Efficacy of a Task-Based Training Approach in the Rehabilitation of Three Children with Poor Handwriting Quality: A Pilot Study

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Summary.—Evidence suggests that task-based training approaches can improve the performance of children with handwriting difficulties. The present case study tests the efficacy of the Handwriting Task Program (HTP). Three male children (9–10 yr. old) with poor handwriting skills and different developmental disorders participated in the HTP, twice per week, for 13 wk. Handwriting legibility was assessed through the Concise Evaluation Scale for Children’s Handwriting, and fine motor performance and handwriting speed were evaluated at pre- and post-treatment with the Visual Motor Integration Test and the Battery for the assessment of writing skills of children from 7 to 13 yr. old. The results showed that motor efficiency and global handwriting quality improved in all the children, although some handwriting difficulties still persisted in one child with Developmental Coordination Disorder (DCD). Further study may confirm on a larger sample that a visual-spatially based training may improve the handwriting legibility of children with DCD.

Hamstra-Bletz and Blöte (1993), based on the work on script legibility of de Ajuriaguerra and Auzias (1975), described dysgraphia as a disturbance or a difficulty in the production of written language that is related to the mechanics of writing. Poor handwriting is one of the warning signs for Developmental Coordination Disorder (DCD) and Specific Learning Disabilities (Miller, Polatajko, & Missiuna, 2001; Rosenblum, Weiss, & Parush, 2003). Most authors believe that poor handwriting quality is not caused by a developmental delay but rather by a specific neuromotor condition (Wing, 1979; Smits-Engelsman, Niemeijer, & van Galen, 2001). They conclude that these problems are typically related to inconsistent fine-motor behavior, neither due to carelessness or ignorance, nor to poor spelling or other psycholinguistic problems. Children that show dysgraphic handwriting are usually referred for occupational therapy (Wilson, 2005). Poor handwriting quality in children is characterized by poor size control (parameterization inconsistency; Wann & Kardirkamanatan, 1991), variability in form, size, and orientation (Wann, 1987; Di Brina, Niels, Overvelde, Levi, & Hulstijn, 2008), and faster movements and spatial inaccuracy.

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Wing (1979) suggested that spatial inaccuracy in handwriting may be the result of less-than-optimal strategies to manage neuromotor noise in the neuromuscular system. More recent studies have shown that motor development is characterized by increased efficiency in inhibiting noise in the neuromotor and muscular systems (van Galen, Portier, Smits-Engelsman, & Schomaker, 1993).

Research has demonstrated that poor handwriting is a persistent trait when untreated and that children with DCD improve their performance; the mean main effect size was Cohen’s $d = 1.46$ after a specific skill intervention (Pless, Carlsson, Sundelin, & Persson, 2000). Intervention procedures can be divided into two categories: deficit-oriented (bottom-up) and performance-oriented (top-down; Wilson, 2005). The deficit-oriented approach is based on the assumption that the learning and motor problems are caused by poor integration of perceptual information. These techniques are directed to provide support for kinaesthetic perception and for sensory integration, and they use sensory inputs to activate planning functions as support to the general intelligence. This kind of treatment is the most popular approach among physical and occupational therapists (Fedder & Majnemer, 2007), but investigations of the effectiveness of deficit-oriented approaches on handwriting performance in children have been inconclusive (Denton, Cope, & Moser, 2006). The performance-oriented approach described in detail by Larkin and Parker (2002) focuses directly on skills improvement, wherein the instructor attends to key task elements as “propulsion” and task dynamics as “control force tasks.” The child selects tasks from those considered both culturally and developmentally appropriate. The child is encouraged to attempt the particular skills, while the instructor attends to key task elements. Prompts and feedback are provided. This approach has strong learning effects (effect size 2.56) at a task-specific level (Revie & Larkin, 1993). The ultimate goal in performance-oriented intervention programs is not only to improve functional task performance during treatment but also to transfer learned skills to daily performance at home (Schoemaker, Niemeijer, & Reynders, 2003) and at school (Sugden & Chambers, 2003). These two approaches are not exclusive, and a combination of the two in the therapy practice is the rule rather than the exception. The complex nature of children’s difficulties frequently leads interventionists toward eclectic and multidisciplinary solutions (Erhardt & Meade, 2005).

For remediation of handwriting problems, a Handwriting Task Program (HTP) has been proposed. The HTP is a performance-oriented training program derived from the assumptions of the cognitive-behavioral intervention (Polatajko, Mandich, Miller, & Macnab, 2001; Jongsmas, Linthorst-Bakker, & Westenberg, 2003; Schoemaker, et al., 2003). It is a child-centered
intervention focused on treating functional goals to be learned, specific for each child. Essential elements of the HTP include objectives of training, task analysis, use of prompting-fading programs, and repetitive practice with structured feedback. All children also receive home activities (homework) to promote practice and repetition and to involve the parents in the therapeutic process.

Given that few data are available on the effectiveness of performance-oriented interventions on handwriting in children (Jongsman, et al., 2003; Zwicker & Hadwin, 2009), the goal of this preliminary investigation was to assess the effectiveness of an HTP in children with handwriting difficulties and different developmental profiles. Pre- and treatment scores were obtained to examine improvements in handwriting quality characteristics.

Hypothesis. Comparison of pre-treatment phase (baseline) and treatment phase scores on handwriting quality will show a significant improvement for each child with intervention.

Method

Participants

Three children attending the public school fourth grade (all boys and right-handed; C1, C2, and C3) participated in this study. A battery of tests evaluated the participants’ neuropsychological abilities (Table 1). C1 had poor handwriting; C2 had poor handwriting and dyslexia; and C3 had poor handwriting, dyslexia, and Developmental Coordination Disorder.

The inclusion criterion was “at-risk” or poor handwriting quality on the Concise Assessment Scale for Children’s Handwriting (BHK; Hamstra-Bletz, DeBie, & Den Brinker, 1987). This standardized norm-referenced test was designed to screen handwriting samples in primary school children. The handwriting task consists of copying a standard text for 5 min. on an unlined sheet of A4 paper. Handwriting quality is rated on 13 features, with a minimum score of 0 and a maximum score of 65. Quality (BHK-quality) is categorized according to legibility. Scores from 0 to 21 are considered to be normal, scores from 22 to 28 indicate “at risk for handwriting

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>PARTICIPANTS’ NEUROPSYCHOLOGICAL PROFILES</th>
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<tr>
<td>Participant</td>
<td>Age (mo.)</td>
</tr>
<tr>
<td>C1</td>
<td>120</td>
</tr>
<tr>
<td>C2</td>
<td>108</td>
</tr>
<tr>
<td>C3</td>
<td>108</td>
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</table>
problems,” and scores of 29 and higher reflect poor handwriting quality. Handwriting scores of the three children were above 22. C1’s handwriting (BHK-27) was characterized particularly by Visual-spatial errors that influence the organization of the written work (alignment, collision, overall letter size), then by Motor Efficiency errors (dysmetria) and Motor Learning errors in the letter formation. C2’s handwriting (BHK-24) was characterized by Visual-spatial errors (alignment and letters collision) and by Motor Efficiency errors (dysmetria). C3’s handwriting (BHK-30) was characterized in particular by Motor Learning and Motor Efficiency errors (dysmetria) and ultimately by Visual-spatial errors (alignment).

Interrater reliability of the BHK has been reported to vary between $r = .71$ and $r = .89$; intra-rater reliability was reported at $r = .87$ to $r = .94$ for Grade 2 and $r = .79$ to $r = .88$ for Grade 3 children (Overvelde & Hulstijn, 2011). Test-retest reliability after 6 mo. ranged from .74 to .86 (Hamstra-Bletz & Blöte, 1993).

Written informed consent to participate in the study was obtained by parents of all children. The study was reviewed and approved by the local Ethics Committee of the IRCCS San Raffaele Hospital in Rome, Italy.

Measures

Handwriting.—The characteristics of the children’s handwriting were used as the dependent variable. All of the children had to copy the following sentence, in which all letters appear twice, from print font to cursive: “L’elefante vide benissimo quel topo che rubava qualche pezzo di formaggio” [The elephant saw very well that mouse stealing some pieces of cheese]. Handwriting performance was rated according to the classification of dysgraphic features proposed by Blason and coworkers (Blason, Borean, Bravar, & Zoia, 2004).

Four dysgraphic features were measured: Visual-spatial errors, Inadequate Motor Learning, Motor Planning, and Motor Efficiency. Each of these areas includes some features listed as errors. Visual-spatial errors were defined as the total number of floating letters (with bases >1.5 mm above or below the line), incoherent slope [number of ascending and descending letters with a significantly incoherent slant (20°–30°) with respect to the individual mean slope of handwriting], collapsed/colliding letters (missing spaces between adjacent letters within a word, letters touch or overlap), reversal (upside-down letters), lack of spacing or excessive spacing between words (number of spaces <2.5 mm or >10 mm), and disproportionate word or letter sizes (disproportion between distinctive traits, ascenders/descenders too long/short, relative to criteria for each type of lined paper). Inadequate motor learning errors were defined as the number of illegible letters (unrecognizable or isolated from their word context), disproportion between letter parts (letters showing disproportion between dis-
Distinctive traits, ascenders/descenders too long/short, relative to criteria for each type of lined paper, and errors in letter formation and joins (formed without respecting conventional writing direction, not respecting “entering stroke-letter body exit stroke” order, erroneously joined). Motor planning errors were defined as the number of self-corrections (number of letters spontaneously overwritten, corrected, or erased) or confusion between similar letters (number of letters substituted by similar ones of the same allographic code). Motor efficiency errors were defined as the total number of dysmetria errors (letters in which the resulting trajectory is displaced with respect to the ideal trajectory, causing unclosed forms, overlapping within the same letters or intrusion into adjacent ones) and perseverations (number of times the same letter is repeated). For each of the above features, a score of 1 was given when a feature was present and 0 when the feature was absent.

Visual-Motor Integration Test (VMI; 5th ed., Beery & Beery, 2004).—The VMI is a culture-free, non-verbal assessment. In this test, a developmental sequence of geometric forms must be copied using paper and pencil within a time limit of 3 min. Graphic responses are scored using the criteria listed in the manual. Shapes that meet specified criteria are given a score of 1, whereas non-passed items receive 0 points. The maximum raw score is 30. Raw scores were converted into standardized scores (VMI-SS), based on the cumulative frequency distribution (Beery & Beery, 2004) and used in analyses. Reliability of the VMI was good (Beery & Beery, 2004; inter-rater: $r = .92$; internal consistency $= .96$; test-retest $=.89$).

Batteria per la valutazione delle competenze ortografiche e di scrittura [Battery for the assessment of writing skills of children from 7 to 13 years old] (BV-COS; Tressoldi & Cornoldi, 2000).—The task was derived from a part of the Battery for the assessment of writing skills of children from 7 to 13 yr. old, a standardized complete writing battery available in Italy (Tressoldi & Cornoldi, 2000). The handwriting task consisted of writing a continuous repetitive alternated sequence of cursive letters (“l” and “e”) in a time interval of 180 sec. on a sheet of paper. Every 5 sec., the experimenter made a small sign on the child’s paper and was careful that the child was continuing to complete the task. Participants (right-handed) used their writing hand for the task and were asked to write clearly. The BVCOS was used to assess handwriting speed, determined by counting the number of correct graphemes (sequence of “le”) written in 1 min. The mean test-retest reliability of writing speed was .83 (Tressoldi & Cornoldi, 2000).

All dependent variables were measured at baseline (A phase), intervention (B phase), and follow-up at 1 mo. (F1) and 3 mo. (F3). To assess the improvement in handwriting abilities and speed with the VMI and BV-COS, each child was tested before treatment (pre-test) and 1 mo. after the end of the treatment (post-test).
Procedure and Research Design

The data collection and analysis were conducted using a single-case ABA design (Kazdin, 1982), chosen for its flexibility and applicability, and have been used extensively over the past decade (Smith, 2012). Participants were tested individually. During the A phase (pre-treatment) of the study, the test sentence was written twice per week for 1 mo. During the B phase (treatment), the sentence was written once per week for 3 mo. During the follow-up phase, two evaluations were performed at 1 and 3 mo. after the end of the intervention program. The total treatment time was 13 wk.

To assess the statistical significance of the results, a Simulation Modeling Analysis (SMA) for time series (Version 8.3.3) was used (Borckardt, 2006; Borckardt, Nash, Murphy, Moore, Shaw, & O’Neil, 2008). Through SMA, it is possible to compare the intervention phase with the baseline phase, to determine the direction and magnitude of change in the dependent variable between two phases of data. SMA corrects for autocorrelation in the time series. The program calculates Pearson’s $r$ predicting Pre-treatment vs Treatment scores. The resulting $r$ values provide a distribution of what to expect if the null hypothesis were true. The expectation is a statistically significant reduction of dysgraphic errors after the onset of the HTP, compared with the baseline phase in which children did not perform the treatment, and that the intervention effects were maintained during the follow-up phase. To assess the reliability, two paediatric therapists were instructed to use the Blason scoring method and independently scored the numbers of errors of the same participant. Two additional paediatric therapists and the first two authors conducted agreement checks on the dependent variables evaluation per phase, per participant. Interrater reliability was examined using point-by-point percent agreement. The minimum standard was set at 80%. For the child who was a poor writer, the average interrater agreement was 97%, 91% for the child who was a poor writer with dyslexia, and 95% for the child with a learning disability and developmental coordination disorder.

Treatment Procedure

The treatment with the HTP consisted of a task-specific training performed twice a week for 13 wk. Treatment sessions were 45 min. Homework was typically from 15 to 20 min. per day for five or six days per week. The HTP comprises modeling specified behaviors and reinforcing the performance of revisions and repairs. Handwriting skill acquisition is facilitated by using prompting programs. The role of prompting is to increase the probability of a correct response. As training progresses, the child should need less prompting. These procedures followed training materials for
The instructional cues are presented on each trial, then if necessary, the therapist uses a sequence of prompts. The therapist can provide one or more of these prompts on a given trial. Mild prompts (e.g., verbal instructions, gestures) are typically delivered prior to more intrusive prompts (e.g., physical contact, pen grip, transparent overlays). This sequencing is planned to ensure that the least necessary assistance is provided. As training progresses, the child should require less prompting. For instance, if a child produced a higher number of floating letters with bases below the line, initially the therapist provides a 2-line paper strip and a plastic overlay with the appropriate model of the line (intrusive prompt). When the child begins to write without touching the plastic overlay, it is removed so only the 2-line paper strip is left (middle visual prompt). When the child writes without going over the line, the 2-line paper strip is removed (no prompt).

The HTP intervention techniques included: pre-writing exercises, movement-based exercises, visual-perceptual training, visual-motor integration activities, and eye-hand coordination exercises. Pre-writing exercises consisted of graphomotor tasks: the child was asked to copy graphemic patterns composed of elements similar to letter forms. Movement-based exercises included specific motor tasks to learn the correct procedure for executive writing and the jointing of each grapheme. The other tasks included visual size discrimination and visual retrieval (search for and localize letters, left-right orientation, and judgment of correctness about graphic forms).

**RESULTS**

Effects of HTP on the four dysgraphic features described by Blason, *et al.* (2004) are presented in Table 2.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Session</th>
<th>Observations (n)</th>
<th>Errors</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Visual-spatial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>C1</td>
<td>A</td>
<td>8</td>
<td>16.6</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>13</td>
<td>3.7</td>
</tr>
<tr>
<td>C2</td>
<td>A</td>
<td>8</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>13</td>
<td>6.3</td>
</tr>
<tr>
<td>C3</td>
<td>A</td>
<td>8</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>13</td>
<td>7.6</td>
</tr>
</tbody>
</table>
Visual-spatial errors are shown in Fig. 1. Pre-treatment baseline data indicated that the number of errors made by C1 was initially higher than both C2 and C3. In comparison with pre-treatment, participation in HTP coincided with significant reduction in all the children’s visual-spatial errors (C1: $r = -.90, p = .02$; C2: $r = -.85, p = .02$; C3: $r = -.72, p = .01$). The number of errors at the last observation was reduced or the same in all the three children: C2 (2 fewer errors), C1 (same number of errors), and C3 (5 fewer errors). This reduction in number of errors was maintained throughout the follow-up period: C1 at F1 (1 less error) and at F3 (same number of errors); C2 at F1 (1 less error) and at F3 (2 fewer errors); C3 at F1 (4 fewer errors) and at F3 (5 fewer errors).

Figure 2 shows the scores related to Inadequate Motor Learning. During pre-treatment, C1 and C3 produced more errors than C2. With specific training, C1 and C2 improved significantly to reach no errors at post-treatment (C1: $r = -.90, p = .004$; C2: $r = -.77, p = .01$). C3 produced significantly fewer errors during the treatment phase (C3: $r = -.82, p = .02$), although at the last session the number of errors was still high (8 errors). Improvements were made during the post-treatment phase: C1 at F1 (1 error) and at F3 (0 errors); C2 at F1 (0 errors) and at F3 (0 errors); C3 at F1 (9 errors) and at F3 (9 errors).

The number of Motor Planning errors by all children was very small in both pre-treatment and treatment phases (Fig. 3). The decrease of errors was negligible.
The number of Motor Efficiency errors is shown in Fig. 4. In the pretreatment phase, C1 produced a higher number of errors than both C2 and C3. The effect of treatment was statistically significant for all three children (C1: $r = -0.91$, $p = 0.01$; C2: $r = -0.96$, $p = 0.001$; C3: $r = -0.66$, $p = 0.03$), and improvements were maintained during the post-treatment phase: for C1 at F1 (1 error) and at F3 (0 errors); C2 at F1 (2 errors) and at F3 (3 errors); C3 at F1 (8 errors) and at F3 (7 errors).

**Fig. 2.** Inadequate Motor Learning errors for three participants (C1, C2, C3) in Sessions A (pretreatment), B (treatment), and F (post-treatment).

**Fig. 3.** Motor Planning errors for three participants (C1, C2, C3) in Sessions A (pretreatment), B (treatment), and F (post-treatment).
Participants’ pre- and post-treatment VMI and handwriting speed scores are shown in Table 3.

The hypothesis, even with the limitations of this sample of three cases, seems to be supported by the children’s improvement trends; the HTP seem to have caused significant improvements in handwriting quality.

DISCUSSION

This study shows that the Handwriting Task Program may improve handwriting performance in children with poor handwriting quality and developmental disabilities. The children with poor handwriting (C1) and poor handwriting and dyslexia (C2) were no longer classified as poor writers after the treatment, based on their handwriting quality. The child

TABLE 3

<table>
<thead>
<tr>
<th>Participant and Session</th>
<th>VMI</th>
<th>Handwriting Speed</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Raw Score</td>
<td>Percentile</td>
</tr>
<tr>
<td>C1 A</td>
<td>17</td>
<td>9th</td>
</tr>
<tr>
<td>C1 B</td>
<td>15</td>
<td>19th</td>
</tr>
<tr>
<td>C2 A</td>
<td>14</td>
<td>6th</td>
</tr>
<tr>
<td>C2 B</td>
<td>16</td>
<td>18th</td>
</tr>
<tr>
<td>C3 A</td>
<td>12</td>
<td>4th</td>
</tr>
<tr>
<td>C3 B</td>
<td>13</td>
<td>6th</td>
</tr>
</tbody>
</table>
with the poor handwriting and learning disability and developmental coordination disorder (C3) showed statistically significant improvements in visual-spatial errors but continued to show poor handwriting quality.

The intensive training program was sufficient to achieve detectable clinical improvement in almost all handwriting performance measures. These results are consistent with previous literature showing improvements in response to task-oriented specific training (ES > 0.70; Revie & Larkin, 1993; Zwicker & Hadwin, 2009). The main limitation of this study is the small number of the observed cases; however, the purpose was to show that the program was successful and provide some data for design of program application in children with varied disabilities.

Considering that fine motor skills are commonly indicated as the core deficits of poor handwriting in Developmental Coordination Disability (DCD), the stability of motor learning and efficiency errors was expected, but interestingly the relative improvement in the handwriting quality of C3 was due to the decrease in visual-spatial errors. An important rehabilitation goal may therefore be visual-spatial based training, which may improve handwriting legibility in DCD, as already suggested by clinical practice (Wilson, 2005). Moreover, HTP involves parents in the rehabilitative program with homework. Involvement of parents has been shown to increase treatment efficacy and reduce treatment discontinuation (Chiappedi, Maltagliati, Amoruso, Dolci, Carniglia, & Bejor, 2009).

The results of this preliminary investigation, using a case study design, suggest that a systematic handwriting training program such as HTP can improve handwriting quality. Further studies with larger and more homogeneous samples are needed to support and extend these conclusions and compare the efficacy of different programs in different subtypes of children with poor handwriting quality.

REFERENCES


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