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The Effects of Central and Peripheral Vision Resulted from Handwriting on Motor Control of Fine Near- and Far-point Copying Skills among Children

Mehdi Rahimzadeh[1], Peyman Honarmand[2*], Soleyman Abdollahzadeh[2]

[1] Young Researchers and Elite Club, Urmia Branch, Islamic Azad University, Urmia, Iran.
[2] M.Sc. in Sports Psychology, Tehran University, Iran.

Corresponding author: peymanhonarmand@ut.ac.ir

Keywords

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Abstract

The present study was aimed at examining the effect of central and peripheral vision resulted from handwriting components including hand, stationery, writing field, and handwriting on motor control of fine near- and far-point copying skills among elementary children. In near-point copying, the individual copies from a pattern that is near him, and in far-point copying, from a pattern that is far. Twelve elementary students in Tehran with an age range of 11±0.9 years were randomly selected as the study sample. Their fine near- and far-point copying skills were examined in 5 stages. During each stage, one of the states of removing the feedback of central and peripheral vision resulted from handwriting components were taken into account. Two criteria were considered in examining the individuals. First, the individuals' handwriting speed in terms of the number of correct words written per minute, and second the quality of their handwriting which was evaluated using Minnesota Handwriting Assessment. By setting statistical significant at 0.05, the results obtained from ANOVA with repeated measures showed that central and peripheral visions resulted from handwriting components had a significant effect on far- and near-point copying speed control and the quality of far- and near-point copying among the elementary students. The results indicated that during copying, individuals did not equally profit from the information obtained from different handwriting components, the information obtained from some components was necessary for handwriting, and visual feedback of some components was less needed.

1. Introduction

Motor skill refers to a task that has a purpose and is carried out intentionally, and moving the body or an organ is needed to reach the purpose of the task. Also, learning is required in order to successfully achieve the purpose. Motor skills are categorized using one-dimensional and 2-dimensional methods. One of the classification criteria in one-dimensional method is based on the muscles used in performing the skill. In this regard, motor skills include gross and fine motor skills. Fine and gross motor skills involve skills in which small and big muscles of the body are used, respectively. Examples of fine motor skills are handwriting, typing, and handling small objects, and weight lifting, swimming, and playing soccer are examples of gross motor skills (1).

As one of the fine motor skills, handwriting is an important communication skill to transfer concepts and knowledge to others. Handwriting is a complex perceptual-motor skill which depends on maturity and integration of perceptual-motor skills (2, 3). On the other hand, it is stated that handwriting is linked with many specific skills including the ability to keep the issue in the mind, arranging the issue in words, depicting the graphical shape of each letter and word, using handwriting tools correctly, and visual and motor memory (4). Written expressions require skills in 3 major domains: handwriting, spelling, and composition (5). Although expression thoughts and feelings may be more important than the mechanical aspects of handwriting, it seems that problems such as illegible handwriting, missing letters, structural disabilities, and poor organization can cause the reader to have difficulty in understanding the meaning of a text. Efficient writers have enough ability in these three domains of writing and can communicate with minimum mistakes. Students with dysgraphia may have some or all of the following characteristics: forming letters poorly, writing letters in very big or very small shape or inconsistencies in their sizes, misusing big and small letters in writing words, writing letters in a messy way, inconsistency in space between letters, writing uneven letters, writing incorrect, crooked, and inconsistent letters together and in a broken way, poor handwriting, and slow handwriting even when they are asked to write as fast as possible (6). For young students with reading and handwriting problems, effective teaching of handwriting includes: a) teacher modeling, b) teaching the name of the letters at the same time the students are writing and copying them, c) providing separate practice for each individual student and writing letters with numbered arrows and then without them, d) writing words, and e) copying sentences quickly to improve fluency in writing (6).

Motor control is another important issue in the field of motor skills. In fact, motor control is a part of kinesiology in which scientists attempt to understand the functions of the central nervous system during performing a movement and its effect on creating the move (7). Vision is an important source of control in handwriting skill. With regard to the role of vision in controlling and learning the movements, direct visual perception view states that the visual system is able to process visual data spontaneously such that it makes the motor system act based on what the visual system has discovered. The visual system perceives the data protruding from the model and makes the body behave in a special way. Therefore, there is no need to convert these data into cognitive codes and preserving them in memory. The visual system can directly provide the basis for coordination and control of different parts of the body (8). Vision flow provides data such as data on balance, movement speed and direction relative to objects and the objects' movement relative to the agent (1). Vision field refers to the individual's vision area without moving his head, with a horizontal extension of 200 degrees and a vertical extension of 160 degrees (8). Scientists recognized that 2 separate visual systems form human's motor behavior substructure. Visual data are sent through two separate paths from retina to two places in the brain. Evidence indicates that these two paths are differently used in controlling behavior. The two visual systems are central vision and peripheral vision. Central visual system is specifically used for recognizing and identifying objects, and peripheral visual system for motor control (9).

Central vision is limited to center and consciously recognizing objects that are mainly placed in the center of the vision field. In fact, this system is used to recognize images like words on a page. In addition, central vision processes the data related to a small area about 2-5 degrees of the visual field. This system helps conscious perception of objects, extremely weakens in the dark, as a result, one cannot read a book in the dark. Peripheral vision is the second visual system. It includes both central and peripheral parts of visual field. Moreover, this system is not seriously damaged in the dark. Peripheral vision makes it possible to walk on an uneven ground even in a very dark place, and there is fear to walk without slipping. Scientists believe that peripheral vision system is specifically used to control movement and actions. This system recognizes the objects' status in the environment and on the move. Moreover, peripheral vision provides data on our movement relative to other objects. Peripheral vision system unconsciously helps control fine movements (9).

Research shows that peripheral vision plays an important role in controlling movements related to handwriting. Smart and Silvers (as cited in (8)) indicated that an individual who had been asked to write while his eyes were covered added extra lines to some letters, missed lines in some letters, and repeated some letters, and if visual feedback were delayed while writing, he would make a lot of mistakes such as adding letters. They recommended that vision carries out two different functions in handwriting: first, helping the writer control spatial arrangement of all words in a horizontal line, and second, helping the writer produce precise patterns of handwriting including appropriate lines and letters necessary for the text (8). On the other hand, poor visual memory, poor visual recognition, and poor motor memory are known as effective factors in dysgraphia (10). In general, there is a general agreement over beneficial effects of visual feedback on handwriting. Vision resulted from handwriting trace enables the writer to control writing and remove the motor program used (in previous handwritings) from the working memory. In addition, vision may facilitate the function of high processing levels of handwriting through the writer's access to what he has already written (11). It is stated that successful handwriting requires the development of visual perceptual skills such as stability of shape, field shape, spatial relations – location in the space, visual discrimination, visual opening, and visual memory. Moreover, it is reported that visual perceptual skills play a significant role in learning of handwriting. These skills also play an important role in copying, changing the sizes, spacing, arranging the written letters, and correcting the words (12). The results of the study carried out by Olive and Piolat (2002) showed that removing visual feedback only affects processes that need to be conducted, but it has no influence on higher level cognitive processes and linguistic-writing processes. When visual feedback is removed, the writers carried out the process of writing and high processing level of handwriting stage by stage, while in case of presence of visual feedback, they activated writing processes simultaneously (11). Dennis et al (2001) and Cornhill (1996) stated that eye-hand coordination is an important predictor of legible writing. Dennis (1996) also showed that eye-hand coordination is very effective in drawing letters and lines (13). Marr et al (2003) introduced factors such as age, visual memory, and visual-motor integration as significant predictors of handwriting speed (14). On the other hand, it is stated that cases like poor eye-hand coordination and visual recognition are referred to as factors of dysgraphia (15). Weisserpike (2005) also indicated that adults with poor vision have difficulty in selective attention as a cognitive and handwriting ability and a fine motor function. Fluent handwriting is also acquired from motor patterns integrated with monitoring visual attention and sensory-motor feedback (16). Handwriting process is an important type of visual attention processing which affects neural receptors (17). In a study, Chakarov (2006) reported that during handwriting with absence of visual control, the patient group exerted less vertical pressure compared to the control group (17). Elio et al concluded that adults under standard writing circumstances (with visual feedback) can simultaneously activate high processing level writing processes. According to the experiments carried out by Elio et al (2002), removing visual feedback only affects coordination of handwriting processes during writing, while handwriting without visual feedback increases processing needs of low-level processes in writing task. The relationship between working memory and visual feedback processes during writing task is mostly carried out by comparing individuals' handwriting in presence and absence of visual feedback (11). Zesiger (as cited in Elio, 2002) observed that handwriting quality decreased progressively with a drop in visual feedback in children who were learning handwriting. Similar results were reported for adults writing with a pen without handwriting trace. These results were obtained by observing lower concentration in forming the writing and the text with irregular arrangement. Young and Flude (as cited in Elio, 2002) observed that individuals whose visual and motor-tactile feedbacks were removed had the same symptoms as those with dysgraphia. On the other hand, with regard to the role of vision in composition, it is indicated that the visual feedback on the effect of handwriting on paper leads to facilitation of high levels of handwriting processes. Researchers showed that as opposed to writing with a pen without handwriting trace or speaking in which the individual has no access to the effect of the words, producing text in normal handwriting acts as a visual storage and causes the individual to have no need to store the presented data in his memory. In normal handwriting; therefore, the writer can use a written text, devotes more units to speaking, and provides a better product. Studies that focused on the effect of removing visual feedback on the quality of the text provided similar results. In general, when the writer is banned from having visual feedback, the quality of their handwriting drops compared to the state of having access to feedback. Moreover, removing visual feedback also affects grammatical structure (11).

Evaluating handwriting is mostly based on analyzing the writing product, i.e. the trace left from the writing on paper and not creating writing. An important criterion in evaluating handwriting is the individual's writing in terms of word per minute (18). Among writing cases are copying from a text and composition. In copying skill, the individual writes from a specified text. There are two types of handwriting: near-point copying and far-point copying. In near-point copying, the writing pattern is near the individual (on the desk) while in far-point copying, it is far from the individual and on a blackboard or a wall. In composition, the individual needs to create the words in his mind and write them on a paper (5).

Although the effect of vision has been focused on in different studies, it is necessary to carry out studies focusing on the slightest role of central and peripheral vision resulted from handwriting components including the employed organ, stationery, writing field, and the written text on fine skills of near- and far-point copying among elementary children. On the other hand, given the role of each components of handwriting, some principles can be used to design different handwriting components which facilitate the individual's writing, and this tools can be employed to teach writing to individuals with dysgraphia or children who are learning to write. Therefore, the present study was aimed at examining the effect of central and peripheral vision resulted from handwriting on motor control of fine near- and far-point copying skills among children.

2. Material & Method

The present investigation was a semi-experimental study. The statistical population included all elementary children attending schools in Tehran. A sample of 12 students with an age range of 11±0.9 years was selected by a randomized cluster method. Inclusion criteria were complete visual and physical health, full consent to participate in the study, and superiority of right hand and eye. A pretest-posttest method with repeated measures during applying different states of visual variable in near- and far-point copying skills was employed. Data collection instruments included a) a chronometer: to record the time of handwriting, b) ink carbon papers: to record the individuals' handwriting in case of removing the vision resulted from the writing, c) lined papers, and d) Briggs-Nibbles questionnaire to determine the superior hand.

Scoring the individuals was based on two criteria: a) measuring their writing speed in terms of the number of correct words per minute and b) evaluating the quality of their handwriting using Minnesota Handwriting Assessment. This tool evaluates 5 factors: a) the alignment of the letters relative to writing lines, b) legibility, c) proportional space between letters and words, d) equal size of letters, and e) correct form of letters. Each factor is given a score between 0 and 2. In so doing, if the criterion is completely observed, the score will be 2, if it is relatively observed, 1, and if it is not observed, 0 (11).

For near-point copying test, an appropriate text was selected and printed on papers. The tests were respectively run. In order to prevent the effect of vision criterion from becoming automatic and being mistaken with the effect of automation, each test was administered on a separate day in order to achieve precise results by creating intervals. During administration of the tests, the handwriting completion time was recorded with a chronometer to be used in evaluating handwriting speed. The tests included: a) Pretest: In this test, the individual had access to central and peripheral vision resulted from handwriting components, the handwriting task was carried out on a lined paper without any visual limits. The time the individuals needed to complete the handwriting task was recorded to determine their speed. b) Removing central and peripheral feedback resulted from the field in which the individuals wrote: In this case, the vision resulting from the writing field, i.e. the lines of the paper, was removed and only the beginning and the end of the lines were visible, and the individual wrote on a white paper in which only the beginning and the end of the lines were seen. c) Removing central and peripheral feedback resulted from all components of handwriting: In this case, a cover was placed between the handwriting components and the individuals' eyes to prevent them from seeing the handwriting components. d) Removing central vision caused by handwriting components when central vision was available: In this case, although handwriting components were within the individuals' vision field and thus central vision resulted from them was accessible to the individuals, central vision was removed by providing the individuals with verbal instructions, and they were required to avoid watching the handwriting components directly while doing the task. Examples of the verbal instructions are: "Dear students, although the handwriting components are within your visual field during writing, please avoid looking at them directly, and direct your attention to the model text." e) Removing just central and peripheral vision resulted from the text of the paper: In this case, the individuals wrote with a traceless pen. To record their writing, there were a carbon paper and another white paper under the first white paper. (Here, the order was as a white paper on the top, an ink carbon paper in the middle, and another white paper under to record the individual's handwriting.).

In order to carry out the far-point copying test, the text was written on the blackboard, and the individuals did far-point copying task.

In order to analyze the collected data, Kolmogorov-Smirnov test (to check the normality of the data), levee's test (homogeneity of variance), and variance test with repeated measures were employed. Statistical analysis was carried out through SPSS 18.0.

3. Results

The results of Shapiro–Wilk test indicated that the collected data were normal ($p>0.05$). Homogeneity of variances was approved using Levee's test. Mauchly test was used to check the sphericity of data, the results of which confirmed the sphericity assumption ($p>0.05$). The first row of intergroup effects table was used to examine the effects of central and peripheral vision feedback resulting from handwriting components on speed control of near-point copying among the elementary children.

Table 1. Test of repeated values in comparison with the trend of changes in near-point copying speed within 5 stages

	Change source	SS	Df	MS	TS	Sig	η^2
Intergroup	Near-point copying speed	74674.3	1	74674.3	456.1	0.001*	0.543
	Error	3765.4	23	163.7			

SS=Sum of Squares; DF= Degrees of freedom; TS= Test Statistics; η^2= Eta squared; significant measure showed with*.

Given the significant level of 0.05, the results presented in the table of intergroup effects indicated that central and peripheral visions resulted from handwriting components had a significant effect on the control of near-point copying speed among the elementary students. In order to see at what stage the effect of central and peripheral visions resulted from handwriting components on near-point copying was significant, the data of Bonferroni post hoc test table were used, and the following results were obtained.

Table 2. The results of pair comparison of different stages of near-point copying speed

Test	MS	SD	LB	UB	Sig
Stage 4-5	3.216	0.758	0.565	5.867	0.014*

MS = Mean difference, SD = Standard deviation, LB = Lower bound, UB = Upper bound, * shows significance measure level at 0.05

Although in standard conditions, no significant difference was observed between any of the four stages, the results presented in pair comparison table showed that there was a significant difference between stages 4 and 5, i.e. the stage of removing central vision resulted from all handwriting components and the stage of central and peripheral visions resulting from handwriting.

Afterward, the effect of central and peripheral visions resulting from handwriting components on the quality of the children's near-point copying was examined, which led to the following results for intergroup effects.

Table 3. The test of repeated measures in comparing the trend of changes in near-point copying quality in 5 stages.

	Change source	SM	DF	MS	TS	Sig	η2
Intergroup	Near-point copying quality	3910.2	1	3910.2	759.6	0.001*	0.728
	Error	118.4	23	5.14			

* Significance level was set at 0.05.

Given the significant level of 0.05, the results presented in the table of intergroup effects indicated that central and peripheral visions resulted from handwriting components had a significant effect on the quality of near-point copying among the elementary students. The results of Bonferroni post hoc test are presented in the following table.

According to the results of pair comparing, the quality of near-point copying at the first stage, i.e. writing in standard conditions, had a significant difference with all other stages.

Table 4. The results of pair comparison of different stages of near-point copying quality.

Test	MD	SD	LB	UB	Sig
Stage 1-2	1.750	0.114	0.314	3.186	0.013*
Stage 1-3	7/583	0.543	5.685	9.482	0.001*
Stage 1-4	6.000	0.408	4.573	7.427	0.001*
Stage 1-5	4.917	0.452	3.338	6.496	0.001*

MS = Mean difference, SD = Standard deviation, LB = Lower bound, UB = Upper bound, * shows significance measure level at 0.05

Afterward, the effect of central and peripheral visions resulting from handwriting components on the speed of far-point copying was examined, and the results are presented in the following table.

Table 5. The test of repeated measures in comparing the trend of changes in near-point copying speed in 5 stage.

	Change source	SS	Df	MS	TS	Sig	η2
Intergroup	Far-point copying speed	2614.2	1	2614.2	12.73	0.004	0.512
	Error	3293.02	23	195.18			

SS=Sum of Squares; DF= Degrees of freedom; TS= Test Statistics; η^2= Eta squared; significant measure showed with*.

Given the significant level of 0.05, the results presented in the table above indicate that central and peripheral visions resulted from handwriting components had a significant effect on the speed of far-point copying among the elementary students. Bonferroni post hoc test also led to the following results.

Table 6. The results of pair comparison of different stages of far-point copying speed.

Test	MD	SD	LB	UB	Sig
Stage 1-3	-3.709	0.949	-7.027	-0.392	0.024*
Stage 1-5	4.748	1.338	0.071	9.426	0.046

MS = Mean difference, SD = Standard deviation, LB = Lower bound, UB = Upper bound, * shows significance measure level at 0.05.

According to the results of pair comparison, there was a significant difference between stage 1 and stages 3 and 5, i.e. writing in standard conditions while removing central and peripheral vision of handwriting components and removing central and peripheral vision of the handwriting.

Afterwards, the effect of central and peripheral vision resulted from handwriting components on the quality of far-point copying among the children was examined. The results are presented in the following table of intergroup effects.

Table 7. The test of repeated measures in comparing the trend of change in far-point copying quality in 5 stages.

	Change source	SM	DF	MS	TS	Sig	η2
Intergroup	Far-point copying quality	7198.42	1	7198.42	31.42	0.01*	0.461
	Error	8404.50	23	728.10			
Intergroup	Practice conditions	7198.42	1.04	6859.79	9.42	0.010*	0.461
	Error	8404.50	11.54	728.10			

* Significance level was set at 0.05.

Given the significant level of 0.05, the results of the above table showed that central and peripheral vision resulted from handwriting components had a significant effect on the quality of far-point copying among the children. Bonferroni post hoc test also provided the following results.

Table 8. The results of pair comparison of different stages of far-point copying quality.

Test	MD	SD	LB	UB	Sig
Stage 1- 3	4.917	0.609	2.778	7.045	0.001
Stage 1- 4	4.500	0.544	2.599	6.401	0.001
Stage 1- 5	3.167	0.548	1.250	5.083	0.001

* Significance level was set at 0.05.

According to the results presented in pair comparison table above, there was a significant difference between stage 1 and stages 4 and 5, i.e. writing in standard conditions while removing central and peripheral vision of handwriting components and removing central and peripheral vision of the handwriting. Diagrams of the speed and the quality of the students' handwriting are presented in the following section.

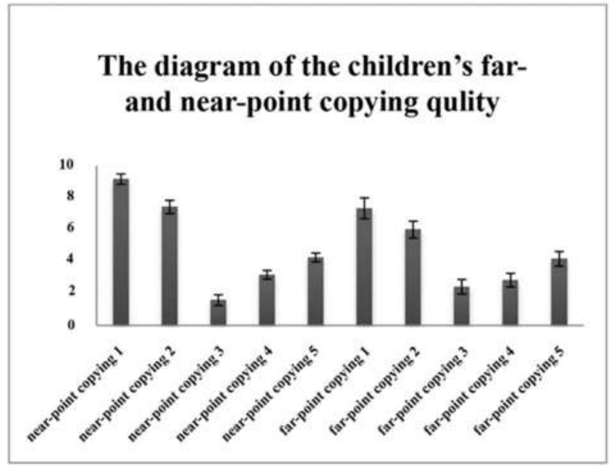

Figure 1: F Diagram 1. The score of copying quality during different stages of applying visual limitations in two states of far- and near-point copying
Diagram guide:
Test 1. Handwriting in standard conditions (without visual limitation)
Test 2. (Removing central and peripheral vision of the writing field)
Test 3. (Removing central and peripheral vision of the writing components)
Test 4. (Only removing central vision of writing components)
Test 5. (Removing central and peripheral vision of handwriting).

4. Discussion

The present study was aimed at examining the effects of central and peripheral vision resulted from handwriting on motor control of fine near- and far-point copying skills among children. The statistical significance was set at 0.05, and the results obtained from variance analysis with repeated measures indicated that central and peripheral vision resulting from handwriting components had a significant effect on the speed and the quality of the children's far- and near-point copying skills. The results of the present study are in line with those of the studies carried out by Smart and Silvers (2004), Chakarov (2006), Olive (2002), Swearingen (2007), Dennis (2001), Cornhill (1996), Weisser, and Longchamp. Smart and Silvers (2004) pointed out that if vision is removed, the individual's handwriting errors will increase. They also showed that an individual who was required to write with closed eyes added extra lines to some letters, missed lines in some letters, and repeated some letters, and if visual feedback were delayed while writing, he would make a lot of mistakes such as adding letters. In the present study, a lot of quality mistakes were observed in the individuals' handwriting when central and peripheral vision resulted from handwriting components were removed. Chakarov (2006) studied the visual control of handwriting among patients, and the results showed that during writing in absence of visual control, patients exerted less vertical pressure compared to the control group, and removing visual feedback led to more use of proprioceptive sensory feedback to control the handwriting. Moreover, it was observed that the quality of handwriting progressively dropped with a decrease in their visual feedback. In their study, Olive et al (2002) maintained that when writers were prevented from visual feedback, the quality of their handwriting decreased compared to the state of visual feedback existence. Removing visual feedback also influences the grammatical structure of the individuals' handwriting. Olive also showed that handwriting trace enabled the writer to control writing and remove the utilized motor program (for previous writings) from their working memory. In addition, vision may facilitate the performance of high processing levels of handwriting through the writer's access to what he has already written. In the study conducted by Swearingen (2007), it is stated that visual perceptual skills play a significant role in copying, changing size, spacing, arranging the writing, and correcting the words. Moreover, regarding the role of vision in handwriting control, Dennis (2001) and Cornhill (1996) showed that hand visual-motor integration is a significant predictor of legible writing. Dennis showed that eye-hand coordination is also important in drawing letters and lines. While writing in absence of visual control in the study conducted by Chakarov (2006), patients exerted significantly less vertical pressure compared to the control group. Based on the experiments carried out by Danna and Velay (2015), removing visual feedback should only affect the coordination of writing processes during writing, while writing without visual feedback enhances processing needs of low-level processes. These results were obtained by observing lower attention in forming writing and text with an irregular arrangement. Young and Flude observed that normal writers whose visual and motor-tactile feedbacks were removed had the same symptoms as those with dysgraphia. On the other hand, with regard to the role of vision in composition, it is indicated that the visual feedback on the effect of handwriting on paper leads to facilitation of high levels of handwriting processes. Researchers showed that as opposed to writing with a pen without handwriting trace or speaking in which the individual has no access to the effect of the words, producing text in normal handwriting acts as a visual storage and causes the individual to have no need to store the presented data in his memory. Studies that focused on the effects of removing visual feedback on the quality of the written text reported similar results. Normally, when the writer is derived from visual feedback, the quality of his handwriting drops compared to the stated of having access to visual feedback. Also, removing visual feedback affects grammatical structure (11).

Like previously conducted studies, the present study highlighted the important and different role of central and peripheral vision in motor control of handwriting. The results indicated that although removing central and peripheral vision resulting from handwriting components had a significant effect on near-point copying speed among the children, this effect is not observed among adults. Moreover, it was specified that there was a difference between the two groups of children aging 10-12 years and adults in terms of the effect of central and peripheral vision resulted from handwriting components, and thus children and adults make different uses of visual data resulted from different components of handwriting in controlling near-point copying skills. Therefore, by designing appropriate tools to evaluate the quality of handwriting especially among adults, and quantifying written product, the effect of vision on the individuals' handwriting can quantitatively be examined.

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