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BRIEF TECHNICAL REPORT

THE MEASUREMENT OF MANUSCRIPT LETTER STROKES[1]

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Incorrect letter formation contributes more to illegible handwriting than any other factor (Craig, 1966; Quant, 1946; Rondenella, 1971). Most handwriting rating scales (Ayres, 1912; Freeman, 1915; West, 1926) are generally unreliable (Anderson, 1965; Feldt, 1962) although a few of the more current attempts to measure handwriting have reported high reliability (Fauke, Burnett, Powers, and Sulzer-Azaroff, 1973; Hopkins, Schutte, and Garton, 1971; Salzberg, Wheeler, Devar, and Hopkins, 1971). Yet, detailed descriptions and systematic testing of handwriting measurement procedures are not generally reported. Therefore, it appears that a description of an objective, simple, and reliable method of measuring letter formation is needed.

METHOD

Model Letters

Five training sheets of 10 model letters were developed using the Zaner-Bloser Creative Growth Manuscript Alphabet (1974). The letters were constructed with a line weight of 1 mm and printed on paper with two sets of four parallel lines. Spaces between the headline and midline, midline and baseline, and descender space below the baseline were 1.1 cm each. The same 10 letters (f, h, m, u, j, q, v, x, b, e) were on each sheet; only the order varied.

Evaluative Overlays

Transparent overlays were designed to measure three ranges of deviations of student samples from model letters. Figure 1 illustrates one overlay.

The first overlay measured deviations from 0 to 1 mm, the second from 0 to 2 mm, and the third from 0 to 3 mm. The three overlays were constructed to form a closed curve around each letter in the following way:

1. Drawing lines parallel and 3, 2, or 1 mm on both sides of all strokes composed of vertical, horizontal, or oblique segments.

2. Drawing two circles: one inside and one outside of the model circle stroke. One circle will be a perpendicular distance of 3, 2, or 1 mm from a tangent on the circle stroke to a tangent on the circle inscribed within the circle. The second circle will be drawn a perpendicular distance of 3, 2, or 1 mm from a tangent on the circle stroke to the circle surrounding this stroke.

3. Drawing arcs 3, 2, or 1 mm on both sides of strokes or parts of strokes constructed of an arc.

4. The ends of all strokes comprised of arcs and/or segments have their boundary lines on both sides joined with a semicircle using a radius of 3, 2, or 1 mm and the end of the stroke as a center.

5. All strokes constructed of arcs and/or segments that do not intersect at an end point have a perpendicular slash mark drawn across the stroke 3, 2, or 1 mm from their end points.

Construction of Overlays

The boundaries surrounding the inside and outside of each letter were first constructed as a pencil

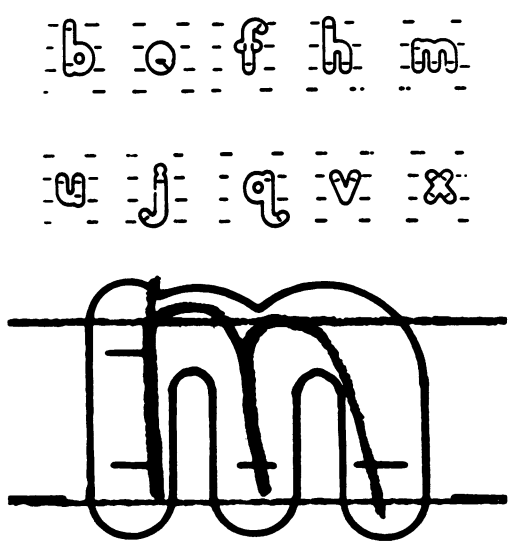

Fig. 1. Illustration of the evaluative overlay and the correct use of the overlay to measure the letter "m". The vertical stroke of the letter was not totally within the confines of the overlay; therefore it did not meet criteria for a correct response. The two-hump strokes met all criteria of the behavior definition.

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copy using the following equipment: (1) A steelspring bow divider with two fine metal points was used to transfer the 1, 2, or 3 mm distance from a standard metric ruler. (2) A Brunery Accutrac Drafting machine was used to draw parallel segments to all strokes that were vertical, horizontal, or oblique segments. (A simple adjustable triangle and T-square could have been used.) (3) A steelspring bow divider was used to inscribe a series of points inside and outside all circles and arcs. (4) An ellipse template was used to join the series of points to form circles and arcs. Pencil copies of the letter boundaries were then traced on vellum tracing paper using India ink. The letters drawn with India ink on vellum paper were used to make transparent overlays using the Diazo Process. (The Diazo Process is a procedure for transposing original art work on clear plastic in one of several colors by a combination of chemicals, heat, and light.)

One original evaluation overlay required approximately 5 hr at a cost of $25.00. Originals of the same model letters in a different arrangement required 1 hr at a cost of $5.00. The clear plastic overlays were made from paper and pencil originals by the Diazo Process at a cost of 40¢ each.

Behavior Definition and Recording

The following criteria were used to define correct manuscript letter strokes.

1. The total stroke must be within the confines of the line of overlay.
   Example: Yes (h) No (h)
2. Each stroke that is not a complete circle must begin and end between the small slash mark and in the line forming the confines of the letter.
   Example: Yes (h) No (h)
3. All circles in the letters a, b, d, g, o, p, q, and the top of the letter *e* must be closed curves.
   Example: Yes (b) No (b)
4. All strokes must intersect each successive stroke at one point except for the dot above the i and j.
   Example: Yes (w) No (w)
5. The letter must be complete with all strokes present.
   Example: Yes (u) No (u)
6. The horizontal stroke in the t and f must intersect the other stroke within the confines of the ellipse near the center of the verticle stroke.
   Example: Yes (f) No (f)

Recording strokes meeting these criteria requires correct usage of evaluation overlays. The placement of the letter boundaries on the evaluation overlays were positioned to match the placement of the model letters on the training sheet both horizontally and vertically. To establish the correct vertical placement of the overlays, the four parallel broken lines of each set of five letter boundaries were placed directly over the guidelines for the same sets of five model letters on the subject's handwriting samples. Horizontal placement was determined by two factors: position of letters on subject's sample, and accuracy in copying the model letter. The overlay was moved to the left or right, keeping the broken lines directly over the guidelines on the subject's sample until all strokes of the letter were within the boundary of the evaluation overlay. When horizontal movement of the overlay would not assist in bringing all strokes of a letter within the boundary of that letter, then horizontal placement was determined by the position that brought the greatest number of letter strokes within the boundary of the evaluation instrument.

A recording sheet was developed listing the 10 model letters down the left side of the page. Figure 2 illustrates the recording sheet. In Figure 2, each letter included graphical pictures of the strokes used to construct the letter beside it, with blanks to record the strokes meeting criteria. The evaluation overlay was used to measure the first letter of the subject's handwriting sample, using all of the six criteria pertaining to the letter. Each letter stroke meeting criteria was recorded with a (√) beside the graphical representation of the stroke. The evaluator measured the second letter and recorded the correct strokes, *etc.*, until all 10 sample letter strokes were measured and recorded.

Collection of Writing Samples

Six subjects were selected by asking a teacher to identify two children in the classroom who were experiencing difficulty in manuscript letter formation. Two were 6, three were 7, and one was 9 yr old. All subjects attended public schools.

Subjects worked at tables in corners of their respective classrooms or in a tutorial room outside of their regular classroom. Subjects were seen three sessions per week at various times during school hours. Depending on the rate of the subjects' letter formations, the length of each session was approximately 3 to 5 min.

Each subject was seated to the right of the experimenter with a set of 10 model letters, two sheets of lined paper, a pencil, and a half sheet of blank paper. The experimenter used from 1 to 3 min for verbal interaction with the subject. The student was then given the copy of 10 model letters, a sheet of lined paper and a pencil with these directions: 1. "I am going to cover five of the letters with this piece of blank paper." 2. "Please use the paper and pencil I have given you and copy the top five letters for me."

When the five letters were copied, the experimenter moved the blank paper to cover the top five letters and

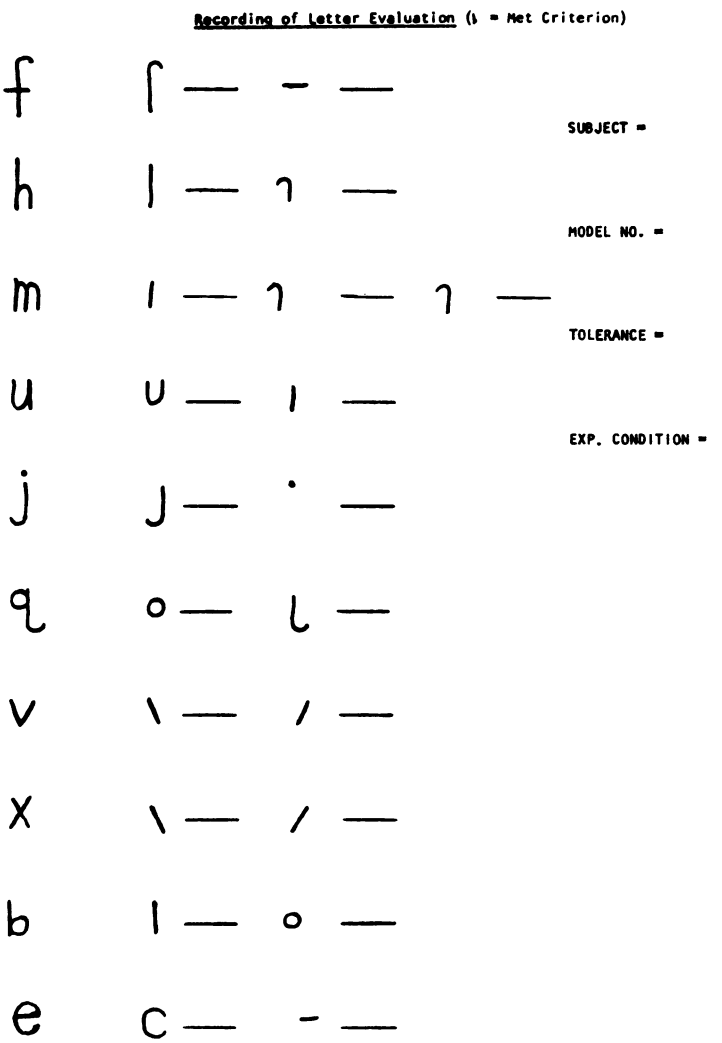

Fig. 2. Form for recording individual letter strokes meeting criteria of a specific tolerance.

asked the subject to copy the last five letters. The subject's 10 sample letters were picked up and 2 to 3 min were again spent in some form of appropriate verbal interaction between the experimenter and subject. The procedure was then repeated, making 20 letter completions in all. At this point, the experimenter thanked the child for helping him, picked up the materials, and left. The experimenter gave no verbal feedback to the student on the quality of his handwriting samples. The only change in sessions was that the order of the letters to be copied was varied.

Interobserver Agreement

Trained observers. Four observers were trained to use the evaluative overlays by measuring at least 252 letter strokes. Following training, 20 handwriting samples with 42 strokes were divided into four sets of 10 samples with 21 strokes each. Each observer measured 10 handwriting samples. The observers compared their results from each sample with the original evaluation of the experimenter.

Naive observers. Six naive people ranging in age from 10 to 38 yr, with a median age of 30, scored manuscript letter samples. The behavior definition and recording procedure was read by and explained to each of the six people. They were given one practice session to measure and record 21 letter strokes and to have any questions answered regarding the use of the evaluative overlays. Following the practice session with 21 letter strokes, the six naive observers measured and recorded four sets of 21 letter strokes, which were compared with the original evaluation of the experimenter. Interobserver agreement measures for both the trained and naive observers were computed by dividing the total number of agreements by the sum of the disagreements and agreements and multi-

Table 1

Summary of Interobserver Agreement Measures of 40 Samples of Manuscript Letters

	Samples (42 letter strokes per sample)	Number of Agreements	Percentage of Agreement
Observer Number 1	1	37	88
	2	35	83
	3	33	79
	4	37	88
	5	37	88
	6	38	90
	7	37	88
	8	36	86
	9	40	95
	10	35	83
Observer Number 2	11	35	83
	12	38	90
	13	38	90
	14	39	93
	15	38	90
	16	35	83
	17	39	93
	18	37	88
	19	38	90
	20	39	93
Observer Number 3	21	41	98
	22	34	81
	23	39	93
	24	38	90
	25	39	93
	26	41	98
	27	40	95
	28	39	93
	29	41	98
	30	39	93
Observer Number 4	31	38	90
	32	33	79
	33	36	86
	34	40	95
	35	36	86
	36	38	90
	37	41	98
	38	37	88
	39	34	81
	40	34	81

plied by 100. Additionally, interobserver agreement measures for the trained observers included: (a) dividing the total number of agreements for correct strokes by the sum of the disagreements and agreements of correct strokes and multiplied by 100; and (b) dividing the total number of agreements for incorrect strokes by the sum of the disagreements and agreements of incorrect strokes and multiplied by 100.

Lapse Time

Lapse time was defined as the duration of time needed to measure and record 21 letter strokes. Lapse time for both the trained and naive observers was determined by using the samples from which interobserver agreement measures were computed. These data were converted to strokes measured and recorded per minute.

RESULTS

Table 1 is a summary of agreement measures from four observers on 40 samples of manuscript letters. Interobserver agreement measures ranged from 79 to 98% agreement, with a mean of 89%.

Table 2 presents agreement measures on letter strokes meeting criteria and letter strokes not meeting criteria on 40 samples of manuscript letters. Interobserver agreement measures for letter strokes meeting criteria ranged from 85 to 100% agreement, with a mean of 94%. Interobserver agreement measures for letter strokes not meeting criteria ranged from 0 to 100%, with a mean of 82%.

Table 3 shows a summary of strokes measured and recorded per minute and a percentage of interobserver agreement by six naive observers.

Table 2

Interobserver agreement measures on letter strokes meeting criteria and letter strokes not meeting criteria.

	Samples (42 letter strokes per sample)	Percentage of Agreement on strokes meeting criteria	Percentage of Agreement on strokes not meeting criteria
Observer Number 1	1	88	100
	2	97	90
	3	93	77
	4	88	100
	5	97	100
	6	100	100
	7	93	77
	8	97	88
	9	97	73
	10	91	82
Observer Number 2	11	97	85
	12	88	82
	13	96	100
	14	88	80
	15	80	76
	16	93	93
	17	100	75
	18	96	87
	19	85	75
	20	93	100
Observer Number 3	21	89	87
	22	100	100
	23	97	71
	24	94	86
	25	87	100
	26	94	100
	27	85	56
	28	90	100
	29	92	83
	30	96	100
Observer Number 4	31	97	80
	32	100	90
	33	97	36
	34	100	75
	35	92	78
	36	100	0
	37	95	67
	38	97	75
	39	92	81
	40	97	86

Strokes measured and recorded per minute for the six naive observers ranged from 4.06 to 12.00, with a mean of 7.46 strokes per minute (approximately four letters measured and recorded per minute). Strokes measured and recorded per minute for three trained observers who have used these procedures over a two-month time period ranged from 5.95 to 22.91, with a mean of 12.89 strokes per minute (approximately six letters measured and recorded per minute). Interobserver agreement measures for the six naive observers ranged from 81 to 95% agreement, with a mean of 88%.

DISCUSSION

Studies by Quant (1946), Craig (1966), and Rondinella (1971) demonstrated that incorrect letter formation may contribute more to illegible handwriting than any other single factor. Use of the evaluative overlays, as described in the present study, may be a significant procedure for measuring individual letter formation. Independent observer agreement measures for 40 handwriting samples were high (trained, X = 89% agreement; naive, X = 88% agreement). Naive evaluators with one training session used the overlays with a little less than twice the same amount of time (naive, X = 7.46 responses per minute; trained, X = 12.89 responses per minute) as trained evaluators. Cost for reproducing overlays and other materials should be within the reach of all school systems or classrooms, regardless of size or finance. These findings strongly suggest a measurement procedure for academic behavior that could be used by teachers, aides, or students.

Table 3

Summary of Strokes Measured and Recorded per Minute by Six Naive Evaluators

Naive Observers	Evaluation Session	Strokes Measured and Recorded Per Minute	Mean Strokes Per Minute	% of Interobserver Agreement
#1	1	4.06	5.48	86
	2	6.46		95
	3	4.67		95
	4	6.74		95
#2	1	4.76	7.66	95
	2	6.81		81
	3	9.00		81
	4	10.08		81
#3	1	9.54	9.31	95
	2	9.63		90
	3	10.70		86
	4	8.00		100
#4	1	8.71	9.60	86
	2	12.00		90
	3	8.40		86
	4	10.00		90
#5	1	5.60	6.32	81
	2	6.00		90
	3	6.26		85
	4	7.00		90
#6	1	6.00	6.00	81
	2	6.00		86
	3	6.00		84
	4	6.70		86

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