

Surface-Induced Handwriting Variation: A Quantitative Forensic Study under Unconventional Writing Conditions

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Abstract:

Handwriting is a combination of class and individual characteristics influenced by multiple internal and external factors which is known as Natural variation. This research analyzes the variations in handwriting characteristics when written under different writing surfaces. A total of 700 handwriting samples were collected from 70 individuals (35 males and 35 females) on conventional surfaces and experimental conditions on unconventional surfaces such as walls, laps, tables, and blankets. The class characteristics of the handwriting samples were examined for changes in the characteristics like slant, tremors, movement, retouching, alignment, and other handwriting features using statistical analysis such as ANOVA and t-test, which shows a significant differences in key handwriting characteristics, particularly in tremors, movement, and retouching, while slant showed minimal variation across different surfaces. The study concludes that writing surfaces influence handwriting stability and movement control, supporting the forensic principle of handwriting examination of Natural variation and it must be carefully considered during document examination. This research contributes to forensic handwriting analysis by providing scientific evidence on how writing conditions affect handwriting features, aiding forensic experts in distinguishing natural variations from potential forgeries.

Keywords: Handwriting, Lap, Natural Variation, Anova Software, Unconventional Surfaces

Introduction

Forensic handwriting examination is founded on the principle of natural variation, whereby a writer's script exhibits fluctuations while retaining identifiable consistency (1). External writing conditions particularly writing surfaces are known to influence motor control, yet their quantitative forensic impact remains under-explored (2,3). Existing studies largely rely on qualitative observations or small sample sizes, limiting courtroom defensibility. By doing so they can extract significant information determining whether the note has been faked and identifying the author who likely wrote it. A Forensic Document Examination (FDE) could determine whether a person's life or freedom will be changed significantly by its results; it can even decide their fate. An FDE (Forensic Document Examiner) may be called upon in court to provide critical replies or information that shall help judges/ juries make decisions regarding issues of authorship and authenticity. However, this document refers to recent studies that have highlighted growing concerns over how human factors and evidence may inadvertently influence forensic examinations, particularly handwriting examinations. Handwriting of an individual consists of several signs or marks, which may be alphabets, words, signatures or initials, digits or figures written in some script or non-script (3). It is usually written with hands but people who cannot write with their hands, write with holding a writing instrument with mouth or foot, in that case also the writing is called handwriting (3). The basic concept in forensic document examination – no two people write the same way. Continuous variation refers to the natural variation in a person's handwriting. In terms of neither internal nor external causes, this change in a person's handwriting is known as natural variation (4). Various influencing factors have resulted in each individual having their own unique penmanship. When it comes to writing instruments like pens, pencils, markers and crayons that we would want to use, they have a significant influence on our handwriting too (5,6). Pencils can produce different degrees of shading and thickness depending on pressure, but pens, with their controlled ink flow, typically produce more uniform and consistent lines. Bold strokes produced by markers often affect letter spacing and formation. These tool-induced quirks become especially relevant during forensic investigations, allowing professionals to distinguish between true differences originating from individual writing habits and those resulting from the use of various writing tools(7,8).

This study addresses this gap by systematically quantifying surface-induced variation in handwriting class characteristics using a large dataset and statistical validation. The aim is to clarify which handwriting features are most susceptible to surface effects and which retain higher evidentiary stability. We

hypothesized that Unconventional writing surfaces would produce statistically significant increases in tremors, retouching, and movement variability compared to table writing.

Materials and Methods

Handwriting samples were collected from total 70 healthy adults (35 males, 35 females; age 21–30 years). Each participant provided standard writing samples under conventional conditions in proper seating position and specimen samples were taken under three unconventional surfaces conditions: wall (vertical), lap, and blanket (soft substrate). A total of 700 handwriting samples were collected.

“All the collected samples were individually scored by two trained forensic examiners blinded to writing surface; inter-examiner agreement exceeded acceptable forensic thresholds.

The collected samples were written using a standardized blue ballpoint pen to control for instrument variability. Class characteristics assessed included slant, tremors, movement, and retouching, scored using established forensic examination criteria. Statistical analysis was performed using one-way ANOVA with significance set at $p \leq 0.05$.

Handwriting characteristics were scored using predefined categorical scales adapted from standard forensic handwriting examination guidelines, with operational definitions established prior to analysis.

Results

Statistical findings shows surface to characteristics variation in several handwriting features. Characteristics like Tremors, movement, and retouching showed highly significant differences with respect to writing surfaces ($p < 0.001$), with large effect sizes. Writing on walls and blankets produced increased tremor frequency, disrupted movement rhythm, and higher retouching incidence. Surface effects were large ($\eta^2 > 0.30$) for tremors, movement, and retouching. In contrast, slant showed no statistically significant variation between surfaces ($p = 0.253$), indicating relative stability despite altered writing condition. Wall surfaces primarily affected movement, while soft surfaces such as blankets increased tremor-related instability.

Combined ANOVA Mean Scores of Handwriting Characteristics Across Surfaces

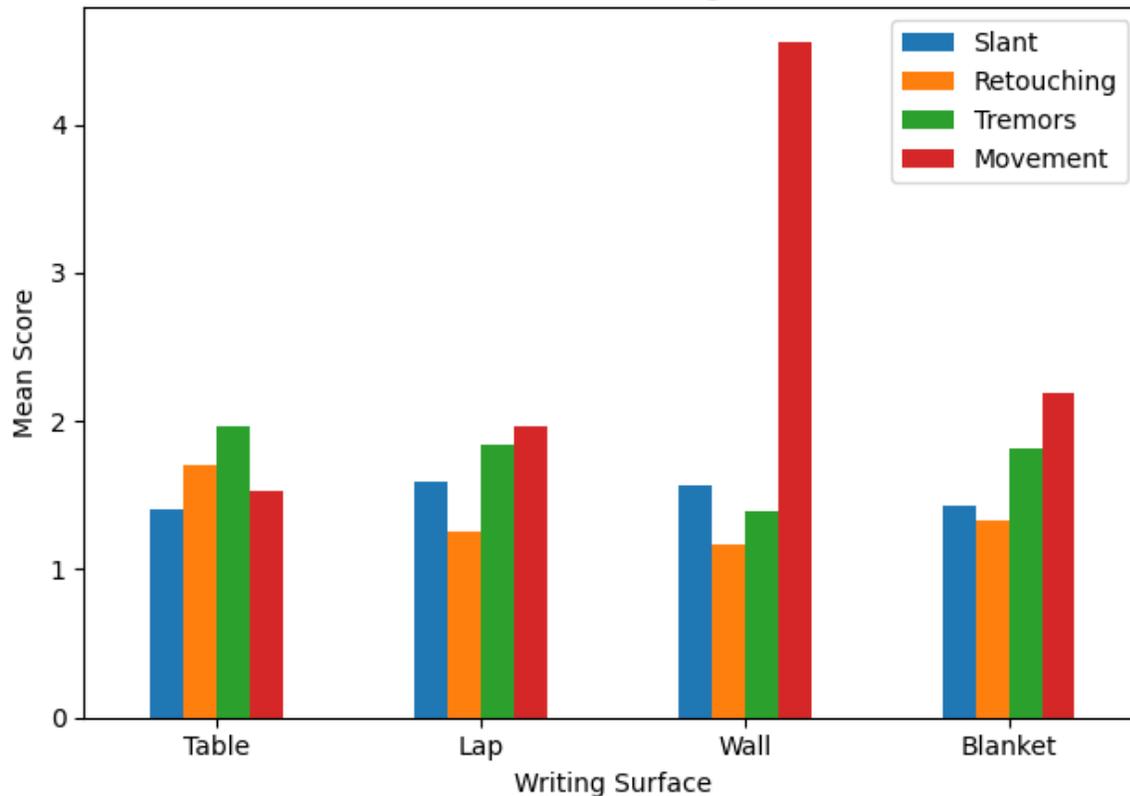


Figure 1: Anova Mean score of handwriting characteristics across surface.

Based on the ANOVA results, the combined chart shows that slant remains nearly uniform across all writing surfaces, visually confirming the non-significant ANOVA outcome ($p = 0.253$), whereas retouching exhibits clear surface-wise variation with the lowest values observed on the wall, supporting a statistically significant ANOVA result. Tremors display a marked increase when writing on the table and lap and a sharp reduction on the wall, indicating a highly significant surface effect, while movement is extremely elevated on the wall compared to other surfaces, reflecting a very large effect size ($p \ll 0.001$).

Discussion

The findings confirm that unconventional writing surfaces substantially affect handwriting stability-related features, primarily due to altered motor control, reduced support, and changes in writing posture. Increased tremors and disturbed movement observed on vertical and soft surfaces should therefore be interpreted cautiously in forensic casework. Importantly, the relative invariance of slant suggests its continued value as a comparative feature under variable writing conditions. Although, the study is limited by a restricted age range and the absence of pathological or elderly writers, which should be addressed in

future research. These results reinforce the necessity of contextual assessment in handwriting examination and provide quantitative evidence supporting examiner discretion when unconventional writing circumstances are indicated. Overall, this research is particularly useful because it condenses four separate ANOVA tables into a single, easily interpretable figure, making it ideal for inclusion in the results section as a “Combined ANOVA Mean Comparison” figure, for conference or poster presentations, and for forensic interpretation by clearly distinguishing handwriting characteristics that are highly surface-sensitive from those that remain relatively surface-stable. This observation supports the finding of Mohit Thareja ,which was that there will be some change in the characteristics of handwriting whenever we are writing in unsuitable conditions and while writing with different writing instruments(9). Furthermore spacing between the words shows the deviation in the handwriting while writing on an atypical surface like a wall and with different writing instruments. It shows the non-uniformity of spacing whenever we are writing on an unusual surface. The observation supports the finding of Amanpreet Kaur, that there is a significant change in handwriting characteristics while writing on atypical surfaces or different writing instruments (10).

Forensic Implications

From an evidentiary standpoint, instability features such as tremors, disrupted movement, and retouching should not be automatically attributed to forgery or disguise without considering surface context. Conversely, features demonstrating surface resistance may carry greater discriminative weight. This study strengthens the empirical basis for forensic handwriting opinions presented in legal proceedings.

Conclusion

This rapid communication provides statistically validated evidence that writing surfaces significantly influence key handwriting characteristics. By distinguishing surface-sensitive features from stable traits, the study enhances the scientific reliability of forensic handwriting examination and supports evidence-based interpretation of questioned documents.

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