

HANDWRITING, BIOMECHANICS AND SIGNIFICANCE: CONCEPTS IN HANDWRITING IDENTIFICATION

by

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In his classic work, *Experiments With Handwriting*,¹ published in 1978, Robert Saudek described the work of Mr. Frank Freeman in videotaping and measuring the movement of the pen, hand, wrist and arm during the writing process, and in calibrating these measurements with the artifact of the handwriting line on the paper. A full explanation of this work appears in Mr. Freeman's *The Handwriting Movement - A Study of The Motor Factors of Excellence in Penmanship*,² written circa 1920.

Frank N. Freeman was an Associate Professor of Educational Psychology at the University of Chicago in 1915 when he began his study into the factors that resulted in excellence in handwriting. With the cooperation of a few primary school teachers and funding by the General Education Board, he took what were then called motion pictures of the act of handwriting and studied them intensively. Quoting from Mr. Freeman's introduction (pgs. 1-2):

The study which is the subject of this report had two aims, a theoretical one and a practical one. The theoretical aim was to analyze the writing activity of good and poor writers and to discover the difference between them. The practical aim was to find and test means of training the poor writer so that his mode of writing would resemble that of the good writer. The theoretical aim was subordinate to this practical aim.

Three phases of the writing activity were examined in the present study. The first was the position of the hand and arm, including the grasp of the penholder. Five aspects of hand position were studied.

The second phase that was studied was the writing movement in its gross aspect, which is usually designated by the terms 'finger movement,' 'hand movement,' and 'arm movement.'

The third phase is perhaps the most important. It concerns the manner in which the movement of the pen varies in rapidity from one part of a letter or word to another. The speed of movement of the pen is never uniform. It fluctuates between slow and rapid flights, which are broken at intervals by actual pauses. The flights of the pen, which are separated from one another by pauses or by marked retardation in speed, may be described as units of movement. Good and poor writers differ in the manner in which they divide the whole movement into units.

This examiner asserts that genuine and non-genuine writings are also differentiated in the manner in which the whole movement is divided into units. There is ample support for this comment in authorities in our field. For example, in *Questioned Documents – Second Edition*,³ pg. 98, Albert Osborn says,

This subject of rhythm, or the balanced quality of movement, producing a natural and not a constrained or artificial result, has a very close connection with the identification of handwriting as genuine or forged or as having been produced by a certain writer.

On page 106 Osborn says,

Forged writing is usually produced by a disconnected and broken movement, and to produce practically the same form requires many more interrupted motions or movement impulses than genuine writing.

In the chapter on Methods and Apparatus, Mr. Freeman explains what he plans to do in his study:

Records can be made from the photographs (motion pictures) by projecting them upon the screen and drawing the outline of the hand from the projected image.⁴

Figure 1, below, shows the setup for this work.

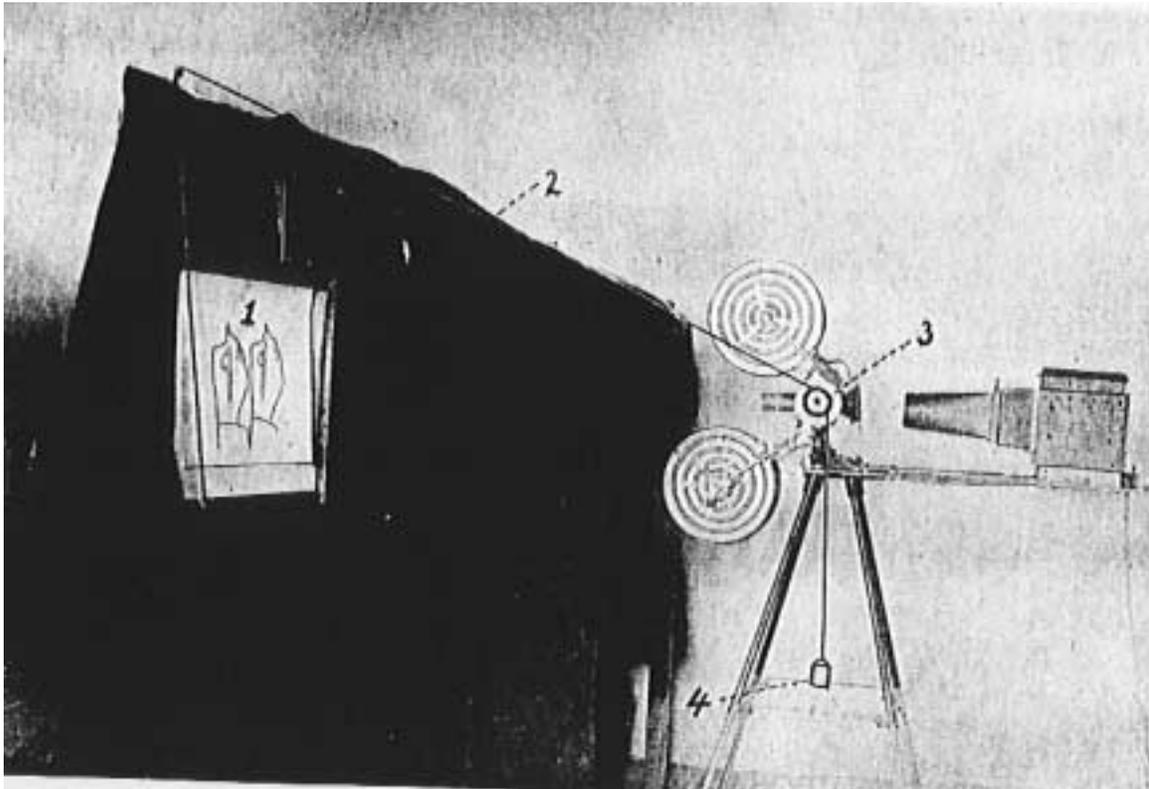


Figure 1 - *The Handwriting Movement* - Frank N. Freeman - Pg. 25

Continuing to quote Mr. Freeman,

By comparing the drawings of the hand which are made at set places in the writing, the hand movements which take place between the positions represented can be indicated.⁵

Figure 2 - *The Handwriting Movement* - Frank N. Freeman - pg. 34

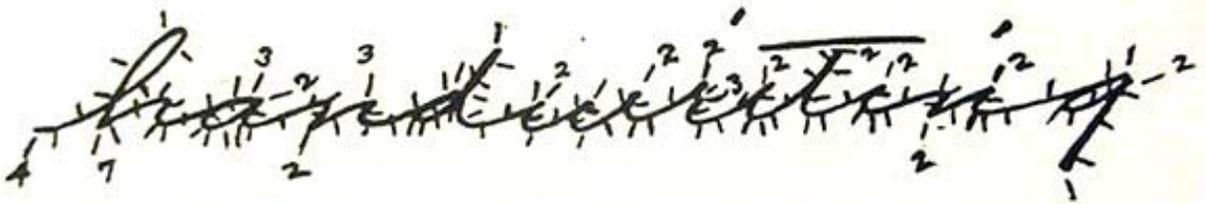
The speed of movement of the pen can be measured by recording the distance which the pen point travels during each exposure of the camera or from one exposure to the next, and a speed curve can be constructed by plotting these successive distances on a chart.⁶

Most photographs have been taken at 25 exposures per second since this proved to be sufficiently rapid in most cases. The rate at which motion pictures are usually taken is 16 per second. The more rapid rate was necessary in order to get a record of the details of the movement.⁷

Saudek refers to 1/25th of a second as a Freeman Unit.⁸ Let's take a quick look at some illustrations of Mr. Freeman's analysis of the motion pictures, which are extraordinarily thorough, methodical and interesting.

The clearest and most convenient way to represent the speed changes in writing is to indicate them directly on the writing itself. This may be done by indicating the position of the pen point at each successive unit of time. The unit of time which is represented is the interval between one exposure of film and the next, which in most cases is about 1/25th of a second.

The interval in any particular record is constant, which is sufficient for the analysis about to be made. The speed of the movement then, corresponds to the distance between the short cross-lines.⁹



-The writing of C. P. Zaner and the analysis of the speed on one word

Figure 3 - *The Handwriting Movement* - Frank N. Freeman - pg. 32

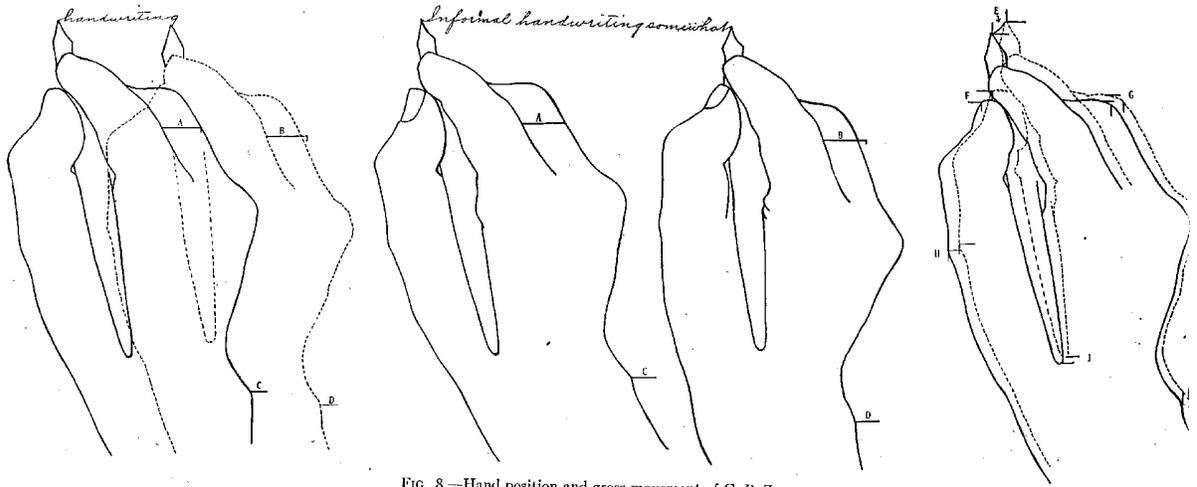


FIG. 8.—Hand position and gross movement of C. P. Zaner

So if we look at this word "handwriting" in Figure 3, we can readily see that the tic marks placed farthest apart indicate the greatest speed of the writing, because more distance was covered during a Freeman unit. The numbers indicate that there was a pause for that number of frames (or that many 25ths of a second).

Mr. Freeman goes on to make a different kind of chart based upon this information for the purpose of studying the rhythm or lack thereof in the speed of the writing. The word "handwriting" has been broken down into actual strokes (amount of writing between measurable pauses) and above each stroke a graph of the pen's activity has been constructed, as in Figure 4 below. Again, in Mr. Freeman's words:

Each horizontal unit represents one exposure of the camera, or 1/25 of a second. The height of the column above each unit represents the distance in millimeters which the pen traveled during the corresponding camera exposure. The absence of a column indicates a pause of 1/25 of a second.¹⁰

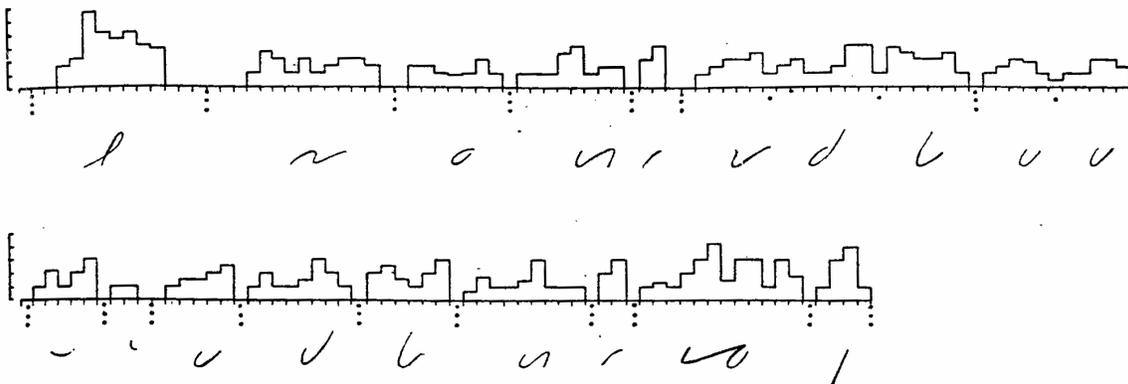
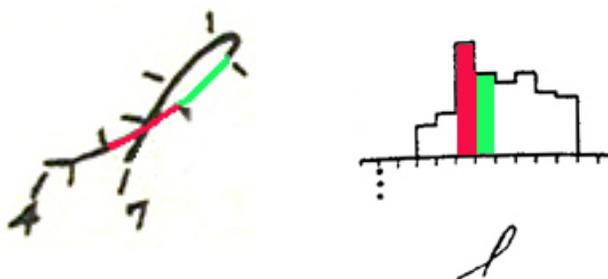


FIG. 7.—Speed curve from the word "handwriting" written by C. P. Zaner

To explain further, the first stroke creates the loop of the “h.” In Figure 3 you can count eight marked divisions of unequal length along the written line from the beginning to the end of this first stroke. The third division contains the greatest space between markers in Figure during that part of the stroke because more distance was covered during $1/25^{\text{th}}$ of a second. Refer to the close-up view in Figure 5 below for clarification. The red and green color mark the pen travel during the third and fourth Freeman Units respectively. The numbers 4 and 7 on the left refer to the number of Freeman units that the pen paused at those locations.

Figure 5



Mr. Freeman goes on to interpret the speed curves of several writers relating the information to the changes in hand positions shown in the moving pictures. One conclusion that is of interest to us is that “good writers organize the movement much more clearly into speed units than do poor writers, and these units are better adapted to the form of the letters which are being written.”¹¹

Contemporary work with the biomechanical aspects of handwriting is being done aggressively by the members of the International Graphonomics Society (IGS)¹² which is headquartered at Nijmegen University in The Netherlands. The IGS is a society dedicated to the study of the science and technology of handwriting and other graphic skills. Granted, much of their interest is directed toward computer recognition of handwriting, and the reader might think, “What does that have to do with Document Examination?” Some possible relationships are:

1. Scientific measurement and efforts to understand any aspect of handwriting are useful to the document examiner who faces criticism of the process of handwriting identification as being non-scientific. As Beryl Gilbertson wrote in her article *On Being Scientific in Handwriting Identification*, “handwriting identification may not in the end, be judged as a science, but it is based upon scientific principles.”¹³
2. If a computer can recognize individual handwriting, as some security systems are now doing, then this is additional proof of what document examiners assert - that handwriting is an individualized activity that can be linked to one person.
3. The IGS itself sees a relationship between its work and forensic science. It lists forensic science as one of its areas of focus for its 2001 biennial convention - and defines forensic science to include document examination, case studies and new scientific techniques, and writer identification procedures.¹⁴

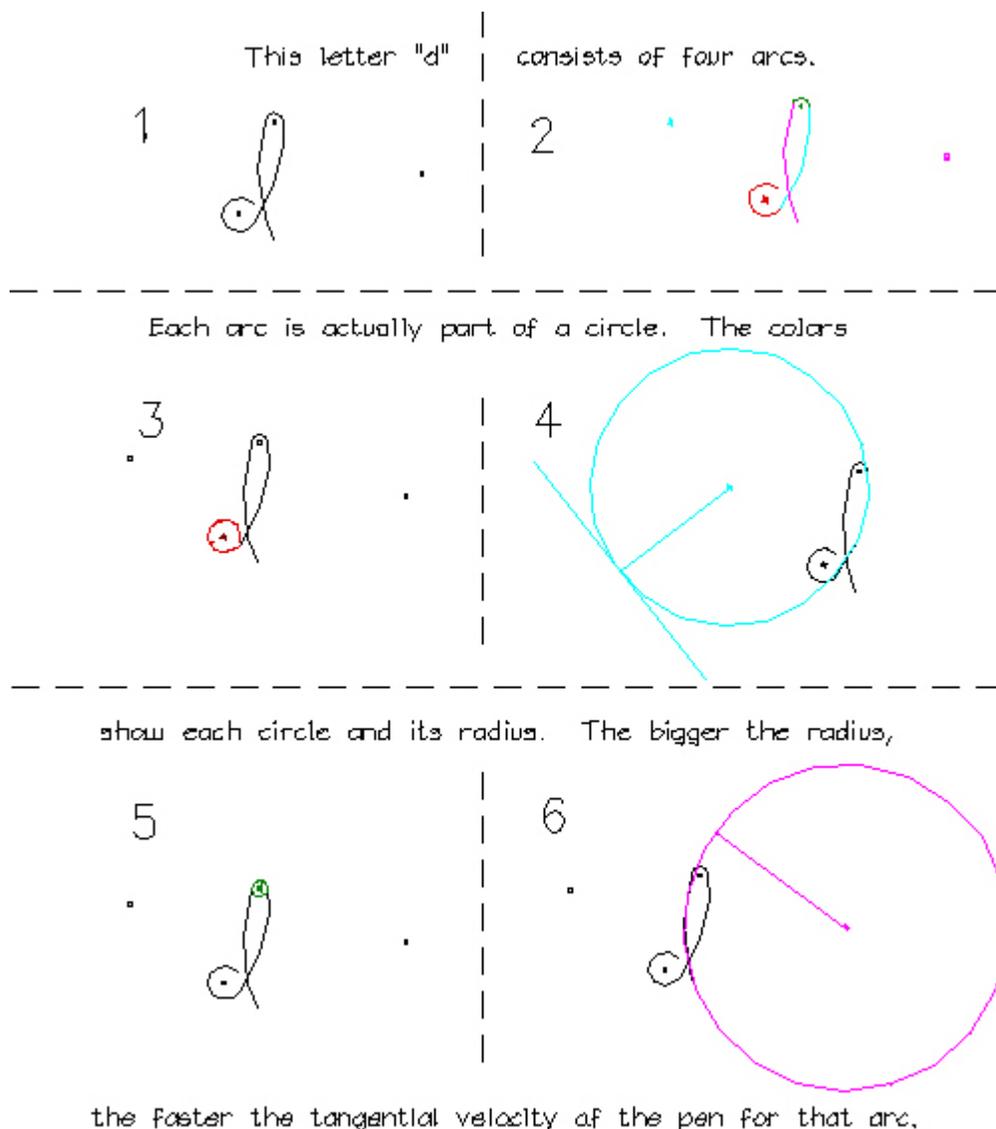
Articles written by members of the IGS use a vocabulary that is not necessarily familiar to the document examiner. For many IGS members the prime area of interest is motor control, and it turns out that by studying handwriting and other graphic tasks, a lot can be learned about motor control. Therefore, much research has been done with handwriting as the focus. Specialists in motor control are the prime audience for the papers resulting from this research, but there is much of interest to handwriting experts if they are willing to learn some new vocabulary. For example, in an article in the October 1999 issue of the IGS Bulletin, Arend Van Gemmert of the Motor Control Laboratory at Arizona State University writes in an article entitled *The Study of Kinematics of Graphic Tasks: A Forensic Perspective*:¹⁵

According to the isochrony principle, the duration of a stroke tends to be independent of its size (Thomassen & Teulings, 1985)

In other words, a longer stroke does not necessarily take a longer time to write. He goes on to quote:

The tangential velocity of the pen along a curved trajectory is directly proportional to the local radius of the curve, which is known as the $2/3$ power law. (Lacquaniti, Terzuolo & Viviani, 1983) Therefore, local pen speed is much higher in parts of the trajectory with only shallow curves than in parts with tight curves.¹⁶

This examiner has constructed a drawing to illustrate an interpretation of this law:



In segment 1 of the drawing you see the letter "d." In segment 2 the same "d" is shown in four colors. Each color represents one of four arcs that form the letter. In segments 3,4,5 and 6 each arc is highlighted individually in the order it would be written, as part of a complete circle with its center and radius included. This helps you to see which circle has the largest radius and contains the most shallow arc, and which circle has the smallest radius and contains the tightest, or deepest arc. The 2/3 power law tells us that the pen was moving fastest during the pink arc in segment 4. The next fastest speed was in the turquoise arc in segment 4, then the red arc in segment 3, and finally the slowest pen speed occurred during the green arc in segment 5.

Beryl Gilbertson discusses the application of the term "scientific" to the field of "handwriting identification," and refers to the "middle way."¹⁷ The 2/3 Power Law is an example of a scientific principle derived in another field of study that may be useful to the document examiner once s/he has made the effort to find and understand that information.

As a final thread, consider some comments upon the use of terminology in reports and testimony. The expression of a document examination opinion often relies heavily upon the words "similarity", "similar", "differences", "different". This examiner opposes the use of these words, thinking that they bring us nothing but trouble. They are non-specific words that mean one thing to one person, and something else to another. One person's "similarity" is someone else's "difference". How close do traits need to be to be "similar" and how dissimilar to be "different"?

When first decided to eliminating the terms "similar" and "different" from the document examination vocabulary, one may be struck silent for some time while deciding on replacements. Perhaps the word "similar" has to go entirely, but "different" could be used with the proper modifiers attached. Here are some alternatives:

1. "The known and questioned signatures have the following characteristics in common:"
2. "Both the known and questioned signatures possess the following individualizing characteristics:"
3. "The following significant, individualizing characteristics appear in both the known and questioned signatures:"
4. "The following significant, unexplained, structural differences appear and serve to differentiate the questioned writing from the known writing."

This is where we come full circle. The term "structural difference" means to this examiner that a difference appearing in the structure of the writing is the result of a second mental and/or physical system at work. Now a knowledge of biomechanics can help us because mechanics deals with structure and formation - with angles, velocity, pressure.

We are no longer talking about how the writing "looks" which is very subjective and open to interpretation. We are talking about how the writing was done, which can be discussed objectively - even scientifically. This change of vocabulary is not a magic potion that will rock opposing attorneys to sleep. There is still the need to explain what are these structural differences and why they are individualizing characteristics. But the discussion can now be elevated.

In his concluding remarks, under the heading of Practical Recommendations, Frank Freeman says:

We are primarily concerned in this study of the efficiency of handwriting, with handwriting as a movement. This preoccupation with the movement phase assumes that the difficulty which confronts the child in learning to write well is concerned more with the movement than with the perception of letters.¹⁸

Isn't this the same problem that confronts the forger and the document examiner - to get beyond the perception of the form of the letter and to get to the movement that actually creates the letters? The word "similar," no matter how it is used by the document examiner, in the minds of the attorney, judge and jury means "looks like," and that is not where we want to focus their attention. We can, instead, draw upon past and present scientific experiments and principles to correctly evaluate the structural differences that appear when two biomechanical systems (two people) produce handwriting.

References:

1. Saudek, Robert, *Experiments in Handwriting*, Second edition, Books for Professionals, Sacramento, California, 1978, pgs. 71-75
2. Freeman, Frank N., *The Handwriting Movement - A Study of the Motor Factors of Excellence in Penmanship*, University of Chicago Press, Chicago, IL, circa. 1920
3. Osborn, Albert S., *Questioned Documents*, Second Edition, Patterson Smith, Montclair, NJ, 1978
4. Freeman, Frank N., *The Handwriting Movement - A Study of the Motor Factors of Excellence in Penmanship*, University of Chicago Press, Chicago, IL, circa. 1920, pg. 15
5. Ibid
6. Ibid
7. Ibid, pg. 20
8. Saudek, Robert, *Experiments in Handwriting*, Second edition, Books for Professionals, Sacramento, California, 1978, pg. 72
9. Freeman, Frank N., *The Handwriting Movement - A Study of the Motor Factors of Excellence in Penmanship*, University of Chicago Press, Chicago, IL, circa. 1920, pg. 38
10. Ibid, pgs. 39-40
11. Ibid, pg. 52
12. International Graphonomics Society, Department of Experimental Psychology, University of Nijmegen, P.O. Box 9104, 6500 HE Nijmegen, The Netherlands
13. Gilbertson, Beryl, *On Being Scientific in Handwriting Identification*, The Journal of The National Association of Document Examiners, Inc., Vol. 23, No. 2, Fall 2000, pgs. 13-17

14. 10th Biennial Conference of the International Graphonomics Society, Call for Papers, Nijmegen Institute for Cognition and Information, The Netherlands

15. Van Gemmert, Arend W.A., The Study of Kinematics of Graphic Tasks: A Forensic Perspective, *Bulletin of the International Graphonomics Society*, Vol.13, Issue 2, October 1999, pgs.35-38

16. Ibid

17. Gilbertson, Beryl, *On Being Scientific in Handwriting Identification*, The Journal of The National Association of Document Examiners, Inc., Vol. 23, No. 2, Fall 2000, pgs. 13-17

18. Freeman, Frank N., *The Handwriting Movement - A Study of the Motor Factors of Excellence in Penmanship*, University of Chicago Press, Chicago, IL, circa. 1920, pg. 159

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