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### **CASE STUDY / RESEARCH**

## Writings of a person with Dissociative Identity Disorder – A Longitudinal and a Kinematic Study

#### Bonnie L. Schwid<sup>1</sup> and Hans-Leo Teulings<sup>2</sup>

**Abstract:** Forensic Document Examiners (FDEs) may confront questioned handwritings of persons diagnosed with a Dissociative Identity Disorder (DID), formerly known as a multiple personality disorder. While there is scientific research on DID, most of the literature related to handwriting in DID is anecdotal. Many articles refer to modifications of handwriting for each personality, but no evidence has been found to indicate that handwriting was analyzed using a kinematic approach to collect dynamic data from the writing. This paper will be the first known study to compare the different personalities of a participant diagnosed with DID by recording pen movements and establishing dynamic variables using a Wacom<sup>®</sup> pen tablet and the MovAlyzeR<sup>®</sup> software,<sup>m</sup> an objective standard for measuring writing for scientific research in handwriting. The results of the kinematic analysis are then compared to a conventional analysis. Initial results show both static and kinematic differences between the personalities. Additionally, this study documents the stability of the personalities over time, from 1993 to 2011.

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Keywords: Dissociative Identity Disorder, DID, Multiple personalities, Multiple personality disorder, Handwriting movement recording and analysis

#### 1. Introduction

Persons who have Dissociative Identity Disorder (DID), formerly known as multiple personality disorder, may become involved in handwriting disputes. DID can develop in persons who suffer early severe abuse,

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Neuroscript
435 E. Carson Drive Tempe, AZ 85282, USA Email: hlteulings@neuroscriptsoftware.com whereupon, they attempt to create alternate personalities to handle the trauma (Lewis et al., 1997). Occasionally, Forensic Document Examiners (FDEs) will face questions whether differences in handwriting are the result of alternate personalities in DID diagnosed persons or whether these differences result from an attempt to disguise the writing. There is currently very little in the research that will answer the questions FDEs will confront in these specialized cases. Most of the papers refer to modification of each personality (Rost, 1992; Whitey, 1999; Friesen, 1991; Lewis et al., 1997). In 1992, Schwid and Goodwin presented a poster session about Mary Reynolds, the first person diagnosed with DID in the country in the early 1800s to the International Society for the Study of Multiple Personality and Dissociation. The presenters, including an FDE and a psychiatrist specializing in Ms. Reynolds, and three additional FDEs studied the writing of Ms. Reynold's three alternate personalities. The FDEs participating in the research were unable to conclude that the same person wrote all three samples of writings because of significant differences among them.

A year later, the author was asked to examine signatures of the current participant, James, who was incarcerated for a crime unrelated to the forensic case concerning forged checks. The forensic examination in 1993 resulted in an inconclusive opinion because of the poor quality of the questioned materials, but the author stayed in touch with James and visited him in prison several times between 1993 and 1997. During an earlier visit, the FDE learned that an alternate personality named George had become interested in handwriting identification. George's interest in handwriting identification motivated him to provide handwriting samples of his and the alternate personalities for this and for later research.

In 2011, the authors decided to conduct research using the MovAlyzeR® software with the Wacom® tablet to compare the results of examining handwriting from the static trace, the conventional method used by FDEs, and by using an objective method to record the dynamic features of the writing. The authors wanted to study more precisely whether there were invariant handwriting characteristics among the alternate personalities and whether there were significant differences. The FDE author collected the handwriting exemplars under the direction of the co-author who developed the kinematic method to record the dynamic features in real time.

#### 2. Participants

#### 2.1 James

The core personality is James who was born in Texas in 1950. Both his mother and

father were abusive. He was beaten for minor infractions such as being scared at a movie or getting his sports clothes dirty. Because of the overwhelming abuse, and, like other people with DID who suffer severe abuse, James was able, on some level, to create alternative personalities to handle threatening situations. The alternate personalities began emerging when he was three years old.

In 1986 James was diagnosed with DID. James' case has been documented in publications (Arneson, 1987; Kerley, 1994), court cases, court records, medical records, presentations, and videos showing how each personality was manifested. There are three major personalities named George, Ray, and Sergeant (Sgt.). Mike Murphy. In addition, there are many minor or fragments of personalities. James calls the group of all of the personalities "The System."

During the writing sessions from 1993 through 1997, James, the core personality, was meeting his attorney and the author, an FDE, through George. James was actually 'sleeping' according to George, but he was called out to participate in the writing sessions. James rocked back and forth, holding his head between his hands because of a severe headache. His nose and eyes ran profusely. He cried and was unable to write a sentence, but was able to write his signature. He signed his name each time in the sessions and quickly went back "inside" whereupon the symptoms of the runny nose, watering eyes, and the headache stopped. James is the only personality within the system with this condition, and was not asked to participate in the 2011 writing session.

#### 2.2 George, Ray, and Sgt. Mike

Table 1 is a summary of characteristics of George, Ray, and Sgt. Mike. When appearing for the writing exercise, each personality could be identified visually or orally and was confirmed by asking the personality's name at each session. Additional details per personality are described next.

As mentioned in the introduction this research began after a forensic examination

in 1993 by the author that involved the participant, James, who was incarcerated for a crime unrelated to the forensic case concerning forged checks.

The handwriting samples were collected from James' main personalities during several

been garnered from previous experiences with attorneys and the legal system. He and another alternate personality, Ray, comprised the 'legal defense team' to handle the legal matters relating to their treatment. George did the research. Ray acted as secretary.

Name of Personality	George	Ray	Sgt. Mike
Birth year.	1987	1954	1953
Age	Same as James	Remains about 30	One year older than James
Visible characteristics.	Confident, strong	Social, nervous, fidgety with large smile	Carries himself as a marine and appears suspicious
Audible characteristics	Deep with slight southern accent	Strong southern accent	Very deep, cryptic content
Wears corrective lenses	Yes	No	No
Diabetes	Yes	Yes	No
Psychogenic seizures	Not observed	Yes	Not observed
Allowed to drive a car	Yes	No	Yes

Table 1. Characteristics of the three alternate personalities.

visits. Originally the different personalities would come out in a fixed sequence with George being first, then Ray, then Sgt. Mike. A personality would fall into a self-hypnotic state that appears as though he is asleep. Upon awakening, the next personality would manifest and reorient himself to the surroundings. In 2011 the personalities were able to switch easily from one to the other. For example, when asking a question of one personality, a different personality may answer because he has more information about the topic. The author learned to recognize each personality visually and by his demeanor. These writings by one individual under different personalities form the basis for the longitudinal study. Table 1 summarizes the behavioral characteristics of George, Ray and Sgt. Mike.

#### 2.2.1 George

George emerged in 1987 while James was in prison. George is pragmatic and was created with knowledge and abilities that had

#### 2.2.2 Ray

Ray is anxious and avoids conflict by "going away." He is sociable and friendly. James developed a facial tic when very young and complained frequently of 'brain aches.' The tic was observed in Ray by the author at the 2011 session. According to Coons (1988), severe headaches and/or the twitching of facial muscles often accompanies the switching from one personality to another. Interestingly, in 1994 Ray reported that he weighed 195 lbs (88 kg) but that George is overweight at 260 lbs (118 kg).

#### 2.2.3 Sergeant Mike Murphy

Sergeant Mike Murphy was one of the first personalities to be created when James was still very young. Sgt Mike's role was to take beatings because he would not cry. He decides whether it is safe for James, himself, to appear. If not, James remains asleep. Sgt. Mike is militaristic,

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	George	Ray	Sgt. Mike
George (1994), Ray (1994), Sgt. Mike (1993)	copy of the an	logg of.	SgT. Mike
Personal pronoun I, by George (1995) Ray (1995), Sgt. Mike (1997)	1 behr	9 kept	I WA.
Personal pronoun I, or name in 1996	1 want To be a	I have .	59T. mike 3-27-96

Table 3: Longitudinal Conventional Analysis 1993-1997 of the 3 personalities George, Ray, and Sgt. Mike. No changes were detected. All images were scaled 300%

## **3.2 Sample Collection for the Kinematic Study**

The kinematic and longitudinal samples were collected in 2011 using an electronic tablet (Wacom® Intuos® Version 2 8x6 pen tablet - XD68USB) and an electronic inking pen (Wacom® Intuos® Version 2, XP-110). The tablet was covered with a sheet of lined paper about 6" x 8.5" or 15.2 cm x 21.6 cm). The sheet was held in place by the participant by using his left hand. The inking pen looked and felt like a normal ballpoint pen. It had a standard mini ballpoint ink refill similar to the refills used in 4-color ballpoints.

The software recorded the horizontal and vertical position of the pen tip on and off the paper (while the pen is lifted up to 1 cm) and the pen pressure on the tablet. Pen-tip position and pressure were sampled at 100 Hz and a resolution of 0.001 cm (corresponding to 2540 dpi). The accuracy of the raw samples had an RMS error of less than 0.01 cm. There may be small differences between ink trace and pen tip movement because the ink deposit is not always centrally under the ball of the ball point pen tip because the pen tip position is measured at the electromagnetic coil that is in the lower part of the pen barrel. Therefore, changes in pen tilt will affect the position measurement. The writing was recorded and processed using

NeuroScript® MovAlyzeR® Version 6.1 software running on an Acer® MS Windows® laptop.

When the participant was writing, the computer display showed the entire writing tablet (Background color was white; Relative luminance 100%). When the pen tip moved across the tablet, the computer displayed the trajectory of the pen tip as it touched the paper as a blue line of medium thickness, (i.e., 2 pixels; Relative luminance 50%). The blue line showed the individual pen-positions recorded as red dots of 2 pixels in diameter and with relative luminance 50%. While the pen was moving off the paper and lifted up to 1 cm, a light gray line was produced with relative luminance 88%.

#### 3.3 Electronic Data Processing

Data processing of pen strokes involved low-pass filtering to reduce the sample errors, velocity estimation, segmenting, e.g., in successive upward and downward strokes, and feature extraction of each individual segment (Teulings & Maarse, 1984). Direction, duration, speed, fluency, and pen pressure were estimated per segment size.

The pen-ink traces were optically scanned at 600 dpi 24-bits RGB color using HP ScanJet 7400c and Adobe Photoshop and stored in PSD

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Figure 1a: George's handwriting collected on Oct. 26, 1994, on letter-size, lined paper using a ballpoint pen.

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Figure 1b: George, performing handwriting tasks on a sheet of steno paper positioned on the tablet and writing with the tablet's inking electronic pen in 2011.

file format. The PSD files were then opened in Adobe Photoshop CS3 and converted into the PNG format. These PNG files were then opened using MS Paint, aligned, pasted into MS Word, cropped and rescaled along both horizontal and vertical axes identically to match the pen movement recordings. Larger images were "stretched" till 50% or 25%, thus downsampling from 600 dpi to 300 dpi or 150 dpi.

# **3.4 Experimental Conditions and Instructions**

Table 2 lists the handwriting tasks (i.e., experimental conditions) from simple (Condition 1) to complex (Condition 6) that participants were requested to perform. Each recording (i.e., trial) started when the pen touched the paper and continued until the pen was lifted off the paper for more than 2 seconds or after a recording time of 10 seconds, whichever occurred first. Each of these conditions were attempted three

times by each participant in a randomized block order. Randomization reduces confounding between condition and practice where one condition always received more practice than another condition. The entire test of 18 trials (i.e., 6 conditions x 3 trials) took less than 10 minutes per personality.

#### 4. Results

#### 4.1 Analysis of the Longitudinal Study

We compared participant handwritings longitudinally from 1993 to 2011. Samples were chosen for similarity or difference of content and/or writing features whenever possible. George's writing remained consistent from 1993 through 2011. There is no evidence in George's handwriting that he attempted to disguise his writing, nor was there an evolution of writing maturity during that time.

Figure 2a: Ray's handwriting collected on Oct. 26, 1994 on letter-size, lined paper using a ballpoint pen.

Figure 2b: Ray performing handwriting tasks on a sheet of steno paper positioned on the tablet and writing with the tablet's inking electronic pen in 2011 (Page 1).

Figure 2c: Ray performing handwriting tasks on a sheet of steno paper positioned on the tablet and writing with the tablet's inking electronic pen in 2011 (Page 2).

The writing pattern for Ray was consistent from 1993 through 2011. Ray's writing did not exhibit maturation of the writing system, nor evolution of writing over time. There was no indication of an attempt to disguise his writing by changing slant, letter formations, size or fluency in Ray's handwriting in 1994, see Figure 2a. In Figure 2d, Ray attempted to copy George's handwriting that was collected a short time before on the same sheet of paper.

Figure 2d: Ray trying to simulate George's writing of the words *my name* on Oct. 26, 1994, He wrote on the same page as Figure 2 using a ballpoint pen.

MIKE. I WAS Good. I SAID I do.

Figure 3a: Sgt Mike's handwriting collected in 1997.

To day is a nece de 2000000000 00000000000000

Figure 3b: Sgt Mike performing handwriting tasks on a sheet of steno paper positioned on the tablet and writing with the tablet's inking electronic pen in 2011.

There are insufficient writing samples from Sgt. Mike for longitudinal comparison because his earlier specimens were hand- printed, and writing for the test was unnatural for him. There is no evidence of maturation or evolution of writing over time (Figures 3a and 3b).

#### 4.1.1 Personality Differentiation

Natural variation is an important feature in a handwriting analysis. George's writing over time remained consistent throughout with some variation of the personal pronoun I. The script is very small and tightly controlled. It is barely legible when taken out of context or to someone unfamiliar with his style. The upper and lower loops are mostly closed or nonexistent. There are few extraneous strokes. The pressure onto the paper visually appears to be moderately heavy with highly diminished fluency. Because of the small size and differences in letter formations, and, in spite of the formations of the personal pronoun I, George's writing can be distinguished from Ray's. Table 3 compares three samples from three personalities over time. It demonstrates that there were minimal changes over time and some similarities among the handwritings but that they are not sufficient to conclude that the samples were written by the same person.

Figure 3b is an example of Sgt. Mike performing handwriting tasks on a sheet of steno paper positioned on the tablet and writing with the tablet's inking electronic pen in 2011

Pictorially, the writing of George, Ray and Sgt. Mike appear to be by different people (See Table 4). George writes in a very small, compact, controlled and nearly illegible script. The upper and lower loops are tightly closed and there is variable spacing between letters with wide spacing between words. Ray writes in a more expansive script with a conflict between fluency and dysfluency. His writing in 2011 is much larger than earlier writing. The loops are open with irregular formations for circle letters. His writing is jerky and he has difficulty adhering to the printed line. In early writing Ray limited the upward extensions to stay within the printed lines on the paper while in the 2011 test, the upper and lower extensions were expanded to twice the height of the early writing. The cause of this anomaly is unknown, but strong anxiety about the test may have contributed to the increase in size and dysfluency. Sgt Mike usually prints in small and precise letters, mixing upper and lower case. The loops are variable, and there is jerkiness in the 2011 writing, perhaps due to inexperience with cursive writing.

In 2008, Dr. Manoj Raghaven, a neurologist at the Veteran's Administration Hospital in Milwaukee, Wisconsin, using MRI imaging, diagnosed James as having psychogenic seizures. Ray also exhibits this type of seizure occasionally when he is present. The seizure manifests as rolling his eyes up into his head, stuttering, thrusting his tongue forward and jerking his body. Dr. Meyers concluded that the results of an electroencephalogram showed abnormal brain activity based on an Electroencephalographic Report from

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West Jefferson General Hospital in Marrero, Louisiana, dated 1/13/65. While they should be noted, it is unknown whether these seizures affect the writing. It also is unknown whether the seizures in 1965 or 2008 were actually experienced by James as himself or by George, Ray or Sgt. Mike acting as James.

## 4.2 Kinematic Analysis Compared to Conventional Analysis

When exemplars are recorded on paper using a pen tablet with an inking electronic pen, kinematic analysis can be performed (See Figures 1b, 2b-2c, and 3b). The kinematic analysis yields accurate information about pen speed, movement sequence, pen movements above the paper, and axial pen pressure. The kinematic analysis shows several additional intriguing similarities and differences between the three alternate personalities that are not revealed by the conventional analysis. We will conduct two types of kinematic analyses: visualization of a particular trial or exemplar and statistical information when trials or exemplars are automatically processed, summarized, and analyzed in terms of averages and standard deviations across all exemplars available.

#### 4.2.1. Kinematic Visualization of Individual Trials

We illustrate only two particular trials or exemplars in each alternate personality. One trial is from Experimental Condition 1 (A sequence of cursive l-loops; See Figures 4a-c). The other trial is from Experimental Condition 6 (The word Today; See Figures 5a-c). It appears that the kinematic comparison reveals a unique feature in each of the alternate personalities.

Figure 4a illustrates that George's handwriting had hesitations (i.e., velocity reversals) in nearly all upstrokes (See Labels 1-10) but virtually not in the downstrokes. The top panel shows the enlarged image on paper based on the 600 dpi scan as in the conventional analysis. The image includes rule lines and overlapping, thick pen strokes. But

James' Personality	George	Ray	Sgt. Mike
Letter height	Tiny	Large	Normal
Slant	Forward	Forward	Upright
Letter height and slant differ.	Mulanul	allalla	ulurell
	Milliandelle	Alle	Dievele
Twisted loops similar	MUM Saala 200%	Utille	Scale 200%
Split <i>today</i> into two	-t- da	The dim	Todas
words	Scale 300%	so my	Today
		to they	Scale 200%

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Table 4a.1: Side-by-side comparison of the handwritings by George, Ray, and Sgt. Mike. Samples are shown in real size unless a scaling is listed. There are noticeable differences and similarities.

the conventional analysis does not show the hesitations clearly. The second panel shows the pen tablet recording using a 2540 lpi tablet. The tablet recording is smoothed to reduce the random data noise and quantization noise, enables us to achieve very high accuracies. It is important that these recordings are free of obscuring factors such as rule lines and overlapping pen strokes. The third panel shows the vertical position as a function of time. This panel highlights the possibilities of the kinematic analysis. Viewing from left to right, the upward segments represent upward strokes. The downward segments represent downward strokes. The horizontal segments here and there are the intervals where the pen stands still. The kinematic analysis enables the automatic segmentation into upward and downward

strokes. The color of the line expresses absolute pen velocity. Where the pen is moving at high velocity the line is given a dark blue color. Where the pen is standing still, the line is given a light pink color. Therefore, this panel clearly shows the light pink segments of the movement stops. These movement stops occur during most upstrokes but not during many downstrokes. The vertical velocity as a function of time is shown in the bottom panel. The positive phases are the upstrokes and the negative phases are the downstrokes. The intervals where the pen stands still are in this chart the zero velocity intervals. They occur mainly during the upstrokes.

A stop or hesitation separates an upstroke or a downstroke into two submovements. Submovements are normally defined as a stop after the highest velocity peak within a stroke

James' Personality	George	Ray	Sgt. Mike
Letter height	Tiny	Large	Normal
. Slant	Forward	Forward	Upright
Misspelled <i>lonely</i> as <i>loney</i> by George and Ray only	Scale 300%	Conety Conety Conety	bould bouched Scale 250%
Similarly shaped letters <i>n</i> and <i>c</i> in the word <i>nice</i>	Scale 300%	Mich Mich Scale 150%	Mile Scale 300%
Different continuous letters o	100000 000000 000000 Scale 300%	05800 08800. 08,000,	-2000 000000 Scale 300%

Table 4a.2: Side-by-side comparison of the handwritings by George, Ray, and Sgt. Mike. Samples are shown in real size unless a scaling is listed. There are noticeable differences and similarities.

(Teulings & Romero, 2003; Caligiuri et al., 2010). Furthermore, hesitations in George's upstrokes usually occurs before the highest velocity peak, rather at the beginning of the upstroke (See bottom panel). Therefore, the standard submovement analysis would not reveal this systematic difference.

Figure 4b illustrates that Ray's handwriting had hesitations at the tops of the loops. (See

Labels 1 and 5.). The enlarged, scanned image (top panel) does not clearly reveal this. The second panel shows the tablet recording colored by absolute pen velocity (dark blue signifies high velocity and light pink signifies low velocity). This panel shows hesitations as pink segments on top of two loops. The third panel shows the vertical position as a function of time. A hesitation is now shown more clearly



Figure 4b: Ray's cursive l-loops. (Top) Scanned image (300 dpi, PNG, scaling 200%). (2nd Panel) Recording on a pen tablet. Line color signifies absolute pen velocity (Blue = high, light pink = low or zero). (Labels 1 - 2) Movement stops as the tops of some loops. (3rd Panel) Vertical position y of the pen tip versus time. (Labels 1 -5) These and additional movement stops can be discerned as horizontal segments at the tops of the up and down strokes. (Bottom). Vertical velocity as a function of time. The movement stops at the tops of the loops are shown as multiple zero crossings between the positive (i.e., upstroke) and the negative (i.e., downstroke) phases of the vertical velocity



Figure 4a: George's cursive l-loops. (Top) Scanned image (600 dpi, PNG, scaling 525%). (2nd Panel) Recording on a pen tablet at 2540 dpi. Line color signifies absolute pen velocity (Blue = high, light pink = low or zero). (Labels 1 - 10) Beginnings of movement stops or hesitations (i.e., submovements). (3rd Panel) Vertical position y of the pen tip versus time. Movement stops begin where vertical position as a function of time starts a horizontal segment. (Bottom panel) Vertical velocity vy versus time. Positive means up stroke. Negative means down stroke. Movement stops begin where vertical velocity line within a positive velocity phase (i.e., up stroke) of the vertical velocity.



*Figure 4c*: Sgt Mike's cursive l-loops. (Top) Scanned image (600 dpi, PNG, scaling 525%). (2nd Panel) Recording on a pen tablet. Line color signifies absolute pen velocity (Blue = high, light pink = low or zero). (3rd Panel) Vertical position y of the pen tip versus time. (Bottom). Vertical velocity as a function of time.



Figure 5a: George's writing of the first word of the sentence: *Today* ... recorded on a pen tablet using the inking pen. (Top) Scanned image (600 dpi, PNG, scaling 575%). (Middle) Recording on a tablet. Line color signifies absolute pen pressure (Blue = high, light gray = zero, i.e., pen is above the paper). (Bottom) Vertical position of the pen tip versus time. (Label 1) Beginning of the upstroke of the word *to*. (Label 2) *t*-bar crossing. (Label 3) Touchdown at letter *d* but no writing. (Label 4) Word *day*.

as a horizontal, gray colored segment at the top of several loops. The bottom panel shows the vertical velocity as a function of time. A hesitation is here shown as an additional zero crossing between the upstroke of the loop and the downstroke. Figure 4c illustrates that Sgt. Mike's l-loop sequence has only incidental hesitations at the tops of loops as in Ray's handwriting and only incidental, minor hesitations in the upstrokes as in George's handwriting. Therefore Sgt. Mike's handwriting has properties in between those of George and Ray.



Figure 5b: Ray's writing of the first word of the sentence: Today ... recorded on a pen tablet using the inking pen. (Top) Scanned image (300 dpi, PNG, scaling 150%). (Middle) Recording on a tablet. Line color signifies absolute pen pressure (Blue = high, light gray = zero, i.e., pen is above the paper). (Bottom) Vertical position of the pen tip versus time. (Label 1) Beginning of the word *to*. (Label 2) Beginning of the word *day*.

Figures 5a-c show the comparison for the complex writing pattern in the experiment, the first word of the sentence *Today is a nice day* (Condition 6).

Figure 5a illustrates that only George's letters *a* and *y* appear angular (See the top and the

middle panels). The kinematic analysis shows that those strokes are produced fluently as the movement is performed without interruptions (See bottom panel). The other two alternate personalities did not use these angular letters.

In the figures, the the color of the line expresses pen pressure (dark blue is high



Figure 5c: Sgt Mike's writing of the first word of the sentence: *Today* ... recorded on a pen tablet using the inking pen. (Top) Scanned image (600 dpi, PNG, scaling 360%). (Middle) Recording on a tablet. Line color signifies absolute pen pressure (Blue = high, light gray = zero, i.e., pen is above the paper). (Bottom) Vertical position of the pen tip versus time. (Label 1) The first stroke is a down stroke of the letter *T*. (Label 2) The second stroke is a left-to-right stroke of the letter *T*. (Label 3) Letter *o*. (Label 4) The letters *day* are written without pen lift.

pressure and light gray is zero pressure, i.e., pen lift). The bottom panel shows the vertical pen tip position as a function of time. The vertical direction is from the bottom of the sheet to the top of the sheet. Labels 1-4 mark the beginnings of the four ink trajectories that are separated by pen lifts. The pen movement on paper begins with a fast upstroke of the word to as revealed by the steep, increasing, blue curve (Label 1). After the first stroke the pen stands still (or

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makes no vertical move) for 0.18 seconds at the top of letter t. This can be deducted from the flat, blue curve. The t-bar is performed within 0.13 seconds (Label 2). Subsequently the pen is lifted for 0.35 seconds. The long, blue, flat line expresses that the pen is on the paper but is not moving for as much as 0.76 seconds (Label 3,). Finally, the pen is lifted and placed again on paper on the same spot while increasing pen pressure very slowly to write the letters day (Label 4).

Figure 5b illustrates that Ray's handwriting has many extra loops, e.g., in letters *d* and *a*. The movement is fluent as the vertical position versus time chart.(bottom panel) shows no horizontal segments representing intervals where the pen stands still. The loops are typically the result of high speed. There is an extended pause of 1.34 seconds between the letters to (Starting at Label 1) and day (Starting at Label 2) as shown by the extended pink segment in the bottom panel.

Figure 5c illustrates that Sgt. Mike begins each pendown segment with a movement in the opposite direction and then a reversal into the planned direction. These reversals are invisible in the scanned image but they are clearly visible in the kinematic data. See the strokes starting at Label 1 (downstroke of the capital T), Label 2 (top stroke of the capital T), Label 3 (letter o), and Label 4 (letter d). There is a large distance between to and day but only a brief pen-lift movement of 0.20 seconds as shown by the pink segment between Labels 3 and 4. Interestingly, the letter a seems to have the same loops as in Ray's writing. However, Sgt. Mike fuses the latter part of the a with the first part of the y yielding letters ej.

#### 4.2.2. Statistical Analysis between Alternate Personalities

The detailed analysis of individual trials should be used to derive features for all exemplars or trials available, yielding statistics for each feature. For this type of analysis we will focus on the standard features and not on the more elaborate features suggested by



Figure 6a: Stroke duration in seconds for Personalities (We reordered the sequence from smallest to largest writing). Vertical bars indicate the 95% confidence intervals. As the confidence intervals overlap between the alternate personalities there are no significant differences.



Figure 6b: Letter height in cm for Personalities (We reordered the sequence from smallest to largest writing to highlight the size sequence). Vertical bars indicate the 95% confidence intervals. As the 95% confidence intervals do not overlap between the alternate personalities and the numbers of . observations are comparable per personality, the differences are significant: George, Sgt. Mike, and Ray have successively larger letter heights.

the previous, detailed individual trial-based analysis. Each trial is segmented into up and down strokes and standard features are calculated per stroke. The averages and standard deviations can be summarized across strokes trials, conditions, or alternate personalities. To visualize significant differences (e.g., at the 5% probability level that the observed data can be explained from a random variation) we will specify 95% confidence intervals. The 5% confidence interval can be estimated by 1.962 times the standard error. The standard error is the standard deviation of the average. The standard error can be estimated by the standard deviation, divided by the square root of the number of independently assumed observations.



Figure 6c: Axial pen pressure for Personalities (We reordered the sequence from smallest to largest writing). Pen Pressure 1000 is approximately equivalent with 300 gram (i.e., 3 Newton) and Pen Pressure 0 with 0 gram (or pen lift). Vertical bars indicate the 95% confidence intervals. As the 95% confidence intervals do not overlap between the alternate personalities and the numbers of observations are comparable per personality, the differences are significant: George, Sgt. Mike, and Ray have successively lower pen pressure.s..

We compared various standard features, averaged across all exemplars between the three personalities of George, Ray, and Sgt. Mike. As Sgt. Mike's handwriting has properties in between those of George and Ray, we reordered the sequence of handwritings into those by George, Sgt. Mike, and Ray, respectively.

Many standard features did not reach significance, likely because six very different task conditions were included. For example, there was no difference in stroke duration between the three alternate personalities (See Figure 6a). This suggests that the alternate personalities wrote at the same speed. However, we could statistically confirm that in 2011, the personalities had different writing sizes: Figure 6b presents evidence that the handwriting by George is significantly smaller than that of the other alternate personalities and that Ray's handwriting is significantly larger. We can tell that because the 95% confidence intervals for the alternate personalities do not overlap. Figure 6c shows that pen pressure by Ray is significantly smaller than by Sgt. Mike or George. These examples illustrate that the kinematic analysis can yield significant differences for features that could be estimated from the static handwriting traces on paper (e.g., writing size) and also significant differences of features that can only be measured via pen tablet recordings (e.g., pen pressure).

#### 5. Discussion

This case study is the first known study to compare the different personalities of a participant diagnosed with DID by recording pen movements and establishing dynamic variables using a Wacom® pen tablet and the MovAlyzeR® software. The results of the kinematic analysis were then compared to a conventional analysis. Initial results show both static and kinematic differences between the personalities. Additionally, this study documents the stability of the personalities over time, from 1993 until 2011 and examines the handwriting of the participant's personalities for similarities and/or differences.

While there might arguably be some similar formations between the writing of George and Ray, it is unlikely that an FDE would be able to reach a definite conclusion that they are one and the same person because of the many differences. Both kinematic and conventional analysis lead to this result. However, kinematic analysis is able to detect differences in movement that are not visible in a static image. An FDE would rightly question whether there is enough material available for Sgt. Mike to reach a conclusion. For those FDE's who do not state conclusions but point out the differences and similarities, the jury or judge would more likely than not be expected to conclude that they are different people.

According to medical records, personalities within the system respond to medications differently, for example, anti-anxiety medication was prescribed for Ray but it adversely affected Sgt Mike's equilibrium. It is unknown whether or how medications any of them take affect the writing of others within the system. Sgt. Mike was able to monitor George while he was writing on the tablet, but Ray was not. Therefore it is unknown whether they benefited from George's initial familiarization with the writing test due to the commonality of the neuromuscular system of the body.

The tablet recordings and the scanned images show minute differences between kinematic and ink data caused by wiggling of the pen because the pen's receptor coil is inside the lower barrel of the pen and because the ink deposits by the ball point may not be in the middle of the ball.

We established that the writing styles of the personalities are sufficiently stable during extended periods. Stable formations suggest that it is unlikely that any of the personalities attempted to disguise any of his writing. Kinematic analysis in a forensic situation would reveal hesitation and features common to disguise as a supplement to conventional analysis.

Additionally, since writing for most people evolves in some way as the person ages, the analyst compares writings over time for signs of natural modifications. There is a commonality of the neuromuscular system amongst the personalities, and some personalities remain the age of the body at the time it was created. It appears that the handwriting also remains at that period of time. For some, the age of the personality is unclear, and George reports that Sgt. Mike has no particular age.

While collection of writing samples from 1993 to 1997 was informal, future studies will follow predefined scientific protocol. FDE's are cautioned about using signatures in research to be sure to have proper release since much of the writing includes signatures. Ascertaining the identity of the personality providing an exemplar in a forensic case may or may not reveal which personality actually performed the questioned writing. FDEs are alerted to the fact that even though DID is rare, it should be a consideration if there are any minute formations in the questioned materials that are also found in the exemplars.

Further studies into brain activities such as brain mapping while each personality is writing would be useful as an adjunct to the kinematic and longitudinal studies.

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Bonnie Schwid. No disclosures.

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#### (endnotes)

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