing tool being utilized. People are able to change the distance between the letters that are forced onto the pen depending on the specifics of the pen they are using. Overall, the combination of statistical analysis and AI-based handwriting analysis of the handwriting characteristics gives a full view of how writing instruments affect the handwriting characteristics. The overlap of both the approaches, i.e. finding the characteristics that are not affected and those that are, makes the findings more valid and emphasizes the ability to combine both quantitative and AI-based approaches in forensic handwriting analysis.

## Conclusion

The current study presents a thorough comparison of the handwriting characteristics produced by ball point pens, gel pens, and fountain pens both through statistical analysis (ANOVA) and by artificial intelligence (AI) analysis. The findings reveal that, despite the fact that some of the handwriting characteristics, including slant and alignment, are habitual and constant, other characteristics such as the size of the letters, fluency, the distance between letters, and the pressure exerted by the pen are significantly influenced by the type of pen that is used. The handwriting produced by gel pens was the most regular and consistent of the three pens due to the even flow of the ink and low pressure.

The image processing approach by using AI and the traditional forensic analysis allowed resolving the issue of how to increase the detection of subtle differences and quantified the visualization of differences in features. This method of analysis gives the objectiveness of handwriting analysis strength.

Forensically, the value of the study is that it highlights the need to distinguish between intrinsic (writer-specific) and extrinsic (instrument-dependent) attributes of handwriting as the means of copyright verification. The study results can be used to develop more standardized approaches to the study of forensic document examination.

Future studies could be conducted to extend this model by incorporating various writing postures, surfaces, and machine learning classifiers for automated authorship prediction.

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## Conflicts of interest

There are no conflicts of interest

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