Development of the Handwriting Legibility Scale (HLS): a preliminary examination of Reliability and Validity

Authors: Anna Louise Barnett, M. Prunty, R. Rosenblum

Highlights

- The HLS gives an easy-to-use, holistic assessment of handwriting legibility
- It discriminates well between good and poor handwriting
- The HLS has potential for use across languages and scripts

1.0 Introduction

As children progress through school, there is a growing demand for the production of legible handwriting at reasonable speed (DfE, 2014). In the early school years the focus is on letter formation and joining, to produce handwriting that is neat and legible, both to the writer and to those trying to read the written product. The child must develop flexibility in their handwriting skill, to produce their very neatest writing when required (as for a wall display) and to be able to write quickly when in an examination. The development of fluent and legible handwriting becomes more and more important as demands increase through the school years. Children are expected to keep up with class work, to produce a greater volume of writing and to work in time-pressured situations. Handwriting has been described as a 'low-level' skill in the broader writing process (Berninger et al., 2002). With a limited working memory capacity, if lower-level skills are not automated, they can impact on 'higher-level' compositional processes (Connelly et al., 2006). This emphasizes the importance of identifying and supporting those with handwriting difficulties to ensure they are able to achieve their potential.

Teacher reports indicate that significant proportions of children in school classrooms have handwriting difficulties. For example, 12-13% has been reported in the UK (Barnett et al., 2006) and 23% in the USA (Graham et al., 2008). These difficulties include having slow and/or untidy writing that is difficult to read. Children may have handwriting difficulties for a variety of reasons. Some have neurological or physical disabilities affecting the muscles or joints. Others have difficulties with motor control and coordination in the absence of a neurological or physical disorder, for example children with Developmental Coordination Disorder (DCD) (Rosenblum, & Livneh-Zirinski, 2008; Prunty et al, 2014). Indeed poor handwriting is mentioned in the formal diagnostic criteria for this condition (APA, 2013). Handwriting difficulties are also common in other developmental disorders, including Attention Deficit Hyperactivity Disorder, Specific Language Impairment and Dyslexia (Dockrell et al., 2011; Rosenblum, Epsztein, & Josman, 2008; Sumner et al., 2014). Another group of children seem to have isolated handwriting difficulties in the absence of a more general motor difficulty or other developmental disorder. Sometimes referred to as 'dysgraphia', this may be associated more with inadequacies in teaching and practice opportunities than a limitation within the child (Berninger & Dagmar, 2003).

Whatever the underlying cause, handwriting difficulties may lead to reluctance to write, underachievement and low self-esteem (Feder & Majnemer, 2007). It is hardly surprisingly therefore that they are often a cause for concern to parents, teachers and to children themselves (Hammerschmidt & Sudsawad, 2004) and are the most common reason for referral to Occupational Therapy (Feder et al, 2000). Despite the recognized importance of handwriting skill and the considerable number of children faced with difficulties in this area, there has been very little research

to describe and quantify handwriting difficulties in children. This has in part been due to the lack of robust assessment instruments. Screening scales for identifying handwriting difficulties have been developed for capturing the teacher's impression from the child's handwriting production in class (Rosenblum, 2008) or the child's perception about his/her own handwriting production (Rosenblum & Gafni-Lachter, 2015). These questionnaires provide a useful overview of various aspects of handwriting (including the motivation to write, speed of production, legibility and fatigue) but do not involve the examination of a specific sample of handwriting, Tests of handwriting speed (e.g. Barnett et al., 2007; Smits-Engelsman et al, 2015; Wallen, Bonney & Lennox, 1996) and digitizing tablets (with various specialized software programs) have been used to detail temporal and spatial aspects of performance (e.g. Rosenblum & Livneh-Zirinski, 2008; Prunty et al., 2014). These allow for an examination of both general and specific aspects of fluency and speed of production across a range of handwriting tasks (differing in length and cognitive demands). However, there is a lack of robust practical tools to assess the quality and legibility of the written product. Some scales have been developed to assess in great detail different components of handwriting legibility (for example the extent to which letters match a standard, the consistency of letter size or spacing between letters) (e.g. Reisman, 1993; Smits-Engelsman et al., 2015). Such assessments require scrutiny and measurement of single letters, can be time consuming to undertake and are therefore not practical for teachers to use in the classroom setting. Furthermore, the requirement to match the written sample to criterion letter 'standards' prevents their application to different written languages, handwriting styles or scripts.

Specially designed computerized assessments (e.g. Falk, Tam, Schellnus & Chau, 2011) allow for a faster and more objective measurement of specific criteria of handwriting quality (e.g. letter size, spacing, alignment). However, the relationships between such criteria and the overall legibility of the written text as captured by a global impression are weak (see Rosenblum,Weiss, & Parush, 2003). Furthermore, unfortunately such technology is not commonly available and using it is not a trivial or intuitive task for class teachers. In fact teachers need a standardized practical tool for the measurement of legibility to help them identify those with difficulties and determine whether the child needs support to develop their skills (Hammerschmidt & Sudsawad, 2004).

The aim of the current study was therefore to develop a quick and easy tool to provide a reliable and valid assessment of handwriting legibility. The focus was on the assessment of a naturalistic (and therefore ecologically valid) handwriting task, which is easy to gather from large numbers of children in the usual classroom setting. The assessment is based on an overall impression of the handwriting (rather than a detailed examination of individual letters), with a view to application in different languages and scripts. The initial development of the tool focuses on children in the UK from the age of 8 years and upwards, who by this age will have received several years of instruction and should be developing effective skills of written communication (DfE, 2014). The analysis of construct validity

focused on the ability of the test scores to discriminate between two groups of children, those with and without DCD. As mentioned above, handwriting difficulties seem to be a hallmark of DCD, frequently mentioned by parents and teachers and even included in the formal DSM-5 (APA, 2013) description of the condition. The ability of the new tool to discriminate performance of these two groups is therefore important. A reliable and valid assessment of handwriting legibility is much needed in order to easily and quickly identify those with difficulties, provide effective support and thereby avoid academic underachievement.

2.0 Methods

2.1. Development of the HLS items and an examination of content and expert validity. Phase One was based on professional experience of the authors (which included work on teacher's impressions of handwriting legibility), validated by a review of the literature. Five legibility criteria were established to form the basis of the new assessment tool, the Handwriting Legibility Scale (HLS). The five criteria were: global legibility, effort required to read the script, layout on the page, letter formation and alterations to the writing. Instructions for scoring emphasized gaining an 'overall impression' of each of the criteria in deciding on scores for each component, rather than a detailed letter-by-letter analysis. Scoring instructions, examples and a 5-point Likert scale (from 1–good, to 5-poor) were developed to assess each of the criteria (see Appendix A). These were applied to samples of 'free writing' gathered as part of an assessment on the Detailed Assessment of Speed of Handwriting (DASH; Barnett et al., 2007). Children had written on lined paper on the topic of 'My Life', with instructions to use their 'everyday' handwriting and to write continuously for 10 minutes, marking their script every 2 minutes. In the UK there is no single, prescribed writing style. Schools are free to choose and there tends to be variability across schools (Barnett et al., 2006), which was reflected in our sample. Some schools teach fully joined ('cursive') from the start but a semi-joined script is most common. The HLS was applied to writing produced in the first six minutes or at least ten lines of handwriting. Total scores ranged from 5 to 25, with higher scores reflecting poorer legibility. A one-page scoring sheet was drafted and scores were summed to provide a global legibility score. Ten scripts from children aged 10-14 years (including those with and without handwriting difficulties) were scored independently by each of the authors. This led to clarification of the wording and layout of the scoring sheet to improve ease of use. In Phase Two content validity was examined by asking 12 experts from different professions (teaching, occupational therapy, psychology) to independently evaluate the tool. They were provided with an example script which had already been marked using the HLS. They were also provided with three further handwriting scripts and were requested to apply the scale to these three and then complete a feedback form which specifically asked for their opinion about the clarity of each of the five criteria and the extent to which they felt each contributed to the construct of 'legible handwriting'. They were also asked for any additional comments on the new scale.

2.2. Examination of internal consistency and inter-rater reliability. Internal consistency (using Cronbach's alpha coefficient) was calculated from the scores of 58 children aged 8-14 years. The writing scripts were obtained from children who had taken part in previous studies and included those with and without handwriting difficulties. Inter-rater reliability was investigated by asking two new raters to independently score the scripts from 20 children aged 9-10 years. This narrower age band was chosen to eliminate any differences associated with age, which might have made it easier for raters to discriminate between scripts. The new raters were both experienced class teachers who were trained by the first author to apply the HLS. Total HLS scores were divided into three categories: low (scores of 5-10), medium (11-15) and high (16-25) and inter-rater agreement was calculated using Cohen's Kappa.

2.3. Examination of construct and discriminative validity. To examine construct validity a Principal Component Analysis (PCA) of the five component scores was undertaken to establish whether the HLS assessed one or more components of legibility. Gender effects on the total and item scores of the HLS were also examined, as handwriting is commonly reported to be poorer in boys than girls (Graham et al, 1998). To examine discriminative validity the ability of the test scores to discriminate between a group of typically developing children and those with DCD (known to be commonly associated with handwriting difficulties) was examined.

2.4 Participants

For the PCA and examination of the effect of gender, a sample of 150 children (74 male, 76 female) aged 9-16 years was used. These children were drawn from the UK stratified sample of 546 children described in the DASH manual (Barnett et al, 2007). As for the full DASH normative sample, the composition of this smaller sample was representative of the UK population in terms of gender, level of parental education and race/ethnicity, in relation to the 2001 UK Census data. Children were selected from a range of schools across the UK, including England, Scotland, Wales and Northern Ireland. The numbers of children at each age year are shown in Table 1. There was no significant difference between the age in years of boys (M=11.47, SD=1.71) and girls (M=11.49, SD=1.72) ($t(148)=-.05$, $p=.961$). For the discriminative analysis, 29 children with DCD (28 boys, 1 girl) and 29 typically developing (TD) children aged 9-14 years and matched on age and gender were included. All children in the DCD group had undergone a full diagnostic assessment, meeting the DSM-5 (APA, 2013) criteria for DCD. Their parents reported difficulties with everyday movement skill and they had Movement ABC-2 (Henderson et al., 2007) Test and Checklist scores below the 5th percentile. Children in the TD group had no reported movement difficulty and had Movement ABC-2 Test and

Checklist scores above the 15th percentile. None of the participating children had a learning difficulty and all were free from sensory and neurological impairments.

2.5 Measures

Detailed Assessment of Speed of Handwriting (DASH, Barnett et al, 2007)

Although the DASH includes several handwriting tasks to measure speed of production, in the present study only scripts from the 10-minute 'free writing' task were used. In this, the child is required to write on the topic of 'My Life'. They are given some time before writing to generate ideas and writing prompts are available during the writing period. This sample of writing was used to apply the newly developed HLS and the speed of writing was not of concern in the present study.

Movement Assessment Battery for Children-2nd Edition (Movement ABC-2, Henderson, Sugden & Barnett, 2007)

The Movement ABC-2 includes two assessment components, a Test and a Checklist. The norm-referenced test is frequently used in clinical and research settings for the identification and description of children with movement difficulties (Smits-Engelsman et al, 2013). It measures performance in three components: manual dexterity, aiming & catching and balance and also produces a total score. Both the Test and Checklist are specifically mentioned in the European recommendations for assessment in DCD (Blank et al., 2012). Based on their psychometric properties, the Test component is recommended for the identification of movement difficulties (Criterion A) and the Checklist for a description of performance in Activities of Daily Living (ADL) (Criterion B).

Institutional research ethics approval had been obtained both for the collection of data from a representative UK sample and for the study of children with DCD and a matched control group.

3.0 Data analysis

A PCA was conducted to determine the factor structure of the HLS and t-tests were used to examine gender effects in the item and total scores. The discriminative analysis was undertaken in three ways; firstly by comparing the HLS scores of the children with and without DCD using a Mann Whitney U test. Secondly a Chi-squared analysis was undertaken on the HLS category scores (low, medium and high) to determine whether the number of children falling into each category was significantly different across the two groups. Finally a discriminant analysis was undertaken to examine the extent to which the total HLS scores accurately classified children to the DCD or TD group.

4.0 Results

4.1. Content and expert validity. Independent feedback was received from each of the 12 experts, based on their knowledge of handwriting, use of other assessment tools and practical experience of working with children. After rating three scripts using the HLS the experts completed a feedback sheet. All considered the criteria to be clear, although some commented that it would be helpful to have further examples where the HLS had been applied to different scripts, to help those new to the scale understand the separate criteria. They also gave some suggestions for revising the wording on the scoring sheet, for example to change the wording of the third criterion from 'organisation' to 'layout'. Overall the expert opinion supported inclusion of the five criteria and feedback led to clarification of the descriptions and scoring instructions.

4.2. Internal consistency and inter-rater reliability. Internal consistency was high (Cronbach's alpha 0.92). Inter-rater reliability was acceptable (Intra-class correlation .92, Kappa 0.67, $p<.001$).

4.3. Construct and discriminative validity. In the PCA, examination of the scree plot and eigenvalues indicated a single factor solution was appropriate; this explained 61% of the variance. Table 2 shows the item loadings on the factor. Item and total scores for boys and girls separately are shown in Table 3. Significant effects of gender were found on the total HLS score and three of the five item scores. The overall mean total score for the HLS was 12.8 (SD=3.24).

Total HLS scores obtained from the scripts of children with DCD (Mean=17.28) were significantly higher than those for the TD group (Mean=9.83), U=42.50, z=-5.89, $p<.001$. There was also a statistically significant difference between the groups on each of the five criteria (Table 4). The number of scripts from the DCD and TD group scoring in the low, medium and high HLS categories are shown in Table 5. The 'high' category here is equivalent to more than one standard deviation above the mean of the larger representative sample of 150 children reported above (i.e. 12.8 plus 3.24 = 16.04 and rounded down to a score of 16). The Chi-square analysis revealed a statistically significant difference in this distribution of scores ($\chi^2 = 31.1$ (df=2), $p<.001$). In the discriminant analysis, one discriminant function was found for the group classification of all participants according to the HLS final score (Wilks Lamda = .41 $p<.0001$). Based on this function 88% of the children in the entire sample were correctly classified to their groups, 86% of the children with DCD and 89.7% of the TD children. A Kappa value of .759 ($p<0.001$) was calculated, demonstrating that the group classification did not occur by chance.

Insert Tables about here

5.0 Discussion

Some children have difficulty using a pen to accurately form letters and words, making their handwriting slow to produce, untidy and hard to read. This may be related to a physical difficulty, poor motor control and coordination or other learning disorders. Alternatively it may be the case that the child has had inadequate teaching of the basics of writing and/or lack of dedicated handwriting practice. Whatever the underlying reason, poor legibility may lead to reduced motivation to write, low self-esteem and academic under-achievement (Feder & Majnemer, 2007).

In order to support children with handwriting difficulties, assessment tools are needed to assist identification and to describe and quantify the problem. The degree of legibility or ease of reading a handwritten script may be different for different readers and hard to quantify. Development of the HLS was an attempt to identify those aspects of the text that contribute to global legibility, using a naturalistic writing task and without the need for detailed letter by letter analysis. The aim was to produce an easy and quick to use practical tool for teachers and clinicians. The five elements included were supported by expert opinion as relevant components. Overall readability and effort required to read the script is based on the extent to which the script can be easily read on the first attempt, without relying on the context of the work. The way in which the words are laid out and organized on the page also has an impact on the ease with which it can be read. This relates to alignment of the writing with the margin, spacing between the words and positioning of letters and words on the base line (Parush et al., 2010). The accurate and consistent formation of letters is another important element, with errors often relating to missing elements of letters, poor closure or varied size (Graham et al., 2010). Finally, alterations to the writing can also impact on the ease of reading (Rosenblum & Livneh-Zirinski, 2008). These include crossing out, the addition of strokes and re-tracing of letters. In the examination of internal consistency, these five elements were found to be closely related to the total score. In order to examine inter-rater reliability the total scores were categorized into three groups: low, medium and high scorers. Inter-rater reliability based on these classifications was acceptable but not as high as usually required for assessment tools. Further analysis revealed that this was largely accounted for by poorer agreement between raters on the ‘layout’ component of the scale. From subsequent discussion with the raters it emerged that they were somewhat unclear about what to consider for this element and so further refinement and clarity of the instructions is required, perhaps with more examples for scorers. The four other components appeared to be clear with much better agreement between raters. In future work it will be important to examine aspects of reliability of the final version of the HLS across the full age range and also in different groups of children with handwriting difficulties.

With any new assessment tool it is important to demonstrate its construct validity, the extent to which it actually measures the construct that it is designed to measure. We set out to develop the HLS to

assess global legibility in handwriting and the PCA of the five items revealed a single factor explaining a large proportion of the variance. This supports the value of the HLS in the assessment of overall legibility. The factor loadings of the HLS items were high (above .8) for three of the items: global legibility, effort required to read the script and letter formation. The loading was lower for 'layout on the page' (.68) and considerably lower for 'alterations' (.41). Rosenblum & Livneh-Zirinski (2008) have previously identified alterations in the text to have a negative impact on legibility. However, in the HLS we included crossing out of letters and words as well as alternations to individual letters (adding strokes and writing over letters in attempts to correct their form). Our findings here and closer inspection of the scoring on this aspect suggest that these different kinds of alterations should be treated differently. While clear crossings out seem to reflect revisions to the written expression, alterations to individual letters are related more directly to letter production and legibility. The current version (Appendix A), therefore includes only the latter. Construct validity is further demonstrated by the finding that the handwriting legibility of boys was generally worse than that of girls, a fairly consistent finding in the literature that would be expected in a robust assessment of handwriting (Barnett et al., 2007; Graham et al, 1998). Discriminative validity was examined by checking the ability of the test to discriminate between the scripts from a group of typically developing children and those with DCD, a condition where handwriting difficulties are known to be very common (Prunty et al, 2014). Not only did the HLS scores differ significantly between the DCD and TD groups, they could also be used to correctly classify over 85% of children into each of the groups. This provides strong evidence to support the construct validity of the HLS. It should be noted that our sample of children with DCD was composed predominantly of boys and that further investigation of use of the tool in DCD should include a larger proportion of girls in keeping with expected incidence rates. In future work, a similar examination should be undertaken with other groups of children with handwriting difficulties. Other aspects of the validity of our new legibility tool should also be investigated. This might include comparison with other more objective measures of components of handwriting quality, such as computerized measures of letter formation, spacing and alignment.

If a test is to be used to identify those with difficulties then it is necessary to select a cut-off score to denote poor performance (Barnett et al., 2007). When the total HLS scores were divided into low, medium and high it was found that none of the scripts from children in the DCD group fell into the 'low' category (scores of 5-10), compared to over 65% of those from the TD group. Using the larger representative sample of 150 children the mean total HLS score was 12.8, with a standard deviation of 3.24. A common cut-off score is more than one standard deviation from the mean (Cascio, Alexander & Barrett, 1988, i.e. 16.04 in this case) and equivalent to the 'high' category used in our analyses (scores of 16-25). With a normal distribution this identifies just over 15% of those with the poorest handwriting, a level which is within the previously described frequency of handwriting difficulties

Feder & Majnemer, 2007; Rosenblum et al., 2003) and is considered appropriate for a screening tool. At present we would recommend this level to identify those with poor legibility and likely in need of support to address their handwriting skill. Further work on the final version of the HLS is needed to confirm appropriate cut off points to distinguish between those within a range of 'borderline' scores where monitoring of handwriting would be appropriate and those with definite problems with handwriting legibility. This might include examinations of sensitivity and specificity as well as ROC curve analysis.

With further refinements the HLS may be useful as a quick and simple screening tool for the clinic or classroom, to identify those with poor handwriting legibility. In many cases, it would be appropriate to follow up those identified by the HLS with a more in-depth assessment of letter formation and aspects of legibility (e.g. Smits-Engelsman et al, 2015). It is recommended in the HLS instructions that the amount of writing produced in a given time is recorded alongside the HLS items on legibility. Although this gives some indication of production rate, any follow up assessment should also include a more thorough and formal examination of handwriting speed (e.g. Barnett et al, 2007). Further studies are needed to examine whether the HLS would also be useful as an outcome measure, to evaluate changes in handwriting performance in relation to the implementation of certain support or intervention. The appropriateness and sensitivity of using the tool in this way needs to be considered by further examination of test-retest reliability as well as by comparing changes in HLS scores with changes on more detailed handwriting assessment tools (e.g. letter-by-letter analysis or temporal/spatial features obtained from a digitizing tablet).

We have outlined the rationale for the content of the HLS, described the stages of development and suggested its potential value as a global assessment of handwriting legibility in the clinic and/or classroom. It is also important to recognize the limitations of this initial work. Firstly, some of our findings suggest that further work is needed to refine the tool, rather than presenting this as a final version. Secondly, as with any single study, we have only examined certain aspects of reliability and validity and ongoing work will need to be undertaken to further evaluate its psychometric properties. Thirdly, our examination of reliability and validity has been restricted to particular age ranges and groups of children. Future work should extend this examination across other groups in which the HLS might be employed.

6.0 Conclusions

The HLS provides an easy to use global score of handwriting legibility. Initial examination suggests good internal consistency and construct validity of the tool. However, further refinement of instructions is needed to improve the reliability of scoring and additional data collection and analysis

to confirm a cut off point to accurately identify those with poor legibility. The HLS may then be a useful tool to identify those with poor legibility, to quantify levels of performance and to help plan how best to support individuals with poor handwriting. It may also be useful as an outcome measure following intervention. Given the global nature of the assessment of legibility in this new tool, the HLS is likely to be applicable across different languages and scripts. Future work will determine the value of its use beyond the UK.

Acknowledgements

We are grateful to the children and families who took part in this research.

Funding: The collection of normative data on the DAS was supported by Harcourt Assessment (now Pearson). Other aspects of the work were supported by a studentship from Oxford Brookes University to the second author.

References

American Psychiatric Association. (2013). DSM-5. *Diagnostic and Statistical Manual of Mental disorders* (5th Ed.). Washington: American Psychiatric Association.

Barnett, A., Henderson, S., Scheib, B., & Schulz, J. (2007). *Detailed Assessment of Speed of Handwriting.* Oxford: Harcourt Assessment.

Barnett, A., Stainthorp, R., Henderson, S. & Scheib, B. (2006). *Handwriting policy and practice in English primary schools*. London: Institute of Education.

Berninger, V. W., & Dagmar, A. (2003). Preventing written expression disabilities through early and continuing assessment and intervention for handwriting and/or spelling problems: Research into practice. In: Swanson, H. L., Harris, K. R., & Graham, S. (Eds). *Handbook of learning disabilities*. , (pp. 345-363). New York, NY, US: Guilford Press, xvii, 587 pp.

Berninger, V., Vaughan, K., Abbott, R., Begay, K., Byrd, K., Curtin, G., Minnich, J., & Graham, S. (2002). Teaching spelling and composition alone and together: Implications for the simple view of writing. *Journal of Educational Psychology, 94,* 291-304.

Blank R, Smits- Engelsman B, Polatajko H, Wilson P. (2012). European Academy of Childhood Disability (EACD): Recommendations on the definition, diagnosis and intervention of developmental coordination disorder (long version). *Developmental Medicine and Child Neurology* 54:54–93.

Cascio, W. F., Alexander, R. A., & Barrett, G. V. (1988). Setting cutoff scores: Legal, psychometric, and professional issues and guidelines. *Personnel Psychology*, 41(1), 1-24

Connelly, V., Campbell, S., MacLean, M., & Barnes, J. (2006). Contribution of lower order skills to the written composition of college students with and without dyslexia. *Developmental Neuropsychology, 29*(1), 175-196.

Department for Education (DfE). (2013). English programmes of study: key stages 1 and 2 National curriculum in England. Retrieved April 2013, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335186/PRIMARY_national_curriculum_-_English_220714.pdfDockrell, J. E., Lindsay, G., & Connelly, V. (2011).The Impact of Specific Language Impairment on Adolescents' Written Text , *Exceptional Children, 75(*4), 427-446.

Falk, T. H., Tam, C., Schellnus, H., & Chau, T. (2011). On the development of a computer-based handwriting assessment tool to objectively quantify handwriting proficiency in children. *Computer Methods and Programs in Biomedicine*, 104(3), e102-e111.

Feder, K., Majnemer. A., & Synnes, A. (2000). Handwriting: Current trends in occupational therapy practice. *Canadian Journal of Occupational Therapy*, *67*(3), 197-204.

Feder, K., & Majnemer, A. (2007). Handwriting development, competency and intervention. *Developmental Medicine and Child Neurology, 49*, 312-317.

Graham, S., Harris, K.R., Mason, L., Fink-Chorzempa, B., Moran, S. & Saddler, B. (2008). How do primary grade teachers teach handwriting? A national survey. *Reading & Writing*, 21(1-2), 49-69.

Graham, S., Struck, M., Santoro, J., & Berninger, V. (2010). Dimensions of good and poor handwriting: legibility in first and second graders: motor programs, visual-spatial arrangement, and letter formation parameter setting. *Developmental Neuropsychology, 29(1),* 43-60.

Graham, S., Berninger, V., Weintraub. N., & Schafer, W. (1998). Development of handwriting speed and legibility in grades 1-9. *The Journal of Educational Research. 92*(1), 42-52.

Hammerschmidt, S. L., & Sudsawad, P. (2004). Teachers' Survey on Problems With Handwriting: Referral, Evaluation, and Outcomes. *American Journal of Occupational Therapy, 58*, 2, 185-192

Henderson, S., Sugden, D., & Barnett, A. (2007). *Movement Assessment Battery for Children – Second edition: Manual*. London: Pearson.

Parush. S., Lifshitz, N., Yochman, A., & Weintraub, N. (2010). Relationships between handwriting components and underlying perceptual-motor functions among students during copying and dictation tasks. *Occupation, Participation & Health,30(1)*, 39-48.

Prunty, M., Barnett, A.L., Wilmut, K. & Plumb, M. (2014) An examination of writing pauses in the handwriting of children with Developmental Coordination Disorder. *Research in Developmental Disabilities*, 35, 2894–2905.

Reisman, J. (1993), Development and reliability of the researchversion of the Minnesota handwriting test, *Physical and Occupational Therapy in Pediatrics* 13 (2) (1993) 41–55.

Rosenblum, S. (2008). Development, reliability and validity of the Handwriting Proficiency Screening Questionnaire (HPSQ). *American Journal of Occupational Therapy, 62*, 298-307.

Rosenblum, S., Epsztein, L., & Josman, N. (2008). Handwriting performance among children with Attention Deficit Hyperactive Disorders (ADHD), on and off medication in comparison to a control group – A pilot study. *Physical and Occupational Therapy in pediatrics, 28(3)*, 219-234

Rosenblum, S., & Gafni-Lachter, L. (2015). Handwriting Proficiency Screening Questionnaire for Children (HPSQ–C): Development, Reliability, and Validity. *American Journal of Occupational Therapy, 69*(3), 1-9.

Rosenblum, S., Livneh-Zirinski, M. (2008). Handwriting process and product characteristics of children diagnosed with developmental coordination disorder. *Human Movement Science, 27(2),* 200-214.

Rosenblum, S., Weiss, P. L., & Parush, S. (2003). Product and process evaluation of handwriting difficulties: A review. *Educational Psychology Review*, 15, 41-81.

Smits-Engelsman, B. C., Blank, R., van der Kaay, A. C., Mosterd-van der Meijs, R., Vlugt-van den Brand, E., Polatajko, H. J., . . . Wilson, P. H. (2013). Efficacy of interventions to improve motor performance in children with developmental coordination disorder: A combined systematic review and meta-analysis. *Developmental Medicine and Child Neurology*, 55, 229–237

Smits-Engelsman, B.C.M., van Bommel-Rutgers, I. & van Waelvelde, H. (2015). Systematic Detection of Writing problems (SOS-2-EN).

Sumner, E., Connelly, V. & Barnett, A.L. (2014). The Influence of Spelling Ability on Handwriting Production: Children with and without Dyslexia. 40(5), 1441-1447. *Journal of Experimental Psychology: Learning Memory and Cognition*.

Wallen, M.A., Bonney, M-A., & Lennox, L. (1996). *The Handwriting Speed Test*. Adelaide, S.A.: Helios Art & Book Co.