Process Versus Product Evaluation of Poor Handwriting among Children with Developmental Dysgraphia and ADHD

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Abstract. Handwriting is a complex activity that entails an intricate blend of cognitive, sensory and motor abilities. The act of writing presents difficulties for children with dysgraphia and ADHD. The objective of this study was to determine ways in which the analysis of both objective, digitizer-based evaluation of the handwriting process and subjective, human-based evaluation of the handwriting product may lead to greater insight about the performance of poor handwriters. Fifty third grade students with dysgraphic handwriting, and 12 children with ADHD performed functional handwriting tasks on a Wacom digitizer. Objective temporal, spatial and pressure measurements of the handwriting process were sampled and analyzed. The handwriting samples were also evaluated according to pre-established characteristics using the Hebrew Handwriting Evaluation (HHE). Both objective and subjective measures differentiated between proficient and poor (dysgraphic or ADHD) handwriting; high correlations were found between the objective measures and subjective measures and discriminant analysis showed that global legibility and In air time were the highest predictors of poor handwriting. These results demonstrated the potential advantage of combining different types of measures in order to achieve a more comprehensive understanding and evaluation of handwriting difficulties. This may facilitate cooperation between handwriting researchers and clinicians and teachers who deal with handwriting difficulties.

1. Introduction
Handwriting is a complex human activity that entails an intricate blend of cognitive, kinesthetic, perceptual-motor components (Bonny, 1992) including visual perception, eye-hand coordination, visual-motor integration, kinesthetic perception, motor planning, dexterity and manual skills (Tseng & Cermak, 1993). The study of handwriting has importance beyond the issues of basic human perceptual-motor control. Handwriting is considered to be proficient when legible text is produced at a minimum of effort. In this case, handwriting is automatic, and does not interfere with the content as generated by the creative thinking process (Scardamalia, Bereiter, & Goleman, 1982). In contrast, poor handwriters are unable to achieve a completely automated process. It has been suggested that children with writing difficulties may suffer serious consequences not only in their academic progress, but also in their emotional well-being and social functioning (Cornhill & Case-Smith, 1996).

The poor handwriting phenomenon may be found among children and adults. The prevalence of handwriting difficulties or dysgraphia among typical school aged children varies between 10-34% (Rubin & Henderson, 1982; Smits-Engelsman, Van Galen, & Michels, 1995). Poor handwriting is also common among children with Attention Deficit Hyperactive Disorders (ADHD) (Tucha, Laufkotter, Mecklinger, Klein & Lange, 2001). Previous studies indicated that ADHD children manifest deficits in handwriting and in the perceptual-motor components related to that skill (e.g., Hickey & Fricker, 1999; Whitmont & Clark, 1996).

The importance of early evaluation of handwriting both in children with dysgraphia or ADHD has been stressed by several researchers (e.g., Raggio, 1999; Simner, 1990). Studies of handwriting difficulties among the above mentioned populations may be divided into two main categories:
1. Studies in which handwriting evaluation for the writing product was developed and examined. Those studies were mainly performed by educators or clinicians (e.g., dysgraphia: Hamstra-Bletz et al. 1987; ADHD: Peebles et al., 1995 )
2. Studies that focused on the handwriting process in order to gain insight about handwriting as a complex psychomotor task, using computerized digitizing system to examine handwriting kinematics and kinetics. These studies have been carried out primarily by motor control researchers, sometimes together with clinicians (e.g., in children: Smits-Engelsman, Van Galen & Portier, 1994 a,b; in ADHD: Tucha, Paul & Lange, 2001).

When each of these methodologies is considered in isolation, specific limitations become apparent (Rosenblum, Weiss & Parush, 2003). Although the use of conventional writing assessments by educators and clinicians have enabled the evaluation of handwriting legibility, the reliability and validity of such tools are, to some extent,
limited due to their dependence on subjective judgment for scoring and interpretation. On the other hand, although the development of computerized analysis has advanced the understanding of the spatial and temporal characteristics of children with poor and proficient handwriting, further study is still needed to determine how these data are related to the actual functional deficit in handwriting. Moreover, the terminology and presentation of results used by motor control researchers hinders their interpretation by some educators and clinicians, especially when they seek to relate them to the daily interaction with children who have handwriting difficulties. The purpose of this study was therefore to compare the relative abilities of objective, digitizer-based evaluation and subjective, human-based evaluation to characterize children’s poor writing product and process in order to determine whether the digitizer provides additional information that cannot be discerned with the human eye.

2. Method
2.1. Participants
Two groups of handwriters (proficient and dysgraphic), each consisting of 50 third grade pupils, aged 8 and 9 years old, and 12 children with ADHD, aged 8 to 10 years were included in the study. Poor handwriters were identified via the standardized and validated Teachers’ Questionnaire for Handwriting Proficiency (Rosenblum, Jessel, Adi-Japha, Parush & Weiss, 1997) and the Hebrew Handwriting Evaluation (HHE) (Erez & Parush, 1999). All subjects were born in Israel, used the Hebrew language as their primary means of verbal and written communication, and were right hand dominant. The ADHD children were diagnosed by a psychiatrist and confirmed by current reports from parents in accordance with the DSM IV criteria (American Psychiatric Association, 1994) and the Conner's rating scale (Goyette, Conners, & Ulrih, 1978). The ADHD group was limited to children who were taking methylphenidate (Ritalin). Children with known neurotic/emotional disorder, autistic disorder, physical disability or neurological disease were excluded from the study.

2.2 Instruments
Digitizing Tablet and On-line Data Collection and Analysis Software
A suite of on-line, computerized handwriting evaluation (POET- Penmanship Objective Evaluation Tool, Rosenblum, Parush, & Weiss, 2002) developed by the researchers via Matlab software toolkits was used to administer the stimuli and to collect and analyze the data. The evaluation was developed in response to the absent of quantitative objective handwriting tool for Hebrew language. All writing tasks were performed on A4 size lined paper affixed to the surface of a WACOM (404 X 306 X 10 mm) x-y digitizing tablet using a wireless electronic pen with pressure sensitive tip (Model GP-110). Displacement, pressure, and pen tip angle were sampled at 150 Hz via 650 MHz Pentium III laptop computer. The computerized system enabled the collection of spatial, temporal and pressure data while the child was writing.

The Hebrew Handwriting Evaluation (HHE) (Erez & Parush, 1999)
The HHE was used to examine the observed ergonomic factors while paragraph copying. The paragraph contains all the letters in the Hebrew alphabet, and included 30 words and 107 letters (Erez & Parush, 1999). The inter-rater reliability of the HHE is r = .75-.79; p < .001. Construct validity of the HHE has been established by demonstrating statistical significant differences (t = -2.34; p = .027) between the performance of children with proficient and poor handwriting (Devash, Levi, Traub, & Shapiro, 1995). The standardized text from the Hebrew Handwriting Evaluation (Erez & Parush, 1999) was also chosen in the current study as the paragraph copying task to be analyzed by the digitizer, in order to enhance the fidelity between subjective (HHE) and the objective (digitizer) approaches.

2.3 Handwriting Tasks
The handwriting tasks included the writing of the letters of the alphabet in order from memory, copying four words, two sentences, and a 100-character paragraph.

2.4 Outcome Measures
The primary outcome measures included various temporal and spatial measures of handwriting kinematics (Rosenblum Parush & Weiss, 2003a) including Total time, On paper and In air time, Total length, On paper and In air length. The outcome measures of the HHE assessment of the written product included global legibility, as well as analytic measurement of legibility such as the number of letters that were erased and/or written over, the total number of letters that could not be recognized, and spatial arrangement.

2.5 Procedure
All subjects performed the experiment under similar environmental conditions in a quiet classroom in their school or in the clinic. Each subject was tested individually during the morning hours. All environmental factors were kept as similar as possible to writing conditions that the child would normally experience. The handwriting tasks were presented on the computer screen. The tasks were written on normal writing paper with printed
lineature, which was affixed to the digitizing tablet. Each subject was instructed in the same fashion about what he or she would be required to do. The testing took approximately 15 minutes. All computerized data collection sessions were carried out by the same individual. The handwriting products were then evaluated using predetermined criteria and the Hebrew Handwriting Evaluation (Erez & Parush, 1999).

3. Results
The first group of variables to be analyzed were the subjective measures, i.e. the results obtained via the HHE for the paragraph copy task. The MANOVA applied to these four variables (global legibility, letters erased and/or overwritten, unrecognizable letters and spatial arrangement) yielded statistically significant differences between the children with proficient and the dysgraphic handwriting during the task (F(4,95)=13.57, p<.001). No significant differences were found for these variables between dysgraphic and ADHD children. To examine the source of the significance, the data from each variable were subjected to univariate ANOVAs. The results of this analysis showed that children with proficient handwriting received significantly lower scores (i.e. performed better) in all the four variables than did the children with dysgraphic or ADHD handwriting for this task.

The second group of analyzed measures included the spatial and temporal variables obtained from the digitizer system. The MANOVA applied to these six variables (total length, “on paper” length, In air length, total time, On paper time, and In air time) yielded statistically significant differences between the children with proficient and the dysgraphic handwriting for the paragraph copy task (F(5,91)=9.82, p<.0001). To examine the source of the significance, the data from each variable were subjected to univariate ANOVAs. The results showed that children with proficient handwriting required significantly less total time, “on paper” time, and In air time when they engaged in paragraph copy than did the children with dysgraphic handwriting. Moreover, they had shorter total, On paper and In air path lengths during the copying task than did the children with poor handwriting. No significant differences were found between the dysgraphic and ADHD children.

Discriminant analysis was then conducted in order to determine whether the eight (four subjective and four objective measures) could predict group membership (i.e., children with proficient versus children with dysgraphic handwriting). The discriminant function was found to be significant for the paragraph copying task (F(8,87)=9.95, p<.0001). The highest predictors during the paragraph copying task amongst the subjective variables, was global legibility (.81). Amongst the objective measures, the highest predictor was In air time (.79). In contrast, “on paper” length was the lowest predictor (.29). Significant correlations, ranging from .31 to .65, were found between all four subjective measures and three of the objective measures (In air time, In air length and On paper time), for paragraph copying task, when the data from all participants were analyzed.

4. Discussion
The current study represents one of the first attempts to utilize objective, digitizer-based data as an adjunct to conventional, subjective handwriting assessment in order to examine the contribution of each method to the identification and characterization of poor handwriting. The fact that the subjective measures used in the current study differentiated significantly between dysgraphic/ADHD and proficient handwriting is not trivial. Researchers over the years have not been satisfied that the criteria that have been relied on thus far truly represent the critical components of handwriting legibility nor comprise the optimal way to measure them (Daniel & Froude, 1998). This sentiment is echoed by Dennis & Swinth’s (2001) recent statement that although legibility is certainly a crucial component of written communication it remains quite difficult to define. In addition, a review of handwriting evaluation scales (Rosenblum et al., 2003) revealed that although many handwriting evaluation developers have attempted to define the characteristics of handwriting that determine legibility, they have not yet been shown to discriminate sufficiently well between dysgraphic and proficient handwriting.

Our results show that the subjective criteria used in this study (i.e., global legibility, letter erased or overwritten, unrecognizable letters, and spatial arrangement) did successfully discriminate between dysgraphic and proficient handwriting. These criteria are consistent with those used in previous studies (Erez & Parush, 1999; Graham, Weintraub, & Berninger, 2001).

Once our data confirmed that all of the subjective and the objective measures were significantly different for dysgraphic or ADHD handwriting versus proficient handwriting, discriminant analysis was used to determine which type of measure, subjective or objective, better discriminated between them. The results indicated that global legibility discriminated best. The fact that subjective measures discriminate so well between proficient and dysgraphic handwriting supports the importance of continuing to include subjective handwriting assessments in the process of evaluating children’s handwriting.

The best discriminator amongst the objective measures was In air time. As shown previously (Rosenblum, Parush, & Weiss, 2001; 2003b) among participants with handwriting problems, the child’s pencil ‘traveled’ above the writing surface between the writing of successive character segments, letters and words (the In air phenomena), for a significantly longer period of time and trajectory than it did among the proficient writers.
The results of the current study shows that it is not just that the objective In air measure is an important measure for differentiation, but also that all four subjective measures were highly correlated with the In air measures (In air length and In air time), mainly among the children with dysgraphic handwriting. That is, the poorer the score a child received for global legibility, the longer the child’s measured In air time and length were found to be. This relationship was almost not found among the children with proficient handwriting. Therefore, one may speculate that these phenomena are an expression of the reduced continuity, consistency and efficiency of writing movements that characterize the writing performance of children with dysgraphia, as described in earlier clinical (Ziviani & Elkins, 1984) and digitizer studies (e.g., Smits-Engelsman & Van Galen, 1997; Van Galen, Portier, Smits-Engelsman, & Shomaker, 1993; Wann, 1987). These results are quite intriguing since they demonstrate that digitizer technology has the unique capability to reveal some of the perceptual-motor processes underlying handwriting that would not be apparent from classical subjective handwriting evaluations. Clearly, further research is needed to determine the actual relationship between the In air phenomenon and the underlying mechanisms that contribute to dysgraphia or ADHD. Indeed, such research may contribute to the formulation of new and improved educational strategies to help children with poor handwriting, as well as determine the effectiveness of such strategies.

In conclusion, the findings of this study serve to expand on the information provided by previous digitizer handwriting research and indicate that a correspondence exists between the subjective appearance of the written product of children with dysgraphia or ADHD and objective digitizer measures In air time and length. Future studies must include tasks designed to differentiate between the way different children perform handwriting tasks in order to achieve an understanding of the underlying difficulties that limit the performance of children with dysgraphic handwriting.

References


