RELATIONSHIP BETWEEN STEREOACUITY AND MOTOR SKILLS OF CHILDREN WITH INTELLECTUAL DISABILITIES

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Abstract: *The goal of this study was to determine the relationship between stereoacuity and proficiency in fine and gross motor skills. Stereovision is one of the information sources for accurate perception of objects in depth, and it is related to performance on motor skills tasks. Studies have shown that children of primary school age with mild intellectual disabilities perform worse than typically developing children on specific fine and gross motor skills. Also, problems in visual functioning, including impaired binocular vision (stereovision), are common in children with intellectual disability. We tested 27 children with intellectual disabilities but without any motor skills deficiency. Research was conducted at the Centre for Education "Velika Gorica" and Elementary School "Nad lipom". For this research, we constructed a Likert-type scale to assess fine and gross motor proficiency. We also tested stereoacuity using the Random Dot 2 Acuity Test with Lea Symbols®. Our results show a relationship between the degree of stereovision and level of proficiency in fine and gross motor skills.*

Since stereovision develops during preschool years and is related to other skills, we need to provide timely assessment of visual functioning and create specific program adaptations for children with intellectual disabilities.

Keywords: *stereoacuity, children with intellectual disabilities, fine motor skills, gross motor skills*

INTRODUCTION

When we reach for an object, it is critical that we estimate the distance to that object accurately. If our estimation is imprecise, our interaction will become strained and take attention away from the primary task (Arsenault & Ware, 2004). Stereovision is the ability to derive information about the distance of an object from the relative positions of the object in the two eyes (Read, 2015). Stereoscopic depth is the information we gain from disparities or differences in relative separation between pairs of image features in the two eyes (Arsenault & Ware, 2004). This positional difference results from the fact that the two eyes are laterally separated and therefore see the world from two slightly different vantage points (Qian, 1997). Stereo is a very strong cue for estimation of relative depth of nearby objects that are nearly equidistant from us, but it is a poor cue for estimation of large depth differences (Arsenault & Ware, 2004). Stereovision depends upon good vision in both eyes, excellent oculomotor control and cortical mechanisms for sensory fusion and it is regarded as the gold standard for binocular visual function (Read, 2015).

Both children and adults with impaired stereovision perform worse on a range of visuomotor tasks than their peers with normal stereoacuity (Fielder et al, 1996; Hrisos et al., 2006; Murdoch et al., 1991; O'Connor et al., 2010). Poor stereovision is a characteristic of people with amblyopia (Greenwood et al., 2015). Problems in stereovision can be associated with reduced motor skills, both in children and adults (Hrisos, 2006; O'Connor 2010; Webber 2008).

Stereovision maturation proceeds rapidly during the first year of life. Most studies agree that stereovision has an abrupt onset at approximately 3 months of age, and that there is a rapid period of maturation during months 4-12 (Birch & Wang, 2009; Fawcett et al., 2005). Furthermore, stereovision continues to improve up to the age of 10 years

(Read, 2015). According to Fawcett et al. (2005), studies indicate that the critical period for susceptibility of stereovision overlaps with the critical period for development.

Some vision impairments affect stereovision. According to Read (2015), early strabismus has a profoundly damaging effect on stereovision. Infantile esotropia is associated with an increased risk of amblyopia and abnormal binocular sensory function (Birch & Wang, 2009). Rogers et al. (1982) noted post-surgical improvement in binocular-dependent motor skills in 35% of children, as well as post-surgical correction of infantile esotropia and an increase in visually directed reaching and grasping in 41% of children. Some abnormalities in stereovision may exist before the onset of esotropia, but others may result directly from abnormal binocular experience (Birch & Wang, 2009). Caputo et al. (2007) found that children with strabismus performed worse than age-matched control subjects on the subscale that assessed manual dexterity. Many persons with amblyopia have little or no stereovision (Fielder et al., 1996). In an investigation of the functional impact of amblyopia in children, fine motor skills performance was worse in children with reduced stereoacuity than in children with normal stereoacuity and those with no measurable stereovision (Webber et al., 2008). In people with amblyopia but no strabismus, stereovision has been found to influence the performance on visual motor integration tasks (Webber et al., 2008).

While stereovision is a uniquely binocular phenomenon, its functional benefits have been largely neglected (Fielder and Moseley, 1996). According to Mazyn et al. (2007), stereovision gives important information for accurate perception of objects in depth, and it becomes increasingly important as the object approaches the "action space" of the individual. Whether stereovision is essential in daily activities has been rarely documented so far, but stereovision might support activities such as participation in ball sports or orientation in traffic situations (Mazyn et al., 2007). The results of a study by Fielder & Mosley (1996) indicate that binocularity appears to be an advantage in certain tasks, including near-distance tasks, comprehension of complex visual presentations, and tasks requiring complex hand-eye coordination. Moreover, O'Connor et al. (2010) found that stereoacuity is related with performance on motor skills tasks, with subjects who have normal stereoacuity performing the best on all the tests.

Webber et al. (2006) tried to evaluate the fine motor skills in amblyopic children with age-matched controls. The results of their study showed that amblyopic children performed significantly poorer than age-matched control children on 15 of 16 fine motor skills sub-items. Moreover, stereoacuity was significantly lower in the children with amblyopia than in the controls. The underlying aetiology of amblyopia and the level of stereoacuity significantly affected fine motor skill performance on both items (Webber et al, 2006).

Vision plays a key role in the control of natural prehensive movements (Watt & Bradshaw, 2003). Mazyn et al. (2004) tried to examine both monocular and binocular performance in a natural catching task in people with good and weak stereovision. The results of their study suggested that people with poor stereovision do not adapt to their lack of stereovision by developing compensatory mechanisms. Furthermore, kinematic analysis of unrestricted natural catching movements revealed differences in the coefficient of straightness and grasping dynamics between participants with poor or good stereovision. Moreover, the study suggests that poor stereovision is disadvantageous not primarily in daily life but in highly temporally constrained situations, such as fast ball games (Mazyn et al, 2004). Another study by Mazyn et al. (2007) aimed to investigate the contribution of stereovision to the acquisition of a natural interception task. The results of that study indicate that the development and use of compensatory cues for depth perception is insufficient for dealing successfully with interceptions under high temporal constraints in the presence of weak stereovision (Mazyn et al., 2007).

Individuals with intellectual disabilities (ID) have limitations in developmental skills in several domains of functioning including cognitive, motor, auditory, language, psychosocial, moral judgment and specific integrative activities of daily living (Vuijk et.al, 2010, according to Pratt & Greydanus, 2007). The results of the Vuijk et al. study (2010) have shown an association between degree of ID and motor performance, specifically the performance of manual dexterity, ball skills and balance skills. Another study, by Westendorp et al. (2011), has shown that children of primary school age with borderline or mild ID perform worse than typically developing children on almost all specific gross motor skills. Moreover, visual anomalies are common in children with ID (Cui et al., 2006) and in people with severe and profound multiple disabilities (van der Broek et al., 2006).

OBJECTIVES

Studies have shown that both children and adults with impaired stereovision perform worse on a range of visuomotor tasks than their peers with normal stereovision (Fielder et al, 1996; Hrisos et al., 2006; Murdoch et al., 1991; O'Connor et al., 2010). In all motor skill tasks, the performance of those with normal stereoacuity was reduced under monocular conditions, which means that stereoacuity plays a significant role in motor skills tasks (O'Connor et al., 2010). Levels of motor and cognitive functioning are related in children with ID (Vuijk et al., 2010; Westendorp et al., 2011). Warbug (2001) has found that prevalence of visual impairment is very high in adults with ID. Van den Broek et al. (2006) have found a correlation between visual functioning and severity of ID, including impaired binocular vision (stereovision).

Based on the results of this and other studies, the goal of the present research was to determine the relationship between stereovision and the level of proficiency in 1) gross motor skills and 2) proficiency in some elements (i.e. manual dexterity) of fine motor skills in children with ID.

HYPOTHESES

According to the objectives of the research, we defined the following hypotheses:

H1: There is a statistically significant correlation between stereoacuity and level of proficiency in gross motor skills

H2: There is a statistically significant correlation between stereoacuity and level of fine manual dexterity.

METHOD

Participants

For the purpose of this study we formed a convenience sample of children with ID that we could reach in schools and for whom reports were available from other experts (psychologists, physiotherapists, medical professionals). We tested 27 children with mild ID, without any motor skills deficiency, and with no visual impairment based on these previous reports. Research was conducted at the Centre for Education "Velika Gorica" and Elementary School "Nad lipom". We had more male (70%) than female (30%) participants. Median age was 11 years (SD = 1.26), which is important to consider because stereovision continues to mature until up to the age of 10 years (Read, 2015).

Measuring instruments

Random Dot 2 Acuity Test with Lea Symbols®

We chose the *Random Dot 2 Acuity Test with Lea Symbols®* to test stereoacuity because the children in our study were already familiar with Lea symbols from earlier testing. We also chose this test because children do not have to name the symbols; they can simply indicate the symbol on a template, meaning that we could test even children with problems in verbal communication if necessary. We selected this test also because it avoids the monocular cues that can occur in stereotests involving stereo glasses (Read JCA, 2015). Monocular cues, according to Fawcett (2005), give false-positive results in patients. The results of the *Random Dot 2 Acuity Test* are expressed as seconds of arc.

Likert-type scale to assess fine and gross motor proficiency

For this research, we constructed a Likert-type scale to assess fine and gross motor proficiency. The scale has two sections: a section for assessment of fine motor proficiency, and a section for assessment of gross motor proficiency. We created one task for assessing motor skills on each scale. Since all children attended a school program involving many graphomotor tasks, we were interested in the relationship between stereoacuity and performance on such a task. Therefore, the task for assessing fine motor proficiency was *colouring between the lines of the default shape,* and the task for assessing gross motor proficiency was *hitting a ball* several times. All of the children were able to complete each task. Nevertheless, we did not rate children on their task completion but on proficiency (smoothness) of task execution. Proficiency was observed and rated for each task on a scale from 1 to 5, where 1 indicated very poor proficiency; 2, poor proficiency; 3, proficiency; 4, good proficiency; and 5, very good proficiency.

Procedure

Prior to the beginning of the research, we obtained informed consent from parents for their children to participate. Each student was informed about the testing and tasks they had to do, and they were allowed to quit the activity whenever they wanted to. Testing was conducted individually, in a separate room or gym room where gross motor tasks could be assessed. Furthermore, testing was completed within 30 min to avoid decreases in attention and concentration.

The performance of tasks was observed by two independent observers: the child's teacher and a researcher. Only task executions in which both observers assigned the same proficiency rating were included in further analysis.

Data analysis

Obtained data were analysed using descriptive statistics available in the Statistical Package for the Social Sciences (SPSS). Since we had a very small sample and the variables were not normally distributed, we used Spearman's rank-order correlation to assess the significance of the relationship between stereoacuity and motor skills. Given the small number of participants in this study, we also used qualitative data analysis based on case study and phenomenology methodology.

RESULTS

The results of our study showed a statistically significant correlation of stereoacuity with level of proficiency in fine motor skills (r_s=0.464; p=0.01) and proficiency in gross motor skills (r_s=0.629; p=0.000) in children with ID. As we can see in Table 1, only 7 participants had good stereoacuity results. Well-developed stereoacuity in children older than 11 years of age should be below 40 seconds of arc (Birch et al. 2009). Based on this criterion, 20 participants had poor stereoacuity, 17 had low stereoacuity, and 1 had no stereovision at all (probably because of exophoria). We were unable to measure stereoacuity in 2 children, perhaps because they did not see any symbol or because they did not understand the task.

Table 1. *Stereoacuity test results*

Stereoacuity result	**N**
12,5″	4
25″	1
32″	1
40″	1
63″	3
100″	2
125″	2
160″	1
200″	2
250″	2
400″	3
500″	2
No stereovision	1
Unable to measure	2
Total	**27**

Fine motor proficiency task results (*colouring between the lines of the default shape*), as presented in Figure 1, showed that participants were proficient and had good skills. One child had very poor proficiency in colouring the shape, and his stereovision was impossible to measure. Four participants had low proficiency, 9 of them were proficient and 12 had good proficiency. One male participant was very good at colouring and he obtained a very good result on the stereoacuity test (25 sec of arc).

The task for assessing gross motor proficiency was *hitting a ball.* In this task, 2 participants had very low proficiency, 5 had low proficiency and 11 were proficient, as presented in Figure 2. Four participants had good proficiency and 5 had very good proficiency. Children who had very low or low proficiency on the gross motor task also had poor stereoacuity.

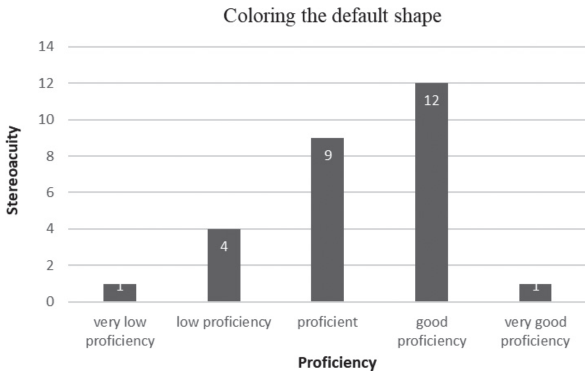

Figure 1. *Results on the "colouring the default shape" task*

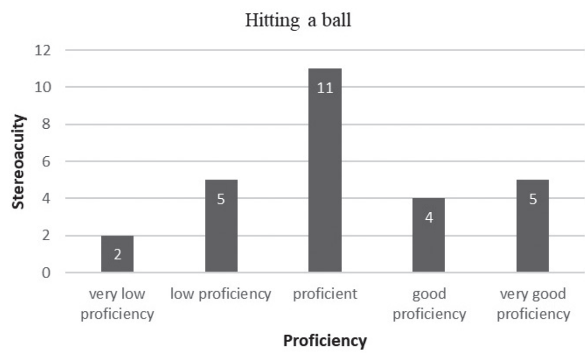

Figure 2. *Results on the "hitting a ball" task*

DISCUSSION

The results of our study have shown that there is a statistically significant correlation between stereoacuity and level of proficiency in fine and gross motor skills in children with ID. Although all our participants were able to complete the fine motor proficiency task, it was interesting to compare children with poor or good stereovision in terms of their task proficiency as well as their drawings. It was especially interesting to analyse the results of the boy who had no measurable stereovision. His colouring was incomplete, crossing the line of the shape and with no adequate colour filling. Therefore, we can conclude that in our children with mild ID, as in typically developing children, losing binocular vision causes problems such as misjudging distances and problems with hand-eye coordination (Fielder & Moseley, 1996; Barry, 2006, O'Connor et al., 2010). This is also supported by study findings that people with no stereovision have difficulties in manual dexterity tasks (Murdoch et al., 1991, Webber et al., 2001).

O'Connor et al. (2010) found that performance on motor skill tasks is associated with reduced stereoacuity, and study results support the need for treatment that will optimise the chances for the development of stereoacuity. Furthermore, adequate levels of motor skills may contribute to lifelong enjoyment of physical activity, participation in sports and healthy lifestyles (Vuijk et al., 2010). Although we did not assess catching a ball, it was impossible not to notice that children with mild ID in our study had problems in estimating the distance of the ball approaching them; therefore they had problems in physical and sports activities. This is in accordance to the results of Mazyn et al. (2004) showing that weak stereovision negatively affects interceptive performance. Nevertheless, there was one boy in our study who had weak stereoacuity but great performance in the gross motor task. However, he might have learned to use monocular cues (and other information sources) to be more effective than other participants with weak stereovision. Therefore, we should also analyse his performance in other aspects of visual functioning in order to reach a definitive conclusion.

As we mentioned before, children with ID perform worse than typically developing children on manual dexterity tasks and in ball activities (Vuijk et. al, 2010), as well as in specific gross motor skills (Westendor et al, 2011). Stereovision is related to motor skill performance (O'Connor et al, 2010). Our results have shown a relationship between stereoacuity and fine and gross motor proficiency in children with ID. However, that does not mean that poor stereovision is the cause of poor motor performance. Perhaps poor stereovision, ID and poor motor skills have the same cause. This is something that has yet to be found out.

According to previous study findings, problems in visual functioning are common in children with ID (Cui et al., 2006), and there is a correlation between visual functioning and the severity of ID, including impaired binocular vision - stereovision (Van den Broek et al., 2006). Hence, we should also test the relationship between stereovision and motor proficiency in children with different levels of ID. These studies should include a larger number of children and more than two activities.

Moreover, although we had two independent observers during testing of fine and gross motor proficiency, one of them was familiar with the children and potentially more biased. Therefore, children's performance on tasks should be recorded with a camera for further analysis in order to allow more objective assessment.

Since stereovision is associated with improved long-term quality of life, including self-image, self-confidence and success in school and sports (Birch et Wang, 2010), we hope this research will encourage new studies about the functional impact of stereovision in everyday life of children with ID. We hope this work will also stimulate development of vision therapy programmes for children with ID, such as optometric eye exercises for stereovision improvement, since some examples of using this kind of therapy have shown improvement in stereovision. One example is Sue Barry, who lost her binocular vision in childhood because of strabismus and who as an adult regained depth perception-stereovision after working with an optometrist and undergoing vision therapy (Sacks, 2006; Barry, 2006). It would be interesting to investigate the causal relationship between stereoacuity and motor skills in children with ID by including younger children and conducting a longitudinal study.

CONCLUSION

The goals of this research were to determine the relationship between stereovision and level of proficiency in gross motor skills, as well as the relationship between stereovision and proficiency in fine motor skills in children with ID. The results of our study show that there is a statistically significant correlation between the degree of stereovision development and level of proficiency in fine and gross motor skills in children with mild ID. However, this study featured a small and unrepresentative sample of children with ID, with imbalance between proportions of female and male participants, and it involved only two tasks for assessing motor skills. Therefore, it may not be possible to generalise our results to the entire population of children with mild ID.

Nevertheless, our results are consistent with the idea that the best time for exercising stereovision is in the early years of life, and that children with ID should be targeted for assessment of functional vision early in life in order to start with vision therapy during the sensitive period of binocular vision development, which could prevent further problems related to poor stereovision.

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POVEZANOST STEREOVIDA I MOTORIČKIH VJEŠTINA U DJECE S INTELEKTUALNIM TEŠKOĆAMA

Sažetak: *Cilj ovog istraživanja bio je utvrditi postoji li povezanost između stupnja razvoja stereovida i spretnosti u gruboj te finoj motorici. Stereovid je jedan od izvora informacija za točnu procjenu percepcije objekata u dubini i povezan je s izvođenjem motoričkih aktivnosti. Rezultati istraživanja pokazali su da su djeca s lakim intelektualnim teškoćama osnovnoškolske dobi lošija u izvođenju motoričkih aktivnosti nego djeca tipičnog razvoja. Također, vizualna odstupanja učestala su kod djece s intelektualnim teškoćama, uključujući i oslabljen binokularni vid (stereovid). Testirali smo 27-ero djece s intelektualnim teškoćama, bez motoričkih teškoća. Istraživanje je provedeno u Centru za odgoj i obrazovanje "Velika Gorica" i Osnovnoj školi "Nad lipom". Za potrebe ovog istraživanja, konstruirali smo skalu Likertovog tipa za procjenu spretnosti u finoj te gruboj motorici. Također, testirali smo i stereovid koristeći stereotest Random Dot 2 Acuity Test with Lea Symbols®. Rezultati su pokazali postojanje povezanosti između stupnja razvoja stereovida i spretnosti u finoj te gruboj motorici. Budući da se stereovid razvija u predškolskoj dobi i povezan je s razvojem drugih vještina, nužno je osigurati pravovremenu procjenu vizualnog funkcioniranja i u skladu s tim, kreirati specifične programe za djecu s intelektualnim teškoćama.*

Ključne riječi: *stereovid, djeca s intelektualnim teškoćama, fina motorika, gruba motorika*