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THE DEVELOPMENT OF VISUAL-MOTOR INTEGRATION, VISUAL PERCEPTION AND MOTOR COORDINATION IN DEAF AND HARD OF HEARING CHILDREN[a]

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SUMMARY

The development of visual-motor integration starts at an early age through the coordination of visual and motor system. With age, as child acquires and develops certain skills, the integration of these systems changes, too. Examining the effect of age on development of visual perception, motor coordination and visual-motor integrationin deaf and hard of hearing children is the aim of this research.The sample covers 40 deaf and hard of hearing children belonging to both sexes (22 boys, or 55%, and 18 girls, or 45%). The respondents, aged from 4 to 7, were divided into three groups. Respondents in the first group were aged 4y – 4y11m (13 or 32.5%), in the second 5y – 5y11m (18 or 45%) and in the third 6y – 6y11m (19 or 22.5%). All the children were with average intellectual capacities, without additional sensory and motor disturbances and disorders and included in the program of early audiologic rehabilitation.

In the research we used the Beery-Buktenica Developmental Test of Visual-Motor Integration, the Test of Visual Perception and the Test of Motor Coordination, and in interpretation of the results we used standard scores.

The greatest average number of points was achieved in the Test of Visual Perception (97.23), then in the Test of Motor Coordination (90.90) and in the last place was the Test of Visual-Motor Integration (85.93). Student achievements in all the three tests grow as they are older, but only in the Test of Visual Perception that difference is statistically relevant (F=25.316; p=0.001).

The results of the research confirmed the influence of the age on the development of visual perception, but not on the development of motor coordination and visual-motor integration, which indicates the existence of a specificity in the development of these skills in deaf and hard of hearing children. The development of these skills should be monitored in order to timely detect a possible interference that can in a later age affect the performance in academic and social skills.

Key words: deaf and hard of hearing children, visual perception, motor coordination, visual-motor integration

INTRODUCTION

Visual-motor integration

Beery (2010:13) defines visual-motor integration as a degree at which visual perception and finger-hand movements coordinated well. Visual-motor integration is

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an ability, needed for many tasks, like writing, copying, paper and pencil tasks, copying from a board and drawing. The research results show the strong relation between visual-motor integration and reading, mathematics abilities and academic achievement (Goldstein & Britt, 1994; Maeland, 1992; Sortor & Taylor, 2003; Taylor, 1999).

Visual-motor integration of fine motor abilities included:

- motor processing, including eye movements, head movements and hand movements,
- sensory processing, including visual, vestibular and somatosensory system,
- sensory perception and action, and
- high level of processing for adaptive and anticipatory aspects of fine motor functions (Shumway-Cook & Woollacott, 2001).

The development of visual-motor integration begins at an early age through cooperation of visual and motor systems. According to the age, when child gets and develops different abilities, the interaction of these two systems changes. Age, complexity and the familiarity with tasks, as well as the practice of task performance are the main factors which change and adapt the role of the visual system in the performance of motor tasks (Shumway-Cook & Woollacott, 2001).

Research results show that deaf and hard of hearing children have lower scores on visual-motor tests compared with tipically developing children (Lotz, Kroese, Puffer & Osberger, 1986) as well as that early deafness is connected with the atypical development of visual-motor skills such as copying/drawing figures and catching (Erden, Otman & Tunay, 1992; Savelsbergh, Netelenbos & Whiting, 1991).

Visual-motor function deficits are manifested while performing activities that require hand movements under the visual control. Some children who have problems in visual-motor functioning, may have difficulties in performing graphomotor activities: poor handwriting skills, untidiness, difficulties in the spatial organization of writing (Krstić, Dukić & Kovačević, 2010).

Visual perception

Visual perception is a complex activity which includes receiving visual stimuli and the interpretation of visual stimuli. It begins to develop in early months, and the most of babies after the forth month of age can follow the moving object under the certain angle. Visual perception is the actuator of the development of main motor functions in the first year of life. The development of visual attention has primary importance for the children with hearing impairment. When parents frequently use visual communication in interaction with their child, they have positive influence on the development of visual function (Spenser, 2000).

Deaf and hard of hearing children get most information through the visual channel, so, the most important thing is to determine the extent in which they correctly perceive and interpret visual information. Visual perception is not just about how much people see clearly or about the state of their eyesight, but how the brain understands and uses visual information (Marschark, 2003). In the adult deaf, who communicate using the sign language, it has been found that they exhibit better performance in certain visual tasks (rapidly shifting attention, visual detection of motion and sign language) than the deaf adults and hearing people who use the proper spoken language. In children, these benefits were not found (Marschark, 2003). The visual attention of deaf and hard of hearing students has been examined by a number of researchers and the results were not consistent. Some of them say that the children with hearing impairment have a deficit of visual perception, while the others found that there are no differences. Smith, Quittner, Osberger, and Miyamoto (1998) and Quittner, Leibach & Marciel (2004) found the difficulties in visual selection. Radoman (1996) reports that hearing loss can affect certain aspects of visual perception, such as: the speed of perception, the distinction of the shape of the object if they are similar or if they are in an unusual position. On the other side, the same author reports that the visual perception of the deaf and hard of hearing is full of details and that they notice physiognomy, gestures, facial expressions, body position and color better than others.

Fine motor coordination

Fine motor coordination develops in consistent and predictable patterns, beginning in early months and continuing until the middle of primary school (Exner, 2001). Children start to use they fingers and hands to explore the world around them in more complex ways and during the preschool period become more familiar with using typical "school" materials, such as pencils, crayons, scissors, glue etc. On the one hand, several studies show that deaf children achieve lower results in motor coordination, balance, visual-motor skills, but also in reaction time and movement speed (Karić & Radovanović, 1999; Savelsbergh, Netelenbos & Whiting, 1991; Siegel, Marchetti & Tecklin, 1991). On the other hand, several studies have found no differences in motor coordination between deaf and typically developing children (Horn et al., 2007), and these differences are associated more with the environmental factors such as the type of schooling, parental engagement and stimulation and supportive environment (Lieberman, Volding & Winnick, 2004).

The connection between motor and cognitive development is very complex. It starts in early childhood and continues into the early adulthood (Diamond, 2000). Some aspects of cognitive performance, including executive functions, are developed from the age of five to ten, while during the same period a rapid progress of motor functions is recorded, including visual-motor coordination (Ferrel-Chapus, Hay, Olivier, Bard & Fleury, 2002). In spite of mentioned correlation, just a few studies confirm that, but researchers confirm the role of attention in motor skills (Baron, 2004; Lezak, Howieson & Loring, 2004). In spite of the relationship between cognitive and motor functions described by researchers, there are only few experimental studies which has confirmed this connection. Researchers agree that cognitive and motor functions are affected by attention (Baron, 2004; Lezak, Howieson & Loring, 2004).

OBJECTIVE

The objectives of this research are to investigate the influence of age on the development of visual-motor integration, visual perception and fine motor coordination. Besides, we investigated factors affecting visual-motor integration, visual perception and motor coordination development (sex, the degree of hearing loss, amplification model, communication mode and parental educational level).

MATERIALS AND METHODS

Sample

The study sample consisted of 40 prelingual deaf and hard of hearing children with audiologic treatment on Department of Audiology, ORL and MFH Clinic, Clinical Center of Serbia. According to the age, the sample was divided into three groups, the first from the age of 4y- 4y11m, 13 children (32.5%), the second from the age of 5y-5y11m, 18 children (45%), and the third from the age of 6y- 6y11m, 9 children (22.5%). The sex structure of the sample consisted of 22 (55%) boys and 18 (45%) girls. According to the degree of hearing loss, the sample was divided into two groups: the first – mild to moderate hearing loss, 22 children (55%), and the second – severe and profound hearing loss, 18 children (45%). The results of the Chi-square test showed there were no significant differences between groups, for age ($\chi2=3.050$, $p=0.218$), for sex ($\chi2=0.400$, $p=0.527$) and for the degree of hearing loss ($\chi2=0.400$, $p=0.527$). According to the amplification model, the sample consisted of 17 (42.5%) children with cochlear implants, 7 (17.5%) children with one hearing aid, 7 (17.5%) children with bimodal amplification and 9 (22.5%) children with two hearing aids. According to the model of communication, the sample consisted of 29 (72.5%) children being able to communicate in oral form and 11 (27.5%) children who use sign language to communicate with their environment. The results of the Chi-square test showed there was a significant difference in respect to the model of communication ($\chi2=8,100$, $p=0,004$). According to the parental educational level, it has been shown that fathers (31, 77.5%) and mothers (24, 60%) frequently have middle school degree, in comparision with 9 (22.5%) fathers and 16 (40%) mothers who have high school degree. The children with intellectual disabilities or additional sensory or motor impairments were not included in this sample. All the children were enrolled in early rehabilitation programs focused on language, speech and auditory development.

Research Techniques and Instruments

In this research the battery of tests were used to collect necessary information: 1. *Visual-Motor Functioning Test*; 2. *Visual Perception Test*; 3. *Motor Coordination Test* – VMI 6th Edition, Beery & Beery, 2010.

The short form of the Beery Visual Integration Test is designed for use with most children aged 2 to 7, which presents combined tasks from the Visual Perception Test and the Motor Coordination Test. It contains 15 figures, including the initial three that are both imitated and copied directly, and three types of marking or scribbling, for a total of 21 scored items. In this test, geometric shapes are arranged in a developmental order, from the simplest to the most difficult shape in order to evaluate the visual-motor integrity.

The Visual Perception Test covers visual perception skills such as: visual discrimination, matching, classification, figure-ground differentiation, spatial relationship and visual memory. It contains 30 shapes and one point is awarded for each correct items are scored or the 3 minute time limit expires, whichever comes first. A maximum of 30 points can be earned.

The Motor Coordination test (the Fine Motor Coordination Test) covers motor skills including hand-eye coordination and it contains 30 shapes. The child is asked to copy the shape on the test booklet in the given order and the test is ended when the child fails to copy three shapes consecutively. A maximum of 30 points can be earned.

The testing was administered individually at a silent and independent room in the surrounding familiar to the children in the Department of Audiology. The test was evaluated according to the evaluation orders given in the manual (Beery, & Beery, 2010). The visual-motor integration, visual perception and motor coordination test scores were acquired for each child.

Data analysis

Frequencies, central tendency, standard deviation measures of variability and parametric tests, t-test and ANOVA test and nonparametric Chi-squred test were used for the analysis of the obtained results. The relationships between the Beery VMI, Visual Perception, Fine Motor Coordination test and parental educational level were calculated by using the Pearson correlation coefficient. In order to gain a better understanding of the development of visual-motor integration and assessing relative visual and motor contributions to the Beery VMI performance, we performed a regression analysis.

RESULTS AND DISCUSSION

Table 1 shows the achievement on visual-motor integration, visual perception and fine motor coordination tests.

Table 1 *Children Performance in Relation to Age*

Test	Visual-motor integration				
Age	N	M	SD	F	p
4y– 4y11m	13	81.38	12.90		
5y – 5y11m	18	86.94	11.29	1.577	0.220
6y – 6y11m	9	90.44	13.00		
Test	Visual perception				
Age	N	M	SD	F	p
4y – 4y11m	13	85.69	7.05		
5y – 5y11m	18	99.2	9.26	25.316	0.001
6y – 6y11m	9	109.89	6.27		
Test	Fine motor coordination				
Age	N	M	SD	F	p
4y – 4y11m	13	87	11.56		
5y – 5y11m	18	92.11	8.85	1.421	0.254
6y – 6y11m	9	94.11	12.18		

The results of our research show that the level of visual-motor integration, visual perception and fine motor coordination increased with increasing age of children, children under the age of 6y to 6y11m had the highest test scores. As they advance in age, children show the progress in sensorimotor development, as the test results in Table 1 show. A statistically significant difference in achievement on the test occurs only on the Visual Perception Test (F=25.316; p=0.001). The post-hoc test showed statistically significant differences for each age group.

Kutz, Wright, Krull & Manolidis (2003) used Mullen Scales of Early Learning to assess language, motor and perceptual abilities between 18 children with profound hearing loss, cochlear implants candidates. They found that there was the negative correlation between age and test scores. The negative relationship between age and fine motor development was found among 22 prelingual deaf babies and children (Horn, Pisoni & Miyamoto, 2006). In conclusion, authors highlight the relationship between motor and language development, and a fact that auditory deprivation may lead to the atypical development of certain motor and language skills, that share common cortical processes. The results of a research carried out on a sample of 104 typically developed children show that there are no significant differences in visual-motor functions skills in respect to the age (Krstić, Dukić & Kovačević, 2010). Other studies show the opposite results and researches have consistently identified significant correlations between age and visual-motor skills. Thus, the study carried out among largest sample, aged 6y – 14y11m, found mentioned correlations and the greatest progress was found in those aged eight to fifteen. The period of two months was found to be the key period for achievement in eight-year-old children, whereas in children over eight, significant difference was noticed in period of two years (Tekok-Kiliç et al., 2010). In a study which was carried out among 276 tipically developed children comparisons were made for all of the four age groups and each showed statistically significant differences on visual-motor and fine motor coordination tests (Memišević & Hadžić, 2013).

Kephart (Kephart, 1960, according to Beery & Beery, 2010) noted that children could have well-developed visual and motor skills but be unable to integrate the two. We were interested in the intercorrelation between visual, motor and visual-motor test performance, and the results are shown in Table 2:

Table 2 *Intercorrelation of applied tests*

	Visual perception/ Fine motor coordination	Visual perception/ Visual-motor integration	Fine motor coordination/ Visual-motor integration
R	0.119	0.365	0.355
P	0.463	0.021	0.025

The low correlation has been found between the Visual Perception Test and the Visual-Motor Integration Test, and between the Visual-Motor Integration and Fine Motor Coordination tests. Beery & Beery (2010) noted that visual-motor integration is not the sum of visual perception and motor coordination, the visual-motor integration can be greater than the sum of its parts and the parts can independently function well but not in combination. The same authors noted that it is important to know that the development of visual-motor integration may not always be smooth; in some cases progress is sharp and may even involve temporary regressions.

The result of regression analysis showed that visual perception and fine motor coordination explained 23 percent of the variance in visual-motor integration (Table 3).

Table 3 *Regression Analysis Summary for Visual Perception and Fine Motor Coordination Predicting Visual-Motor Integration*

	B	B	t	p
Visual perception	0.338	0.327	2.254	0.030
Fine motor coordination	0.367	0.316	2.175	0.036

Futhermore, we were interested in test scores below the average range (< 1 SD to <2 – borderline and < 2 SD – impairment), and the results are shown in Table 4:

Table 4 *Children's scores lower than the average*

	Visual perception		Fine motor coordination		Visual-motor integration	
	F	%	f	%	f	%
1 SD, < 1 SD	6	15.0	8	20.0	9	22.5
2 SD, < 2 SD	/	/	2	5.0	6	15.0

The deviating of 2 SD or more than 2 SD has been found in six children on the Visual-Motor Integration Test and in two children on the Fine Motor Coordination Test. The deviating of two standard deviations indicates the existence of hindrances in these areas. The obtained results clearly indicate that these children should be included in the programmes for the stimulation of the development of visual-motor integration.

Table 5 shows test scores in relation to sex:

Table 5 *Test scores in relation to sex*

Test	Visual-motor integration				
Sex	N	AS	SD	T	P
Male	22	84.59	11.95	0.748	0.459
Female	18	87.56	13.06		
Test	Visual perception				
Sex	N	AS	SD	T	P
Male	22	97	11.82	0.129	0.898
Female	18	97.5	12.55		
Test	Fine motor coordination				
Sex	N	AS	SD	T	P
Male	22	91.91	9.73	0.656	0.516
Female	18	89.67	11.89		

Considering that girls spend more time in drawing than boys and that there are other sex differences in maturation during childhood, we expected to find differences on test scores. However, average scores of girls and boys were about the same. The results indicate there were no significant differences on any of the three tests. Our findings are similar to the other studies which have been carried out on a sample of preschool or lower school children where significant difference in visual-motor integration between boys and girls have not been founded (Coetzee &Du Plessis, 2013; Tekok-Kiliç, Elmastaş-Dīkeç & Can, 2010).

Table 6 shows the results in relation to the degree of hearing loss:

Test			Visual-motor integration		
Hearing loss	N	AS	SD	T	P
Mild to moderate	22	87.18	13.31	0.704	0.485
Severe to profound	18	84.39	11.36		
Test			Visual perception		
Hearing loss	N	AS	SD	T	P
Mild to moderate	22	96.82	13.74	-0.234	0.816
Severe to profound	18	97.72	9.83		
Test			Fine motor coordination		
Hearing loss	N	AS	SD	T	P
Mild to moderate	22	92.18	11.53	0.836	0.408
Severe to profound	18	89.33	9.62		

The variance analysis has showed that there are no statistically significant differences in achievement on tests in relation to the degree of hearing loss. Research results (Gkouvatzi, Mantis & Kambas, 2010) have showed that there are no significant differences in visual-motor integration between deaf and hard of hearing students. By consulting literature, we can conclude that researchers' focus is not directed to examining influences of the degree of hearing loss on the quality of visual-motor integration, but to the comparison with typically developing children (Dodd, Woodhouse & McIntosh, 1992; Horn et al., 2007; Lotz et al., 1986; Spencer & Delk, 1989).

The researchers were interested in influence of the cochlear implant to the quality of visual-motor integration rather than the influence of the degree of hearing loss.

Table 7 shows the results of students in relation to the model of amplification:

Table 7 *Test scores in relation to model amplification*

Test			Visual-motor integration		
Model of amplification	N	AS	SD	F	p
Cochlear implant	17	87.47	14.91	0.401	0.753
Hearing aid	7	87.14	10.90		
Cochlear implant and hearing aid	7	81.43	11.35		
Two hearing aids	9	85.56	9.69		
Test			Visual perception		
Model of amplification	N	AS	SD	F	p
Cochlear implant	17	94.12	14.26	1.552	0.218
Hearing aid	7	102.43	7.91		
Cochlear implant and hearing aid	7	93.57	8.63		
Two hearing aids	9	101.89	10.565		
Test			Fine motor coordination		
Model of amplification	N	AS	SD	F	p
Cochlear implant	17	93.18	11.48	0.497	0.686
Hearing aid	7	87.71	11.61		
Cochlear implant and hearing aid	7	90.14	8.45		
Two hearing aids	9	89.67	10.71		

Our study did not find evidence supporting an association of the model of amplification with test scores concerning visual-motor integration, fine motor coordination and visual perception. The children with cochlear implant showed greater performance only on the fine motor coordination test, compared to the children with other models of amplification. Tiber (1985) investigated visual-motor integration skills of prelingually deaf children from 2.5 to 17 years of age, six months before implantation, and six months after implantation. He found out that prelingually deaf children were lagging behind their hearing peers for 1.5 years, but after implantation he noticed a rapid progress. A study (Schlumberger, Narbona & Manrique, 2004) among the sample that consisted of three different populations from 7 to 9 years of age, they being normal hearing children, the profoundly deaf with the cochlear implant and the profoundly deaf children with hearing aids, found out that all the three groups performed similarly on simple motor tasks across all ages. However, the profoundly deaf children with cochlear implant or hearing aids reported lower levels on complex motor tasks compared to their normal hearing peers. The results of these studies indicate that children who received a cochlear implant at an earlier age tended to have higher visual-motor integration scores. The authors (Horn et al., 2007) found a strong relationship between visual-motor and language skills in deaf children before and after implantation, and based on those findings, they concluded that figure copying tasks can be used clinically to predict benefit from cochlear implantation.

Table 8 shows test scores in relation to a mode of communication (spoken or signed language):

Table 8 *Test scores in relation to a mode of communication*

Test	Visual-motor integration				
Mode of comm.	N	AS	SD	t	p
Spoken language	29	86.17	12.818	0.202	0.841
Signed language	11	85.27	11.765		
Test	Visual perception				
Mode of comm.	N	AS	SD	t	p
Spoken language	29	97.21	12.932	0.015	0.988
Signed language	11	97.27	9.655		
Test	Fine motor coordination				
Mode of comm.	N	AS	SD	t	p
Spoken language	29	90.52	11.513	0.718	0.302
Signed language	11	91.91	8.467		

Both groups of children achieved similar average test scores, whether they used spoken language or sign language. In a study (Hauser, Cohen, Dye & Bavelier, 2005) that examined visual-motor and visual constructive skills by comparing the performance of deaf native singers to that of hearing non-singers (average age 20 years), the researchers did not find a significant difference between these two groups. The results of longitudinal researchs showed that perceptual-motor development is closely related to the early preparation for language development and to speech and language development at a later age, as reported by Locke et al. (Locke, Bekken, McMinn-Larson & Wein, 1995). In addition, the results could be brought in connection with the model of communication, because some studies have proven that there is a high correlation between reading and writing skills, as well as between academic achievement and achievement on tests of figures copying, in deaf and hard of hearing children who use sign language (Hauser et al., 2007).

To determine the correlation between test scores and parental educational level we used Perason correlation, and the results are shown in Table 9:

Table 9 *The correlation between test scores and parents' educational level*

Parental educational level	Test					
	Visual-motor integration		Fine motor coordination		Visual perception	
	r	p	r	p	r	p
Father	0.365	0.021	0.232	0.149	0.232	0.149
Mother	0.009	0.955	0.002	0.991	0.105	0.519

The only statistically significant correlation was found between fathers' educational level and visual-motor test scores (r=0.365; p=0.021), where correlation coefficient of 0.3 is considered as low positive correlation. One earlier study has found no significant correlation between three outcome measures and parental educational level (Goyen, Lui & Woods, 1998). In a study (Ercan, 2011) which examined visual-motor integration skills, visual perception skills and fine motor coordination skills of tipically developed 60- to 72-month-old children in relation to low and high socioecomic status, no statistically significant differences were found. Numerous researchers have found high correlations between academic abilities and visual-motor integration in children, as well as the high correlation between academic achievement and parental educational level, so we expected to find mentioned correlations. The children in our study were pre-school children and their parents had not been fully involved in their activities yet, and this could be a possible reason why we did not find expected correlations.

CONCLUSION

As they advance in age, children show the progress in visual-motor integration, visual perception and fine motor coordination, as the test results show. But, we did not find any significant difference between the three age groups. Given these results, we would be inclined to say there are specificies in visual-motor development between deaf and hard of hearing children, but for generalization a larger sample would be needed and a control group of typically developing children.

Our sample consisted of children who began audiologic and speech-language rehabilitation immediately after the diagnosis of hearing impairment. No statistically significant differences between the children with different levels of hearing loss confirm the efficacy of an early rehabilitation and its role in detecting, preventing and overcoming delays in visual-motor integration performance. The high values of standard deviations in all three tests indicate the high individual differences, as well as the importance of individualized rehabilitation training programs for all deaf and hard of hearing children, especially in the preschool period.

The consideration of environmental factors which can affect the examined skills presents another limitation of our study (we only examined the influence of parental educational level). Environmental factors, first of all stimulating environment, have a beneficial effect on visual-motor integration (Oliver, 1990; Dankert, Davies & Gavin, 2003), which we suggest for further research.

Usually the visual-motor disabilities are not recognized until starting school. The problems with writing, drawing/colouring and use of school materials may be the first signs that there is a problem. There is a lot of activities to improve visual-motor integration skills: drawing on small or large areas, colouring, paper-cutting, stacking blocks and practicing everyday activities such as buttoning, tying shoelaces, folding clothes etc. Besides activities mentioned above, many educational computer games have been designed to improve visual perception and visual-motor integration (Radovanović, Radić-Šestić, Karić & Milanović-Dobrota, 2013).

The research results confirm the importance of visual-motor integration in the development of skills such as tracing, writing, handwriting, reading, math skills, and overall academic achievement in studies that included a sample of children with typical development (Maeland, 1992; Goldstein, Britt, 1994; Taylor, 1999; Sortor et al., 2003) and children with disabilities (Feagan, Merriwether, 1990; Maeland, 1992). Moreover, the research results confirmed that visual-motor integration is a good predictor of academic achievement and that might be the promising area for future research among deaf and hard of hearing preschoolers.

The research in the assessment of visual-motor integration, visual perception and motor coordination has practical and empirical applications, since the identification of problems in these areas is important to prevent or minimize risks in other areas, to recognize the causal factors and to find a good strategies for overcoming the difficulties.

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