We investigated a visual–perceptual and haptic–perceptual training program to enhance motor skills and Chinese handwriting performance among children with handwriting difficulties. The participants were 28 first- and second-grade children with handwriting difficulties. They were matched according to age and then randomly assigned into a control group or an experimental group. Participants in the experimental group received 12 sessions of a training program, whereas those in the control group received conventional handwriting training. The Test of Visual Perceptual Skills—Third Edition (TVPS–3), Tactual Performance Test (TPT), and Battery of Chinese Basic Literacy (BCBL) were all administered before and after 6 wk of intervention. Repeated-measures analysis of variance revealed that the experimental group showed significant improvement on the TVPS–3 but not on the TPT. Along with the improved visual–perceptual skills, the experimental group showed a significant difference in far-point copy speed and handwriting accuracy, as reflected in the BCBL.

Handwriting is an essential fine motor skill in school-age children. Children’s ability to produce fluent and legible script is important for expressing, communicating, and recording ideas; this ability is also important for educational development, achievement in school, and self-esteem (Phelps, Stempel, & Speck, 1985; Weil & Amundson, 1994). A report on the activities in an elementary school classroom found that 30%–60% of the time is spent in fine motor activities, with handwriting predominating over other tasks (McHale & Cermak, 1992). Surveys on occupational therapy service in elementary schools have found that the most common referrals are for handwriting problems (Tseng & Cermak, 1993). Most occupational therapy practitioners use a sensorimotor approach in their clinical practice to remedy the handwriting problems of school-age children (Feder, Majnemer, & Synnes, 2000; Woodward & Swinth, 2002).

In the current study, we focused on investigating the effectiveness of a sensorimotor program to improve handwriting problems in school-age children. The sensorimotor approach used in this study includes providing multisensory input through selected activities to reinforce learning. When given various meaningful sensory opportunities at a level that permits assimilation, the child’s nervous system can integrate information more efficiently to produce a satisfactory motor output (e.g., legible letters in a timely manner; Schneck & Case-Smith, 2015).

Previous literature has shown that visual function significantly distinguishes among children with or without mild academic problems (Goldstand, Koslowe, & Parush, 2005). Visual–perceptual skills are crucial factors for predicting handwriting performance, including both legibility and speed (Klein, Guiltner, Sollereder, & Cui, 2011). Longcamp, Anton, Roth, and Velay (2003) proposed that the visual representation of letters is based on a multicomponent neural...
network built up while learning concomitantly to read and write. Although such visual–perceptual skills are important to phonetic script, they are even more important to logographic script, such as Chinese characters. In studying logographic handwriting involving visual–perceptual skills, Lai and Leung (2012) revealed evidence of the cognitive processes of school-age children’s visual–perceptual abilities.

Chinese handwriting is composed of the dynamic combination of perceptual–cognitive–motor activities. When a person writes in Chinese, the writer must first retrieve the visual–spatial characteristics of that word. In contrast to this example, for a phonetic word, its linguistically defined entity is more important (Lai & Leung, 2012; van Galen & Teulings, 1983). According to Kao (1999), the psychogeometric theory of Chinese character writing is based on the writer’s reflection on the visual–spatial characteristics of the Chinese characters. In a study in which Chinese handwriting in school-age children was investigated, Tseng and Chow (2000) revealed that children with a slow handwriting speed seem to rely more on visually directed processes, including sequence memory and visual–motor integration. These studies have shown the importance of visual–spatial perception and processing abilities to the logographic nature of Chinese handwriting.

In addition to visual perception, haptic perception was also found to be significantly related to legibility and speed of handwriting in a study in which the relationship between tactile function and Chinese handwriting was investigated (Yu, Howe, & Hinojosa, 2012). Better scores in tactile function were also significantly associated with better handwriting legibility (Cox, Harris, Auld, & Johnston, 2015). In addition, Bara and Gentaz (2011) revealed that visual–haptics training resulted in more improvement in letter recognition and handwriting quality than visual training alone. These studies have illustrated the importance of haptics skills training with respect to handwriting improvement.

Among the studies based on a sensorimotor program, a direct and regular occupational therapy service demonstrated improved letter legibility; however, speed and numeral legibility did not demonstrate positive intervention effects (Case-Smith, 2002). The sensorimotor program in two other studies also showed promising results for the improvement of handwriting (Peterson & Nelson, 2003; Weintraub, Yinon, Hirsch, & Parush, 2009). One study included handwriting practice in the program, and the other incorporated “higher level” functions (e.g., cognitive or executive functions). However, there was no direct evidence that showed that the improvement was contributed by the sensorimotor program. Denton, Cope, and Moser (2006) revealed that children receiving therapeutic practice moderately improved their handwriting, whereas children receiving sensorimotor intervention had a decline in handwriting performance. Because of advances in digital technology, a computerized visual–perceptual and visual–motor integration training program has been developed and tested in improving the Chinese handwriting of children with handwriting difficulties. Poon, Li-Tsang, Weiss, and Rosenblum (2010) revealed that children using this program showed improvements in their visual–perceptual skills and in their handwriting time; however, the training program did not seem to improve the handwriting legibility of the children.

These studies on sensorimotor programs did not seem to provide consistent results in the remediation of handwriting difficulties. Most supported sensorimotor programs for improving visual–perceptual skills but provided no direct evidence on improvement of handwriting speed and fluency. The purpose of this study was to investigate whether a program addressing visual–perceptual and haptic–perceptual skills can improve handwriting performance in children with handwriting deficits. In this study, we worked with the handwriting of logographic Chinese characters.

Method

Participants

Participant recruitment consisted of a two-step process. The first step was to screen children with dysgraphic characteristics on the basis of referral from teachers in two public elementary schools in southern Taiwan. The teachers checked and confirmed the deficit by the administration of the Chinese Handwriting Evaluation Questionnaire (Chang & Yu, 2005, 2010). Children reporting a history of any medical, neurological, or pervasive developmental disorders; intellectual disability; or oncological, musculoskeletal, sensory (hearing, vision), or skin disorders were excluded from this study. Of 194 first graders and 218 second graders, 36 children were referred by the school-teachers in the first step.

The next step was the identification of a handwriting deficit by the administration of the Battery of Chinese Basic Literacy (BCBL; Hung, Chang, Chen, Chen, & Lee, 2003). This standardized test was used to confirm the handwriting deficit and to measure the improvement across the intervention program. A handwriting deficit was confirmed when the BCBL score was lower than the 20th percentile.

Twenty-eight children with dysgraphia were identified and then recruited into the study; 16 children (14 boys and 2 girls) were in Grade 1, and 12 children (10 boys and
The participants were then randomly allocated into the sensorimotor or control groups. Their ages ranged from 78 to 99 mo in the sensorimotor group and from 77 to 100 mo in the control group. The mean ages (and standard deviations) in the sensorimotor and control groups were 82.14 (6.62) and 82.36 (6.90) mo, respectively. In the sensorimotor group, 3 children were left-hand dominant, and in the control group, 2 children were left-hand dominant. All the participants came from public schools in the same district, where handwriting in the Chinese language is taught from Grade 1. No significant difference was present between the two groups in all the demographic data. The textbooks, curriculums, and total studying hours were identical in every class.

**Measurements**

The measurements in this study included tests for visual–perceptual skills and tactile performance as well as a Chinese handwriting test. The measurements were scheduled before and after the 6-wk intervention period. None of the participants underwent any of these tests or similar measurements before participating in this study. Each participant was instructed in the same fashion about what he or she would be required to do in the tests.

**Test of Visual Perceptual Skills—Third Edition.** The Test of Visual Perceptual Skills—Third Edition (TVPS–3; nonmotor) is used to evaluate visual perception across seven subtests: (1) Visual Discrimination, (2) Visual Memory, (3) Visual Spatial Relationships, (4) Form Constancy, (5) Visual Sequential Memory, (6) Figure-Ground, and (7) Visual Closure (Martin, 2006). Each subscale has a maximum score of 16, with higher scores indicating better visual perception. Raw scores are converted into scaled, standard, and centile scores for interpretation. The basic, sequential, and complex visual–perceptual index scores, as well as an overall score, are calculated. The TVPS–3 has high test–retest reliability \( (r = .97) \) and has shown correlations with the Developmental Test of Visual Perception, Second Edition \( (r = .62; \) Hammill, Pearson, & Voress, 1993).

**Tactual Performance Test.** The Tactual Performance Test (TPT; Reitan & Wolfson, 1985) is a form board test in which a person who is blindfolded adjusts the wooden blocks with his or her tactile perception. The TPT requires that examinees are presented with blocks of differing shapes and a matching form board with holes. They are instructed to insert the blocks into the board as quickly as possible, first with the dominant hand, then with the nondominant hand, and finally with both hands together. TPT performance is reported according to the time taken to complete the task for the dominant and nondominant hands, the time taken to complete the task for both hands together, and the total time for all three tactile trials. Shorter completion time indicates better tactile perception. The reliability coefficients ranged from .59 to .90 for internal consistency (Charter, 2000).

**Battery of Chinese Basic Literacy.** The BCBL is a standardized Chinese reading and writing test (Hung et al., 2003). It is composed of seven subtests and two complementary tests. A dictation test and three copy tests (near-point, far-point, and short-paragraph) were applied in the assessment of writing performance. These tests were used to confirm the handwriting deficit in the recruited participants. According to the test manual, the handwriting deficit could be confirmed when all scores were lower than the 20th percentile. This standardized test was also used to test the training effect across the intervention program. In addition to writing speed, the analysis included the number of incorrect characters and the ratio of this number to the total number of written characters. Incorrect characters included substitution of one character for another, substitution of one component for another, absence of a required stroke, an extra stroke, incorrect stroke placement, and substitution of one type of stroke for another. In every test, the number of incorrect characters was considered in measuring the handwriting quality.

**Test Procedure**

All the participants performed the experiment under similar environmental conditions in a quiet classroom in their school that was designed for children with special needs. Each participant was given instruction individually during the morning hours. Each test began after the participant confirmed that he or she fully understood the instructions. The participants were seated on standard school chairs with standard school desks appropriate to their age and height.

**Intervention**

The first author (Chang), an experienced pediatric occupational therapist, was the principal investigator (PI) and provided advice on appropriate therapeutic intervention strategies. The focus was on training visual–perceptual and haptic–perceptual activities, which focused mainly on visual perception, including visual discrimination, visual memory, visual closure, and visual searching (e.g., match the picture, object, direction, sequence with one of the choices; identify the figures partially hidden; draw the missing parts of the picture). Additional training activities required active touch without vision (e.g., match shapes, identify the common objects in a box). Over the course of
the training program, the difficulty of the activities was increased by adding to the number of choices, changing the complexity of shape pattern, and incorporating real-life applications (e.g., finding the prices of train tickets).

The training program was conducted in groups. Each session lasted 45 min and was conducted by six experienced trainers who were proficient in the sensorimotor programs and were trained by the PI to serve as interventionists. Before the start of the study, each of the interventionists participated in 6 hr of classroom training emphasizing the principles and techniques of intervention. The PI designed the sensorimotor intervention plans, which specified the objectives for each session. A training protocol was used to maintain the fidelity of the intervention program. After instruction provided in a step-by-step manual, the interventionists were trained to modify the plan according to the actual situation, and these modifications were recorded with the interventionists’ observations of the child’s occupational performance.

In the training program, approximately the first 5 min of each session were devoted to preparatory activities for the review of previous activities and warm-up activities such as “follow me singing/dancing.” Each preparatory activity was followed by the main training session for the major sensorimotor components. During 35 min of each session, activities were addressed in regard to sensorimotor components, including visual and haptic perceptions. The last 5 min in each session were for summarizing what children did and learned in the program.

The 14 participants in the intervention group were divided into two groups according to school (8 in Guan-In Elementary School and 6 in Ren-Wu Elementary School). The same sensorimotor training program and process were used in each group. Treating therapists were supplied with a toolbox of games, activity work sheets, equipment, and treatment ideas for each component.

Twelve sessions (two per week) of training were administered. In the group receiving the sensorimotor program, no additional handwriting practice was provided. For both the intervention and the control group, handwriting practice continued normally in the regular school with no intervention provided by teachers in their classes. Children in both groups continued to have their regular classes at school with typically developing children. The handwriting skills of all participants were evaluated pre- and postintervention.

**Statistical Analysis**

To test the improvement achieved through intervention and to compare the effect on the two groups, we used a 2 × 2 repeated-measures analysis of variance (ANOVA) to examine the differences in the measures of the TVPS–3, TPT, and BCBL. The factors were group (sensorimotor, control) and time (preintervention, postintervention). A significant interaction effect (Group × Time) indicated a difference in the time effect between the two groups, that is, evidence of an intervention effect.

**Results**

Table 1 shows the results of the TVPS–3 and TPT. The result of repeated-measures ANOVA showed significant group effects only in the sequencing index of the TVPS–3 (p = .023). When both pre- and posttest data were combined, the sensorimotor group showed a higher sequencing index score than that of the control group. The results also showed the time effect in the basic index, complex index, and overall scores of the TVPS–3 and TPT (all ps < .049). When the two groups were pooled, these measures showed significant improvement across the period of intervention. The interaction effect indicated that the changes in sequencing index, complex index, and overall scores of the TVPS–3 were significantly different between the two groups (all ps < .048).

After the intervention period, in addition to improvement in the basic index, participants in the sensorimotor group showed significant improvement in all the other scores of the TVPS–3. Children in the control group did not show significant improvement in any of these measures. TPT scores showed a significant time effect but not a group or interaction effect. After the intervention period, both groups showed improvement on the TPT score. However, the improvement was not significantly different between the two groups.

As shown in Table 2, on the handwriting performance test of the BCBL, the repeated-measures ANOVA did not show any significant time or group effect (all ps > .072). However, it did show significant interaction of group and time effects in the far-point copy test (p = .042). After the intervention period, the sensorimotor group showed significant improvement in the far-point copy test compared with the control group.

Table 3 shows the results of the ratio of incorrect characters to total written characters in the two groups before and after the intervention. The result of the repeated-measures ANOVA did not show any significant group effect (all ps > .208). However, the time and interaction effects in all tests were significant (all ps < .049): They showed a medium to large effect from the estimate of partial eta squared. After the intervention period, the sensorimotor group showed significant improvement in reducing the ratio of incorrect character number to the total written character number in dictation and copy tests.
### Table 1. TVPS–3 and TPT Results

<table>
<thead>
<tr>
<th>Group</th>
<th>TVPS–3</th>
<th></th>
<th>Complex</th>
<th>Overall</th>
<th>TPT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic</td>
<td>Sequencing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>F</td>
<td>dfs</td>
</tr>
<tr>
<td>Sensorimotor (before)</td>
<td>47.00</td>
<td>10.47</td>
<td>11.36</td>
<td>1.60</td>
<td>18.29</td>
</tr>
<tr>
<td>Sensorimotor (after)</td>
<td>49.86</td>
<td>9.83</td>
<td>12.85</td>
<td>2.54</td>
<td>20.50</td>
</tr>
<tr>
<td>Control (before)</td>
<td>46.86</td>
<td>10.81</td>
<td>10.43</td>
<td>3.32</td>
<td>17.57</td>
</tr>
<tr>
<td>Control (after)</td>
<td>47.14</td>
<td>10.35</td>
<td>10.29</td>
<td>3.27</td>
<td>17.64</td>
</tr>
<tr>
<td>Group effect</td>
<td></td>
<td>0.14</td>
<td>1.26</td>
<td>.714</td>
<td>.005</td>
</tr>
</tbody>
</table>

Note. dfs = degrees of freedom; M = mean; SD = standard deviation; TPT = Tactual Performance Test; TVPS–3 = Test of Visual Perceptual Skills—Third Edition. *p < .05. **p < .01.

### Table 2. Means and Standard Deviations of Correct Dictation and Writing Speed in Copy Tests of the BCBL

<table>
<thead>
<tr>
<th>Group</th>
<th>Dictation Test</th>
<th>Near-Point Copy Test</th>
<th>Far-Point Copy Test</th>
<th>Short-Paragraph Copy Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>F</td>
<td>dfs</td>
</tr>
<tr>
<td>Sensorimotor (before)</td>
<td>15.21</td>
<td>8.84</td>
<td>10.57</td>
<td>3.87</td>
</tr>
<tr>
<td>Sensorimotor (after)</td>
<td>16.00</td>
<td>8.64</td>
<td>10.71</td>
<td>4.30</td>
</tr>
<tr>
<td>Control (before)</td>
<td>14.43</td>
<td>6.52</td>
<td>8.21</td>
<td>4.48</td>
</tr>
<tr>
<td>Control (after)</td>
<td>14.79</td>
<td>4.12</td>
<td>9.36</td>
<td>4.75</td>
</tr>
<tr>
<td>Group effect</td>
<td>0.16</td>
<td>1.26</td>
<td>.696</td>
<td>.006</td>
</tr>
<tr>
<td>Time effect</td>
<td>0.28</td>
<td>1.26</td>
<td>.601</td>
<td>.011</td>
</tr>
<tr>
<td>Interaction effect</td>
<td>0.04</td>
<td>1.26</td>
<td>.844</td>
<td>.002</td>
</tr>
</tbody>
</table>

Note. BCBL = Battery of Chinese Basic Literacy; dfs = degrees of freedom; M = mean; SD = standard deviation. *p < .05.
Table 3. Means and Standard Deviations of the Ratio of Incorrect Character Number to Total Written Character Number on the BCBL

<table>
<thead>
<tr>
<th>Group</th>
<th>Dictation Test</th>
<th></th>
<th>Near-Point Copy Test</th>
<th></th>
<th>Far-Point Copy Test</th>
<th></th>
<th>Short-Paragraph Copy Test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>F</td>
<td>dfs</td>
<td>p</td>
<td>η²</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Sensorimotor (before)</td>
<td>0.46</td>
<td>0.23</td>
<td>0.20</td>
<td>0.10</td>
<td>0.32</td>
<td>0.11</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>Sensorimotor (after)</td>
<td>0.38</td>
<td>0.12</td>
<td>0.15</td>
<td>0.09</td>
<td>0.22</td>
<td>0.10</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Control (before)</td>
<td>0.42</td>
<td>0.18</td>
<td>0.22</td>
<td>0.09</td>
<td>0.31</td>
<td>0.12</td>
<td>0.09</td>
<td>0.04</td>
</tr>
<tr>
<td>Control (after)</td>
<td>0.42</td>
<td>0.20</td>
<td>0.20</td>
<td>0.10</td>
<td>0.31</td>
<td>0.14</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>Group effect</td>
<td>0.00</td>
<td></td>
<td>1.19</td>
<td>1.26</td>
<td>.968</td>
<td>.001</td>
<td>1.11</td>
<td>1.26</td>
</tr>
<tr>
<td>Time effect</td>
<td>4.51</td>
<td></td>
<td>81.86</td>
<td>1.26</td>
<td>.043*</td>
<td>.148</td>
<td>11.15</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Note. BCBL = Battery of Chinese Basic Literacy; dfs = degrees of freedom; M = mean; SD = standard deviation.

*p < .05. **p < .01. ***p < .001.
Figure 1 shows the ratio of incorrect characters to total written characters. The highest ratio can be found in the dictation test, whereas the lowest ratio was in the short-paragraph copy test. In all the postintervention sensorimotor program copy tests, the ratio was significantly reduced, especially in the far-point copy test. The short-paragraph copy test did not show as much reduction as the far-point copy test; it showed the lowest incorrect ratio before the intervention.

Discussion

In this study, we developed a sensorimotor program aimed to enhance visual–perceptual and tactile–perceptual skills and then to improve the handwriting performance in children with dysgraphia. After the intervention program, the sensorimotor group showed improvement in visual–perceptual skills but not in the tactile performance test. This result suggests that children at such an age could be trained to improve their visual–perceptual skills. Through systematic training, these children appeared to show improved handwriting speed in the far-point copy test and in the reduction of the ratio of incorrect characters in the posttest.

This study echoes the results of previous research (Case-Smith, 2002; Denton et al., 2006), indicating that the sensorimotor group showed improvement in visual–perceptual skills in comparison with the control group. However, Denton et al. (2006) found that there was no significant improvement in the handwriting performance in the sensorimotor group with improved visual–perceptual skill. The current study shows a different result, with a significant improvement in handwriting speed on the far-point copy test. Note that the program used in this study addressed both visual–perceptual and haptic–perceptual skills during a longer intervention period. The range of age in children of this study was 6–8 yr compared with 6–11 yr in Denton et al.’s study. In this study, the longer and specific program, as well as less diversity in the age of the children, may explain the inconsistencies. Poon et al.’s (2010) study also showed that visual–perceptual training improved the speed of Chinese handwriting. This finding, along with those of the current study, may indicate the different natures and relevance of sensorimotor components between the phonetic and logographic language systems. Both studies showed the effectiveness of perceptuomotor training on the improvement of handwriting speed.

When we analyzed the performance of children across the intervention, there was a decrease in the number of incorrect characters in the posttest, indicating that a program specifically designed to intervene in visual–perceptual skills provided a favorable situation that seemed to positively influence the quality of handwriting. As stated by both Kao (1999) and Lai and Leung (2012), Chinese handwriting requires a highly complex process for visual perception, making visual perception a key element in Chinese handwriting. In this context, the improvement in visual perception in the sensorimotor group, in the current study, may explain the improvement in handwriting accuracy. The results show that the sensorimotor program can help improve handwriting legibility and quality. They also have important implications for the teaching of handwriting and remedial therapy because they illustrate the positive connection between visual–perceptual improvements and actual handwriting accuracy.

The sensorimotor training in this study did not show evidence for the improvement of haptic perception of children.
with handwriting difficulty. No significant difference in the improvement of the TPT scores between the two groups makes it difficult to come to a conclusion regarding the effectiveness of sensorimotor training. Because the improvement was found in both groups, the change in the scores probably was due to a retest practice effect. However, we also lack the norm data of the TPT for identifying the level of tactile performance. Further studies are needed to ascertain the deficit of tactile function in children with handwriting difficulty.

In this study, the improvement in visual perception might lead to faster far-point copy and better handwriting quality. However, on the basis of the scores for dictation and the writing speed of the near-point and short-paragraph copy tests, the children did not seem to benefit from the sensorimotor training program. Many researchers have stated that handwriting involves the combination of many skills, including visual perception, orthographic coding, finger function, visual–motor integration, and eye–hand coordination (Klein et al., 2011; Poon et al., 2010; Tseng & Murray, 1994; Weil & Amundson, 1994). Training in visual–perceptual and haptic–perceptual skills might not be enough to cause improvement in all copy tasks in a relatively short period. Further investigation is required to determine the effect of a prolonged training program on the remediation of handwriting speed.

The acquisition of proficient handwriting skill has culture-related contexts. Chinese handwriting, a logographic-based writing system, is significantly different from a phonetic alphabet spelling system. With thousands of unique characters, this logographic writing system creates different challenges compared with a phonetic alphabet. This complex process needs the fundamental components, such as perceptual and motor skills, especially visual perception. This finding may explain why children with a handwriting deficit can benefit from sensorimotor training to improve Chinese handwriting significantly.

Weintraub et al.’s (2009) work revealed that children with handwriting difficulties could benefit from intervention programs that include instruction in higher level strategies to support and enhance handwriting performance. In the current study, we recruited participants in Grade 1 or 2 for whom handwriting is a regular practice in everyday school activities. However, most of the children were referred by teachers because of the children’s difficulty with handwriting despite the practice received in regular handwriting classes. Clinical evaluation and therapies are therefore needed for the remediation of impairment. Because of the cognitive complexity of Chinese handwriting, future studies may combine a sensorimotor program with higher level strategies for learning this skill.

Limitations and Future Studies

A possible limitation of this study is the similarity of tasks in the intervention program and outcome measures in the TVPS–3. The children in the sensorimotor group were practicing tasks similar to those used in the tests to measure improvement. In the retest, they may have been more familiar with the tests than those in the control group. Future studies could be suggested to add a follow-up of the TVPS–3 after a period from the end of intervention to exclude the possibility of practice effect.

No objective assessment of Chinese handwriting legibility exists for the comparison of pre- and post-intervention handwriting outputs. Therefore, in this study, we did not include the measurement of legibility evaluation. In the future, an objective legibility evaluation method should be developed to assess children’s legibility objectively.

To offset the difficulties encountered in the use of the BCBL because of lack of reliability and validity measures in handwriting legibility, we used the ratio of incorrect character numbers to total number of characters to measure Chinese handwriting accuracy. This test was used to assess the legibility of handwriting scripts from the different aspect of measuring the mistake frequency. A previous study revealed the enhancement of legibility by visual strategies, which were found useful for learning new words and correct character formation (Daly, Kelley, & Krauss, 2003). The handwriting accuracy measured in this study is one of the assessments in the analysis of correct character formation. However, before an objective assessment of handwriting legibility can be directly applied, the measurement could be suggested for assessing the handwriting accuracy. Further studies should include investigations to verify its reliability and validity.

Implications for Occupational Therapy Practice

The findings of this study have the following implications for occupational therapy practice:

- Our findings suggest that a sensorimotor training program focusing on visual–perceptual skills appeared to be effective in enhancing handwriting performance.
- Along with the improved visual–perceptual skills, the sensorimotor program showed a significant improvement in far-point copy speed and handwriting accuracy.
• Additional research is necessary to examine the most effective strategies and adaptations to assist children exhibiting dysgraphia with logographic handwriting.

Conclusion

In this study, the sensorimotor program resulted in significant improvement in visual–perceptual skills and handwriting accuracy in the dictation test and all copy tests. The sensorimotor intervention also resulted in improved handwriting speed in the far-point copy task. This study provides clinical evidence for the benefit of applying a sensorimotor program for children exhibiting dysgraphia with logographic handwriting, such as in Chinese handwriting. Unfortunately, this intervention cannot be generalized to all handwriting at this time. However, it is important to clinical practice because it can be used to evaluate the results of a treatment model providing a sensorimotor program for children exhibiting dysgraphia with logographic handwriting difficulties as identified by their teachers. It also provides clinicians and schoolteachers with a systematic intervention for the improvement of handwriting difficulties.

Acknowledgments

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