

The Effect of Sensory-Motor Training on Visual Perception Skills and Attention in 8- and 9-Year- Old Students with Slow and Normal Handwriting Speed in Hamedan

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Abstract

Introduction: The aim of this study was to evaluate the effect of sensory-motor training on visual perception skills and attention of 8- and 9-year-old students with slow and normal handwriting speed in the city of Hamedan. **Materials and Methods:** This study was a quasi-experimental study with a pre- and post-test design. Fourteen slow hand writers (I) and 30 normal hand writers were selected using a purposeful sampling method. Normal hand writers were randomly divided into experimental (II) and control (III) groups. The two experimental groups (I, II) participated in sensory-motor training with emphasized visual perception (16 sessions of 45 minutes) and the control group performed the normal school activities. All participants underwent the Stroop color test and Frostig Visual-Perceptual before and after the training. **Results:** Frostig and Stroop scores increased significantly in both training groups I and II ($P < 0.05$). Writing speed increased in both experimental groups, but only in third grade students of group II was there a significant increase ($P < 0.05$). **Conclusion:** Sensory-motor training increased visual perception and attention abilities in second- and third-grade elementary school students. Therefore, it can be concluded that increasing the ability to perceive vision and attention can affect the performance of fine skills such as writing.

Keywords: Attention; Learning Disability; Slow Handwrite; Visual Perception; Writing Speed

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Introduction

Writing is a complex perceptual-motor skill (1, 2) that involves the interaction of cognitive and motor processes and requires delicate manipulation of the pencil to produce different forms of letters in a fluent manner. This skill includes a combination of visual-motor coordination, movement planning, cognitive and perceptual skills, and touch and movement sensitivities (3, 4). Two important elements in writing performance are readability and speed. Difficulty in shaping the letters, distance, size, slope, or order of the letters may affect the legibility of handwriting (5). Writing speed is also an important aspect of writing ability, which helps the child cope with homework demands. The writing speed depends on the text, the instructions given, and whether the child copies the text or writes freely (5).

One of the types of learning disorders that are mostly diagnosed in primary school age is writing disorder or dyslexia (6). Between 30% and 60% of children's time in school is spent on writing and other fine motor tasks (7), which must be completed quickly (8). According to studies, 27% of children experience writing problems (9, 10), which may hinder their academic progress, lower self-esteem, and behavioral problems (11, 12). These children are often given wrong labels such as lazy or unmotivated, which causes more disappointment and despair in them (11). Fluent writing is produced by coordinated movements under the supervision of the visual system and sensory-motor feedback (13). In addition, visual-motor integration is the best predictor of handwriting reading at school age (14, 15). Motor and perceptual components related to writing may include fine motor control (hand manipulation, bilateral integration and motor planning, proper timing, force control in coordinated arm, hand and finger movements (16)), visual motor interaction, visual

perception skills (acuity, awareness of the body and awareness of space, orientation, quality of receiving sensory information), and attention maintenance (12).

James's study showed that in learning letters, writing is more effective than other forms of practice such as sight, hearing, and even typing (17). This issue was demonstrated by fMRI studies that perception and motor systems interact when learning is created in people through self-productive actions. Learning letters through writing increases many abilities such as eye-hand coordination (18), depth perception (19), sound recognition (20), space perception (21), and even verbal development (22). Writing with numbers requires sensory systems (such as vision and hearing) and the motor cortex of the brain to produce letters by hand movements.

Identifying the components required for writing is very important in designing effective intervention strategies; however, to date, most studies have investigated the relationship between illegibility and different visual perception skills, fine motor skills, and visual-motor interaction (16, 23-26). The relationship between illegible handwriting and other functional defects was also investigated. For example, Levine et al. (1981) showed that 72% of 26 children with "developmental defects" have difficulty performing fine motor tasks, are uncoordinated in their finger movements, have less pencil control, and need to write. With more effort, they become delayed, slow, and unreadable (24).

Although slow handwriting (SHW) in time-limited assignments affects the performance of the individual, few studies have focused on this form of writing weakness. In Berninger and Rutberg study, finger function was considered the best predictor of writing disorders. For example, fine motor skills accounted for 52.5% of the variance in writing speed (27). In addition, Sovik *et al.* found that weakness in coordination of hand movements has a direct relationship with writing speed (13). While others did not find any relationship between SHW writing and other writing disorders, the findings show that children with dyslexia write at a slower than children without reading disorders. These results show that in addition to visual perception, cognitive skills may also affect writing speed. In addition, the study of Tseng and Chow showed that coordination of the upper limbs, visual memory, and attention play an important role in writing speed (12).

In addition, the results of the pilot study conducted by the authors of this article, with the aim of investigating the relationship between SHW and visual perception in 7-12-year-old children, showed that only 8- and 9-year-old children with SHW in the variables of eye-hand coordination, perception of the situation in space, and perception of spatial relationships had a significant difference from the control group. Therefore, to

investigate the effect of training on visual perception, 8- and 9-year-old children were used in this study. On the other hand, attention ability was also evaluated in this study to identify other factors influencing SHW. Therefore, the question of this research was whether sensory-motor interventions offered to children based on games can improve the capacity of visual perception and attention in children. Is it possible to improve writing speed in children by increasing their perceptual capacity and attention?

Materials and Methods

The type of study

This research was a quasi-experimental with a pretest-posttest design and two experimental groups and one control group.

Participants

The statistical population of this study included all female students in the second and third grades of elementary school in Hamadan city. Using cluster random sampling, a girls' school was selected. In the first, all the second and third grade students of this school were given a writing test, and the students were purposefully divided into two groups: slow handwriters and normal. The criteria for entering this study included the age and educational level of the students, absence of hearing and vision problems (correction with glasses), and natural intelligence according to the school report. The exclusion criteria included not regularly participating in training sessions, taking psychiatric drugs, history of mental illness, obvious physical illness, having other mental and learning disorders, hyperactivity, and attention deficit in children.

Writing speed test

The CHAST (12) method was used to determine the students' writing speed. In this test, the participants were asked to rewrite the text that was prepared in consultation with their teacher with a pencil within 5 min (parallel form text was prepared, and was presented to the participants in the pre- and post-test stages). Then, the number of letters was counted among the words that were written correctly, and the writing speed in 1 min was calculated. After estimating the mean and standard deviation in each age group, a standard deviation below one was used as a cut-off point to determine slow handwriters (SHW) (12). The internal correlation coefficient (ICC) for the reliability of this test was calculated using a one-week interval of approximately 0.98.

Initially, 70 second and third-grade students from the school were selected for a writing speed test. Individuals with a standard deviation lower than the mean of their age group were

selected as SHW (experimental group I, $n=14$). Then, using the G*Power software with $\alpha=0.05$ and 80% statistical power ($n=28$), it was determined that a minimum of 12 participants in each group was necessary for this study.

As a result, of the 56 students with normal writing speed, 30 were randomly assigned to experimental group II (performing training similar to group I) and the control group (regular school activity). Experimental groups I and II consisted of 7 second-grade students and 8 third-grade students each, whereas the control group included 6 second-grade students and 8 third-grade students.

The pre-test and post-tests included the Stroop visual test and the Frostig visual perception test. Before the training, the visual perception ability of students in all three groups was assessed using the Frostig visual perception test, and the attention capacity of participants was determined using the Stroop color test. Then, both experimental groups I and II participated in games aimed at enhancing sensory-motor skills for 16 sessions, 3 sessions per week, each lasting 45 min. The process of this research is shown in Figure 1.

After the training sessions, the post-test included a rewriting test from a text to assess writing speed along with the Frostig and Stroop tests. The ethical code for this study was obtained with the number IR.IAU.H.REC.1400.002 from the Islamic Azad University, Hamedan Branch, and a consent form for participation in this study was signed by the parents of the participants.

Research tool

Stroop test

The Stroop test is used to measure selective attention, flexibility, and cognitive inhibition through visual processing. The software for this test was developed by the Ravantajhiz Sina Company. In the Stroop test, 96 consonant and inconsistent stimuli are displayed randomly and sequentially. The subject's task is to identify only the color of the words presented, regardless of the actual meaning of the words. Each stimulus is displayed on the screen for 2 s, with an interval of 800 ms between the presentations of two stimuli. The software records the number of correct and incorrect responses, the number of ignored stimuli, and the response time for each stimulus for every individual (28) (Figure 2).

Frostig test

This test is used as a tool to identify visual perception and has five subscales: (1) hand and eye-motor coordination, 2. figure ground, 3. form constancy, 4. position in space, 5. spatial relations. The reliability coefficients reported for the Frostig test using the retest method for the total score are between 0.69 and 0.98 (29).

Method for performing training

After conducting the pre-test, perceptual-motor training were designed and performed for groups I and II under the supervision of the school sports coach and the researcher. These training were divided into three categories, which include the practice of manual fine motor skills with the aim of movement and coordination in the small muscles of the hand and fingers, the second category of perceptual and coordination skills training on a table, and the third category of pencil paper training with the aim of improving visual perception (30).

After a brief period of preparation and warm-up, the participants in each session engaged in ball and balance skill activities for 10–15 min. These activities included tasks such as receiving and throwing the ball, rolling the ball on the ground and through obstacles, hitting the ball with hands and feet toward fixed or random targets, hitting a balloon, throwing the ball toward letters, numbers, or shapes based on the coach's instructions, throwing the ball into a basket, playing bowling, and darting. Balance training were combined with object manipulation training. The difficulty of the training increased progressively by adjusting the distance from the target, altering the size of the ball, or adding more obstacles to the path. Training lasting approximately 10–15 min involved activities such as bead threading, various words puzzles to enhance understanding of different word forms, and modeling with clay. Pencil and paper training were also conducted for approximately 10–15 min. These training included activities such as connecting dots according to instructions, tracking targets, finding hidden objects in images, and matching objects with shadows. These activities were conducted during a period when the COVID-19 situation was classified as "yellow," with all necessary health protocols being followed under the supervision of school authorities.

Statistical analysis

According to the normal distribution of the data, parametric tests were used to assess intra-group and inter-group differences. The dependent t-test was used to examine intragroup differences, and one-way analysis of variance was used to examine intergroup differences. All statistical processes were performed using SPSS software with a significance level of $P<0.05$.

Findings

Table 1 shows demographic information including age, height, and weight of the participants along with writing speed (number of letters per minute) in the SHW and normal groups.

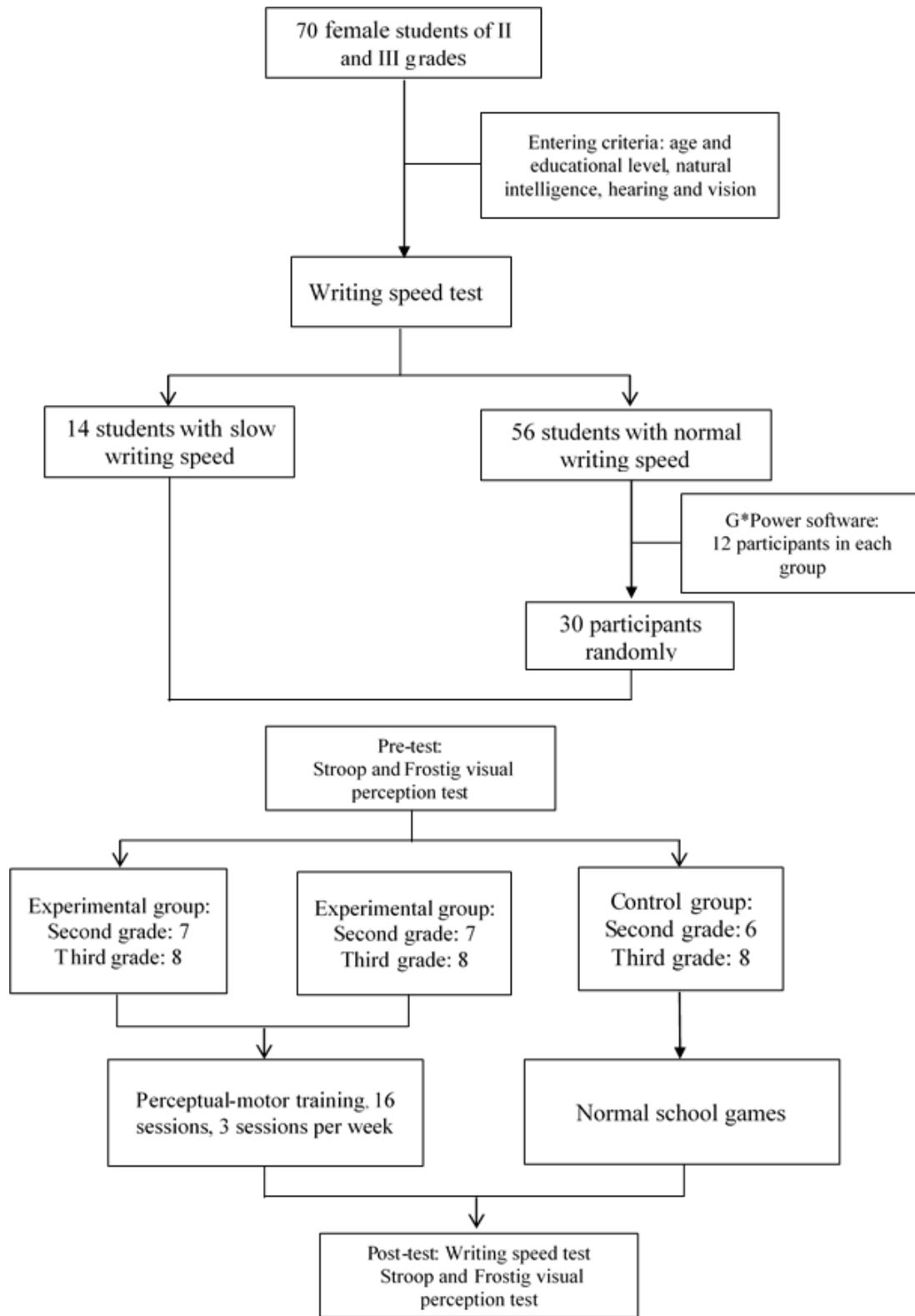


Figure 1. The process of this research



Figure 2. Stroop test (right) and Frostig test (left)

Stroop test

The pre/posttest difference in the first group and in the second grade showed that the number of incorrect answers in this group decreased significantly ($t=2.70$, $P=0.04$) and the number of correct answers increased significantly ($t=3.70$, $P=0.02$). The pre/posttest difference in group I and third grade showed a significant increase in the variables: the number of correct answers in consonant stimuli ($t=2.65$, $P=0.049$), and response time, significant decrease in consonant and inconsistent stimuli ($t=3.88$, $P=0.018$, and $t=5.05$, $P=0.007$, respectively). This means that exercise had a positive and significant effect on these variables (Table 2).

The pre/post-test difference in group II and second grade was significant in response time to consonant and inconsistent stimuli ($t=4.75$, $P=0.001$ and $t=4.73$, $P=0.001$, respectively). In the third grade, the variable of the number of incorrect answers in consonant stimuli decreased significantly ($t=2.47$, $P=0.03$), the number of correct answers increased significantly ($t=2/2$, $P=0.02$) and the response time to consonant and inconsistent stimuli was significantly lower than the pre-test (respectively, $t=6.12$, $P=0.0001$ and $t=7.14$, $P=0.0001$). However, in group III, the pre/post-test difference was not significant in any grades (Table 2).

The results regarding the between group difference in the pre-test stage in the second grade students showed that the number of correct responses to the consonant stimulus was significantly lower in group I than in groups II and III, (respectively, $F=5.58$, $P=0.016$, and $F=5.47$, $P=0.019$). In inconsistent stimuli, the difference in the number of incorrect answers in group I with groups II and III ($F=17.91$, $P=0.001$, and $F=15.60$, $P=0.008$, respectively) and the number of correct answers ($F=18.81$, $P=0.001$ and $F=8.92$, $P=0.01$, respectively)

were reported to be significant. In addition, in the pre-test, the number of ignored stimuli in group I was significantly higher than in group II ($F=4.62$, $P=0.049$). In the post-test, there was a significant difference between group I and group II in interference score ($F=5.57$, $P=0.03$), response time to consonant stimuli ($F=7.49$, $P=0.016$) and the number of correct responses to the inconsistent stimulus ($F=5.12$, $P=0.04$). The difference in the post-test scores of groups I and III was not significant.

The results of the difference between groups in the pre-test and in the third grade students showed that the difference between I and II groups during the interference time ($F=8.82$, $P=0.01$) the number of incorrect answers to the consonant and Inconsistent stimuli ($F=4.84$, $P=0.045$, and $F=4.49$, $P=0.05$, respectively), the number of ignored stimuli to consonant and Inconsistent stimuli (respectively, $F=24.19$, $P=0.0001$, and $F=6.19$, $P=0.026$) and the number of correct responses to consonant and Inconsistent stimuli (respectively, $F=27.97$, $P=0.0001$, and $F=13.64$, $P=0.002$) are significant. The difference between groups I and III in the pre-test was not significant.

In the post-test phase, a significant difference between the groups was observed only in the response time to the inconsistent stimulus; in other words, after training the response time to the stimulus in both the second and third grades in group II compared to group III, the significance decreased (Table 2).

Frostig test

The results of inter-group comparison showed that the average scores of this test improved in both training groups. As can be seen in the Table 3, the increase in scores in group I compared to the pre-test in the form constancy ($t=2.89$, $P=0.04$ in the second grade and $t=2.68$, $P=0.04$ $P=0$ in the third grade), spatial relationships ($t=3.16$, $P=0.03$ in the second grade) and total score ($t=7.27$, $P=0.002$ in the second grade and $t=6.39$, $P=0.003$ in the

Table 1. Mean (SD) of demographic information of research groups

Group	N	Age	Weight	Height	Writing Speed
Slow Handwriting					
Grade 2	6	8.45 (2.5)	24.79 (4/81)	1.27 (0.05)	13.0 (2.72)
Grade 3	8	9.08 (4.2)	30.39 (6/84)	1.29 (0.04)	16.89 (4.18)
Normal Speed Handwriting					
Grade 2	14	8.35 (3.2)	25.64 (4/44)	1.33 (0.06)	35.27 (15.68)
Grade 3	16	9.32 (3.2)	29.45 (6/10)	1.35 (0.07)	80.30 (23.35)

Table 2. Mean (SD) of stroop test scores in research groups

		Group I		Group II		Group III	
		Grade 2	Grade 3	Grade 2	Grade 3	Grade 2	Grade 3
Interference							
Score	Pre	11.0 (9.7)	6.4 (4.5) ^{bc}	3.4 (2.7)	2.6 (1.6)	3.2 (2.3)	2.4 (2.6)
	Post	5.6 (1.9) ^b	4.4 (1.3)	2.8 (2.2)	2.9 (1.2)	3.8 (1.2)	2.2 (0.9)
Time	Pre	44.6 (39.6)	76.6 (43.7) ^{bc}	52.6 (38.4)	32.8 (6.7)	54.3 (7.1)	33.5 (8.7)
	Post	34.8 (26.3)	46.4 (21.5)	31.2 (21.4)	34.9 (7.3)	51.5 (8.7)	32.1 (5.8)
Consonant stimulus							
Error	Pre	5.4 (2.3) ^a	4.6 (3.1) ^{bc}	0.9 (0.9)	0.09 (0.03) ^a	1.8 (1.2)	1.1 (0.5)
	Post	0.6 (0.5)	1.2 (0.8)	2.1 (2.0)	1.0 (0.2)	1.3 (1.0)	1.4 (0.3)
Ignored	Pre	8.4 (5.2)	7.0 (4.2) ^{bc}	3.4 (2.1)	0.6 (0.1)	4.1 (1.2)	0.6 (0.1)
	Post	6.0 (5.1)	1.4 (1.05)	2.1 (1.9)	0.7 (0.4)	3.5 (2.4)	0.7 (0.4)
True	Pre	34.2 (9.3) ^{bc}	36.4 (7.0) ^{abc}	43.6 (4.9)	47.3 (0.9) ^a	42.1 (5.1)	47.3 (0.9)
	Post	41.4 (5.5)	45.4 (1.95)	43.8 (3.7)	46.2 (1.2)	43.2 (4.3)	46.2 (1.2)
Time test	Pre	1185.4(217.6)	1282.8(289.5) ^a	1249.1(179.9) ^a	1173.9(151.0) ^a	1232.4(152.1)	1193.5(143.9)
	post	1108.6 (152) ^b	870.0 (128.1)	946.3 (87.5)	867.1 (76.1)	1201.1(116.5)	1189.8(176.1)
Inconsistent stimulus							
Error	Pre	14.4 (9.7) ^{bc}	7.0 (9.5) ^{bc}	2.0 (1.9)	1.1 (0.8)	2.4 (1.1)	2.1 (1.0)
	Post	4.6 (3.2)	4.0 (2.6)	2.7 (1.8)	2.6 (1.8)	2.3 (0.7)	1.8 (0.7)
Ignored	Pre	11.2 (2.5) ^b	9.0 (8.0) ^{bc}	5.3 (2.8)	2.1 (1.2)	5.5 (1.9)	2.7 (0.8)
	Post	6.4 (3.8) ^b	3.0 (2.6)	2.8 (1.4)	1.3 (0.6)	4.9 (3.1)	2.9 (1.4)
True	Pre	22.4 (8.9) ^{abc}	32.0 (11.3) ^{bc}	40.7 (7.4)	44.8 (2.6)	40.1 (8.7)	43.2 (5.3)
	Post	37.0 (4.7) ^b	41.0 (3.1)	42.5 (4.3)	44.2 (4.4)	40.8 (5.1)	42.1 (6.8)
Time test	Pre	1222.0(166.1)	1329.2(232.9) ^a	1271.0(171.0) ^a	1217.4(146.1) ^a	1312.2(143.2)	1267.4(127.9)
	Post	1073.8(133.0)	894.8 (90.1) ^d	967.9 (94.7) ^d	888.0 (64.5) ^d	1298.9(194.7)	1276.0(167.6)

^a. denote statistical differences between pre-post training. ^b. denotes statistical differences between training groups (group I with group II). ^cdenotes statistical differences between group I with group III. ^ddenotes statistical differences between groups II with group III.

Table 3. Mean (SD) of comparison of Frostig visual perception test subscales in research groups

		Group I		Group I		Group III	
		Grade 2	Grade 3	Grade 2	Grade 3	Grade 2	Grade 3
Eye-motor coordination	Pre	19.6 (5.4)	22.4 (3.1)	22.6 (3.7) ^a	24.6 (3.3) ^a	22.1 (2.9)	24.3 (2.9)
	Post	25.2 (3.1)	25.2 (3.8)	27.7 (1.8)	28.0 (2.1)	22.8 (2.6)	24.6 (4.5)
Figure ground	Pre	11.8 (4.4)	11.0 (5.4) ^{bc}	14.8 (3.9) ^a	16.5 (2.6) ^a	14.4 (1.7)	16.9 (2.6)
	Post	17.2 (4.1)	17.4 (2.5)	18.2 (1.5)	17.9 (1.7)	14.8 (3.5)	17.2 (1.7)
Form constancy	Pre	6.8 (2.8) ^{abc}	6.2 (3.8) ^a	10.0 (1.9) ^a	9.4 (2.8) ^a	9.9 (2.5)	10.2 (3.7)
	Post	11.8 (2.8)	12.0 (2.3)	13.7 (1.6)	12.6 (3.1)	10.1 (1.4)	10.7 (2.6)
Position in space	Pre	7.0 (1.4)	5.8 (1.3)	6.4 (0.8) ^a	6.7 (0.9)	6.5 (1.2)	6.7 (1.5)
	Post	6.8 (1.1)	6.8 (0.8)	7.3 (0.6)	7.4 (1.0)	6.7 (0.8)	7.0 (1.4)
Spatial relations	Pre	6.4 (0.9) ^a	5.6 (1.1)	6.3 (1.0) ^a	6.7 (1.6)	6.6 (0.6)	6.5 (0.9)
	Post	7.4 (0.6)	6.8 (1.6)	7.5 (0.7)	7.1 (1.8)	6.8 (1.2)	6.8 (1.2)
Total	Pre	51.6 (10.5) ^a	51.0 (6.9) ^{abc}	59.8 (8.2) ^a	63.8 (6.6) ^a	59.5 (6.0)	64.5 (8.5)
	Post	69.2 (10.1)	68.2 (4.3) ^b	74.6 (2.9)	73.3 (4.6)	61.2 (6.4)	66.2 (6.8)

^a denote statistical differences between pre-post training. ^b denotes statistical differences between training groups (group I with group II). ^c denotes statistical differences between group I with group III

third grade) have shown a significant increase. In group II, all subscales have improved significantly compared to the pre-test (eye-motor coordination: $t=4.53$, $P=0.001$, figure ground: $t=2.63$, $P=0.025$, form constancy: $t=4.96$, $P=0.001$, position in space: $t=2.65$, $P=0.02$, spatial relations $t=3.32$, $P=0.008$, overall score $t=6.39$, $P=0.001$). Comparison of pre-test and post-test scores in group III showed no significant difference ($P<0.05$).

In the Frostig test, the results of the comparison between groups of the second grade showed that group I has a significant difference with two groups II and III in the variable of form constancy in the post-test ($F=7.16$, $P=0.018$ and 54.54 respectively). $F=6$, $P=0.002$) and no significant difference was observed in the post-test. In the third grade, in the pre-test, the score obtained in the figure ground in group I was significantly lower than the other two groups ($F=7.75$, $P=0.015$ and 15 $F=8.8$, $P=0.012$) and there was also a significant difference in the overall score of this test between group I and two groups II and III ($F=12.68$, $P=0.003$ and 63 , respectively) $F=13$, $P=0.002$). In other cases, no significant difference was observed between the groups.

Slow writing test

The comparison between groups in the speed writing test scores before and after the intervention showed a significant difference in writing speed (number of letters per minute) between the scribbler and normal students ($t=9.74$, $P=0.001$), but after the sensory-motor intervention, the average writing speed in the third grade of group II increased significantly compared to the pre-test ($t=4.81$, $P=0.001$). In other groups, the difference between the pre- and post-tests was not significant.

Discussion

The purpose of this study was to investigate the effect of sensory-motor training on writing speed, attention, and visual perception of SHW and regular students. Based on many studies, perceptual-motor skills are essential in improving three educational and training areas (cognitive, emotional, and psycho-motor) and in the development of motor skills (31). Comparing the results of the Stroop test in the pre-test shows attention problems in SHW children compared with normal children. However, after the implementation of sensory-motor training, although the level of scores in the SHW group was still not the same as that of groups II and III, the difference between the groups had decreased significantly. The comparison of the pre-test and post-test also showed that in both training groups, the number of correct responses to consonant and inconsistent stimuli had increased, as well as the number of incorrect responses to both types of stimuli. The stimuli showed a

decrease, whereas the response time to the stimuli was significantly decreased only in the third-grade SHW students. According to others, the students in both experimental groups could provide more correct answers to the stimuli after the training in a shorter time.

Sandler *et al.* showed that math ability, verbal IQ, and attention performance are lower in children with writing disorders than in normal children (11). The results of some studies have also shown that until writing becomes automatic and fluent in a person, a person needs attention resources to write (32, 33). When rewriting the text, attention resources are used to create subtle movements in the production of letters, whereas beginners usually do not pay attention to the meanings of words, and all attention resources are spent on the production of letters (34). According to these results, the lack of attention resources in SHW children may be a cause of their writing speed reduction. Research has shown that perceptual-motor training cause mental and cognitive development in children (35), which may be due to the interaction between perceptual and motor actions (36). Movement also requires the transfer of information between the two hemispheres of the brain; the more children move, the more information they obtain from the environment and the more they learn. Every time a movement occurs, it helps children interact and understand their environment. This issue has been confirmed by perception action theory (37, 38).

The results of Frostig visual perception scores in the pilot study showed that the scores of second- and third-grade SHW students are significantly lower than those of normal people in several subscales. In addition, the results of that study clarified that there is a high correlation between writing speed and the overall score of visual perception, and this relationship was higher in second- and third-grade students. In the pre-test conducted in this study, it was also shown that the overall score of this test and its three subscales (figure ground, form constancy and spatial relations) in the SHW group compared with groups II and III significantly. It is less, which indicates weakness in the visual perception of SHW children. However, after the intervention, the scores of this test improved significantly in both practice groups, especially in the second grade of group II. Previous studies have shown that writing speed has a significant relationship with visual perception, visual-motor coordination, and manipulation skills (39-41). Therefore, in line with the results of this study, students who have writing disorders also have weak visual perception (30). In addition, the results of several studies have shown that performing training that emphasize visual perception skills has increased these skills in students with writing disorders (30, 42, 43). In this regard, the results of the present study also showed that after performing

sensory-motor training, the total score of visual perception in both training groups improved significantly compared with the pre-test. Sensory-motor training combine body recognition training, differentiation and integration, cognitive flexibility, perceptual-motor adaptation, and vision control (44).

The findings of the current research on the effect of sensory-motor intervention on writing speed showed that in both practice groups, the writing speed increased after the intervention, and this increase was significant in the third grade students from group II. The implementation of sensory-motor intervention improved attention capacity and visual perception ability and as a result increased writing speed in normal people. The writing speed before and after the intervention in the SHW group was significantly lower than that in the normal group, but after intervention the writing speed in the SHW group increased and caused the difference between the groups to decrease, although even after the training, the difference between the SHW group and the normal group was still significant. The results of many studies have also shown that this type of training, in addition to improving gross (45) and fine motor skills (44), improves cognitive skills (attention, executive functions) (46) and improves reading and recognizing letters (37).

The results of interventions involving written training programs have shown that such training lead to increased fluent writing (30, 32), writing speed from a text (47), and improved spelling of words (47, 48) in students. These studies emphasize the importance of enhancing this skill during the early years of learning. According to the speed accuracy trade-off principle, readability is considered more important than speed in writing. Improving automaticity in forming letters during the initial stages of learning to write is crucial because a child's inability to achieve this automaticity will negatively impact their writing speed. Therefore, most studies have focused on this area.

Another type of intervention involving cognitive, sensory, and motor training has also been shown to result in improved handwriting (49) and spelling of words (50) in children. However, some studies, such as the study by Sudsawad *et al.* indicated that cognitive-motor training had no effect on the handwriting legibility of first-grade children (51). Overall, the results generally indicate a positive impact of sensory-motor interventions on handwriting. Thus, interventions aimed at improving writing performance have been effective in enhancing the handwriting legibility of children (43, 52).

Examining the results of studies evaluating writing speed revealed that some studies did not show significant changes in writing speed (30, 32, 53). However, in a study by Chang and Yu, it was found that writing speed significantly improved with cognitive-motor interventions (42).

Another type of intervention involving perceptual, sensory, and motor training has demonstrated improvements in handwriting (49) and spelling skills (50) in children. Nevertheless, certain studies, such as the research by Sudsawad *et al.* indicated that perceptual-motor training had no effect on the handwriting of first-grade children (51). Overall, the effect size observed in these studies generally indicated a positive impact of sensory-motor interventions on handwriting. Hence, interventions aimed at enhancing children's writing performance have proven to be effective (43, 52). In the analysis of studies assessing writing speed, it was noted that while some studies did not show a significant change in writing speed (30, 32, 53), the study by Chang and Yu revealed a significant improvement in writing speed through perceptual-motor interventions (42). Past studies have highlighted the correlation between gross motor skills (54), strength, balance (55), academic performance, and the development of fine motor skills. The coordination of the upper limbs necessitates the integration of visual information and subsequent control and guidance of the hands to execute tasks. On the basis of these findings, sensory-motor training focusing on enhancing balance and coordination skills may positively impact the refinement of fine motor skills.

Conclusion

According to the results of this study, training that increase coordination between sensory-motor processes can significantly affect children's ability to write and recognize letters. The results obtained from this study indicate the need to target physical education programs in primary school children. Therefore, it is suggested to use long-term training programs in future studies as well as the combination of sensory-motor interventions with writing skill training. In addition, in future studies, other factors affecting motor development, such as body mass and perceptual-motor skills, should be evaluated in SHW children.

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Ethical considerations

In the implementation of the research, ethical considerations were considered in accordance with the instructions of the ethics committee of the Islamic Azad University of Hamedan branch, and the code of ethics has been received under the number IR.IAU.H.REC.1400.002.

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Conflict of interest

None.

Authors' contributions

All authors contributed equally to the preparation of this manuscript.

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