

Age Related Variation in Feminine Handwriting among Population Groups of Delhi, India

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Abstract

Background: Handwriting is a uniquely human trait which progresses and evolves during lifetime and declines with age. The aim of the present paper is to assess variation in handwriting features with age among female writers of select population groups of Delhi, India (for roman script).

Method: A total of 405 handwritten samples were obtained from female (n=405) writers in the age range of 14-60 years. Writers were stratified into three age groups (≤ 18 years, 19-38 years and ≥ 39 years) in accordance to population group. Macro- and micro-features of handwriting were extracted from the scanned handwritten samples. These features were subjected to statistical analysis in the objective driven research.

Result: The mean difference among age groups for pen pressure, height of handwriting and handwriting connectivity was statistically significant ($p < 0.001$). Significant difference was also observed among age groups for all micro-features of handwriting selected in the present study, namely, nature of 'i' - dot ($p < 0.001$), nature of lower loop of 'g' ($p < 0.01$); nature of 'd' - stem ($p < 0.01$), nature of 'm' - hump ($p < 0.05$) and 'r' - shape ($p < 0.001$).

Conclusion: The present study showed that there was a significant variation in both macro- and micro- features of handwriting with respect to age of the writer. Pen pressure, height of handwriting and handwriting connectivity were prominent macro-features that addressed age related variation in handwriting. In addition, significant variation was observed among age groups for all micro-features of handwriting selected in the present study. The present study has immense forensic significance as it can assist to analyze age of the writer on the basis of handwriting characteristics.

Keywords: Demographic Characteristic; Neuro-Muscular Degeneration; Cognitive Performance; Micro Feature; Handwriting Analysis

Introduction

Handwriting is a complex skill which simultaneously necessitates cognitive and motor - control processing and visual-motor co-ordination of a writer. Handwriting, as a trait, progresses and evolves during lifetime and declines with age owing to neuro-muscular degeneration [1-3].

Age of the writer has a significant impact on his/her writing skill. It has been opined that age related changes in handwriting are evidenced as general reduction in pen pressure, irregularity of inter-letter and inter-word spacing, deterioration in the quality and structure of letter forms and variants, inconsistency in the locations of 'initial' strokes and direction and length of terminating strokes, occurrence of erratic movements and above all appearance of fine tremor [1].

Age was observed to significantly predict handwriting parameters, indicating the deterioration in handwriting performance among older persons [4]. Engel-Yeger *et al.* [2] found that, with age, writing time was longer which lead to writing slow-ness. This increased writing time might be linked to degraded sensory-processing abilities, which can lead to ineffective visual-motor performance and deteriorated motor and cognitive performance [5,6].

The aim of the present paper is to assess age related variation in handwriting characteristics (roman script) of female writers of select population groups of Delhi, India. Earlier studies have been carried out with an aim to characterize age either by visual

observation by assessing features such as letter size, slant, spacing, alignment (with reference to baseline) and number of pen lifts or by automatic feature extraction through computational procedures [7-10]. The present study has made an attempt to employ a set of both quantitative (features extracted at document level using computational algorithm) and qualitative (character shape level features extracted through manual observation) handwriting features to study age differences in handwriting. The study holds immense potential in forensic domain. The study of variation in handwriting features with age has forensic significance because it can assist to analyze age of the writer on the basis of handwriting characteristics.

Materials and Methods

The methodology is divided into three phases: **data collection, feature extraction and statistical analysis**. The study was approved by the Institutional Ethics Committee of the Department of Anthropology, University of Delhi, Delhi, India. Subjects were well-informed about the motive of the study and a prior consent was taken from all the subjects.

Data collection

Handwritten samples were collected from 405 female subjects, in the age-range of 14-60 years, residing in Delhi and Gurugram (Haryana), India. Delhi is a metropolitan city (also called National Capital Territory of Delhi, India) inhabited by people linked with several ethnic/ caste groups and diverse cultural traditions. Gurugram is a cyber city located in Indian State of Haryana; which is 30 km away from Delhi. It is included in National Capital Region (NCR) of India. The data, in the present study, was collected from female subjects belonging to four population groups – Khatri (Non-Sikh) (n=52), Arora (Non-Sikh) (n=92), Yadav (n=161) and Hindu Sindhi (n=100) using random sampling technique.

Khatri and Arora represent two north-Indian mercantile communities primarily following Punjabi linguistic tradition. Sindhi represent mainly an urban community identified by their linguistic tradition (Sindhi), their traditional dress, form of religion (the cult of Varun and the river god, Jhulelal), structure of their name (with the suffix *ani*) [11]. In present study, Hindu Sindhi have been taken into consideration. The *Yadav* community, which traces their descent to Lord Krishna of *Yadu* lineage, has prospered in variety of occupations such as entrepreneurs and businessmen, while adhering to traditional occupation of cattle rearing and dairying [12].

Subjects, in the present study, were stratified into three age groups- ≤ 18 years (n=191), 19-38 years (n=138) and ≥ 39 (n=76) years in accordance to population group (Table 1). The age range was formulated on the basis of statistical percentiles (keeping in mind the concept of graphic maturity). Only right handed female subjects were taken into consideration.

Population Group(%)	Age Intervals		
	≤ 18	19-38	≥ 39
Khatri Non-Sikh	21.2	53.8	25.0
Arora Non-Sikh	23.9	50.0	26.1
Yadav	83.9	14.9	1.2
Hindu Sindhi	23.0	40.0	37.0

Table 1: Writer distribution in accordance to demographic characteristics

Subjects were asked to fill the pro-forma which comprised of general information regarding socio-demographic and other cultural attributes. Each subject was also asked to copy the source document (in roman script) in his/her natural handwriting onto a plain sheet with the help of a blue ball pen. The source document comprised of a pangram and a short passage. The short passage had punctuation marks such as comma, inverted comma, exclamation mark and question mark, abbreviations, numerals (0-9) and words of choice. The collected handwritten samples (N=405) were digitally scanned at 400 dpi (dots per inch) and then used for further analysis. The scanned image was pre-processed to remove noise from the image.

Feature Extraction

In the present study handwriting features were obtained from scanned images with the help of MATLAB 2016a and Image J 1.6 software.

These features were divided into two classes [13]:

- **Macro-features** (obtained at the document level (entire handwritten manuscript) or at the paragraph, line, word, and character levels) and;
- **Micro-features** (obtained at the allograph, or character shape level)

Table 2 provides the list of macro and micro features used and the method used to obtain the handwriting feature. The selected handwriting features can effectively assist in analyzing age related variation in handwriting. Moreover Huber and Headrick [1] have also emphasized that age related changes in handwriting are manifested in pen pressure, inter-letter and inter-word spacing, quality and structure of letter forms and loop features.

S. No.	Handwriting features	Computing method
I		
Macro-features		
1	Pen pressure	Gray- level threshold algorithm; computed in Matlab [14] The higher threshold value indicates light pressure and vice-versa.
2	Slant angle (in degrees)	Image processing software (Imagej); computed as the inclination of axes of letters in relation to baseline and averaging it over the entire document. (Acute angle represents inclined slant, right angle represent vertical slant and obtuse angle represents reclined slant)
3	Height of Handwriting (in pixels)	Image processing software (Imagej); Computing distance (in pixels) between the maximum and minimum point of the vertical dimension of the capital letters and averaging it over the entire document.
4	Handwriting connectivity	Assessing number of connected components; greater number of connected components specifies printed handwriting.
II		
Micro features		
1	'm'- hump shape	Manual observation
2	Nature of 'i'- dot	
3	Nature of 'd'- stem	
4	Nature of lower loop of 'g'	
5	'r'- shape	

Table 2: List of Handwriting attributes and respective computing method

Statistical Analysis

Data was entered and statistically analysed using SPSS software (version 23.0). ANOVA (Analysis of Variance; F-test) test was used to compute mean difference among age groups for macro features (continuous variables). In order to assess difference between age groups for micro-features, chi-square (χ^2) test was used.

Results

Table 3 represent variants or forms of the micro features observed in the feature acquisition process. Figure 1 and 2 depict the types of select macro and micro features obtained in the present research. Table 4 exhibits mean, standard deviation and ANOVA test values of four macro features in accordance to age of female writer (for roman script). It was found that the gray threshold value for age group ≤ 18 years was significantly lower in comparison to other age groups. The mean difference among age groups for pen pressure was statistically significant ($p < 0.001$). The mean value of height of handwriting for age group ≥ 39 years was found to be lowest in comparison to other age-groups. The difference among age intervals for mean value of height of handwriting was also statistically significant ($p < 0.001$). The mean value of connected component (used as a measure of handwriting connectivity) was found to be highest for age group ≥ 39 years in comparison to other age-groups. Differences were found to be statistically significant among all age groups for mean value of connected components ($p < 0.001$).

Micro features	Classification				
'm'- hump shape	Curved	Angular	-	-	-
Nature of 'i'- dot	Dot	Circle	Slash	Any- other	-
Nature of 'd'- stem	Looped	Retraced	Simple-downward	-	-
Nature of lower loop of 'g'	Cramped	Broad	Triangular	Open	Without Loop
'r'- shape	Arcade	Parochial	-	-	-

Table 3: Classification of Micro-features

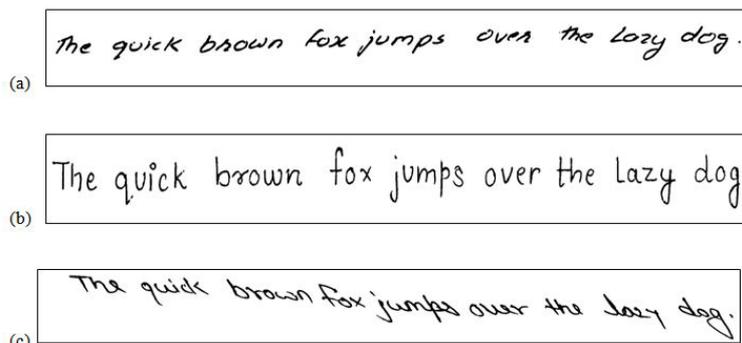


Figure 1: Variants of macro and micro features
Slant: (a) Inclined Slant, (b) Vertical Slant, (c) Reclined Slant
Nature of 'i':dot: (a) Dot, (b) Circle
Shape of 'r': (a) parochial (c) arcade

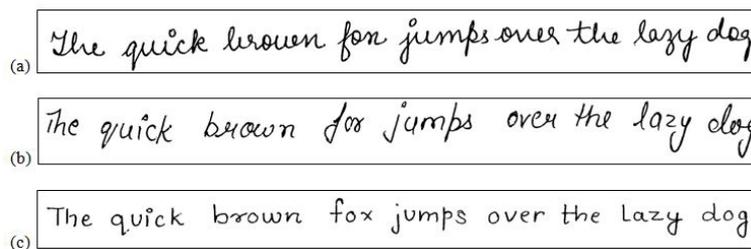


Figure 2: Classes of handwriting connectivity
 Increase in number connected components with decrease in connectivity between allographs: (a) Cursive: connected components=9; (b) Cursive printed composite: connected components=27; (c) Printed: connected components=45

Macro-features	Age interval			F-value
	≤18	19-38	≥39	
Pen Pressure (Gray threshold value)	0.713±0.03	0.714±0.03	0.731±0.03	12.01***
Slant angle (in degree)	85.59±10.66	84.45±9.48	85.42±9.76	0.59
Height of Handwriting (in pixel)	88.41±12.71	83.42±11.72	76.78±10.34	26.63***
Handwriting connectivity	20.76±7.01	21.40±7.21	27.67±8.44	25.39***

***p < 0.001

Table 4: Statistical patterns of macro features in accordance to age range (in all the four groups)

Table 5 depicts the percentage distribution of micro features in accordance to age of female writer (for roman script). Chi-square (χ^2) value has also been calculated to indicate the difference among age groups for micro-features of handwriting. Handwriting samples obtained from writers in age group of ≥ 39 years exhibited highest percentage (~80%) of dot over 'i'- stem. While handwriting samples obtained from writers in age group of ≤ 18 years exhibited highest percentage (~73%) of circle over 'i'- stem. The age-group ≤ 18 years was associated with highest percentage (~57%) of broad lower loop of 'g' followed by age groups of 19-38 years and ≥ 39 years respectively. The age- group 19-38 years was associated with highest percentage (~80%) of retraced'd'- stem followed by age groups of ≤ 18 years and ≥ 39 years respectively. The age- group ≤ 18 years exhibited highest percentage (~90%) of curved 'm'- hump followed by age groups of ≥ 39 years and 19-38 years respectively. Arcade form of 'r' was most prevalent for writers in age group ≥ 39 years (~59%) and parochial form of 'r' was most prevalent for writers in age group ≤ 18 years (~79%). The difference among age groups for all micro-features was found to be statistically significant.

Micro-Features	Age interval			χ^2
	≤18(%)	19-38(%)	≥39(%)	
Nature of 'i' - dot				
Dot	27.2	50.0	80.3	94.55***
Circle	72.8	49.3	11.8	
Slash	0.0	0.7	7.9	
Nature of lower loop of 'g'				
Cramped	25.1	31.9	51.3	23.10**
Broad	57.1	51.4	35.5	
Triangular	3.1	2.9	0.0	
Open	7.3	10.1	10.5	
Without loop	7.3	3.6	2.6	
Nature of 'd'- stem				
Looped	24.6	16.7	39.5	15.94**
Retraced	71.2	79.7	53.9	
Simple Downward	4.2	3.6	6.6	
Nature of 'm'-hump				
Curved	89.5	79.7	81.6	6.66*
Angular	10.5	20.3	18.4	
'r'- shape				
Arcade	20.9	32.6	59.2	36.55***
Parochial	79.1	67.4	40.8	

*p<0.05; **p<0.01, ***p < 0.001

Table 5: Statistical Patterns of micro features in accordance to age range (in all the four population groups)

Discussion

Studies on handwriting kinematics in advanced age reveal multiple findings such as slower speed of handwriting movements, reduced and more uniform pen pressure across strokes, greater stroke variability, increased time of the decelerative phase of movements, and greater reliance on visual feedback compared with younger writers [7,15-21].

The present study was conducted to assess variation in handwriting characteristics with age. It was found that there was a gradual increase in mean gray threshold value (measure of pen pressure) with age. In other words there was a gradual decrease in pen pressure with advancing age. The pen pressure finding is consistent with previous studies [2,7,22-24]. The decline in pen pressure in old age might be linked with degenerative neuro-physical function and ineffective perceptual motor abilities.

There was a gradual decrease in mean value of height of handwriting with advancing age. While, there was a gradual increase in number of connected components (indicative of handwriting connectivity) with age. This suggests that handwriting becomes more printed with advancing age. This might be linked with increase in the number of pen lifts with age and the gradual and progressive loss of control of the writing instrument. Walton [7] found an association between age of the writer and number of pen lifts and stated that younger writers (mean age of 22) lifted the pen on an average 2.7 times within a sentence, whereas the oldest writers (mean age of 75) lifted the pen on average 6.0 times while writing. The increase in number of pen lifts with age might be associated with degenerative neuro-muscular control in the old age.

Most of the handwriting specimen obtained from age group ≥ 39 years exhibited dot over 'i'-stem, cramped lower loop of 'g', retraced 'd'-stem, curved 'm'-hump and arcade form of 'r'. There was a significant variation among age-groups for all micro features of handwriting. Moreover it has been shown that individual characteristics of handwriting such as design of letters, letter connections and location of dots are more frequently retained even as time progresses and the writer becomes older [8].

Age related changes in handwriting attributes might be linked with several factors, such as decline in performance speed degeneration in neuromuscular function affecting hand strength, speed, and coordination object manipulation; dexterity abilities; and impaired perceptual motor skills, all of which are linked with sensory processing [25-27].

Conclusion

The present study was conducted to assess variation in handwriting characteristics with age among female writers for roman script. There was a significant variation in both macro- and micro- features of handwriting with respect to age of the writer. Significant differences among age groups were observed for pen pressure, height of handwriting and handwriting connectivity. Age related variation was also found in all micro-features of handwriting selected in the present study.

The study provides crucial insight on the age related variation (an extrinsic parameter) upon handwriting characteristics. The present study has immense significance in forensic research as it can aid to examine and assess age of the writer from handwritten document. Further it can serve as corroborating evidence aiding in authorship determination in questioned document examination. Moreover computer assisted handwriting analysis provide repeatability and objectivity to the result to a certain extent.

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