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The Effect of Perceptual-Motor Exercises on the Neuropsychological Skills of Children with Visual Impairment: A Single-Subject Study

Zinat Tavakoli[1], Maryam Nezakt-Alhosseini[2], Salar Faramarzi[3], Sheila Safavi-Homami[4]

Original Article

Abstract

Introduction: The purpose of the present study is to investigate the effect of perceptual-motor training on neuropsychological skills in children with visual impairment.

Materials and Methods: A single-case experimental study was conducted on three children (2 boys and 1 girl, aged between 4 and 7 years old) with visual impairment (20/70 and 20/200) who referred to Department of Social Welfare of Isfahan, Iran. The participants were selected through convenience purposive sampling method for the perceptual-motor training. The Language Development Scale, Guzel perceptual-motor Scale, Stanford-Binet scale, and Conner's Neuropsychological questionnaire were used to collect the data. The multiple baseline design (MBA) was used in the present study, followed by the perceptual-motor intervention. The baseline position for the first, second, and third participants lasted three, five, and seven weeks, respectively, and the intervention duration for each participant was eight weeks as three sessions per week with each session lasting for one hour. Exit of the participants according to their entry into the training program was made in the step by step manner. The data were plotted and then the stability envelope and the trend of all three participants in the baseline and intervention positions were plotted and compared.

Results: The perceptual-motor training was effective on neuropsychological skills [percentage of non-overlapping data (PND) = 87.5%] in three participants.

Conclusion: The perceptual-motor exercise may be an appropriate training method to improve neuropsychological skills in children with visual impairment.

Keywords: Neuropsychological skills; Perceptual-motor training; Visual impairment; Cognitive development; Children

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Introduction

Theories and investigations related to children's cognitive development show that they go through different stages of development from birth to adulthood. During the first year of life, a child's brain weight doubles (1) due to an increase in the number of brain cells and the growth of connections among them and different parts of the brain. These connections are made by stimulating the five senses (2) and the child begins to learn through these connections in different parts of the brain (3). To develop a child's mental development, the senses of sight, hearing, and motor skills must develop in harmony (2).

The child's intelligence is dependent on the senses and body movements (4). During infancy, the child goes through the sensory-motor stage and progresses to the perceptual-motor stage (1), both of which are the basis of his/her development and growth to the cognitive level (3). The perceptual-motor development aim to develop the child's displacement skills, which affects other aspects of development, including cognitive, linguistic, social, and neuropsychological development (4). The perceptual-motor term is any voluntary movement that relies on sensory information to process the function information. In fact, all voluntary movements may be viewed as a perceptual-motor action (3).

1- Department of Motor Behavior, School of Sports Sciences, University of Isfahan, Isfahan, Iran
2- Associate Professor, Department of Motor Behavior, School of Sports Sciences, University of Isfahan, Isfahan, Iran
3- Associate Professor, Department of Psychology and Education of Children with Special Needs, School of Education and Psychology, University of Isfahan, Isfahan, Iran
4- Assistant Professor, Department of Motor Behavior, School of Sports Sciences, University of Isfahan, Isfahan, Iran
Corresponding Author: Maryam Nezakt-Alhosseini, Email: mnezakat2003@yahoo.com

Although auditory and muscle-touch senses play an important role in the perceptual stage, the main mediator of learning in this stage is visual perception (4). This perception is the ability to create meaning through visual stimuli, which is a learned process transforming images obtained through sharpness into useful information (3). Accordingly, visual impairment is a barrier to receiving visual information. Therefore, review of studies has shown differences in perceptual-motor abilities of individuals with visual impairments (4). This impairment covers a wide range of vision problems, ranging from low vision to complete blindness. Although many vision diseases are currently preventable, in some cases, despite all efforts, some individuals may lose central vision or peripheral vision (5).

Visual impairment is more disabling than any other sensory impairment and causes severe damage to motor development and other aspects of children's development and causes interruptions in this process (6). Numerous factors interfere with the perceptual and motor processes of subjects with visual impairments. Piaget stated that inadequate environment detection contributes to impaired perceptual-motor skills of visually impaired individuals (7). Additionally, sensory-perceptual abilities may develop at a slower rate in individuals with visual impairments (3). A third component that may explain the difference in perceptual-motor processing is derived from functional magnetic resonance imaging (FMRI), which is attributed to different processing pathways in the brain (8).

Researchers make two hypotheses about the adaptation of people to visual impairment; one is the sensory compensation hypothesis, which refers to the superior ability in other senses (8), and the other is the general loss hypothesis, which refers to inappropriate changes in sensory structures (7). Differences in FMRI can be identified using neuropsychological assessments (2). These assessments are a comprehensive measure of cognitive, adaptive, and emotional functions that reflect the inadequacy of cortical functions (3). Since direct observation of the human brain functions is not always possible, cognitive components are used for evaluation (8).

Researchers consider the sensory-motor and perceptual-motor stages as the bases of cognitive development (1,3) and report the relationship between cognitive and neuropsychological skills (8). In other words, children with visual impairment have limitations in motor areas on the one hand and on the other hand, lay in a lower category compared to naturally homogeneous peers due to the dependence of cognitive development on cognitive and motor skills in creating cognitive structures and cognitive development. Experience plays an important role in different stages of developmental period, especially the cognitive development stage (3,8). According to Piaget and Inhelder, children who go through the cognitive development path without various experiences are 3 to 5 years behind their peers in terms of creating and developing mental strategies and measures, as the cognitive and motor functions are important to develop cognitive abilities at a high level (1,7). Advocates of the perceptual-motor method believe that motor learning is the source of learning, and that higher mental processes take place after the proper development of motor and perceptual systems, as well as the links between motor and perceptual learning (4).

Therefore, by providing an environment rich in perceptual-motor experiences that underlie cognitive development, it may be possible to take a step towards improving and accelerating the stages of sensory-motor and perceptual-motor development towards cognitive development of these children. Although studies have been conducted on physical activity of blind and visually impaired children in the country (9-11), little investigation has been performed on the effect of perceptual-motor experiences on children with special needs (12,13) and review of studies on the effect of perceptual-motor exercises on children with visual impairment were limited to only one study (14). Therefore, the aim of this study is to determine the effect of a period of perceptual-motor training on neuropsychological skills of children aged 4 to 7 years with visual impairment in Isfahan, Iran.

Materials and Methods

This was a quasi-experimental single-subject study with a multiple-baseline-across-subjects design (15). 10 boys and girls with visual impairments under the supervision of Isfahan Welfare Department were selected using the convenience-purposive sampling method from whom three children (two boys and one girl) were included in the study. The study inclusion criteria were determined based on the children's record at Tavakol Center for Blindness and assessment by a skillful expert of exceptional children. These criteria included an intelligence quotient (IQ) score of 75 to 90 based on the Stanford-Binet test, optimal language-speech and perceptual ability according to the exceptional children expert, age range of 4 to 7 years, visual acuity of 20/70 and 20/200, gaining parental satisfaction, and lacking a physical disability and other disorders including Attention Deficit Hyperactivity Disorder (ADHD), autism, and Developmental Coordination Disorder (DCD). Lack of cooperation and absence at the treatment sessions, presence of the participants in organized physical motor activities during and after the intervention, and parents' dissatisfaction with continuation of cooperation were also considered as the exclusion criteria. The subjects were evaluated and intervened for three months.

The tools used are described in detail below.

Linguistic Development Scale: To assess the children's language development, the language development scale proposed by Faramarzi and Malekpour was applied. This scale has been classified based on age. The reliability and validity of this instrument were obtained as 0.89 and 0.74 using Cronbach's alpha coefficient and the internal consistency (IC) method, respectively (16).

Guzel Perceptual-Motor Development Scale: This scale was first developed and standardized by Guzel and was used to match children in terms of perceptual-motor development. This tool has also been classified based on age. In this scale, Guzel has divided mental development from birth to age 16 into seven stages. Stage one from birth to one month, stage two from 1 to 7 months, stage three from 7 to 18 months, stage four from 18 months to 3 years, stage five from 3 to 5 years, stage six from 5 to 10 years, and stage seven from 10 to 16 years old. The validity of this scale has been calculated to be 0.95 (17).

Stanford-Binet Test Form: This intelligence test has been developed based on the two principles of "defining age and the concept of general mental abilities" and is employed to measure the intelligence of children aged 2 years old to adults. If a person's IQ is or close to 100 in this test, it is considered normal or moderate. The content of the Stanford-Binet test consists of two types of verbal and non-verbal questions (17). The scale has a validity coefficient of 0.98, 0.95, and 0.96 for total, non-verbal, and verbal scale scores, respectively, using the split-half method and correction with Spearman-Brown formula (18).

Conners Neuropsychological Test: This test was designed by Conners to assess the neuropsychological skills of children aged 5 to 12 years old. "Attention function, memory and learning function, executive function, sensory-motor function, educational function, and cognitive processing" are the functions that are evaluated by this scale and are scored in four ranges of unobserved, mild, moderate, and severe with scores 0 to 3, respectively (3). This questionnaire has been translated and standardized by Abedi and Malekpour (19).

First, the Guzel Perceptual-Motor Development Scale, Linguistic Growth Scale, and Stanford-Binet Intelligence Test were used to equalize the participants' development and IQ. The Guzel Perceptual-Motor Development Scale was completed through providing a questionnaire to the parents and also by direct observation of the child. Before submitting the Guzel and Linguistic Development questionnaires, the child's parents were asked to closely monitor their child at home for two days. Then the Conners neuropsychological test was utilized to evaluate the neuropsychological problems of the samples.

Intervention: The multiple baseline (MBL) design with the stepwise entry of the subject enables the researcher to eliminate the effect of the disturbing variables and explain the changes of the dependent variable only on the basis of the independent variable (15). This design includes two test situations. The first position is A, which is the baseline, and the second position is B, in which a therapeutic intervention is performed (6).

In the first phase of the project, all three participants were in a baseline position. The baseline position lasted for three, five, and seven weeks for the first participant, second participant, and third participant, respectively and the researcher completed the Conners test questionnaire while observing the subjects' behavior individually. It should be noted that the duration of the baseline and intervention steps for the whole participants lasted 15 weeks.

In the second stage, only the first participant participated in the training sessions for three weeks (3 sessions per week) and the other two participants were in the baseline position (considered as a control group) to control the variables threatening internal validity.

In the third stage, while the training sessions of the first participant continued, after 5 weeks of the baseline for the second participant, he/she also received his/her first intervention session in the third week of the intervention for the first participant; while the third participant was still in his/her control position and did not receive any intervention.

Finally, in the fourth stage, the third participant received his/her intervention after 7 weeks at the same time as the beginning of the third week of the second participant, and thus all three subjects participated in the training sessions. The training program was performed individually for eight weeks (three sessions per week, on Saturdays, Mondays, and Wednesdays, one hour per day) and, as in the baseline position, the subjects participated in the Conners Neuropsychological Test on a weekly basis. After the intervention of the third subject was completed, three stages of evaluation as a follow-up were performed for all three participants four weeks after the end of all baseline and intervention courses. Accordingly, the exit of the participants was as stepwise in accordance with their entry into the study. Three follow-up tests were performed for each participant once every two weeks after the last training session.

The study environment was the same for all participants. Each child was trained individually by an instructor in a closed hall, in the mornings for 8 weeks (three days a week, once a day) apart from other children and instructors during the training hours at Tavakol Center for Blindness. Each session lasted about 60 minutes and the sessions were recorded by a camera and used for further analysis.

The protocol of the perceptual-motor training sessions in the present study included visual perception, spatial perception, shape perception, auditory perception, balance, kinetic and tactile perception, body awareness and role of organs, eye-hand coordination, eye-foot coordination, and fine movements, which were selected based on the book Development and Strengthening of Perceptual-Motor Skills in Children (19). Table 1 represents the exercises used in the study.

In single-subject designs, to compare data from different experimental situations, the data are plotted on a graph and apparent differences are taken into account. As a result, these differences should be obvious and significant (15).

Results

The demographic characteristics of the participants are presented in table 2.

Figure 1 demonstrates the effect of perceptual-motor exercises on the first subject's neuropsychological skills in the baseline, intervention, and follow-up stages.

Given figure 1, the data levels in the baseline, intervention, and follow-up situations were described as stable; Because 100% (3 points out of 3 points) of the data points in the baseline position, 87.5% of the data points in the intervention position (7 points out of a total of 8 points), and 100% of the data points in the follow-up position (3 points of 3 points) were in the stability envelope.

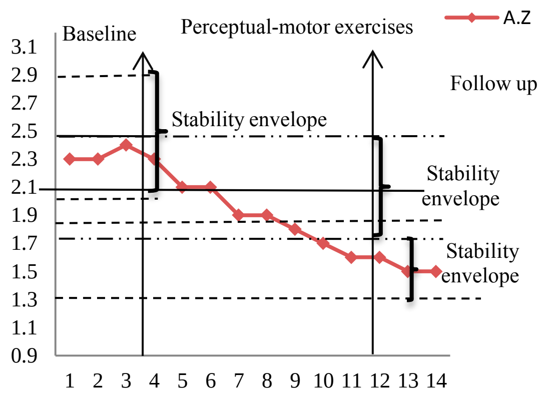

Figure 1. Subject 1 stability envelope

Thus, percentage of non-overlapping data (PND) and percentage of overlapping data (POD) were 87.5% and 12.5%, respectively.

Figure 2 indicates the effect of perceptual-motor exercises on the second subject's neurological skills in the baseline, intervention, and follow-up stages. Accordingly, the data levels in the baseline, intervention, and follow-up situations were described as stable; Because 100% (5 points out of 5 points) of data points in the baseline position, 100% of data points in the intervention position (8 points out of a total of 8 points), and 100% of data points in the follow-up position (3 points out of a total of 3 points) were in the stability envelope. Thus, PND and POD were 87.5% and 12.5%, respectively.

Table 1. Exercise program performed by participants

Week	Goals	Exercises
First	Visual perception	Visual perception of length and depth, puzzle, star (buttons), threading beads, and shapes
Second	Spatial perception	Familiarity with directions, similarities and differences, puzzle, laying bricks, and ball pool
Third	Shape perception	Recognizing geometric shapes, tactile recognition of geometric shapes
Fourth	Auditory perception	Auditory discrimination cans, stories, poems
Fifth	Balance	Balance routes, balance ladders, balance boards, balance tires, Physiobal
Sixth	Kinetic-tactile perception	Olfactory and taste perception cans, tactile catalog, touch boxes
Seventh	Body awareness and role of organs	Body awareness catalog
Eighth	Eye-hand coordination, eye-foot coordination, fine movements	Button set, dropping coins in the box, threading shapes with a special needle, dribbling with the ball, separating shapes

Table 2. Demographic characteristics of the participants

Subject	Age (year)	Gender	Right visual acuity	Left visual acuity	Duration
A.Z	5	Boy	20/160	20/80	Since birth
A.K	6	Boy	20/200	20/120	Since birth
Gh.G	5	Girl	20/160	20/140	Since birth

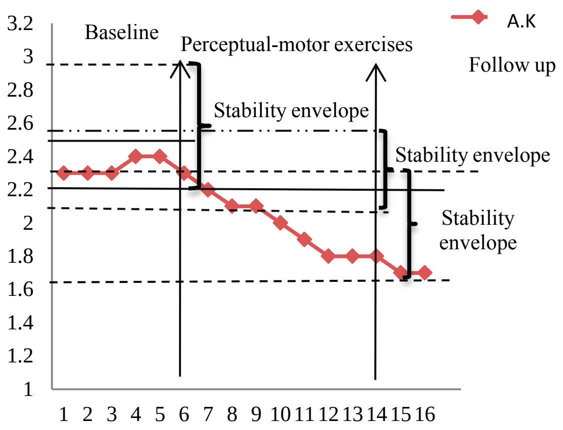

Figure 2. Subject 2 stability envelope

Figure 3 shows the effect of perceptual-motor exercises on the third subject's neuropsychological skills in the baseline, intervention, and follow-up stages.

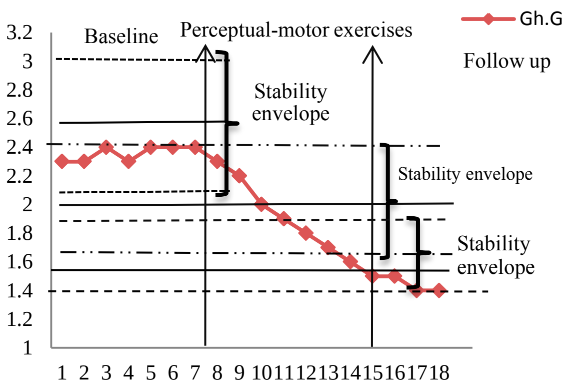

Figure 3. Subject 3 stability envelope

Figure 3 suggests that the data levels in the baseline, intervention, and follow-up situations were described as stable; Because 100% (7 points out of 7 points) of data points in the baseline position, 100% of data points in the intervention position (8 points out of a total of 8 points), and 100% of data points in the follow-up position (3 points out of a total of 3 points) were located in the stability envelope. Thus, PND and POD were calculated as 87.5% and 12.5%, respectively.

Discussion

The current study was carried out with the aim to determine the effect of a period of perceptual-motor exercises on neuropsychological skills of children aged 4 to 7 years with visual impairment. The high dependence of cognitive functions on the sense of vision is a factor in the analysis of cognitive skills in the blind and their lower efficiency in cognitive tests (3). Many individuals with visual impairments have difficulty developing neuropsychological skills (8). The results obtained here were in agreement with the findings of other studies on children with visual impairment that examined the effect of perceptual-motor exercises on social development (14), the effect of play on sensory stimulation, body recognition, spatial awareness, and stability of objects (20), improving gross motor skills (22) proficiency in Bruininks-oseretsky motor test subtests (2), improvement of sleep disorders, balance, concentration, and mental states including anxiety and depression (23), and the effect of playing goalball on improving auditory reaction time, listening time, and reduction of neuropsychological problems and the development of these skills (24).

Individuals with visual impairment at birth have a slight delay in all stages of development (motor, cognitive, social, emotional, etc.) compared to other people (22). For example, preschool children with visual impairment show delays in the development of gross, fine movements and skills such as throwing and grabbing (8). There are theories about the reasons for this delay, including the one considering it to be mostly due to lack of experience (2,7). Most researchers believe that vision plays a fundamental role in obtaining environmental information and acting on it (2,7,8). Vision provides perception of features such as color, clarity, size, and movement immediately after observation, and the absence of this sense in children leads to their delayed cognitive development (22).

Theories related to human cognitive development date back at least to the Middle Ages. Descartes referred to the concept of the early development of cognitive processes (8). According to Hupp's theory of cognitive development and information processing, disruption or barriers to the coding of new stimuli may inhibit developmental processes (3,8). He argued that children who did not adequately encode the dimensions of new stimuli did not benefit from experiences designed to help in the acquisition of more advanced rules (8). Improved coding leads to improved learning ability. Therefore, it can be considered as a cognitive growth mechanism (3). One of the assumptions is that the lack of vision may lead to disruption of coding processes (2). Many researchers and experts acknowledge that vision affects a person's cognition, and that coding of the physical properties of an image must be sent automatically through the optic nerves to provide an image for the nervous system (20).

Cognitively, children with visual impairments cannot gain much experience from their environment due to their visual impairment. As a result, they will interrupt the formation of concepts and will grow slowly (23). Due to vision problems, imitation, which is the basis of many learnings in this period, is severely damaged in these children (8). Mental images and mental visualization of children with visual impairment are weak and rudimentary, causing many cognitive problems (11). Finally, although according to Piaget's theory, the cognitive development process in humans takes place continuously and throughout life, during which the mind and body interact constantly (2), but it must be acknowledged that this interaction is pronounced in the childhood years, especially in the sensorimotor (from birth to 2 years old) and preoperational (2 to 7 years old) stages (7). In Piaget's cognitive development continuum, in the preoperational period, thinking and reasoning are at the direct perception level; because learning in a child is direct and without the use of reasoning (3). The child is not able to think logically or deductively and imitation plays an important role in this stage which is manifested in their play at the age of 3 to 5 years and forms the basis of many learnings of this period (20). Children with visual impairment suffer severe trauma during this period due to failure to benefit from this advantage, and due to the coincidence of the preoperational period with preschool age, this age period is of special importance (8,20).

Some researchers believe that perceptual and motor functions are necessary for the development of cognitive abilities at a high level, and the lack of necessary motor experiences will delay cognitive development. According to Luria's theory, complex multi-sensory integration is essential for cognitive development, and interaction with the environment, especially through perceptual-motor exercises, is necessary to achieve this integration (7). In his theory, Kephart also introduced perceptual-motor processes as a unit that act together (8). In fact, he believes that the perceptional and cognitive development has a motor base; in a way that for the child to reach full mental development, he must have reached the generalized movement stage. In other words, in order for the child to achieve his full mental and cognitive function, he needs certain motor generalizations (3).

Jorma believes that the perceptual-motor differences between sighted and blind children are due to slower (but not more inefficient) development of the sense of touch compared to the sense of sight (7). There is a significant relationship between perceptual and motor abilities of individuals with visual impairment (3,8). The motor development of blind people in the Piaget sensorimotor phase may be slower than that of the sighted people; this is because, first, blind children must rely on auditory cues to stimulate active movements, and the ability to process auditory information does not develop until 8 months of age, therefore, there is a delay in the child movement. Second, lack of vision has a negative impact on fine motor tasks such as grasping (7). Motor function is inseparable from tactile perceptual ability. The development of the sense of touch requires movement (21); Therefore, perceptual and motor performance should be examined together (6,8,20). Therefore, it can be concluded that due to the limitations in motor fields and the dependence of cognitive development on sensory and motor skills, the cognitive structure of the blind children is not fully formed and as a result, their cognitive development is lower than their normal peers. The use of perceptual-motor exercises in the present study may have enhanced cognitive development in children with visual impairment by creating sensory integration.

Limitations

The present study was a single-subject study. It is suggested that similar studies be conducted in this area in the future with a larger sample size for more generalizable results.

Recommendations

There are differences in educational performance test between sighted children and children with visual impairment, and educationally, children with visual impairment are about two years behind in reading skills and 0.8 years behind in math skills compared to their sighted peers. On the other hand, educational differences between blind and sighted children may lead to some differences in perceptual-motor functions. Therefore, to supplement the present study, it is suggested that future studies examine the effect of perceptual-motor exercises on the educational performance of children with visual impairments.

Conclusion

Based on the results of the present study, it seems that creating an environment rich in perceptual and motor experiences can pave the way for the development of cognitive aspects in children aged 4 to 7 years with visual impairment.

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Authors' Contribution

Zinat Tavakoli: Data collection, analysis and interpretation of results, manuscript preparation; Maryam Nezakt-Alhosseini: Study design and ideation, study support, executive, and scientific services, evaluation of the manuscript in terms of scientific concepts, confirmation of the final manuscript for submission to the journal office, responsibility for maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Salar Faramarzi: providing study equipment and samples, Sheila Safavi-Homami: specialized statistical services, specialized evaluation of the manuscript in terms of scientific concepts.

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Conflict of Interest

The authors declare no conflict of interest.

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