



Naif Arab University for Security Sciences
Arab Journal of Forensic Sciences and Forensic Medicine
المجلة العربية لعلوم الأدلة الجنائية والطب الشرعي
<https://journals.nauss.edu.sa/index.php/AJFSFM>



A Comparative Study on Class Characteristics of Devanāgri Script Writers From Three Different States of India

دراسة مقارنة حول الخصائص النوعية لكتّاب النص بالخط الديفانغري من ثلاث ولايات مختلفة

في الهند

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Received 10 Jul. 2022; Accepted 12 Mar. 2023; Available Online 06 Jun. 2023



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Abstract

India is a multilingual country. Hindi is the national language of India and Devanāgri script is used to write Hindi language. Various documents with legal value are made in Devanāgri script, which may be questioned for their authenticity and authorship. Sufficient research has been done and reported about different scripts. However, researches based on Devanāgri script are limited. This study focuses on finding the significant class characteristics of writers from three different states of India, namely, Bihar, Madhya Pradesh and Punjab. The data was also statistically analysed using Pearson's Chi-Square test for its significance. Handwriting samples from 300 subjects were collected from three different states of India to analyze various class characteristics in Devanāgri script. The samples were examined qualitatively and statistically. Various general characteristics were selected for the analysis and characteristic features were tabulated after qualitative examination. Statistical analysis showed that the data was statistically significant. The general characteristics selected for the analysis and comparison of the handwriting samples in Devanāgri script were found to be significant. The impact of regional scripts on the Devanāgri script should be performed, as the influence of regional language could be seen in the samples collected from Punjab.

Keywords: Forensic science, questioned documents, Hindi, devanāgri, class characteristics, chi-square test.

المستخلص

الهند بلد متعدد اللغات. اللغة الهندية هي اللغة الوطنية للهند ويستخدم النص الديفانغري Devanāgri لكتابة اللغة الهندية. ويتم عمل العديد من المستندات ذات القيمة القانونية بخط Devanāgri، والتي قد تكون موضع تساؤل حول أصالتها ومؤلفها. لقد أجريت بحوث كافية وصدرت تقارير حول نصوص مختلفة. ومع ذلك، فإن البحث القائم على نص الديفانغري محدود. وتركز هذه الدراسة على إيجاد الخصائص الطباقية المهمة للكتّاب من ثلاث ولايات مختلفة في الهند، وهي بيهار وماديا براديش والبنجاب. تم أيضًا تحليل البيانات إحصائيًا باستخدام اختبار مربع كاي لبيرسون لأهميته. وتم جمع عينات بخط اليد من 300 شخص من ثلاث ولايات مختلفة في الهند لتحليل الخصائص الطباقية المختلفة في نص الديفانغري. كما تم فحص العينات نوعيًا وإحصائيًا. وتم اختيار الخصائص العامة المختلفة للتحليل وتم جدولة السمات المميزة بعد الفحص النوعي. وأظهر التحليل الإحصائي أن البيانات كانت ذات دلالة إحصائية. أظهرت هذه الدراسة أن الخصائص العامة المختارة لتحليل ومقارنة عينات خط اليد بخط ديفانغري ذات دلالة إحصائية. يجب إجراء فحص لتأثير المناطق الإقليمية للكتابة على نص الديفانغري، حيث تم رؤية تأثير اللغة الإقليمية في العينات التي تم جمعها من منطقة البنجاب.

الكلمات المفتاحية: علوم الأدلة الجنائية، فحص المستندات، اللغة الهندية، النص الديفانغري، خصائص الفئة، اختبار مربع كاي.

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doi: 10.26735/AXEB7234



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1. Introduction

India is a multi-linguistic country. Different languages are written and spoken in daily usage. Hindi is the national language of India. The Devanāgri script is used to write Hindi language. It consists of 13 Swara (vowels) and 36 Vyanjan (consonants). Hindi is used as an official language in seven states of India namely, Delhi, Himachal Pradesh, Haryana, Uttar Pradesh, Bihar, Madhya Pradesh, and Rajasthan [1, 2]. The Devanāgri script uses combination of various sub-divisions which are called Akshara (letter) to form a Shabda (word) which are joined by a straight horizontal line called Shirorekha (head score). The documents with legal values like wills, contracts, letters, agreements, and testaments, etc. are mostly prepared in Devanāgri writing system. These documents act as an important part in social and economic life. A large number of documents executed in Devanāgri script are encountered in different forensic laboratories for comparison, identification and to establish the authenticity of the writer.

Leung et al. [3] studied the style and characteristics of Chinese handwriting. Saxena et al. [1] classified the writing elements in Devanāgri script. Jasuja et al. [4] provided a brief history and the guide to the examination of the Gurmukhi script. Cheng et al. [5] investigated the class characteristics of Chinese, Malay and Indians in Singapore. Turner et al. [6] studied the class characteristics in Gurmukhi script of 1st and 2nd generation Punjabis in United Kingdom population. Turnbull et al. [7] identified the class characteristics in English writings of Polish people. Sorate et al. [8] analyzed the class and individual characteristics in Hindi and Marathi languages. Chapran et al. [9] performed task related study of population characteristics in handwriting analysis. Saini et al. [10] examined the class characteristics in English handwriting of the three states of India

namely, Andhra Pradesh, Punjab and Kashmir. Jyadevan et al. [2] surveyed the off-line recognition of Devanāgri script. Mittal et al. [11], Ling [12], Li et al. [13] and Saini et al. [14] also analysed various individual and class characteristics which were helpful in this study.

A thorough study of literature shows that a plenty of research has been done and reported about different scripts including Arabic, Chinese, English, Devanāgri, and Gurmukhi. However, research based on Devanāgri script is limited. Therefore, this study is focused to find whether writers of the three states of India namely Bihar, Madhya Pradesh and Punjab are differentiable on the basis of the class characteristics, and whether any peculiar similarity or difference can be found due to the influence of the regional language. The class characteristics in the handwriting samples collected from Bihar, Madhya Pradesh and Punjab were compared. The data was then analyzed statistically using the Pearson's Chi-Square Test.

2. Materials and Methods

Handwriting samples were collected from 100 subjects each belonging to Bihar, Madhya Pradesh and Punjab. Total 3 samples each were collected from 300 subjects using random sampling method. Sample collection was performed in various universities and colleges of Bihar, Madhya Pradesh and Punjab, as people from all regions of the state can be found there. Male and female writers above the age of 16 were chosen to write the samples. The minimum qualification of writers was secondary education with one subject as Hindi. The subjects were provided a standard paragraph containing all alphabets of Devanāgri script and three non-ruling A4 size, 80 GSM white sheets. The writers were asked to write the provided text with their accustomed hand on all the three sheets. The handwriting specimens



of writers from three states were analysed qualitatively and statistically. Ethical clearance was received from the Institutional Ethics Committee.

2.1 Qualitative Analysis

For qualitative examination, various characteristics were selected. The characteristics included writing slant, alignment, size of handwriting, margins, spacing between preceding and succeeding letters and punctuation marks, forms of punctuation marks, indents, underscoring the heading, size of diacritic marks, angularity of matras, angularity of letters, connecting strokes, style of writing, letter forms, and spelling mistakes [5-7, 9, 15]. All the characteristics were studied for each handwriting sample and the findings were tabulated.

2.2 Statistical Analysis

The qualitative parameters were marked using a binary system for their presence (1) or absence (0) to evaluate the class characteristics. The data was analysed by using Pearson's chi-square test to find out significant class characteristics in the handwriting of three different states of India. The null hypothesis (H_0) believed that there was no difference in the handwriting characteristics between the population of Bihar, Madhya Pradesh and Punjab. If the null hypothesis is true:

$$P_{(B)} = P_{(MP)} = P_{(Pb)}$$

Where, P represents the probability of observed characteristics features in Hindi handwriting of respondents, 'B' represents Bihar, 'MP' represents Madhya Pradesh and 'Pb' represents Punjab. The findings were tabulated and Chi-square values (χ^2) were calculated using Microsoft Excel according to the following formula.

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

A 3x2 component table was constructed for each characteristic to compute the Chi-square value. The significance level of 0.05 was chosen, which is commonly an accepted level in scientific research studies. At the degree of freedom of 2, the critical value of Chi-square (χ^2), at the significance level 0.05, is 5.991. The Null Hypothesis would be rejected if the χ^2 value is higher than 5.99. The computed value of Chi-Square (χ^2) that is larger than χ^2 denoted statistical significance of the particular characteristic feature which proved the significance of the findings.

3. Findings

3.1 Qualitative Analysis

In total, 3 handwriting samples, each from 300 subjects, were examined for analysing various class characteristics in Devanāgri script of Hindi language. The class characteristics of all the three states are compared and tabulated; Table 1. The following prominent features were observed on qualitative examination of the samples from each state.

3.1.1 Class characteristics observed in the handwriting samples collected from Bihar

The handwriting samples from Bihar mostly showed the presence of horizontal alignment Fig. 1. The letters and matras were rounded. Connecting strokes were mostly absent Fig. 2. Formation of punctuation marks was like a spur Fig. 3. Tapered initial and terminal stroke were mostly observed Fig. 4. Most writers from Bihar used to place margins on top, bottom, left and right Fig. 5. Handwriting samples from Bihar showed mixed placement of pooranviram. Indents were mostly absent and showed medium size of diacritic mark Fig. 6. The size of handwriting was also medium. No spacing was observed between commas and preceding/succeeding letters. Hand printed style of writing was



Table 1- Chi-square values of various characteristic features observed in the handwriting samples collected from Bihar, Madhya Pradesh and Punjab.

Description and Type	Character Observed	Observed Values			Expected value	Chi Square Value
		Punjab	Bihar	M.P.		
Writing Slant						
Forward Slant	Yes	16	10	15	13.66	2.88
	No	84	90	75	83	
Backward Slant	Yes	22	27	10	19.66	9.66
	No	78	73	90	80.33	
Vertical Slant	Yes	49	52	28	43	13.95
	No	51	48	72	57	
Vertical + Forward	Yes	13	1	30	14.66	33.93
	No	87	99	70	85.33	
Vertical + Backward	Yes	0	5	8	4.33	7.87
	No	100	95	92	95.66	
Vertical + Forward + Backward	Yes	0	5	9	4.66	9.14
	No	100	95	91	95.33	
Alignment						
Horizontal	Yes	43	56	14	37.66	39.38
	No	57	44	86	62.33	
Uphill	Yes	17	29	20	22	4.54
	No	83	71	80	78	
Downhill	Yes	23	9	26	19.33	10.55
	No	77	91	74	80.66	
Mixed	Yes	17	6	40	21	36.28
	No	83	94	60	79	
Size of Handwriting						
Small (1-3mm)	Yes	0	0	15	5	31.57
	No	100	100	85	95	
Medium(3-6mm)	Yes	63	57	81	67	14.11
	No	37	43	19	33	
Large(6-10mm)	Yes	37	43	4	28	43.75
	No	63	57	96	72	
Placing of Pooran Viram						
On the baseline	Yes	48	28	35	37	8.83
	No	52	72	65	63	
Above the baseline	Yes	25	14	5	14.66	16.03
	No	75	86	95	85.33	
Mixed	Yes	13	47	40	33.33	29.01
	No	87	53	60	66.66	
Below the baseline	Yes	15	11	20	15.33	3.13
	No	85	89	80	84.67	



Description and Type	Character Observed	Observed Values			Expected value	Chi Square Value
		Punjab	Bihar	M.P.		
Form of Punctuation marks						
Spur	Yes	40	56	77	57.66	20.01
	No	60	44	33	45.66	
Looped	Yes	11	14	9	11.33	1.26
	No	89	86	91	88.66	
Hooked	Yes	17	11	7	11.66	4.91
	No	83	89	93	88.33	
Mixed	Yes	32	19	9	20	16.62
	No	68	81	91	80	
Indents						
Indents	Yes	42	9	12	21	40.14
	No	58	91	88	79	
Underscoring the heading						
Underscoring the heading	Yes	71	47	0	3933	109.32
	No	29	53	100	60.66	
Size of diacritic						
Small(1-2mm)	Yes	0	0	28	9.33	61.76
	No	100	100	72	90.66	
Medium(3-6mm)	Yes	68	57	67	64	3.21
	No	32	43	33	36	
Large(7-10mm)	Yes	32	43	5	26.66	39.1
	No	68	57	95	73.33	
Angularity of letters						
Angular	Yes	73	46	10	43	81.51
	No	27	54	90	57	
Round	Yes	27	54	90	57	81.51
	No	73	46	10	43	
Angularity of matras						
Angular	Yes	50	31	9	30	40.09
	No	50	69	91	70	
Round	Yes	50	69	91	70	40.09
	No	50	31	9	30	
Connecting strokes						
Connecting strokes between letters and matras	Yes	20	38	40	32.66	11.03
	No	80	62	60	67.33	
Style						
Printed	Yes	60	79	57	65.33	12.56
	No	40	21	43	34.66	
Mixed	Yes	40	21	43	34.66	12.56
	No	60	79	57	65.33	



Description and Type	Character Observed	Observed Values			Expected value	Chi Square Value
		Punjab	Bihar	M.P.		
Initial and Terminal strokes						
Blunt	Yes	36	11	25	24	17.21
	No	64	89	75	76	
Tapered	Yes	64	89	75	76	17.21
	No	36	11	25	24	
Margins						
Left Margin	Yes	78	92	68	79.33	17.72
	No	22	8	32	20.66	
Right Margin	Yes	36	74	15	41.66	73.59
	No	64	26	85	58.33	
Top Margin	Yes	67	83	84	78	10.6
	No	33	17	16	22	
Bottom Margin	Yes	52	69	12	44.33	69.39
	No	48	31	88	55.66	
Space between coma and preceding letter						
No spacing	Yes	21	39	27	29	8.15
	No	79	61	73	71	
Spacing of 1 letter	Yes	36	25	42	34.33	6.59
	No	64	75	58	65.66	
Spacing of 2 letter	Yes	21	12	13	15.33	3.74
	No	79	88	87	84.66	
Mixed	Yes	22	14	18	18	2.16
	No	78	86	82	82	
Space between punctuation mark and succeeding letter						
No spacing	Yes	34	53	23	36.66	19.83
	No	66	47	77	63.33	
Spacing of 1 letter	Yes	36	19	46	33.66	16.68
	No	64	81	54	66.33	
Spacing of 2 letter	Yes	24	13	12	16.33	6.48
	No	76	87	88	83.66	
Mixed	Yes	6	15	19	13.33	7.67
	No	94	85	81	86.66	

mostly observed in the handwriting samples from Bihar; Fig. 7. Underscoring of heading was mostly absent; Fig. 8 and the handwriting samples had vertical slant in the handwriting; Fig. 9 and Table 1. The reason for vertical slant could be the execution of Devanāgri script in hand-printed form.

3.1.2 Class characteristics observed in the handwriting samples collected from Madhya Pradesh

The handwriting samples from Madhya Pradesh showed more than one type of alignment, that is,

mixed alignment Fig. 1. The letters and matras were rounded. Connecting strokes were mostly absent Fig. 2. Formation of punctuation marks was like a spur Fig. 3. Tapered initial and terminal stroke were mostly observed Fig. 4. Most writers from Madhya Pradesh were habitual of placing margins on top and left margins Fig. 5. Handwriting samples from Madhya Pradesh showed mixed placement of pooranviram. Indents were mostly absent and showed medium size of diacritic mark Fig. 6. The



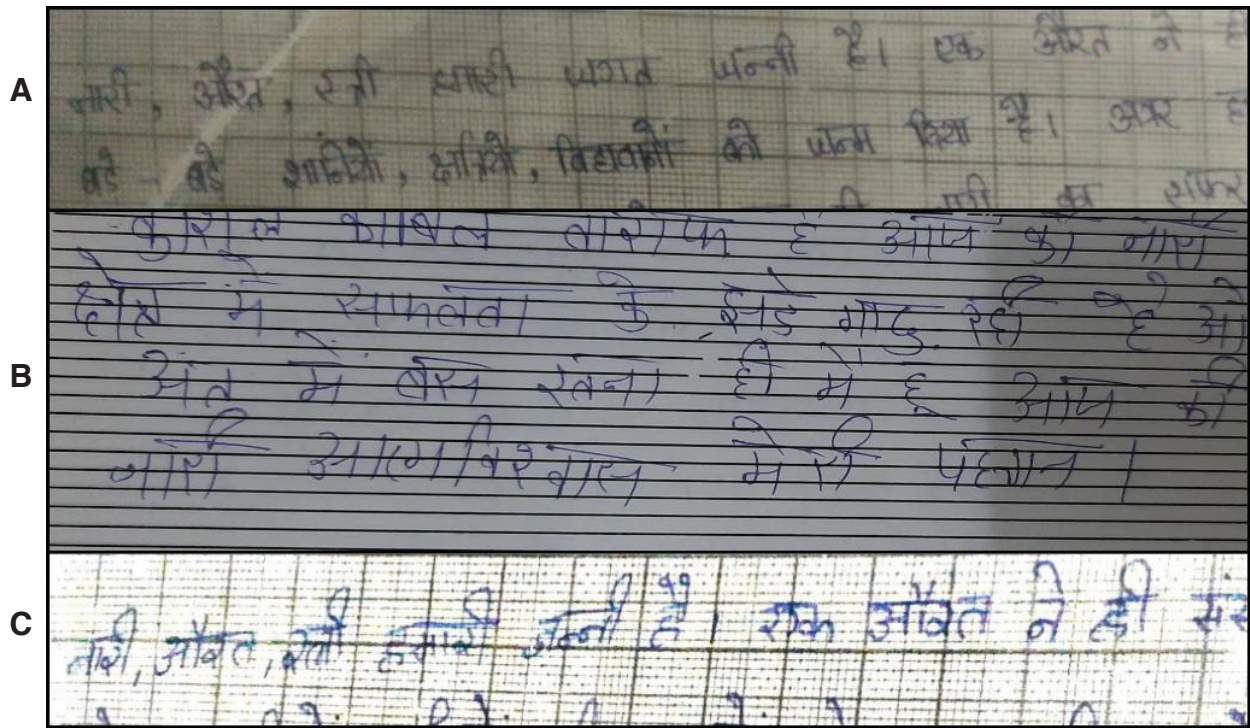


Figure 1- Alignment: (A) Horizontal alignment in Bihar samples; (B) Mixed alignment in MP samples; (C) Horizontal alignment in Punjab samples.

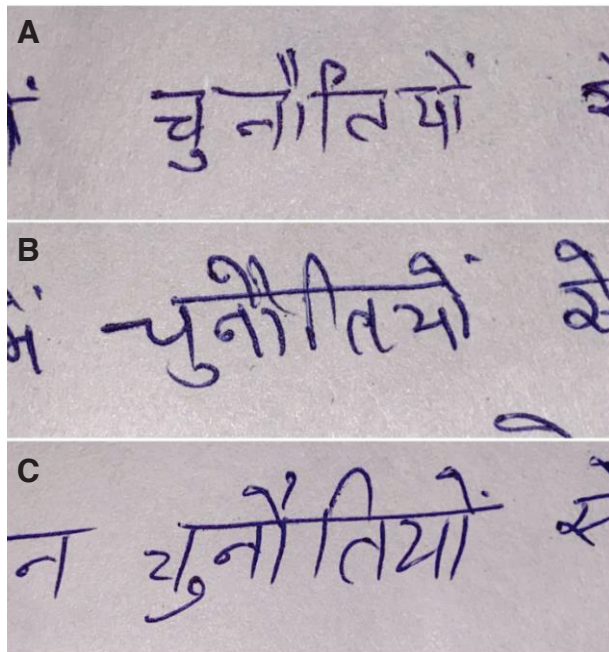


Figure 2- Connecting strokes: Connecting strokes absent (A) In Bihar samples. (B) In MP samples. (C) In Punjab samples.

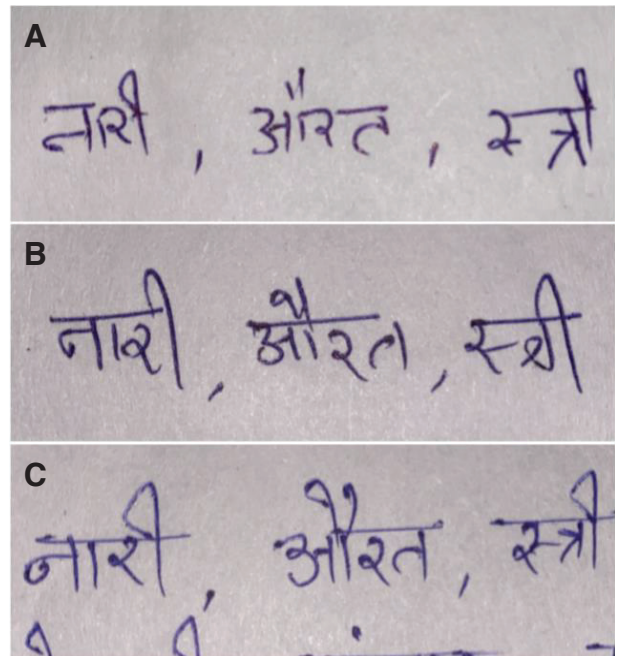


Figure 3- Punctuation marks: Spur like punctuation marks (A) In Bihar samples. (B) In MP samples. (C) In Punjab samples.



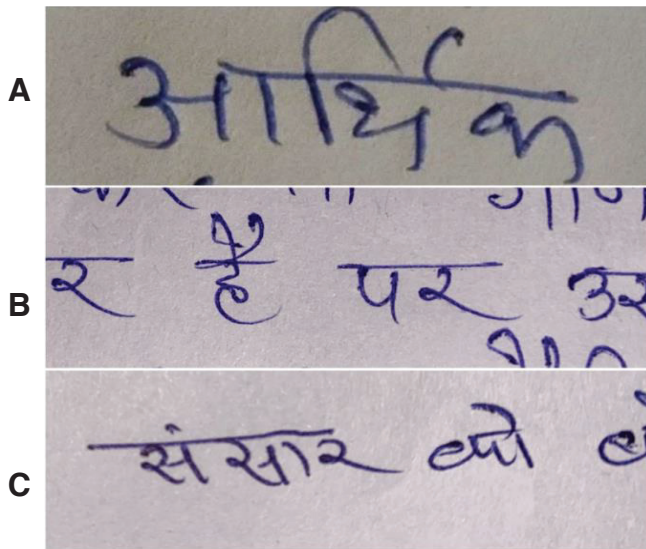


Figure 4- Initial and terminal strokes: Tapered initial and terminal strokes (A) In Bihar samples. (B) In MP samples. (C) In Punjab samples.

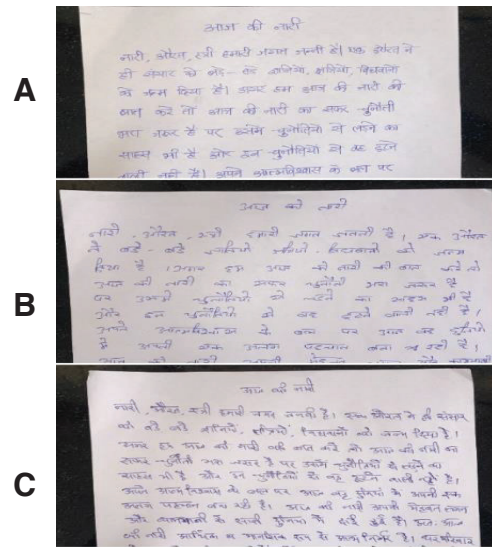


Figure 5- Margins: (A) Top, bottom, left, and right margins in Bihar samples. (B) Top and left margins in MP samples. (C) Top and left margins in Punjab samples.

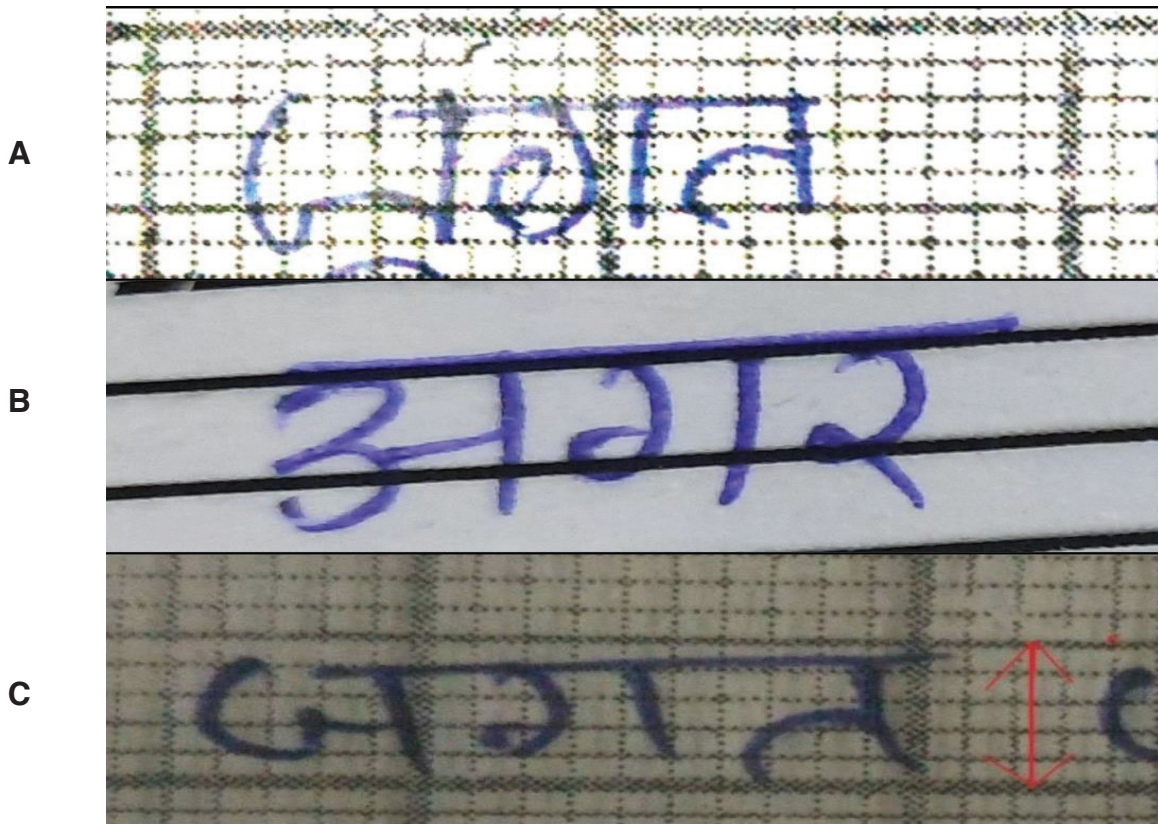


Figure 6- Size of letters and diacritic marks: Medium size of letters and diacritic (A) In Bihar samples. (B) In MP samples. (C) In Punjab samples.



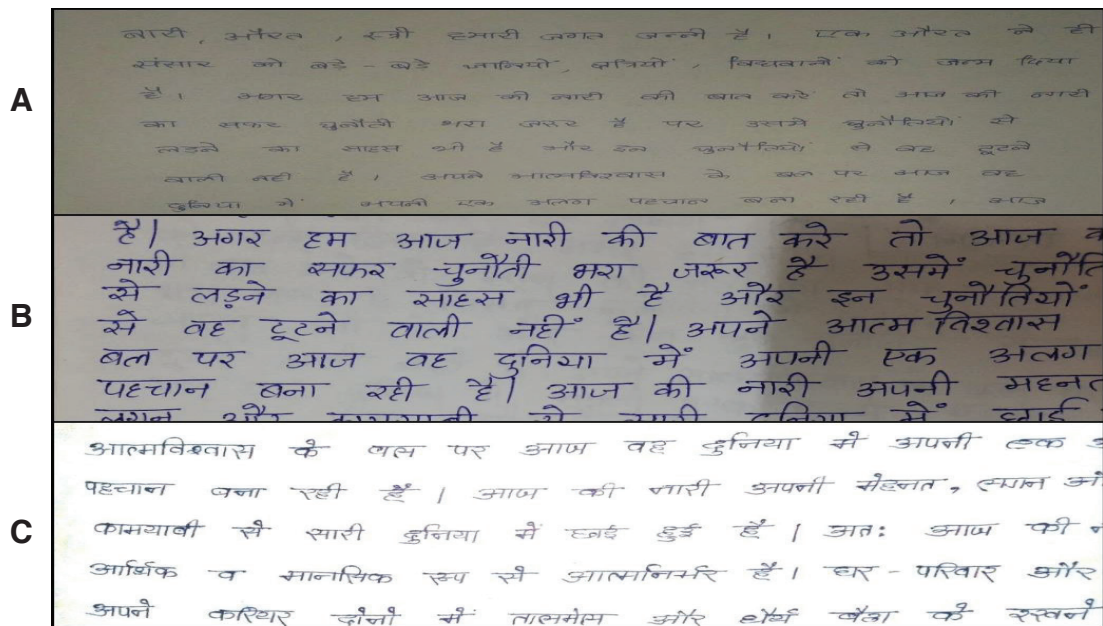


Figure 7- Style of writing: Handprinting style of writing diacritic (A) In Bihar samples. (B) In MP samples. (C) In Punjab samples.

size of handwriting was also medium. Spacing equal to one letter was observed between commas and preceding/ succeeding letters. Hand printed style of writing was mostly observed in the handwriting samples of Madhya Pradesh; Fig. 7. Underscoring of heading was mostly absent and combination of vertical and forward slant (A1) was common in majority of handwriting samples Fig. 9 and Table 1.

3.1.3 Class characteristics observed in the handwriting samples collected from Punjab

The handwriting samples from Punjab mostly showed the presence of horizontal alignment as shown in Fig. 1. The letters were angular. However, the matras were both angular and round. Connecting strokes were mostly absent as shown in Fig. 2. Formation of punctuation marks was like a spur as it was appeared in Fig. 3. Tapered initial and terminal stroke were mostly observed as shown in Fig. 4.

Most writers from Punjab used to place margins on top and left margins, look at Fig. 5. Handwriting samples from Punjab mostly showed the placement

of pooranviram on the baseline. Indents were mostly absent and showed medium size of diacritic mark as in Fig. 6."

The size of handwriting was also medium. Spacing equal to one letter was observed between commas and preceding/ succeeding letters. Hand printed style of writing was mostly observed in the handwriting samples of Punjab Fig. 7. Underscoring of heading was a common feature Fig. 8 and the handwriting samples had a vertical slant in the handwriting Fig. 9 and Table 1. The reason for vertical slant could be the execution of Devanāgrī script in hand-printed form.

3.1.4 Letter Formations

Handwriting samples from all the three states were studied and examined qualitatively to be aware of the letter formation. The percentage distribution of different forms of letters found in handwriting was tabulated in Table 2. There were a few letters found to be different from their copybook form. The influence of Gurmukhi script (regional



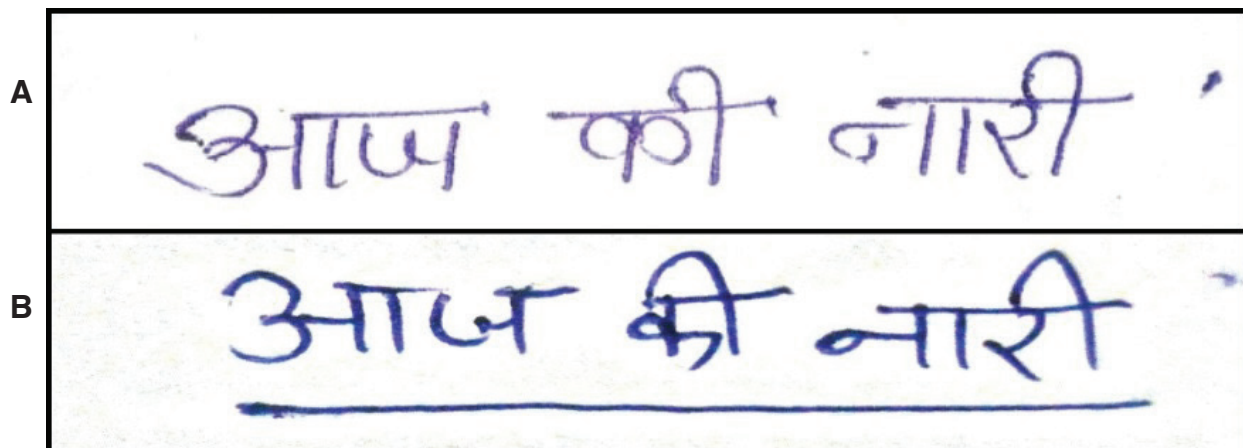


Fig. 8 - Underscoring of heading: Underscoring of heading absent (A) In Bihar samples. (B) Underscoring of heading present in Punjab samples.

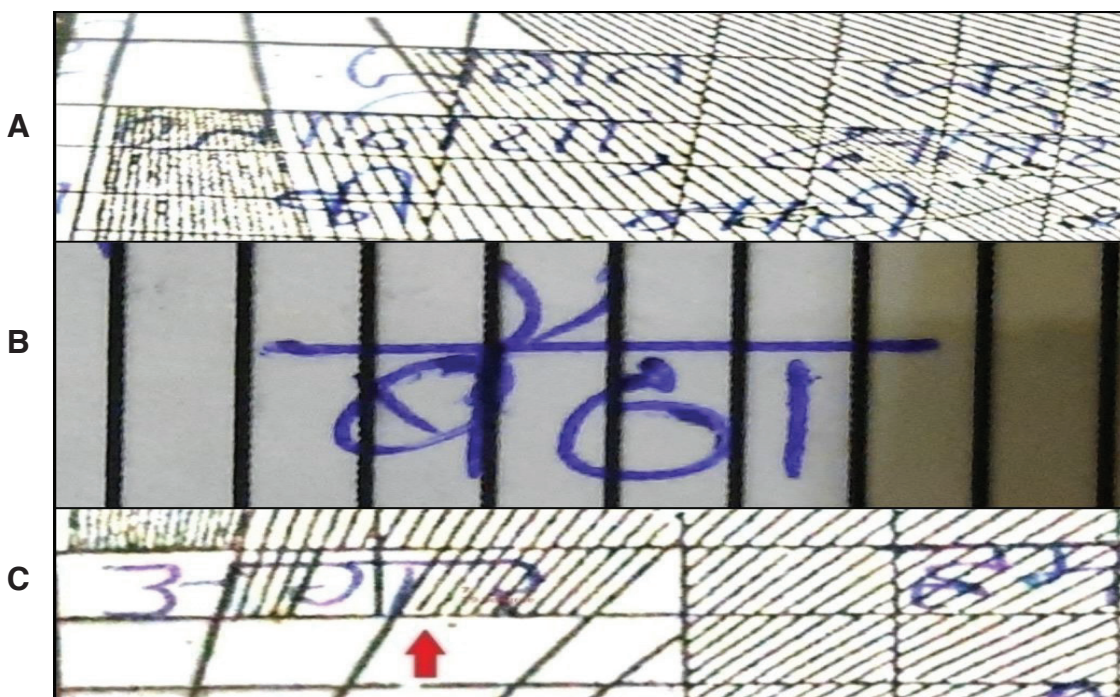


Figure 9 - Slant: (A) Vertical slant in Bihar samples. (B) Vertical and Forward slant (A1) in MP samples. (C) Vertical slant in Punjab samples.

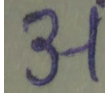
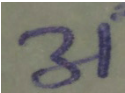

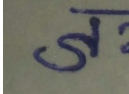
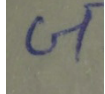
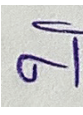
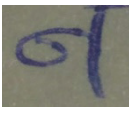
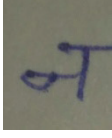
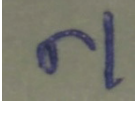
language) was evident. It was observed that 56% of handwriting samples from Punjab followed Gurmukhi script when writing the Devanāgri script. Few letter forms of Devanāgri script and Gurmukhi script were similar.

3.1.5 Statistical Analysis

The handwriting features having no significant difference among the handwriting of participants of three states included forward slant, uphill alignment, placing of pooranvram below the baseline,



Table 2- Percentage distribution of various letter forms observed in the handwriting samples collected from Bihar, Madhya Pradesh and Punjab.

Copy book form	Bihar		Madhya Pradesh		Punjab	
	Letter form	Percentage distribution	Letter form	Percentage distribution	Letter form	Percentage distribution
अ		48%		41%		20%
		12%		25%		33%
		21%		23%		10%
	Other forms	29%	Other forms	11%	Other forms	37%
ज		12%		31%		8%
		49%		28%		38%
		20%		21%		34%
	Other forms	29%	Other forms	20%	Other forms	20%
न		49%		15%		51%
		16%		54%		19%
		5%	-	-		31%
		10%		21%	-	-
	Other forms	20%	Other forms	10%	Other forms	9%



त		68%		68%		23%
		12%		19%		51%
	Other forms	10%		13%	Other forms	26%
म		61%		9%		30%
		32%		86%		22%
	Other forms	6%	Other forms	5%	Other forms	48%
ल		29%		30%		15%
		25%		42%		42%
	-	-		11%		30%
	Other forms	46%	Other forms	17%	Other forms	23%
ल		39%		22%		42%
		21%		56%		30%
		12%		10%		20%
	Other forms	18%	Other forms	12%	Other forms	1%



medium size of diacritic, the form of punctuation mark (loop and hook), two letter space between comma and preceding letter. Hence, after applying Pearson's Chi-Square test, the null hypothesis was accepted, and the alternate hypothesis was rejected for these features. However, significant differences were observed in most of the features which included Backward Slant, Vertical Slant, A1 (Vertical + Forward), A2 (Vertical + Backward), A3 (Vertical + Forward + Backward), horizontal alignment, downhill alignment, mixed alignment, size of handwriting, placing of pooranvaram (on the baseline, above the baseline, and mixed), the form of punctuation mark (spur, and mixed), presence of indents, under-scoring of heading, and size of diacritic (small, and large), the angularity of letter and matra, presence of connecting strokes, writing style, initial and terminal stroke, margins, space between comma and preceding letter (no space, and space of one letter), and space between comma and succeeding letter.

4. Discussion

The study aimed to analyse and compare the class characteristics of Devanāgri script for handwriting samples collected from three Indian states, namely, Bihar, Madhya Pradesh and Punjab. According to Sethi [16] and Chaterjee (1976), the Devanāgri script is structurally more complex than the English language. Classification of Devanāgri characteristics is complex due to the variability in size and shape of alphabets [2]. Baker [17] stated that the advancement of the general system of writing and their aspects were only used to determine the authorship of the writing. Some peculiarities were so idiosyncratic in any writing system in which they reflect their nationality. Once the style and the manner of writing were accomplished by the people after their maturity, it would remain same throughout the life with some variations. Formation of letter

played an important role in identifying the writer. Cheng et al. [5] investigated the class characteristics of Chinese, Malay and Indians in Singapore and noted that the nationality of the individuals can be differentiated on the basis of habitual characteristics in handwriting. Stable features of handwriting and personal characteristics can be used to establish the writer in case of forgeries [9]. According to Jasuja et al. [4], a questioned document examiner should have the knowledge of the script for submitting a valid opinion to the court. The unfamiliarity with the class features of a given population could lead to the misidentification of a feature by a document examiner as unusual when it is in fact a common feature [7]. However, Mittal et al. (1989) and Mathur et al. [18] presented the analysis of the handwritten document with unfamiliar script of different languages. Saxena and Singh (1992) reported a method to analyse the handwritten document in Devanāgri script for experts who were familiar and unfamiliar with the script. Turner et al. (2008) provided the questioned document examiner with a great assistance for quick identification by showing the importance of the class characteristics of Gurmukhi script which could be used to identify or isolate the population of the writer along with their generation of the population. Sorate et al. (2017) analyzed the class and individual characteristics in Hindi and Marathi languages. Saini and Kaur [10] examined English handwriting by applying Pearson Chi square formula on the class characteristics in handwriting samples of three states of India. The method was useful to narrow down the search by establishing the nationality and the origin of the subjects. The writing system and teaching methods are the two major factors responsible for the fact that variation is evident in class characteristics within the handwriting among different geographical locations. Baker [17], Harrison [19], Hilton [20],



Kelly et al. [21], and Ellen [22] well established this in their works. The samples were analyzed qualitatively as well as statistically. For a qualitative analysis, the class characteristics were studied and for statistical analysis, Pearson's chi-square method was used. Cheng et al. [5], Shlafer [15], Turnbull et al. [7], Al-Hadhrami et al. (2015), and Saini et al. [10] also supported their studies with statistical analyses. From the analysis and comparison of class characteristics of the handwriting samples in the Devanāgrī script, a significant outcome, that on the basis of class characteristics and the origin of writers can be identified. The study also showed the variation that took place in handwriting written in the Devanāgrī script because of the influence of other scripts. Data from every state must be collected to analyze the class characteristics of handwriting of Devanāgrī script to examine the influence of other regional languages on it. Such data will be helpful to narrow down the investigation and also assist the examiner, who is unfamiliar to the Devanāgrī script, in examining the document written in the Hindi language.

5. Conclusion

Hindi is used as an official language in various states of India. The Devanāgrī script is used to write Hindi language. The study has been performed to analyse and compare the class characteristics of Devanāgrī script of handwriting samples collected from three Indian states, namely, Bihar, Madhya Pradesh and Punjab. From the findings of the study, it was concluded that analysis and comparison of class characteristics of the handwriting in the Devanāgrī script can be used to identify the origin of the writer. The main aim of the study was fulfilled, as significant difference was evident after statistical analysis of the handwriting characteristics of three different states covered in this study.

Influence of other scripts was evident in the class characteristics of various handwriting samples of Punjab. Handwriting samples from other states with regional scripts similar to Devanāgrī script can also be analyzed to make a database for forensic examination in real life cases by the forensic questioned document examiners.

Conflict of interest

The authors declare no conflicts of interest.

Source of funding

The authors received no financial support for the research, authorship or publication of this paper.

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