FORENSIC EXAMINATION OF HANDWRITTEN ARABIC NUMERALS

Komal Saini and Navneet Kaur

ABSTRACT

The present study has been conducted for the analysis of handwritten Arabic numerals of respondents from two states Andhra Pradesh and Punjab. Characteristic features like slant, relative position of strokes, angularity of turning, shape of initial and ending strokes etc. of numeral digits from '0' to '9' have been studied. Data was analyzed using chi square test to find out class characteristics in handwritten numerals of different respondents from two far off states. It has been concluded that irrespective of structural simplicity of numerals, the analysis is found to be effective in finding significant class characteristics.

Keywords: Forensic science, Arabic numerals, statistical study

INTRODUCTION

India is a country where persons from different states are exposed to different writing systems and the forensic document examiners may get questioned handwriting samples for examination from persons of different states. The handwritten documents include both handwriting and numerals in almost every civil and criminal case. Questions are raised on numerals especially in the cases related to financial deals such as embezzlements, bankruptcies and other transactions. The problems involving numerals are more difficult as numerals are written in disconnected manner and few characteristics are involved. Examination of numerals is based on three fundamental factors, that is, form, writing quality or movement and variation that involves the complete analysis of the factors of the design (Osborn, 1929; Hilton, 1982; Conway, 1959). Strach (1998) described the system for classification of handwritten numerals. Li *et al.* (2005) analyzed Arabic numerals of 187 subjects using cluster analysis to discriminate the handwriting subjects of Hong Kong population.

This study is aimed to examine the handwritten Arabic numerals of respondents from two widely separated states, that is, Punjab and Andhra Pradesh. The data

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has been analyzed statistically to find out class characteristics in the handwriting pattern of numerals between respondents from two far off states. The study also reports the class characteristics which are prominent in either of the state.

MATERIAL AND METHODS

Sample Collection

The samples were randomly collected from two hundred respondents of two widely separated states, that is, Punjab and Andhra Pradesh. Hundred respondents from Andhra Pradesh included 69 males and 31 females aged between 18-42 years. Two respondents were left handed and rest were right handed writers. Hundred respondents from Punjab included 46 males and 54 females aged between 18-44 years. Four respondents were left handed and rest were right handed writers. All respondents had studied in their respective states up to their high school. Respondents were asked to write the passage consisting of numerals 0 to 9 four times on separate A4 sheets with their accustomed hands.

Analysis

Different characteristic features were examined for numeral '0' to '9'. For example, the characteristic features observed for numeral '1' were slant, initial hook, serif and ending position .The characteristics were observed in every handwriting and their range of variations was also determined. Therefore, slant of numeral '1' was categorized into forward (F), backward (B), upright (U), forward to backward (F+B), forward to upright (F+U), upright to backward (U+B) according to the range of variation (Figure 3). Similarly, other numerals were examined for their characteristic features in all samples and range of natural variations was also observed (Table 1). The respondents, who exhibited characteristic feature and those who do not were counted as two different parameters. Therefore, the observed data was coded to binary variables 0 and 1 for the absence and presence of characteristic features. This is an important factor in the evaluation of class characteristics. The data was statistically analyzed with SPSS 6.0 software for chi square test to find out significant characteristic features of two states and the class characteristics which were prominent in either of the states (Table 2).

RESULTS AND DISCUSSIONS

Two hundred handwriting samples (100 respondents each from Andhra Pradesh and Punjab) have been examined in detail for numerals. Pearson chi square test has been applied using SPSS software on the data and have been found to be useful for finding significant features between two states.

The null hypothesis held that there is no overall difference in handwritten numerals of two states. If the null hypothesis is true:

$$P_{(A)} = P_{(Pu)}$$

Where, P is the probability of observing a characteristic feature in handwritten Arabic numerals of respondents. 'A' denotes Andhra Pradesh, 'Pu' denotes Punjab.

The alternate hypothesis would be:

$$P_{(A)} \neq P_{(Pu)}$$

For each characteristic feature, 2*2 component table has been constructed to compute chi square with the significance level chosen 0.05 which is commonly accepted level in scientific research studies. At the degree of freedom 1, the critical value of chi square would be 3.84 (rounded up to 3 significant features). The computed value that is larger than 3.84 denoted statistical significance of particular characteristic feature. The tested characteristic features have been found to have sum of chi square value greater than 3.84 which proved the significance of results, that is, the null hypothesis has been rejected. Out of 252 characteristic features of numeral 0 to 9, fifty six characteristic features have been found to give statistical significance, that is, these features show their prominence in the respondents of their respective states. The results have been tabulated (Table 1). The Prominent class characteristics in handwritten numerals of Andhra Pradesh are described in Fig. 1-9; of respondents from Punjab are described in Fig. 10-16.

Li *et al*. reported statistical study on writing habits for Arabic numerals of 187 subjects and supported the hypothesis of individuality in handwriting. It is found that numeral '5', '8' and '9' are most informative numerals.

The present study provides statistical examination and determination of class characteristics in handwritten Arabic numerals of respondents from two states of India- Andhra Pradesh and Punjab. Using these findings one may be able to determine the significant class characteristics of handwritten Arabic numerals of different states.
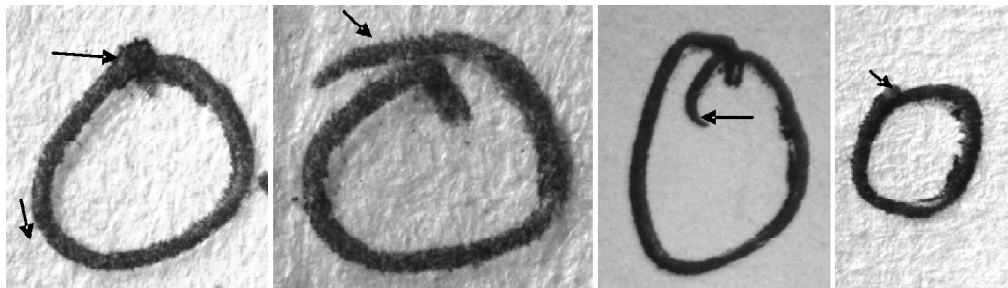

Figure 1: Numeral 0 -oval shape, vertical slant, and closed body, 'left' stroke crossing position and ending stroke direction varies from upward to lower respectively
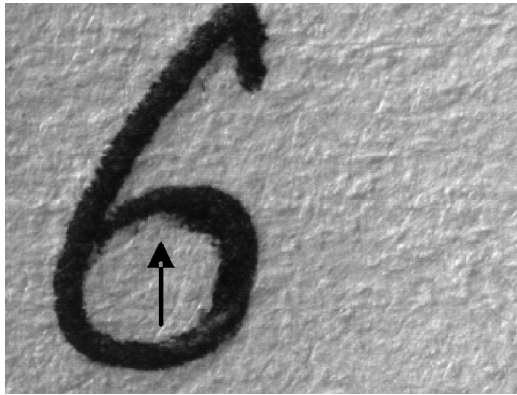
Figure 2: Numeral 6- vertical slant

**Figure 3: Numeral 1- backward slant**
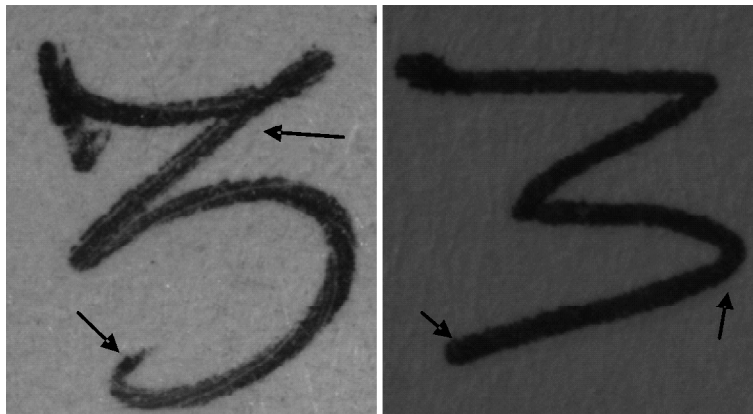
Figure 4 : Numeral 3- shape of upper turning angular to round, shape of lower turning angular, ending portion hook to simple and dissimilar upper lower parts
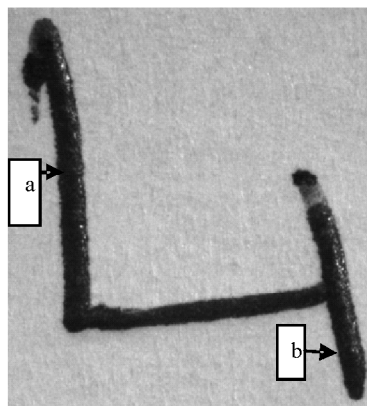
Figure 5: Numeral 4- the connection between slanting and vertical stroke is open, left slant stroke (a) with respect to portion of vertical stroke below horizontal stroke (b) – longer
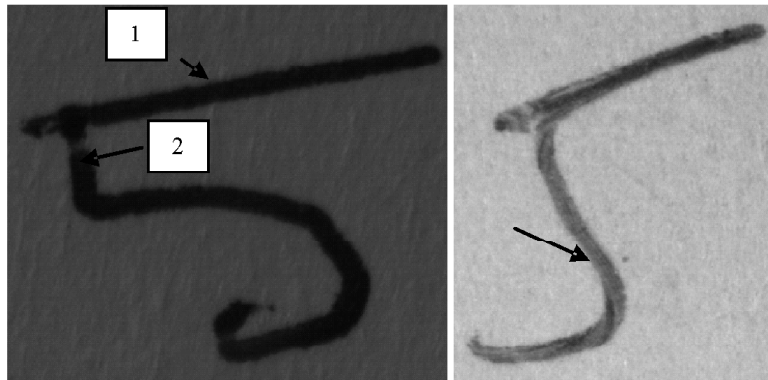
1- Horizontal stroke, 2- vertical stroke

Figure 6: Numeral 5- horizontal stroke crosses from top position of vertical stroke, shape of bottom portion varies from hook to straight and angular
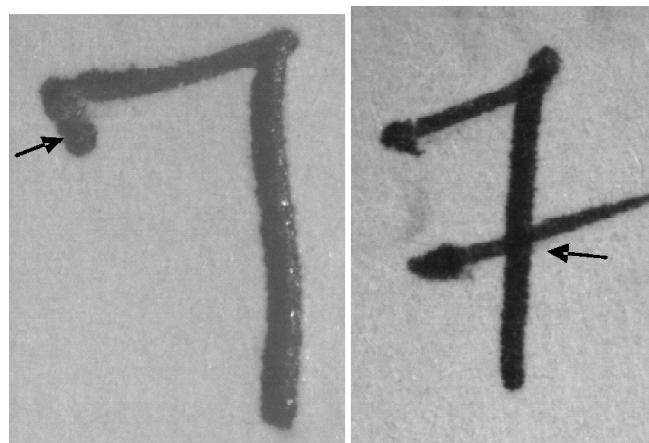
Figure 7: Numeral 7- presence of initial small stroke at horizontal bar, crossing bar present and crossing position middle
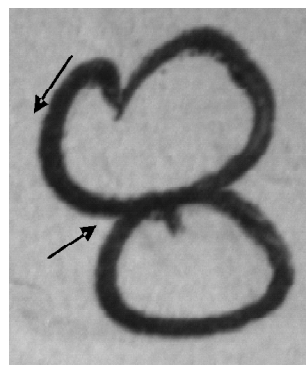
Figure 8: Numeral 8- shape with two circles and anticlockwise writing direction
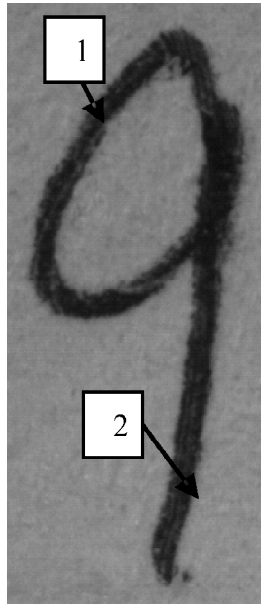
1-loop, 2- vertical

Figure 9: Numeral 9- loop crossing is vertical

Figures 1-9: Significant characteristic features in numerals of respondents from Andhra Pradesh
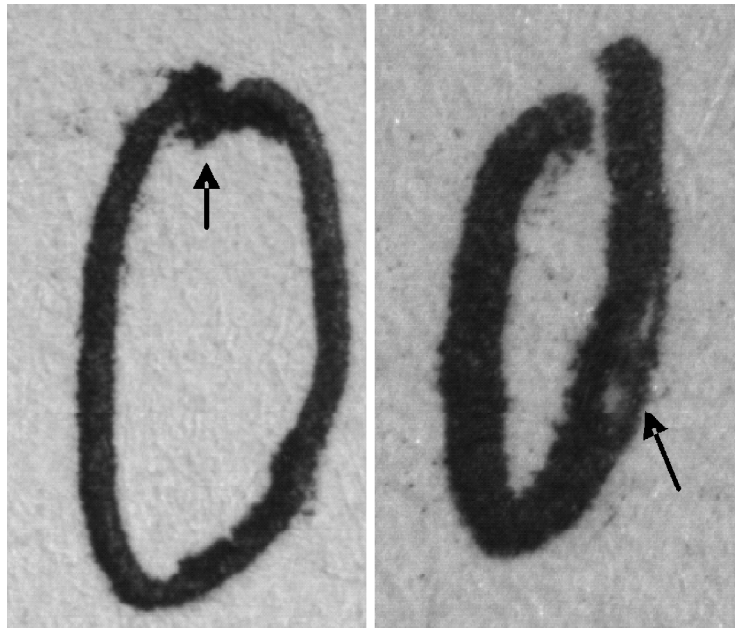
Figure 10: Numeral 0- elongated to flatten body, Ending is in downward direction
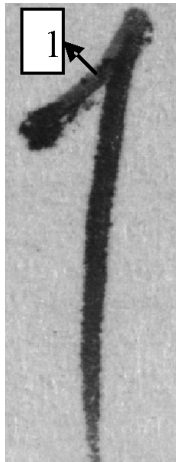
1- Initial hook

Figure 11: Numeral 1- forward slant and initial hook varies from left to right side of body
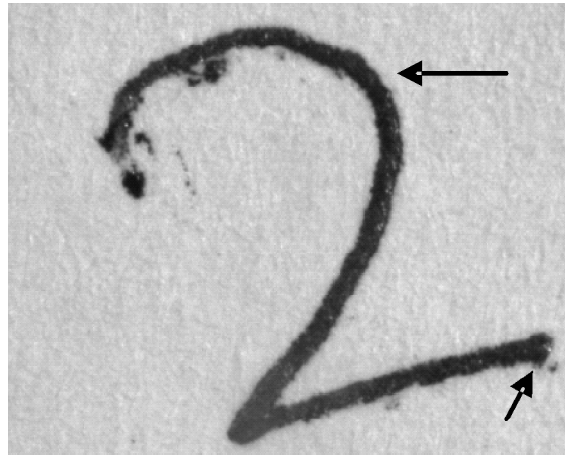
Figure 12: Numeral 2-initial stroke forms round shape and ending stroke is in upward direction
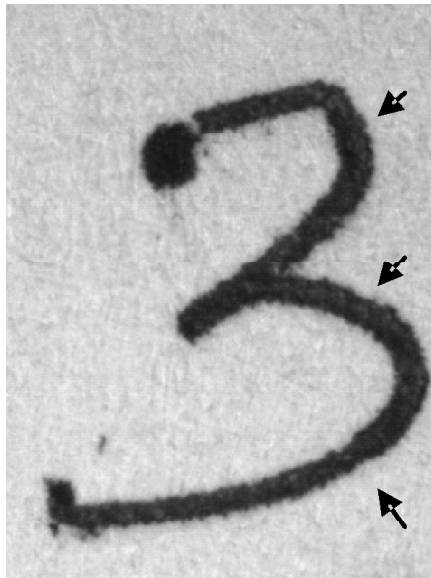
Figure 13: Numeral3: Shape of lower turning round, shape of upper lower parts similar
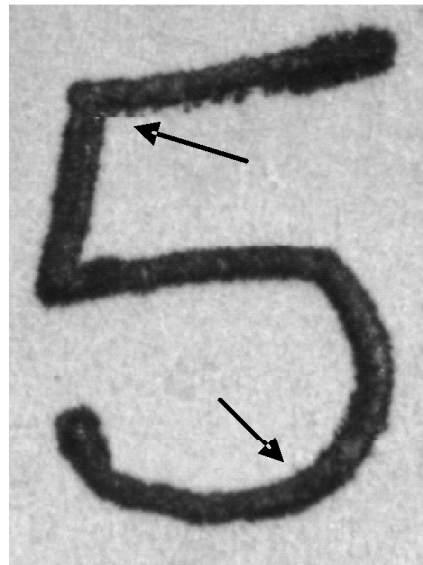
Figure 14: Numeral 5- Similar horizontal and vertical stroke and round shape of bottom portion

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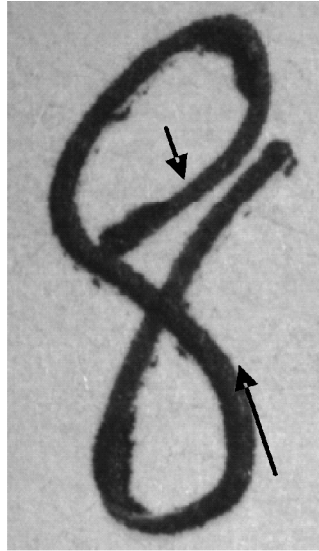
Figure 15: Numeral 8- E shape of body and backward slant
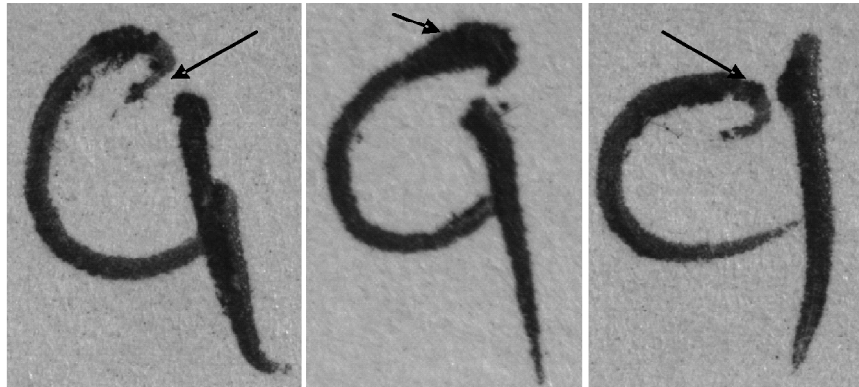
Figure 16: Numeral 9 – Open loop, Stroke starting position varies from left to right and top to upper half

Figure 10-16: Significant characteristic features in numerals of respondents from Punjab

CONCLUSION

The examination of writing specimens from 100 respondents each from state of north and south is a statistical examination and determination of class characteristics of handwritten numerals of respondents from two widely separated states. Fifty six class characteristics of handwritten numerals have been found to be statistically significant out of 252 characteristic features observed. So, it can be concluded that it is possible to determine the significant class characteristics in handwritten Arabic numerals of different states.

**Table 1: Chi square values of 56 characteristic features found to be statistically significant.
Those exceeded value 3.84 were**

Sr. No.	Characteristics			Andhra Pradesh	Punjab	(x)2 (sum)	P value
1.	**Slant forward of numeral 1**	Yes	Observed	41	62	8.8	0.0
			Expected	51.5	51.5		
			Chi-Square	2.1	2.1		
		No	Observed	59	38		
			Expected	48.5	48.5		
			Chi-Square	2.3	2.3		
2.	**Slant backward of numeral 1**	Yes	Observed	42	26	5.7	0.0
			Expected	34.0	34.0		
			Chi-Square	1.9	1.9		
		No	Observed	58	74		
			Expected	66.0	66.0		
			Chi-Square	1.0	1.0		
3.	**Slant upright of numeral 0**	Yes	Observed	14	2	9.8	0.0
			Expected	8.0	8.0		
			Chi-Square	4.5	4.5		
		No	Observed	86	98		
			Expected	92.0	92.0		
			Chi-Square	0.4	0.4		
4.	**Slant upright of numeral 6**	Yes	Observed	6	0	6.2	0.0
			Expected	3.0	3.0		
			Chi-Square	3.0	3.0		
		No	Observed	94	100		
			Expected	97.0	97.0		
			Chi-Square	0.1	0.1		
5.	**Slant forward to backward of numeral 0**	Yes	Observed	15	30	6.5	0.0
			Expected	22.5	22.5		
			Chi-Square	2.5	2.5		
		No	Observed	85	70		
			Expected	77.5	77.5		
			Chi-Square	0.7	0.7		
6.	**Writing direction anticlockwise of numeral 8**	Yes	Observed	91	71	13.0	0.0
			Expected	81.0	81.0		
			Chi-Square	1.2	1.2		
		No	Observed	9	29		
			Expected	19.0	19.0		
			Chi-Square	5.3	5.3		
7.	**Initial and ending stroke of numeral 0 closed**	Yes	Observed	88	76	4.9	0.0
			Expected	82.0	82.0		
			Chi-Square	0.4	0.4		
		No	Observed	12	24		
			Expected	18.0	18.0		
			Chi-Square	2.0	2.0		
8.	**Ending position left to middle of numeral 0**	Yes	Observed	11	22	4.4	0.0
			Expected	16.5	16.5		
			Chi-Square	1.8	1.8		
		No	Observed	89	78		
			Expected	83.5	83.5		
			Chi-Square	0.4	0.4		

Sr. No.	Characteristics			Andhra Pradesh	Punjab	$(x)2$ (sum)	P value
9.	**Stroke crossing position left of numeral 0**	Yes	Observed	52	29	11.0	0.0
			Expected	40.5	40.5		
			Chi-Square	3.3	3.3		
		No	Observed	48	71		
			Expected	59.5	59.5		
			Chi-Square	2.2	2.2		
			Chi-Square	2.2	2.2		
10.	**Stroke crossing position no of numeral 0**	Yes	Observed	19	40	10.6	0.0
			Expected	29.5	29.5		
			Chi-Square	3.7	3.7		
		No	Observed	81	60		
			Expected	70.5	70.5		
			Chi-Square	1.6	1.6		
11.	**Tapered ending of numeral 5**	Yes	Observed	77	95	13.5	0.0
			Expected	86.0	86.0		
			Chi-Square	0.9	0.9		
			No Observed	23	5		
			Expected	14.0	14.0		
			Chi-Square	5.8	5.8		
12.	**Shape oval of numeral 0**	Yes	Observed	87	6	131.9	0.0
			Expected	46.5	46.5		
			Chi-Square	35.3	35.3		
			No Observed	13	94		
			Expected	53.5	53.5		
			Chi-Square	0.1	0.1		
13.	**Shape flatten of numeral 0**	Yes	Observed	0	6	6.2	0.0
			Expected	3.0	3.0		
			Chi-Square	3.0	3.0		
		No	Observed	100	94		
			Expected	97.0	97.0		
			Chi-Square	0.1	0.1		
14.	**Shape elongated to flatten in numeral 0**	Yes	Observed	0	20	22.2	0.0
			Expected	10.0	10.0		
			Chi-Square	10.0	10.0		
			No Observed	100	80		
			Expected	90.0	90.0		
			Chi-Square	1.1	1.1		
15.	**Slant backward of numeral 8**	Yes	Observed	37	42	4.0	0.0
			Expected	30.5	30.5		
			Chi-Square	1.4	1.4		
		No	Observed	63	76		
			Expected	69.5	69.5		
			Chi-Square	0.6	0.6		
16.	**Ending position lower of numeral 0**	Yes	Observed	6	26	14.9	0.0
			Expected	16.0	16.0		
			Chi-Square	6.3	6.3		
			No Observed	94	74		
			Expected	84.0	84.0		
			Chi-Square	1.2	1.2		

contd. table 1

Sr. No.	Characteristics			Andhra Pradesh	Punjab	(x)2 (sum)	P value
17.	**Ending position upper middle of numeral 0**	Yes	Observed	21	3	15.3	0.0
			Expected	12.0	12.0		
			Chi-Square	6.8	6.8		
			No Observed	79	77		
			Expected	88.0	88.0		
			Chi-Square	0.9	0.9		
18.	**Ending position middle + lower of numeral 0**	Yes	Observed	16	0	17.4	0.0
			Expected	8.0	8.0		
			Chi-Square	8.0	8.0		
			No Observed	84	100		
			Expected	92	92		
			Chi-Square	0.7	0.7		
19.	**Initial hook absent in numeral 1**	Yes	Observed	96	5	165.6	0.0
			Expected	50.5	50.5		
			Chi-Square	41.0	41.0		
		No	Observed	4	95		
			Expected	49.5	49.5		
			Chi-Square	41.8	41.8		
20.	**Initial hook left to right in numeral 1**	Yes	Observed	0	89	160.4	0.0
			Expected	44.5	44.5		
			Chi-Square	44.5	44.5		
			No Observed	100	11		
			Expected	55.5	55.5		
			Chi-Square	35.7	35.7		
21.	**Ending stroke direction upward in numeral 2**	Yes	Observed	26	39	3.9	0.0
			Expected	32.5	32.5		
			Chi-Square	1.3	1.3		
		No	Observed	74	61		
			Expected	67.5	67.5		
			Chi-Square	0.6	0.6		
22.	**Turning at top round in numeral 2**	Yes	Observed	91	98	4.7	0.0
			Expected	94.5	94.5		
			Chi-Square	0.1	0.1		
			No Observed	9	2		
			Expected	5.5	5.5		
			Chi-Square	2.2	2.2		
23.	**Upper turning angular + round in numeral 3**	Yes	Observed	66	12	61.3	0.0
			Expected	39	39		
			Chi-Square	18.7	18.7		
			No Observed	34	88		
			Expected	61	61		
			Chi-Square	12.0	12.0		
24.	**Lower turning angular in numeral 3**	Yes	Observed	13	1	11.1	0.0
			Expected	7.0	7.0		
			Chi-Square	5.1	5.1		
		No	Observed	87	99		
			Expected	93	93		
			Chi-Square				

contd. table 1

Sr. No.	Characteristics			Andhra Pradesh	Punjab	$(x)2$ (sum)	P value
25.	**Lower turning round in numeral 3**	Yes	Observed	85	98	10.9	0.0
			Expected	91.5	91.5		
			Chi-Square	0.5	0.5		
		No	Observed	15	2		
			Expected	8.5	8.5		
			Chi-Square	5.0	5.0		
26.	**Ending portion hook in numeral 3**	Yes	Observed	30	16	5.5	0.0
			Expected	23	23		
			Chi-Square	2.1	2.1		
		No	Observed	70	84		
			Expected	77	84		
			Chi-Square	0.6	0.6		
27.	**Ending portion simple in numeral 3**	Yes	Observed	54	74	8.7	0.0
			Expected	64	64		
			Chi-Square	1.6	1.6		
		No	Observed	46	26		
			Expected	36	36		
			Chi-Square	2.8	2.8		
29.	**Size of upper lower- lower larger to similar in numeral 3**	Yes	Observed	10	25	7.8	0.0
			Expected	17.5	17.5		
			Chi-Square	3.2	3.2		
			No Observed	90	75		
			Expected	82.5	82.5		
			Chi-Square	0.7	0.7		
30.	**Upper lower relationship dissimilar in numeral 3**	Yes	Observed	17	7	4.7	0.0
			Expected	12	12		
			Chi-Square	2.1	2.1		
		No	Observed	83	93		
			Expected	88	88		
			Chi-Square	0.3	0.3		
31.	**Upper lower relationship similar in numeral 3**	Yes	Observed	69	82	4.6	0.0
			Expected	75.5	75.5		
			Chi-Square	0.6	0.6		
			No Observed	31	18		
			Expected	24.5	24.5		
			Chi-Square	1.7	1.7		
32.	**Connection between slanting and vertical stroke open in numeral 4**	Yes	Observed	80	92	6.0	0.0
			Expected	86	86		
			Chi-Square	0.4	0.4		
		No	Observed	20	8		
			Expected	14	14		
			Chi-Square	2.6	2.6		
33.	**Left slant stroke a/ portion of vertical stroke below horizontal stroke b – longer in numeral 4**	Yes	Observed	40	20	9.5	0.0
			Expected	30	30		
			Chi-Square	3.3	3.3		
		No	Observed	60	80		
			Expected	70	70		
			Chi-Square	1.4	1.4		

contd. table 1

Sr. No.	Characteristics			Andhra Pradesh	Punjab	$(x)2$ (sum)	P value
34.	**Position of starting of horizontal stroke related to vertical stroke – similar in numeral 5**	Yes	Observed	14	27	5.2	0.0
			Expected	20.5	20.5		
			Chi-Square	2.1	2.1		
		No	Observed	86	73		
			Expected	79.5	79.5		
			Chi-Square	0.5	0.5		
35.	**Crossing of horizontal stroke/ curve –yes in numeral 5**	Yes	Observed	21	6	9.2	0.0
			Expected	13.5	13.5		
			Chi-Square	4.2	4.2		
		No	Observed	79	94		
			Expected	86.5	86.5		
			Chi-Square	0.7	0.7		
36.	**Crossing of horizontal stroke /curve – no in numeral 5**	Yes	Observed	45	63	6.5	0.0
			Expected	54	54		
			Chi-Square	1.5	1.5		
			No Observed	55	37		
			Expected	46	46		
			Chi-Square	1.8	1.8		
37.	**Position of crossing- top in numeral 5**	Yes	Observed	25	0	28.6	0.0
			Expected	12.5	12.5		
			Chi-Square	12.5	12.5		
		No	Observed	75	100		
			Expected	87.5	87.5		
			Chi-Square	1.8	1.8		
38.	**Position of crossing – no in numeral 5**	Yes	Observed	49	69	8.3	0.0
			Expected	59	59		
			Chi-Square	1.7	1.7		
		No	Observed	51	31		
			Expected	41	41		
			Chi-Square	2.4	2.4		
39.	**Bottom portion hook in numeral 5**	Yes	Observed	22	36	4.8	0.0
			Expected	29	29		
			Chi-Square	1.7	1.7		
		No	Observed	78	64		
			Expected	71	70		
			Chi-Square	0.7	0.7		
40.	**Bottom portion round in numeral 5**	Yes	Observed	43	71	16.0	0.0
			Expected	57	57		
			Chi-Square	3.4	3.4		
		No	Observed	57	29		
			Expected	43	43		
			Chi-Square	4.6	4.6		
41.	**Bottom portion hook + straight and angular in numeral 5**	Yes	Observed	18	8	4.4	0.0
			Expected	13.0	13.0		
			Chi-Square	1.9	1.9		
		No	Observed	82	92		
			Expected	87.0	87.0		
			Chi-Square	0.3	0.3		

contd. table 1

Sr. No.	Characteristics			Andhra Pradesh	Punjab	$(x)2$ (sum)	P value
42.	**Turning stroke round in numeral 5**	Yes	Observed	21	51	19.5	0.0
			Expected	36.0	36.0		
			Chi-Square	6.3	6.3		
		No	Observed	79	49		
			Expected	64	64		
			Chi-Square	3.5	3.5		
43.	**Turning stroke angular in numeral 5**	Yes	Observed	43	13	22.3	0.0
			Expected	28	28		
			Chi-Square	8	8		
		No	Observed	57	87		
			Expected	72	72		
			Chi-Square	3.1	3.1		
44.	**Stroke initial present in numeral 7**	Yes	Observed	20	6	8.7	0.0
			Expected	13.0	13.0		
			Chi-Square	3.8	3.8		
		No	Observed	80	94		
			Expected	87.0	87.0		
			Chi-Square	0.6	0.6		
45.	**Crossing bar present in numeral 7**	Yes	Observed	70	36	23.2	0.0
			Expected	44.5	44.5		
			Chi-Square	6.1	6.1		
		No	Observed	72	39		
			Expected	55.5	55.5		
			Chi-Square	4.9	4.9		
46.	**Crossing position middle in numeral 7**	Yes	Observed	56	33	10.7	0.0
			Expected	44.5	44.5		
			Chi-Square	3.0	3.0		
		No	Observed	44	67		
			Expected	55.5	55.5		
			Chi-Square	2.4	2.4		
47.	**Connection between horizontal and vertical stroke open in numeral 4**	Yes	Observed	89	99	6.2	0.0
			Expected	94	94		
			Chi-Square	0.3	0.3		
		No	Observed	11	1		
			Expected	6	6		
			Chi-Square	4.2	4.2		
48.	**Special shapes E- shape in numeral 8**	Yes	Observed	20	39	8.7	0.0
			Expected	29.5	29.5		
			Chi-Square	3.1	3.1		
			No Observed	80	61		
			Expected	70.5	70.5		
			Chi-Square	1.3	1.3		
49.	**Special shape – 2 circles in numeral 8**	Yes	Observed	8	0	8.3	0.0
			Expected	4.0	4.0		
			Chi-Square	4.0	4.0		
		No	Observed	92	100		
			Expected	96.0	96.0		
			Chi-Square	0.2	0.2		

contd. table 1

Sr. No.	Characteristics			Andhra Pradesh	Punjab	(x)2 (sum)	P value
50.	**Position of loop crossing vertical in numeral 9**	Yes	Observed	68	53	4.7	0.0
			Expected	60.5	60.5		
			Chi-Square	0.9	0.9		
		No	Observed	32	47		
			Expected	39.5	39.5		
			Chi-Square	1.4	1.4		
51.	**Position of loop crossing open in numeral 9**	Yes	Observed	4	14	6.2	0.0
			Expected	9	9		
			Chi-Square	32	47		
		No	Observed	96	86		
			Expected	91	91		
			Chi-Square	0.3	0.3		
52.	**Position of loop crossing vertical + loop in numeral 9**	Yes	Observed	6	0	6.2	0.0
			Expected	3	3		
			Chi-Square	3.0	3.0		
			No Observed	94	100		
			Expected	97	97		
			Chi-Square	0.1	0.1		
53.	**Position of loop crossing open+ touch in numeral 9**	Yes	Observed	0	7	12.1	0.0
			Expected	3.5	3.5		
			Chi-Square	3.5	3.5		
		No	Observed	100	93		
			Expected	96.5	96.5		
			Chi-Square	0.1	0.1		
54.	**Starting position of loop related to vertical left to middle in numeral 9**	Yes	Observed	0	17	18.6	0.0
			Expected	8.5	8.5		
			Chi-Square	8.5	8.5		
		No	Observed	100	83		
			Expected	9.5	9.5		
			Chi-Square	0.8	0.8		
55.	**Starting position of loop related to vertical right to middle in numeral 9**	Yes	Observed	0	6	6.2	0.0
			Expected	3	3		
			Chi-Square	3	3		
		No	Observed	100	94		
			Expected	97	97		
			Chi-Square	0.1	0.1		
56.	**Starting position loop top to upper half of numeral 9**	Yes	Observed	0	28	32.6	0.0
			Expected	14	14		
			Chi-Square	14	14		
			No Observed	100	72		
			Expected	86	86		
			Chi-Square	2.3	2.3		

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