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Forensic Examination of Multilingual Documents

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Abstract:- In forensic document examination, handwriting examination plays a key role, especially in the case of disputed documents. With multilingual population all across the globe, forensic experts are often challenged to examine and establish authorship in documents with multiple scripts. The main aim of the research is to determine if class and individual handwriting characteristics are sustained or altered whrn the same individual writes in two different scripts. Handwriting samples collected from individuals who are proficient in Hindi-English and English-German scripts are analysed in this research to compare handwriting characteriastics in multiple scripts within a multilingual context. For the study, 50 individuals provided handwriting samples in Hindi and English script, and 50 individuals provided samples in English and German script. The total 200 handwriting samples were collected from the bilinguals belonging to the age group of 18-55 years. Handwriting samples were analyzed manually for individual characteristics and class characteristics. Chi square test was applied to perform the statistical analysis, ensuring the accuracy and replicability of the results. The findings suggest that there are certain handwriting traits whoch remain stable across different scripts. The results also show that due to changes in letter formation, some individual traits may vary to a certain extent although some class properties remain the same. The research highlights the significance of inter-script comparison in forensic science casework, this research contributes to the growing field of forensic handwriting examination.

Keywords: *inter-script, multilingualis, handwriting comparision, forensic science, document examination, German, English, Hindi*

1. Introduction

One of the complex scientific art created by human beings is handwriting. It is an essential motor skill that takes years to learn. Handwriting requires learning of letter sizes and forms, which eventually become a sub-conscious habit with constant practice. [1,2] Because handwriting is based on neuromuscular coordination, every individual's handwriting is very unique. It is a process that involves physical movement on paper or any writing surface, as well as cognitive planning of information. [3] It is possible with the availability of a system that involves limb joints, angles, necessary torque, and muscle activity. [4]

Questioned document is one that bears marks, symbols, or signs, which require expert opinion to establish its legitimacy, origin, or potential alterations. [5] It focuses on the legal aspect and could also be define as an item which at some point during the judicial process becomes a point of concern regarding its authorship and authority. [6] Both perspectives highlight the significance of forensic document analysis regarding the authentication of written or printed materials. Forensic handwriting identification is based on simple concepts that distinguish between specific handwriting characteristics. [7] To determine the author, forensic document examiners look at peculiarities such as pen pressure, slant, spacing, strokes, etc. It involves applying the systematic analysis of handwriting, signatures, typewriting, printed documents, inks, materials, and other security features. To establish document integrity and aid in law enforcement, FDEs rely on manual examination of the documents along with digital imaging, spectroscopy, and microscopy. [8]

Many a times handwriting experts come across cases where handwriting samples are not available in the same script or content is written in multilingual format. In such cases, handwriting inter-script comparison makes it

possible to analyse handwriting samples. For determining authorship, forensic document examiners look for similar handwriting characteristics. Similar principal can be applied in the case of inter-script comparisons. Despite the potential of inter-script comparisons, there are a few issues, particularly with regard to the range of handwriting styles and the potential for disguise or simulation, which may make authorship conclusions much more challenging in some cases.

There are certain studies which increase the understanding of handwriting analysis across several scripts, by highlighting the viability of cross-script comparisons, the significance of regional handwriting traits, and the impact of multilingualism on handwriting features. In a study, where the class characteristics of Polish handwriting were analysed, supported the belief that the learned writing system had a huge effect on class characteristics. [9] Another study discussed the complexity of handwriting analysis in multilingual regions. It highlighted the importance of comprehensive investigation in multilingual forensic casework to aid the administration of justice by examining 50 documents in 10 Indian scripts. [10] The difference between Vietnamese and English Australian handwriting in order to find nationality-based handwriting features were identified and it turned out that this study found four essential features distinguishing these groups with a very good prediction accuracy using logistic regression and classification models. [11] In an another study, handwriting samples provided in Punjabi, Hindi, and English script were collected and analysed to examine the feasibility of inter-script handwriting comparison. The study also addressed the difficulties presented by script-specific differences while highlighting obvious characteristics that aid in writer identification. Curves and strokes, which are basic elements of handwriting, may help in identifying patterns in different scripts that may be written by the same author. [12] Handwriting characteristics such as direction of stroke and letter slant, though studied in primarily in relation to handedness may also offer critical insights that can aid in the examination of multilingual documents. [13]

2. Objective

This study aims to conduct a forensic comparison of multilingual handwriting samples, focusing on Hindi–English and English–German scripts from 100 individuals. It seeks to identify cross-script handwriting features, assess similarities and variations within a single writer, and establish reliable parameters to enhance forensic examination of multilingual documents.

3. Methods

The handwriting samples from the individuals who are bilingual and well-versed in scripts were collected with their consent.

Group A: For the collection of handwriting samples, participants wrote materials in both Hindi (Devanagari writing system) and English (Latin writing system) as shown in figure 1.

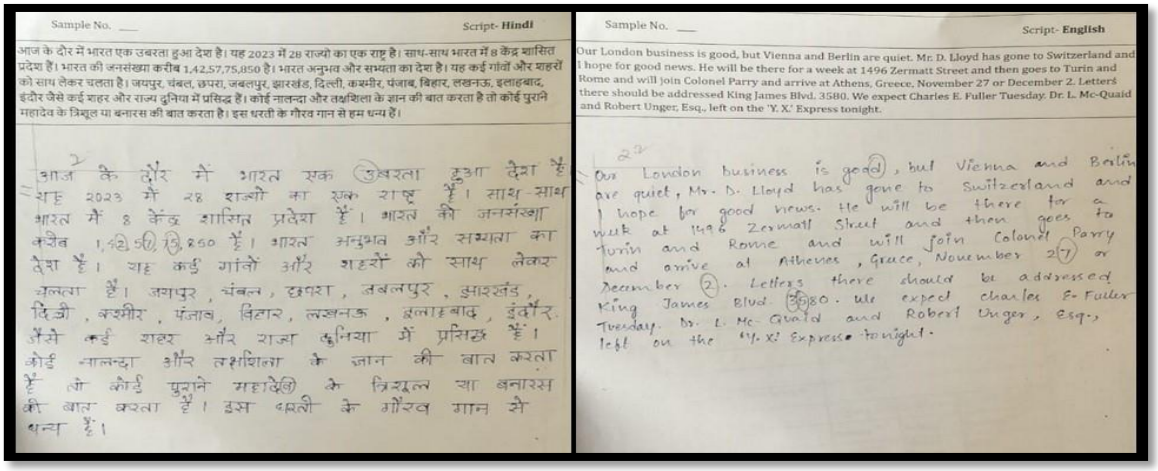


Figure 1: Samples Collected in Hindi and English Script

Group B: Participants provided handwriting samples in both German (Latin writing system) and English (Latin writing system) as shown in figure 2.

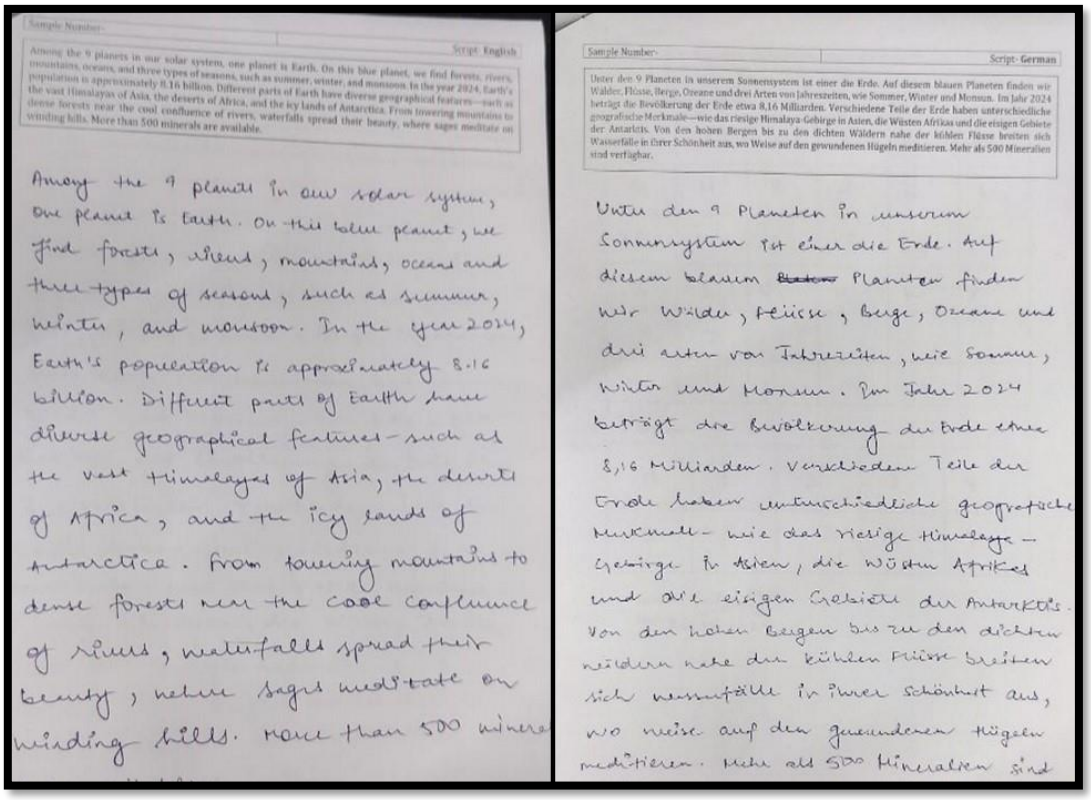


Figure 2: Sample collected in English and German Script

The inclusion criteria for both the group are given in Table 01 and Table 02 respectively.

Table 01: Inclusion Criteria for Group A

Inclusion Criteria for Group A (Hindi and English)	
Bilingual Volunteers	Proficient in Hindi and English script in terms of speaking, reading and -writing
Age	18-55 years
Region	North Indian Region

Table 02: Inclusion Criteria for Group B

Inclusion Criteria for Group B (English and German)	
Bilingual Volunteers	Proficient in English and German script in terms of speaking, reading and –writing
Age	18-55 years
Region	North Indian Region

Exclusion Criteria-

- Individuals who were not proficient in the required scripts

- Age limit beyond 18-55 years

Each group consisted of 50 individuals within the age group of 18-55years, belonging to North-Indian region and each one of them provided 2 samples in the respective scripts. Every participant provided their handwriting samples on A4 Size, un-ruled white paper sheet using ball blue pen. The volunteers were asked to write the content in the Performa which was given to them. Factors such as skill level, proficiency and educational level were considered. To minimize insignificant variables such as writing surface, pen type, and posture, the samples were collected under closely controlled conditions.

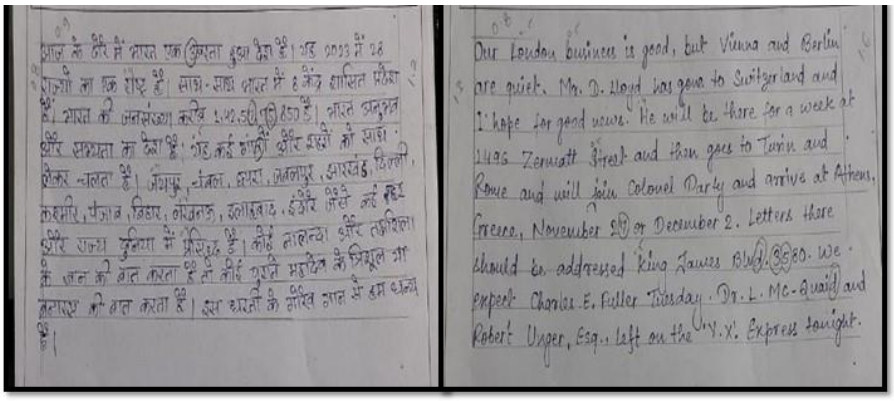
The handwriting samples were analysed manually. The frequency of similarity and consistency were recorded and Chi Square goodness of fit tests were applied to determine the statistical significance for basic 8 handwriting traits such as alignment, slant, speed etc.

4. Observations

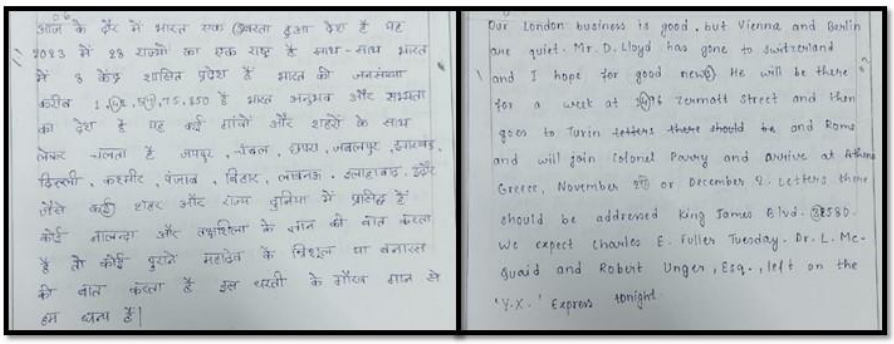
A total of 200 handwriting samples (100 bilingual pairs) were analysed manually. This analytical approach provides an organized framework for inter-script comparison of handwriting. The manual inspection of bilingual handwriting features is helpful for forensic handwriting analysis and authorship identification study because it gives an insight into the script-specific influences on handwriting characteristics. Patterns of consistency and divergence were found in the samples in the Hindi-English and English-German groups.

Hindi and English Writing Group A-

Each Hindi sample has been compared with the English sample of the same individual for class and individual handwriting characteristics. Similarities were seen in handwriting features among samples provided by the individuals in the both scripts such as pictorial appearance (including alignment, baseline, slant, rhythm, speed, margins, etc.) as shown in figure 3 and 4.



(a)



(b)

Figure 3: Similar Handwriting Characteristics found in Hindi and English Group Bilinguals

(a) shows similar alignment, baseline, slant, line quality among the samples written by an individual in different scripts,

(b) shows similar spacing

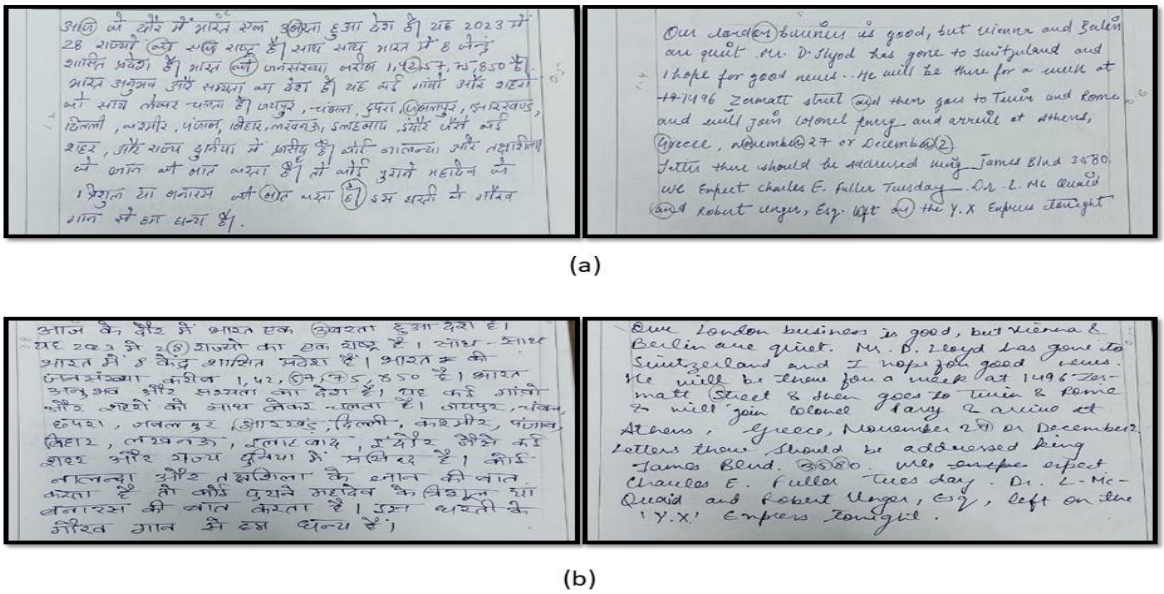


Figure 4: Similar Handwriting Characteristics found in Hindi and English Group Bilinguals

(a) shows similar margins

(b) shows similar ink deposition

During inter-script comparison, we observed that some people write Hindi letters in a way that resembles English letters and vice versa. The juxtapose shown in Figure 5, has images selected from multiple individual's samples.

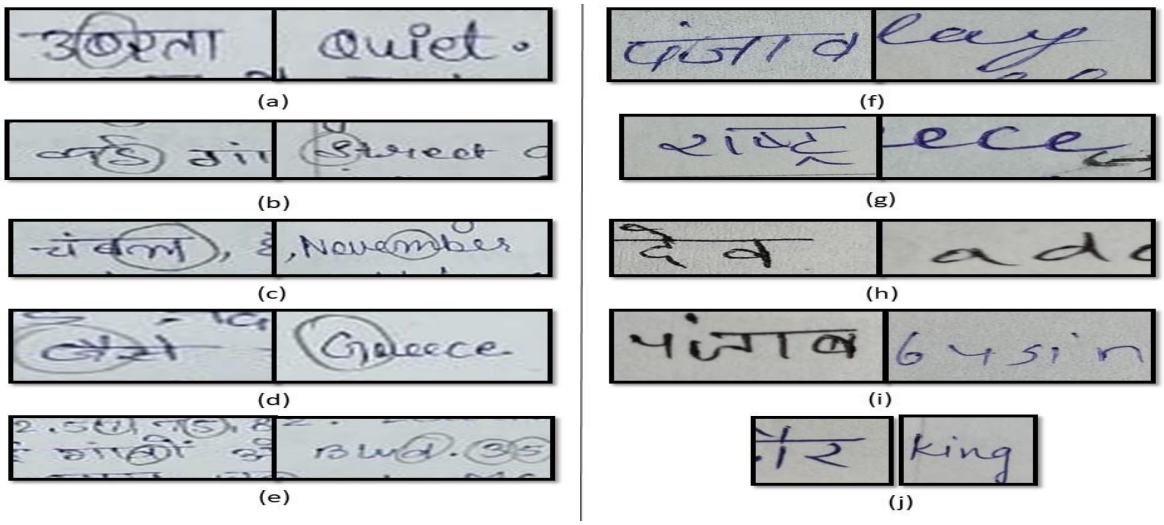


Figure 5: Similar Letter Formation among both the scripts

(a) Similarity between formation of "ब" and "Q" by a writer

(b) Similarity between formation of "ई", "इ" and "S" by a writer

(c) Similarity between formation of "ल" and "m" by a writer

(d) Similarity between formation of "ज" and "G" by a writer

(e) Similarity between formation of "व" and "d" by a writer

(f) Similarity between formation of "प" and "y" by a writer

(g) Similarity between formation of "ट" and "C" by a writer

(h) Similarity between formation of "व" and "a" by a writer

(i) Similarity between formation of "प" and "u" by a writer

(j) Similarity between formation of "र" and "K" by a writer

Many habitual characteristics such as direction of making Shirorekha and T crossing, incomplete letter formation, also showed varied range of similarity.

English and German Writing Group B-

The samples provided in English and German script by the bilingual participants, showed similarity and certain peculiarities in their handwriting. The Features such as Use of Z and Ẓ, Use of (..) Instead of (.), Disconnected letters, Stroke Consistency, Habitual Errors, Dominant Scripts, Word Structure, Letter length, Letter Style, Loops were observed as key parameters for individualities. As English and German follows the same writing system, the maximum similarity was seen in the overall appearance of the handwriting sample written by the same individual. Also characteristics such as alignment, slant, speed, rhythm, angularity were responsible for overall similarities depicted well in figure 6.

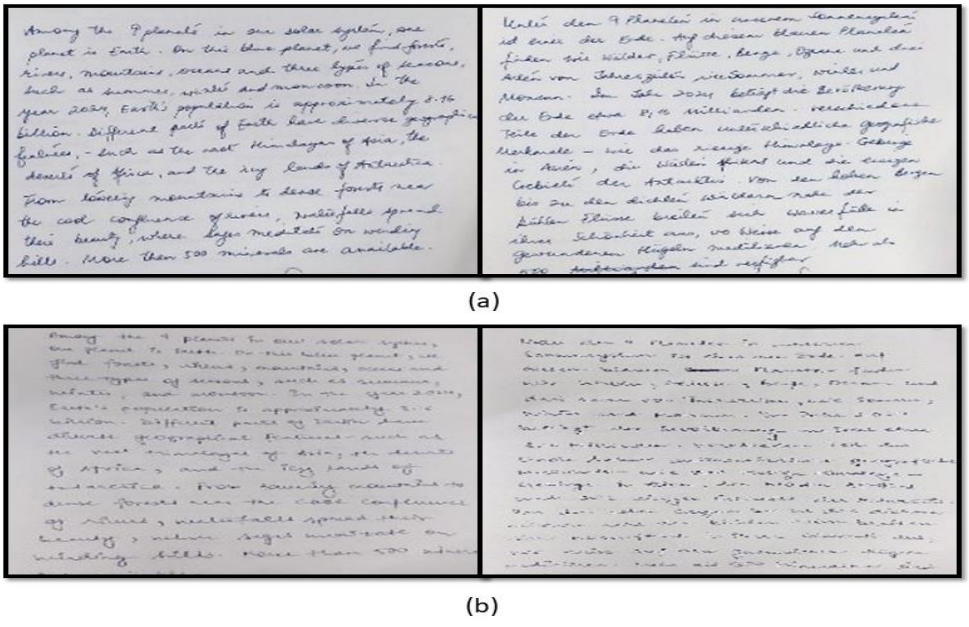


Figure 6: (a) and (b) shows similar pictorial appearance seen in English and German Group Bilinguals while performing inter-se comparison of their samples.

The overall similarity percentage of the handwriting traits selected for statistical analysis is shown in table 03.

Table 03: Similarity Percentage of Handwriting Traits among both the group

Handwriting Comparison							
S.No	**Handwriting Characteristics**	**Hindi & English**			**English & German**		
		Same	**Total**	**Percentage**	**Same**	**Total**	**Percentage**
1	Alignment	42	50	84%	49	50	98%
2	Diacritics	40	50	80%	49	50	98%
3	Flourishes and Embellishments	41	50	82%	50	50	100%
4	Margins	40	50	80%	46	50	92%
5	Proportions	40	50	80%	50	50	100%
6	Slant	48	50	96%	49	50	98%
7	Spacing	44	50	88%	40	50	80%
8	Style of Writing	42	50	84%	50	50	100%

5. Result and Discussion

This study's findings reveal that in different scripts, people's handwriting features are at once consistent and variable. The assumption that handwriting retains inherent individual characteristics even across several linguistic systems is supported by the structural changes and stylistic tendencies that reveal the influence of the primary script. In group A (Hindi-English), Slant showed the highest observed similarity (96%) followed by spacing (88%), style of writing (84%) and alignment (84%). Whereas in group B (English-German) several features such as flourishes, proportions, and style of writing demonstrated 100% similarity. These similarity and consistency pattern are depicted in figure 7.

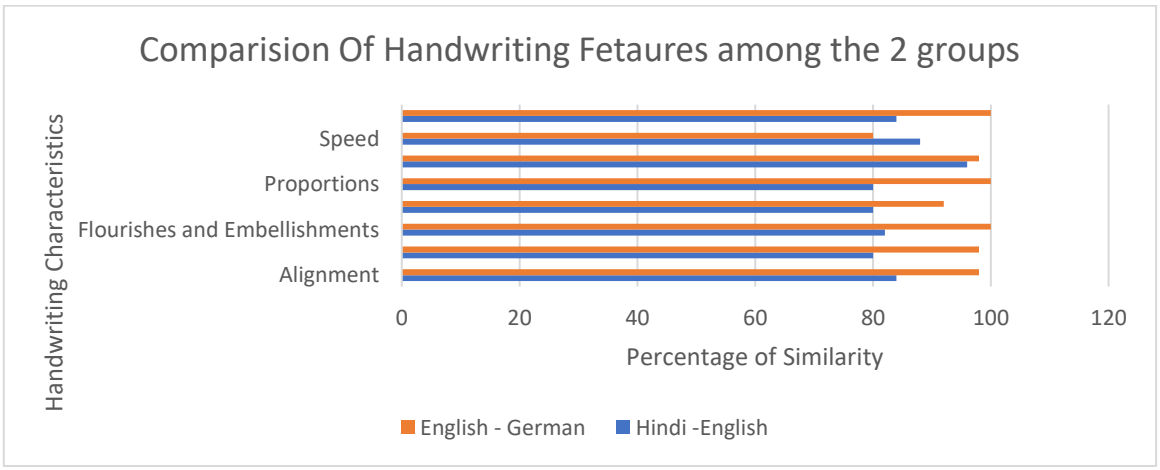


Figure 7: Representing percentage of similarity among both the group

In order to determine the statistical significance of these observed consistencies, Chi-Square (X^2) goodness of fit tests were conducted for following 8 parameters- Alignment, Diacritics, Flourishes and Embellishments, Margins, Proportions, Slant, Speed and Spacing. The *P* value and X^2 are listed below in Table 04 and Table 05 for both the group respectively.

Table 04: Statistical data for Group-A (Hindi-English)

S.No.	Feature	X^2 Value	P-Value	Significance
1	Alignment	11.58	0.0006672	$P < 0.0001$
2	Diacritics	8.62	0.0033334	$P < 0.0001$
3	Flourishes and Embellishments	10.03	0.0015428	$P < 0.0001$
4	Margins	8.62	0.0033334	$P < 0.0001$
5	Proportions	8.62	0.0033334	$P < 0.0001$
6	Slant	24.56	0.0000007218	$P < 0.0001$
7	Spacing	15.15	0.0000994	$P < 0.0001$
8	Style of Writing	11.58	0.0006672	$P < 0.0001$

Table 05. Statistical data for Group-B (English-German)

S.No.	Feature	X^2 Value	P-Value	Significance
1	Alignment	27.49	0.0000001575	$P < 0.0001$
2	Diacritics	27.49	0.0000001575	$P < 0.0001$
3	Flourishes and Embellishments	30.72	0.0000000298	$P < 0.0001$
4	Margins	19.43	0.00001045	$P < 0.0001$
5	Proportions	30.72	0.0000000298	$P < 0.0001$
6	Slant	27.49	0.0000001575	$P < 0.0001$
7	Spacing	8.62	0.003333	0.0033
8	Style of Writing	30.72	0.0000000298	$P < 0.0001$

These findings suggest that bilinguals who are skilled writer in Hindi and English both the scripts exhibit a high degree of consistency with *P* value < 0.001 across Hindi and English scripts. In case of group A, reinforce that the handwriting consistency with *P* value < 0.001 remains intact particularly in characteristics like proportions, style and flourishes.

The observations support forensic handwriting analysis by providing a basis for understanding the role that inter script plays in authorship determination. The inherent structural differences between scripts are one of the principal challenges of inter-script handwriting analysis. English, with its Latin alphabet of more angular forms, is compared to Hindi script, which is written in Devanagari, characterized by a typical horizontal line and rounded forms. Similarly, diacritical marks and other letter forms that do not exist in standard English exist in German script. It can be difficult to maintain individual handwriting characteristics between scripts because of these structural differences. The research highlights that certain individual characteristics, like slant are relatively stable between scripts despite these challenges. This means that handwriting production is greatly dependent on motor abilities, making it possible to identify an individual's writing even if they employ different scripts. Drastic changes occur in letter shapes and stylistic differences, however, indicating that forensic document examiners must consider these factors while analysing questioned documents. The influence of linguistic and cognitive processes on handwriting is yet another factor to consider. Moreover, handwriting is also significantly shaped by educational and cultural backgrounds because individuals who have been educated in multiple writing systems could exhibit unique characteristics that monolingual writers lack. Inter-script handwriting analysis has pros and cons from a forensic perspective. Forensic experts should exercise care when establishing authorship on the basis

of handwriting alone, although recognizing shared motor patterns can be useful. The cross-script analysis is mostly done by emphasizing on commonalities in copybook letterforms, individual handwriting characteristics, and script basics. [12] This notion was further explored by a study considering three different script for the study. It showed that the pictorial features resonate among the handwriting samples collected from the same individual written in multiple scripts. [14]

6. Conclusion

It is evident that questioned document examination holds a legal dimension within forensic science. There has always been a demand to have higher accuracy standard procedures. To meet this, the field of questioned document is continuously expanding and growing to achieve evidently precision. [15] In conclusion, research in inter-script handwriting is an encouraging but challenging area of research in forensic document examination. Research provides forensic examiners with the basic framework of analysing multilingual documents and provides valuable information about how handwriting features vary between scripts. To better enhance the accuracy of inter-script handwriting comparisons, future research will need to look into automated systems and machine learning algorithms. The intricacy of handwriting analysis across scripts in forensic science is brought out by this research. The research demonstrates that while elementary handwriting characteristics such as pressure and slant maintain a level of consistency, letter shape and stylistic differences that are script dependent complicate the authentication of authors. The findings underscore the need for forensic document examiners to analyse multilingual handwriting samples with both linguistic factors and motor control deficits in mind. It is possible to use handwriting as an investigational tool both in national and even in cross-national settings. Forensic examiners can build more credible systems for establishing authorship in the bilingual, multi-national world through enhancing these methodologies. [16,17,18,19]

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