



Identification of Violent Behavior in Serial Killers Using Handwriting

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Abstract:

This review paper highlights the hidden violent and aggressive behavior in serial killers by analyzing its handwriting features. Identification of violent behavior in handwriting is very important as it has close relation with personality disorder or psychopathy and its associated crimes that can be overcome in future. Graphology is a scientific method to identify an individual's personality, temperament, professional and intellectual behavior, social and inner capacities by evaluating and understanding patterns revealed in handwriting. Handwriting analysis describes a psycho-social-behavior like that of a psychologist who emphasizes on biological and psychic components interactions revealed in one's handwriting e.g. serial killers. Graphology experts approach advanced technology and research studies to facilitate the process of handwritten images of general public data and observe the signs of violence in their graphical handwritten features. It can be used as a coherent and resourceful profiling instrument to enrich the information and to assist the forensic psychologists, psychiatrists and investigators in their investigation.

Keyword: Graphology, Violent Behavior, Personality Disorder/Psychopathy, Serial Killers.

1. Introduction

Currently crime rate is accruing rapidly with unique cases reported on news and social media that involve violent and aggressive nature. Among these cases, gang rape committed in Delhi India in 2014 was the most famous case in which four accused brutally raped the girl in some dishonorable and indescribable violent ways [1]. Ryan International School was another highlighted crime case in India that involved murder of class two student by the accused who was in

class eleven just for delaying class exams. However, it was difficult to believe that the accused could be such violent and aggressive as he was composed and well-known for performing musical instrument in school [2]. Similarly, three men were killed in 2013 by a British woman Joanna Dennehy who was 31-year-old [3] and 30 people were murdered by Ted Bundy, the most famous serial killer in America [4].

It is easy to criticize one's evil conduct but more difficult to understand him [5]. Aggressive and violent nature is common behavior

behind calm and cool exterior of criminals that leads them to commit brutal crimes [6]. This behavior differentiates them from normal people and categorizes them as personality disordered or psychopathic [7, 8, 9]. Psychopathy accounts for a set of personality traits including low emotional responses, lack of sympathy and being impulsive with deprived behavioral controls that results into criminal or antisocial behavior. Additionally, psychopathic behavior exhibits extreme egoism, inability to express love, and failure to establish personal relationships and environmental interaction. Psychopaths show tricky and scheming interpersonal style that leave vast destructive impact on their personal as well as social life and work. Nearly 1% of general population and 15-25% of prison population as compared to offenders, contribute to psychopathy including serial killers with more serious violence predominantly in men than women [5].

Psychopathy especially Antisocial Personality disorder (APD) mainly in serial killers has been assessed in various ways mainly from two aspects, psychological and psychiatric [9, 10]. Psychological studies involve behavior analysis based on sets of lengthy structured interviews, while psychiatry studies involve understanding of mental features such as amygdale and fMRI study etc. [11]. Likewise, self-report scales are highly associated with observing measures of psychopathy such as Levenson Self-Report Psychopathy Scale. However, self-report scales are of limited efficacy in clinical or forensic settings to detect APD as dishonesty and lack of understanding are the signs of APD. For that reason, handwriting analysis should be supplemented as supportive tool to self-report scales for assessing the negative personality traits including

dishonesty, aggression, violence, emotional instability, unreliability and insincerity in serial killers. Two instruments namely Psychopathy Checklist-Revised (PCL-R) and Psychopathy Checklist-Screening Versions (PCL-SV) are considered as gold standard for diagnosing and assessing psychopathy in forensic samples. PCL-R is structured as a two-factor model i.e. emotional and interpersonal traits, while PCL-SV is classified as four factor model i.e. life style, affective, antisocial and interpersonal components. However, emotional and interpersonal deficits compel the psychopaths towards crime rather than any other factor or motive. Handwriting analysis can be used as precautionary approach to have awareness about antisocial personality disorder and its possible threat ahead of time [5].

Graphology or handwriting analysis is still an intact scientific study to determine the personality disorder or traits, writer behavior or psychological temperament [12]. Human beings have used handwriting for centuries as a way of communication, nevertheless, studies have proved that it also links to human psychological and brain activities [13]. Like all other actions, handwriting is considered an important feature of human brain that forms neurological characters and pattern based on writer habits. These patterns are driven by unique neuromuscular movement (hand) to write [14]. Central nervous system controls the writing organ that makes writing as an unconscious yet revealing process. Forensic graphologists use handwriting as an investigative tool to determine and reveal emotions, mood and mental health from brain impulses in criminal personality [15]. Psychopathic people that have personality disorder, reflect dysfunctional amygdale in their handwritings [16].

Many research used Apriori Algorithm [17] while some used computers as an advanced technology for various applications and crime analysis. Several studies considered handwriting as an identification tool as it is used as a biometric behavior [18]. Graphologists, psychologists, investigators and specialists should follow a common rule that there is no such thing as a psychopathic handwriting as there is no completely honest (normal) or dishonest (psychopath) one and every individual has a negative potential or choice to let run his/her actions (conscious) or to control it (unconscious). Psychopathy, dishonesty or hypocrisy has no equivalent and fixed sign, thus hypotheses should be built for graphological analysis of a psychopath as it requires to associate marks between negative feature and a writing sample [5]. Large number of research is available on handwriting analysis that predict personality traits [3, 5, 6, 10, 13], however research that predict violent and aggressive behavior in psychopath's or serial killer's handwriting is limited [19]. Research studies [15] show that exceptionally larger alphabets should be considered as red flag in handwriting sample and visualized writer's personal importance [20]. Handwriting is considered as a major element to study red flags that can lead to violent behavior in future. It requires further research that can assist to diagnose antisocial personality disorder from handwriting sample and will be a great support for the society [1].

2. Graphological Analysis of Dangerous Signs

There are measurable handwriting features that can be used as an identification tool to describe writers and can be significant for

forensics, library science, data science and biometric purposes [1, 4, 9, 18]. Graphologists go through set of specific features in an individual handwriting that conveys a specific message primarily describing aggressive and violent behavior. Some of the potential features for aggressive and violent behavior are discussed as followings;

- **Level of Organization:** psychopath's handwriting with respect to graphology can be comparatively conformist with little rhythm, somewhat ordinary, repetitive, rigid and number of abnormalities. An organized writing is defined as precise, ordered, simple and balanced. However, the graphic gesture in a more common public situation is simplified, combined and calligraphic apparently with more positive sense of writing [21, 5].
- **Overly Wide Spaces between Words:** individual placing words with abnormal distance indicates paranoia and the distance put between each words represents the distance that the writer maintains between him and other people. People with abnormal distanced handwritings are distrustful and tend to be nervous for others motives intentions. They want to control everyone that makes them aggressive and paranoid. They hardly trust in others and there is lack of intimacy in their lives [13, 22].
- **Word Height:** word height is another feature that shows violent nature of an individual and Upper Zone with extremely larger alphabets indicates severe ethics. In most of the cases, graphologists noticed that the middle zone is more evident as compare to upper and lower zones which are instable and tense. Such features

indicate special consideration for sensations, unfulfilled desires and instinctive frustrations, imbalance and extreme structure of goals or motives and dishonesty [21].

- **Closely Spaced & Overly Spaced Letters:** these features indicate an individual is suffering from two negative aspects and confirm their uptight and paranoid nature. People with these feature are socially unstable and have real social problems. Loops that come to a point in Upper Zone represents frustration, pressure, irritation, nervousness and fear [23, 13].
- **Incoherent Baseline:** individual with incoherent baseline shows aggression in personality, failure to maintain a coherent or clear four dimensional pattern and trouble to fit with any kind of society. People with this type of feature tend to be sociopath who disconnect from the society and disrespect the societal norms [24].
- **Heavy Pressure, Uneven Slant & Baseline:** individual with this feature represents extreme angularity with heavy pressure in writing that suggests aggression, violent and defensive tendencies [13, 25]. Rigidity, anxiety, alertness, cruelty, insincerity, sadism and lack of cooperation are negative features associated with vertical writing slant. People with twisted and deformed handwriting tend to be potentially dangerous, crooked, biased, abnormal in thinking if they are forced to change themselves [13, 26]. Psychopaths whose writings are connected to the left slant or margin indicate connection to the past, very deep attachments for parents particularly mother, vulnerable childhood,

and lack of independencies or positive activities [21].

- **Disconnected Writing:** people with this type of writing feature represent isolation, little coordination and withdrawal from positive life experiences that lead them to violent behavior. Narrow or mirrored elements in the writing may represent a sign shallowness of strong environmental influence and disproportionate reactions on writer. On the other hand, flat writing with false connection represents no sign of feelings or empathy for others and self-interest [1, 21].

East Tennessee University published a report on handwriting which contains a list of signs representing dangerousness and personality disorder as explained in figure 1 [7]. Handwriting features identified by handwriting analysis as well as by speech patterns are listed in figure 2 that represent signs of dishonesty and Personality disorders [27].

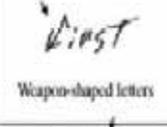
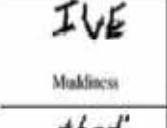
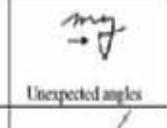
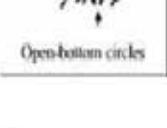
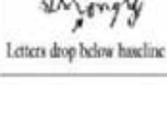
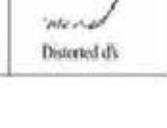
		
		
		
		

Figure 1: Signs of dangerousness in handwriting [1].

<i>company</i> Slow writing speed	<i>posting</i> Unnatural writing structure/style	<i>company</i> Unstable, thrifty, formless structures
<i>selling</i> Touching up letter formations	<i>person</i> Letters written as other letters	<i>with</i> Blibbed or punctuated writing
<i>you</i> Pen lifts	<i>company</i> Important parts of letters omitted	<i>allow</i> Oval letters open at the baseline
<p>THE TRUTH MUST ALWAYS BE ACCURATE</p> <p>Marked initial emphasis</p>		

Figure 2: Signs of dishonesty in handwriting [1].

3. Graphopathology of Psychopaths: serial killers under the microscope

According to Wertham's theory that states that every criminal has the tendency to suffer from extreme pathological disorder and its deepened analysis should be considered to approach the essential parts of the problem. From a psychiatric perspective, schizophrenics, alcoholics, paranoiacs, rare case of neurotics or obsessive compulsives and extreme cases of hysteria are found among the most dangerous criminals. In the hierarchy of criminals, cases that can be categorized at the highest step are those that involve people mostly with schizoid personality i.e. the well-known serial killers. At this point, it is a valid question to ask about this category of perpetrators that "why the serial killers are psychopaths and why it is not listed in mentioned disorders" [21]. This statement was well explained by the scientist Florence Wittkowsky who devoted her studies for the

diagnosis of psychopathology through handwriting analysis. She identified that a specific symptom cannot define the psychopathy as it is not a disorder but a personality complex which is of more common classes of psychiatric diagnoses. This type of people is incapable of growing with the society, suffer from imbalance, and become psychopaths when they face rejection [28]. Hence, the serial killer is termed as psychopath as it has all signs of disorders mentioned earlier. The serial killer describes him as person who is intelligent or at times a genius with feeling of control and disobey imposition of the limits by others. They exhibit self-hatred as they suffered parent's negligence, severely abused and grown up in a violent family environment.

It would be fascinating and interesting step to analyze the criminal's handwriting where three names David Berkowitz, Ted Bundy and John Wayne Gacy represent the most important examples in behavioral analysis as followings;

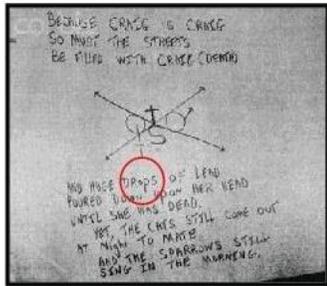
Case Study No. 1: "David Berkowitz"

David Richard Berkowitz is an American serial killer and arsonist who murdered 6 people and wounded 7 others. He is also known as Son of Sam and .44 Caliber Killer, and committed crimes between July 1976 and August 1977 in New York. He is a common example of psychopathic character with disturbed childhood as he was born as a consequence of an affair marriage and was adopted by an average family. He disliked his step mother and sister who were accused of witchcraft and introducing him to punishment. He had a normal life by serving in the army and doing blue collar jobs regardless of no interest for school and obsession for minor theft and pyromania in his childhood. He claimed that he was introduced to

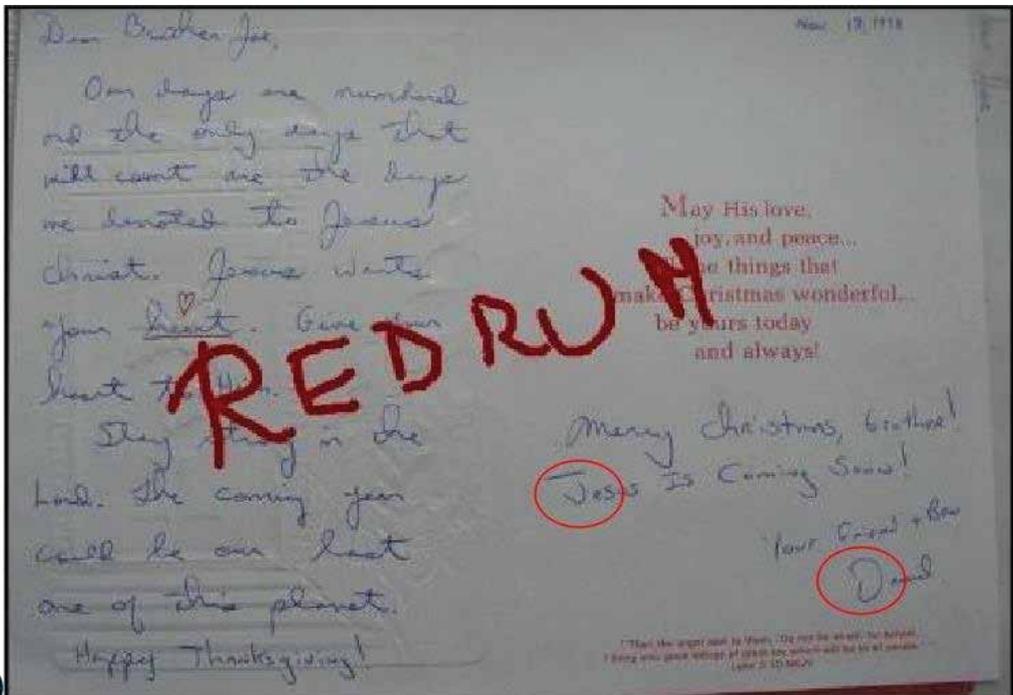
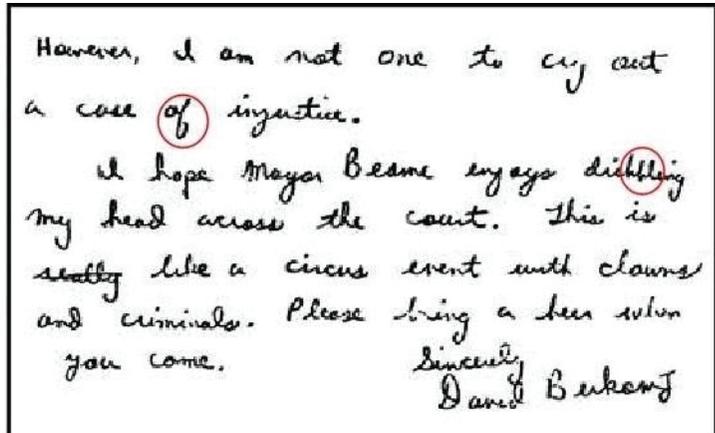
drugs, violent crime and pornography after contacting with the occult in a cult in 1975 that involved only séances and fortune telling harmless activities [21, 29, 30].

Some letters were found throughout this period of time that proved to be useful to the investigation and to solve the puzzle. The analysis of

these letters confirmed that psychiatrists described the killer as neurotic who was suffering from paranoid schizophrenia and believing that he was in possession of demon. David Berkowitz writing is vertical with horizontal lines running upwards sometimes, distance between the letters and words and line is small and normal, respectively.



3. a)



3. b)

Figure 3: a) & b) Handwriting samples of David Berkowitz [21].

The upper zone is reduced with double loops, lower zone is ended rightward with “f”s that claims attention and zone which is best developed is the middle one. Arcades and semi angular connections is used with medium speed and pressure, keeping a bookish formation of certain letters like the “m”s and representing a 5th grader’s handwriting impression. However, some lightly peculiar appearance of “J”s and “D”s, and regressive ending traits are also detectable in this copy book writing samples [21, 29] as shown in figure 3.

The overall writing of Berkowitz represents the signs of abnormality that are deceptively subtler and important for the analysis. Nevertheless, these signs point towards a person who is disturbed, easy to be influenced, unable to maintain a healthy relationship, having a narrow concept of life and powerful inferiority complex, and incapable to associate his actions and their outcomes [21].

Case Study No. 2: “John Wayne Gacy Jr”

John Wayne Gacy was an American serial killer and rapist, also known as the Killer Clown who assaulted and murdered 33 young boys and men (1972-1978). He born in a middle class family with three children and was the only son in close affection with his mother and sisters. However, he had a difficult relationship with his abusive and alcoholic father who constantly demeaned him. He was molested by a family friend when he was 9 years old and later on after two years he suffered an accident with serious consequences that caused his father to ignore him. Similar to Berkowitz, he also had no interest in school but he succeeded in his own business and became an outstanding member of the society. He tried to hide his violent and bisexual tendencies by living a normal life but he failed to do so and as a result caused termination of his two marriages [21, 30].

During his trial, a team of psychiatrists diagnosed and described him as a person who depicts himself as a victim of hostile circumstance and denies for everything happened to him as an alibi to assure a sympathetic response. Technically some important features should be highlighted such as winding left margin and filling the page shows little space for others. The writing has rightward slant, little winding horizontal lines, letters with slightly reduced, words with large and rows with normal spacing. When considering zones, the upper zone is sharp, filled with ink, has low closed loops with hooked or clubbed debut, middle zone is thread like, lower zone has elongated with loops towards right and hooks such as “f”s. The writing is connected with semi angular inferior traits and angular arcades, achieved by medium speed and pressure [21, 29].

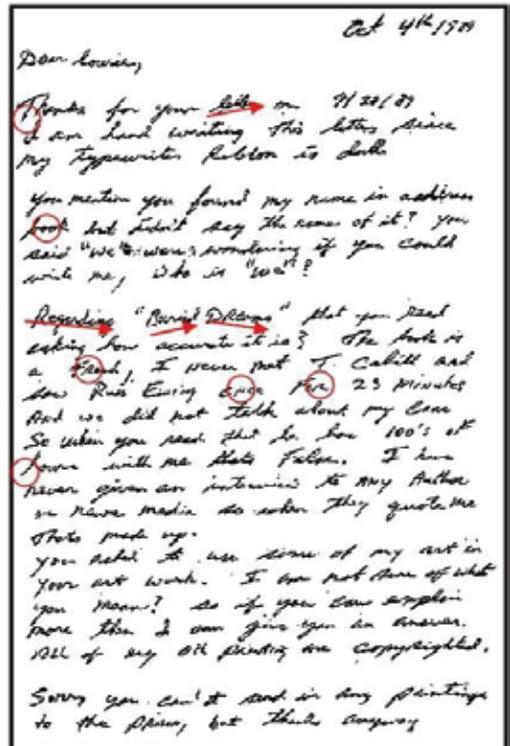


Figure 4: Handwriting sample of John Wayne Gacy [21].

According to professionals, Gacy's handwriting analysis represents a smudged writing with many signs of confusion, unpleasant pastosity, letters with clubbed or hooked debuts, using of capital letters within or at the beginning of words and displaying certain letters formation in awkward manner. The graphological interpretation represents a person with considerable issues when obeying the rules of society but he behaved as a proper individual when living through such rules. Other than this, he is discovered to be a confused and disturbed person with an explosive temper who struggles to fulfil his strong desires and to repress his anger that lead him into a violent human being [21, 29, 31].

Case Study No. 3: Theodore Robert "Ted" Bundy

Theodore Robert Ted Bundy is the most publicized psychopath serial killer, rapist, kidnaper and necrophiliac who was convicted for 30 murders and many other atrocious deeds between 1974 and 1978. The birth certificate of Ted Bundy clearly recognized his paternity but he was suspected to be the son of his own abusive and violent grandfather who pretended to be his parents and representing his mother as his older sister. He raised up in a violent environment and went through spotting traumatic electroconvulsive therapy of his grandmother for depression. These factors caused a young boy to show a vicious and disturbing behavior that accumulated with the passage of time into a large collection of pornography and establishing attraction towards knives. However, he claimed that these were the results of observing a suspicious ritual at the age of three when he found his aunt sleeping and surrounded by knives in her bed [21].

Though his mother's new husband adopted and loved him, he always felt isolated from him but found his support in reading various detective magazines, crime novels and documentaries, getting appeal towards people involved in sexual violence and displaying photos of mutilated or dead bodies. The main triggering event that led to his criminal development was his separation from his university sweetheart and it was a strong enough experience to discover the truth for a man who admitted and shown no interest in interpersonal relationships. Distress and rejection caused him to change his area of interest to psychology and started working at a suicide hotline emergency center. Later on, he commenced law classes and participated in a local reelection operation that led to the beginning of his horrifying violence acts [21, 29, 30].

After his arrest, the psychiatric diagnose found him a very kind, charming and caring person who can decide between wright and wrong but his apparent behavior shows little guilt or sorrow, narcissism, scheming behavior and a weak decision maker. His extremely thorough research and skills of minimizing physical evidence increased his personal charm, and his caring ability led to difficult, frustrating and a longer investigation that unfortunately suggested a large number of victims.

As compared to previous samples explained, Ted Bundy has a more structured handwriting with paragraphs that show interest for his writing appearance. His writing has winding right margin and linear left margin with considerably narrow and tall rightward slant. The writing represents dominant middle zone, low upper zone possessing loops or sharp booklets and more developed lower zone with rounded and big loops. The slightly arising and horizontal lines with reduced space between

letters, varying space between words while small between lines shows embarrassments on various events. The writing is connected with semi angular traits and arcades follows by good speed and even pressure, representing a writing effort. However, a display of crooked letters or artistic interpretation of letters such as “f, l, h” was also found in this writing sample by constant use of long and hooked debut that shows beginning of a curious trait [21] as shown in following figure;

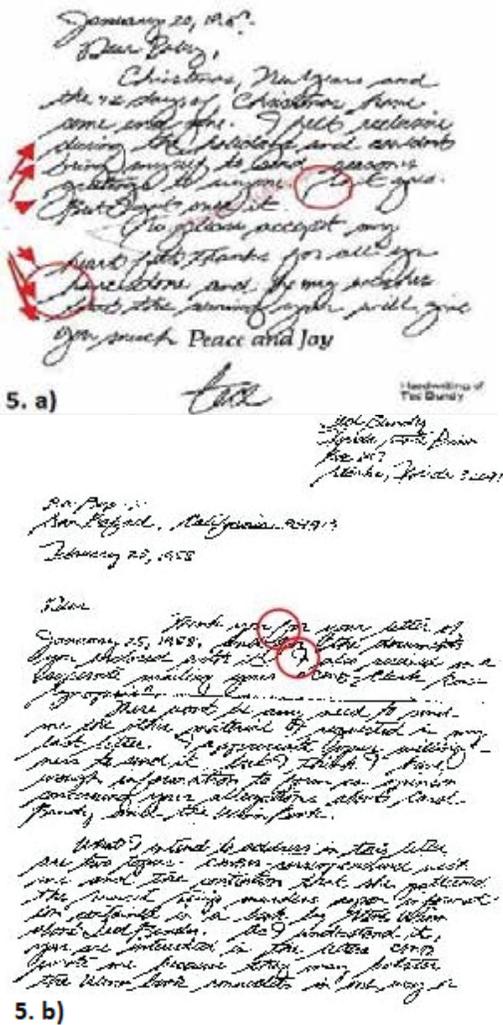


Figure 5: a) & b) Handwriting sample of “Ted” Bundy [21]

Handwriting features of Ted Bundy represents a graceful, charming and seductive, and creative person who is smart, educated, logical, thorough, determined and resourceful. However, the writing also shows the sign of pride, parsimony, arrogance and intellectual adoration. The presence of inner conflicts and absence of feeling liberty led to the emotional instability, personal wildness, and gives the sign of aggressive, malicious sexuality, willful and brutal tendencies [21, 31].

The above three examples only give a general idea of graphology that can be used as a viable method of investigation for criminal profiling and understanding a criminal’s mind. Therefore, graphologists with respect to specific criminal investigation should be involved in the judicial process prior to the suspect identification or during the interrogations as they can deliver useful information regarding the culprit and the best questioning methods.

4. Handwriting Feature Selection & Proposed Process

Significant features present in handwriting can help to distinguish writers and violent behavior in their personality. Automated approach such as machine learning techniques for the analysis of handwriting has gain a vital role for forensics, biometrics and data science etc. Most of the research predicted personality by analyzing handwriting features but few of them considered the hidden personality traits like signs of aggression and violent nature. A recent research [1] has explored some of the main handwriting features such as baseline, spacing between letters, words and lines, writing speed and pressure, word slant and stroke connectivity to study violence and aggression in an

individual personality. These features and their types with examples as explained in the research can be observed in following table [12];

Table 1: Extracted Features [1].

The name of the graphical properties	Description (Holyst, 2004)	Indicator (all are numerical variables)
Letter Size	-Small size letters: lowercase letter height is less than 2.5 mm; - Medium size letters: lowercase Letters height is between 2.6mm and 4 mm; - Large size letters: lowercase Letter height is over 4 mm.	Indicates the number of letters of each size in the text
Letter Connectivity	Connectivity types between the letters in a word: - syllable (without giving pause two/three/four letters are written) - phrase (phrase constitute of connected words) - word (word written without pause); - letter (each letter is separately written in a word);	Indicates the number of words written in each type of connectivity in the text
Baseline Direction	Possible directions of the basic Line (sinusoidal, horizontal Descending).	Indicates the number of lines of each type of direction
Three letter Zone Size	Three zones of letters (height of the lower, middle, and upper zones measured in mm).	Indicates the average height of each zone given in millimeters in the text
Letters Slant	Slant of the handwriting: left, right, mixed (right and straight, left and straight, left and right, left right and straight)	Indicates the number of words written in each type of slant in the text

4.1 Image Feature Extraction Techniques

Image analysis is required to extract the desired features from handwriting samples that predict the violent and aggressive behavior. It involves the conversion of features and objects into image data and then quantitative information followed by some basic steps. Multiple image processing steps are required for the extraction of meaningful quantitative information as developed images are noisy, composite and artifact –laden as outlined in following steps;

- Normalization: The first step is to read the digital image by removing or correcting imperfections such as noise formation due to low level light, uneven illumination and defective pixels etc. acquired during image acquisition steps. The features of interest in the image is highlighted through enhancing the image contrast by using various spatial filters and image transformation techniques. Second step also known as pre-processing step involves conversion of image to gray scale that follows bitwise not process for converting black pixels to white ones.
- Noise Reduction: Three filters are used to remove noise and unwanted points or lines disconnected strokes from the scanned image that cause distortion and thresh holding operation is performed to remove the blur effect from the image. For example, Boolean filters are preferred over other morphological methods to remove the textured background as they provide better processing time and accuracy. Similarly, edge sharpening is removed by using ramp width reduction filter and

image contrast is adjusted by using Adaptive un-sharp masking as a common method.

- **Contour Smoothing:** Optimal local weighted averaging method is preferred for reducing possible errors by filtering out unwanted glitches and strokes in handwriting sample because this method provides accurate estimation of essential contour point positions, deviation angles and tangent slopes for handwriting analysis [1]. This step also identifies the contours and medium handwriting should have alphabets between 2.5 to 3.5mm. Contours height between 5 and 50 were selected as standard for all images. Hence, average height of letters present in image is retrieved by calculating height of each contour [25].
- **Compression:** Compression techniques such as global threshold is used to convert the color images to binary as this provides better performance and regulated by modified histogram. As handwriting analysis requires only handwritten sample, so white space thinning method is used as it is fast and simple.
- **Row Segmentation:** Vertical Projection Profile (VPP) method is used for row segmentation because it gives best classification accuracy. Sum of pixels for each row in the image were analyzed by calculating highest pixel sum and considering pixel sum lower than 7.5% of threshold value which was obtained by using trial and error method. Leave-one-out approach was used for conducting test on handwriting samples with average accuracy of 97.2% for correct row segmentation.

This step was followed to make a corresponding bounding rectangle in each row of the handwriting script.

- **Spacing Between Lines Feature:** Bounding rectangles determine the amount of overlap between two succeeding rows by delimiting each rows. The rows are considered evenly spaced if the overlap value is lower than 12% of the sum of both row bounding rectangles and crowded if it is higher than 12% [1].
- **Baseline Features:** Baseline features for each row can be determined by method discussed in [32] that studies the pixel density of each segmented row rectangle which is rotated within the angle thresholds of -30; +30. This process is repeated to obtain a horizontally centered highest pixel density. This method is broadly used for extraction of baseline features because this method as compared to other state-of-the-art methods gives faster convergence and higher classification accuracy. Rotation within -6; +6 angle threshold considered to give align highest pixel density, leveled and ascending baseline within -31; -6, and descending baseline within +6; +31 [1].

4.2. Handwriting Sample's Simulation

Proposing the basic idea of handwriting analysis can facilitate the process of identifying and recognizing hidden signs of aggression and violent behavior in an individual handwriting which are associated with some types of personality disorders or psychopathy. Different researches have been conducted to study one of the psychopathy by speech samples and social media service analysis [27, 33]. However, forensic psychologists and graphologists

evaluate the psychopathic behavior and handwriting samples through tedious processes. Considering sensitivity and shortage of data, publically available handwriting samples have been collected from authenticated graphologists who have handwriting samples of serial killers and anti-social people [34]. It involves reading and pre-processing of original image as shown in figure 6, follows by grey-scaling, applying threshold and high contrast to the image as shown in following figure 7;

and you stand a 100% chance of getting her back. You and your family are under constant scrutiny as well as the authorities. Don't try to grow a brain John. You are not the only fat cat around so don't think that killing will be difficult. Don't underestimate us John. Use that good southern common sense of yours. It is up to you now John!

Victory!
S.B.T.C

Figure 6: Original Image [1].

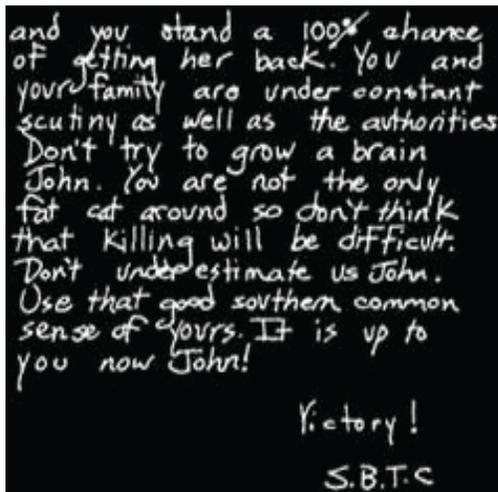


Figure 7: Image after pre-processing [1].

Polygonization is used as the main technique for finding the baseline slant and formed the closed polygon around one of the lines that further coordinates to form the slop. Threshold algorithm is used to calculate writing pressure by converting the image into a binary one. Grey level threshold is used to determine a particular threshold that maps the eyelevel pixel values present in the image. Pixel value is mapped to pure black (foreground) if it is below the set threshold and to pure white (background) if it is above the threshold. The threshold value calculates the writing pressure e.g. light pressure was indicated by higher threshold. The number of the black pixels counts the number of foreground pixels and indicates the writing size, pressure and stroke thickness. The contours of texts plotted on the image as rectangles are detected from the image that intern calculates size of the letters as shown in figure 8;

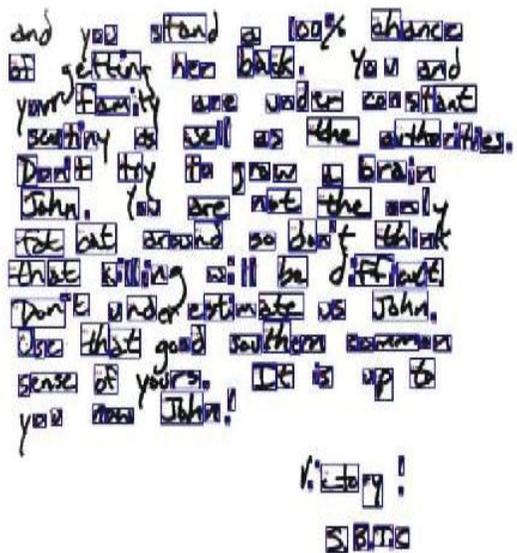


Figure 8: Image after Contour plot [1].

Height of words is calculated when these contours of texts are highlighted and gives an

average height of all the contours. Features like zones including upper, middle and lower zones, lowercase letter size and connectivity, leftward and mixed slant, loops in ovals and writing pressure were extracted from following processed images of violent and normal handwritten [1] samples;

The cold winds of War are blowing;
It is the time to draw forth the broken
Shield and Maud forth to the Pissing
The Battle surrounds me,
Shield at my back; ... I thought
at Ebb and my feet from the
as long as there is my Idea
all Man. —————

Figure 9: Violent handwriting sample image

Intention took 4 years to line
up - there is much more
to this world of mine than
Nyxon could hold - what
make you think your like
style got a glass left

Figure 10: Violent handwriting sample [1]

Police officers just for jolly wouldnt
you Keep this letter back till I
do a bit more work. then give
it out straight My knife is new
and sharp I want to get to work
right away if I get a chance.
Good luck.
yours truly
Jack the Ripper
Don't mind me giving the bad name

Figure 11: Violent handwriting [1].

you feel like you thought push
you outside of any possible
friendship with someone who doesn't
always agree with you... as I said,
relax.

You could have 20 tattoos, a
double mastectomy and purple hair
hang by your feet in a cashat
at night and dream of really
unusual things - so? So what?

Figure 12: Violent handwriting [1].

of everyone - to speak their mind - including those who
routinely call me "socialist" or worse.

I sincerely believe that the health care reform bill
was the right thing to do for the country. It certainly
wasn't the smart "political" thing." And I hope that
in the months to come, you will keep an open mind and
evaluate it based not on the political attacks but on
what it does or doesn't do to improve people's lives.

Figure 13: Normal handwriting sample [1].

"You got me scattered in pieces.
Shining like stars and screaming.
Lighting me up like Venus.
But then you disappear and
make me wait ..."
~ The heart wants what it wants ~
☺

Figure 14: Normal handwriting sample [1]

4.2.1. Simulation Results

Above images are some examples of processed samples of violent and normal handwriting samples that were cleaned and processed to extract graphical features. Results obtained from calculation of various features were formalized [1] as shown in table 2.

The given table shows the comparison between violent/aggressive and normal handwriting features. The processed images of violent handwriting have lower zone with 0.8mm size

and upper zone with 6.88mm on average. It is noticed that violent handwriting as compared to an average person, has much larger height of contours with 8.4mm. Some letters were observed to drop below the baseline that indicates the sign of dangerousness as depicted with supporting facts in figure 1 and table 1. Violent people have tendency to make loops in writing ovals as discussed in above literature

and depicted maximum value of 14.7mm on higher side in table 2. Greater leftward slants were observed in some of the handwriting samples presenting distorted handwriting with signs of anxiety and violence [25, 35]. Some of the handwriting samples shown intense writing pressure with maximum value of 23.1mm that supports and predicts sign of dangerousness presented [1] in figure 1.

Table 2: Comparison of features extracted in handwritten image [1].

Graphical Properties	Violent/ aggressive features			Normal handwriting features		
	Min(mm)	Max(mm)	Mean (mm)	Min(mm)	Max(mm)	Mean(mm)
Upper zone size	1.2	6.88	1.3	1.01	5.02	0.8
Middle zone size	1.20	2.65	1.2	1.2	1.07	1.12
Lower zone size	0.8	0.9	0.8	0.7	0.8	0.9
Avg height contour	1.59	15.23	8.4	1.61	9.01	5.3
Left Slant	1.5	13.1	16.1	1.4	9.02	15.2
Mixed Slant	1.5	12.1	19.3	1.5	9.32	20.1
Lower zone size	1.21	4.31	0.8	1.23	5.12	0.9
Medium zone size	1.22	5.02	1.3	1.3	8.05	1.2
Upper zone size	1.21	13.21	1.2	1.21	9.3	0.8
Line Horizontal	1.12	12.23	11.7	1.02	8.34	12.5
Line Descending	1.12	9.02	2.9	1.12	7.02	2.5
Letter Connectivity	1.32	6.82	16.8	1.2	4.3	17.0
Phrase Connectivity	1.1	1.07	1.1	1.02	2.09	1.2
Intense handwriting pressure	12.1	32.2	23.1	8.6	21.2	21.9
Loops in writing ovals	11.3	12.2	14.7	4.3	7.2	8.7

5. Other Relevant Research Work

Most of the handwriting analysis carried out by graphologists involves identification of personality traits and behavior through set of questionnaires and its result review. Several

state-of-art research and studies on handwriting analysis are presented that describe psychological and personality traits, mental status and behavior of an individual [1] as listed in following table 3 and 4;

Table 3: List of relevant research work [1].

Paper Title	Aim	Technique Applied	Features Extracted	Results
[20]	A Machine Learning Approach to Employability Evaluation Using Handwriting Analysis	Naive Bayes, Random Forest and Support Vector Machine	margin, baseline, letter size, t characteristics and the applied pen pressure.	The employer can discern the traits of the interviewee which may not have been apparent otherwise
[21]	Personality Detection using Handwriting Analysis: Review	Handwriting analysis System using various features like slant, baseline size, spacing and margin	baseline, size, slant, spacing, margin, pressure etc. and a greater number of features like zone, f, i, speed of handwriting	Successfully identified personality of a person using HAS.
[22]	Handwriting Analysis for Detection of Personality Traits using Machine Learning Approach	K-NN classifier	Polygonization for baseline, margin will be calculated using the method of vertical scanning.	It will also assist the HR/company employer in decision making.
[23]	A Comprehensive Survey on Handwriting and Computerized Graphology	Diff techniques discussed	Various features in different papers	Survey of handwriting and computerized graphology
[24]	An Algorithm to Extract Handwriting Feature for Personality Analysis	Image Processing was used for feature extraction using MATLAB.	Title over letter i.	help identifying those people who are emotionally disturbed or depressed and need psychological help to overcome such negative emotions.
[25]	Human Behavioral Analysis Based on Handwriting Recognition and Text Processing	Matlab, TOPOCR, RAPID MINOR	four parameters: pressure, slant, baseline, and dimension.	Successful in predicting human behavior
[26]	Perception Based Decision Support System for Handwriting Behavior Analysis	The MANOVA was performed using IBM-SPSS ver.22.0	pressure, temporal (stroke duration on digitizer and in air) and spatial measures	spatio-temporal features extracted which showed significant differences in true and distorted cases.
[27]	Identification of Personality Trait by Handwriting Analysis Using SVM Classifier	SVM	spacing between words and characters	The classifier SVM is being used. 90% accuracy is achieved.
[28]	Detecting features of human personality based on handwriting using learning algorithms	Feature Vector and Generalized Discriminant Analysis (GDA), Matlab	Line tilt, word extension, word space, line space, word tilt, margin of the first page, character size	Learning algorithm was able to predict features of human personality.
[29]	Human Behavior prediction through handwriting using BPN	BPN	Alignment and Thickness	terms of each letter, obtained recognition accuracy of 56%.
[30]	Handwriting Analysis Based Human Personality Prediction Using Sugeno Fuzzy Model	Sugeno based fuzzy system designed using MATLAB	spacing, size, slant, shape, loop, dot, pressure, signature, zones and page margin.	Performance of the model has been evaluated using mean square error (MSE) and root mean square error (RMSE).
[31]	Handwritten Text Recognition using Deep Learning...project	Convolutional Neural Network (CNN)	classifying words directly and character segmentation	CNN found accurate results for recognizing handwritten text.
[32]	An Empirical Study on Writer Identification & Verification from Intra-variable Individual Handwriting	SVM and Convolutional Neural Network (CNN)	Macro-Micro features, Contour direction and hinge level features, Direction and curvature features at key-points.	It was noted that the state-of-the-art methods do not perform well.
[9]	Writer identification using machine learning approaches: a comprehensive review	Review Paper	Multi script features with deep learning approach	Writer identification can be applicable in forensic, historical and handwriting analysis
[33]	Identifying Personality Traits, and Especially Traits Resulting in Violent Behavior through Automatic Handwriting Analysis	Different softwares like WANDA and MoValyzer, Foster and freeman,	Lewinson-Zubin scale was described, Handedness, education, was described.	Different characteristics were uncovered related to violent and non-violent were explored.
[34]	Automated Prediction of Human Behavior System for Career Counselling of an Individual through Handwriting Analysis /	ANN	size, slant, word spacing, pen pressure, line spacing, upper zone loops.	Algorithm designed for letter and for words to extract features
[35]	Human Character Recognition by Handwriting using Fuzzy Logic	ANN using Matlab	Only design arch is given	Architecture shows character recognition by fuzzy logic

Table 4: List of relevant research work [1].

Paper Title	Aim	Technique Applied	Features Extracted	Results
[36]	Off-line Text-independent Writer Identification Using Local Convex Micro-Structure Patterns	Local Convex Micro-Structure Patterns (LCxMSP) descriptor and 1NN (Nearest Neighbor) classifier and ICDAR2011 database	Traditional Local Binary Patterns and Local Convex Micro-Structure Patterns	To identify and characterize the query writers, proposed framework demonstrated superior Performance from ICDAR2011 database.
[28]	Detecting features of human personality based on handwriting using learning algorithms	MMPI personality test and neural network	Using dependent and Independent features of text like word expansion, characters sizes, line spaces, word spaces etc.	Proposed method achieved 76% efficiency
[37]	Personality Trait Identification Using Unconstrained Cursive and Mood Invariant Handwritten Text	SVM and ANN	Up-Hill Line Down-Hill Line Constant line	The results were about 98% for SVM & 70% with ANN. The analysis was done using single line
[10]	Detection of Deception Via Handwriting Behaviors Using a Computerized Tool: Toward an Evaluation of Malingering	The sociodemographic questionnaire and Computerized Penmanship Evaluation Tool (ComPET), MATLAB	Temporal measures, stroke path length, stroke height, stroke width, angular velocity of the stroke	Results confirm that handwriting measures are sensitive to deceptive writing, and are aligned with previous results.
[38]	Measuring the Frequency Occurrence of Handwriting and Hand-Printing Characteristics	Attribute Agreement Analysis (AAA) is a statistical method	multiple characteristics of letters (cursive and hand printed), numbers and punctuation marks	Statistical studies in this report have concluded as to the very high degree of independence of cursive and hand printed entries
[14]	Forensic Analysis of Handwritten Documents with GRAPHJ	GRAPHJ	text lines and words in the document; specific character and detect its occurrences in the handwritten text.	GRAPHJ can be effectively used to perform the analysis of handwritten documents.
[33]	Identifying Personality Traits, and Especially Traits Resulting in Violent Behavior through Automatic Handwriting Analysis	NEURO SCRIPT, WANDA, CEDAR-FOX, and Gaussian Mixture Model.	Incline (slant to the left or right) 2. Shape (evenness of letter size) 3. Form (roundness)	The comparisons were helpful in determining if an individual had the potential to further commit violent crimes.
[39]	Statistical Examination of Handwriting Characteristics using Automated Tools	PGMs (Bayesian networks) and undirected PGMs (Markov networks) Probability of random correspondence (PRC)	QD Examiner determined characteristics, automatically determined characteristics.	Correct classification of an average of 94.5%.
[40]	Detecting Honest People's Lies in Handwriting: The Power of the Ten Commandments and Internalized Ethical Values	Theoretical Model of Communication and Detecting Lies like "Decoding"	Left margin, right margin, pen pressure, context	Executives and educators can easily learn the tacit knowledge, skills to detect lies.
[41]	Individuality of Handwriting	Software tools such as FISH (Forensic Information System for Handwriting)	Micro features like line separation, slant, character shapes etc. and Macro features like darkness features, contour features, grey level threshold etc.	They were able to validate handwriting individuality with a 95% confidence with promise of aiding the FDE (Forest Document Examination).
[19]	The writing of criminal minds, criminology and handwriting analysis	Graphology and graphopathology	Writing zones, rightward slant, blurred.	Along with graphology, scientific instruments need to be added.
[42]	Predicting the Big Five personality traits from handwriting	FMM and Graphology A	Baseline, Writing pressure, lowercase "r" feature, lowercase "f" feature	Prediction accuracy is around 77%.

6. Conclusion

This paper reviews the signs of dangerousness and violent tendencies reflected in one's personality and its identification through handwriting analysis. Certain features like presence of loops, connectivity, space and zone size, slant and baseline direction, speed and pressure obtained from handwriting samples were studied to identify the red flags. It is highly challenging to identify violence and aggressive behavior from handwriting due to vast areas of graphology. It is very difficult but more interesting for graphologists to solve crimes because of the influence of their actions. Graphologist's opinion should be considered during an investigation to avoid prolonged, delayed and a slow interrogation process that mainly lacks the correlation between strategies and personality of the target suspect or victim or witness. One should know the limits and errors of this instrument resulted from insufficient knowledge of the specialist or illegal management of given data, however, this method is inspired scientifically and its remarkable results strongly recommend its usage in complex criminal investigation. It is authoritative to promote this scientific method with its advantages on a wider scale in professional as well as in academic environment. Further research studies and development can be accomplished by discovering wide range of graphical structures and patterns, perfecting programs and training new specialists. Hence, handwriting can become a valuable tool to identify violent signs in one's personality.

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