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Stimulation of Functional Vision in Children with Perinatal Brain Damage

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ABSTRACT

Cerebral visual impairment (CVI) is one of the most common causes of bilateral visual loss, which frequently occurs due to perinatal brain injury. Vision in early life has great impact on acquisition of basic comprehensions which are fundamental for further development. Therefore, early detection of visual problems and early intervention is necessary. The aim of the present study is to determine specific visual functioning of children with perinatal brain damage and the influence of visual stimulation on development of functional vision at early age of life. We initially assessed 30 children with perinatal brain damage up to 3 years of age, who were reffered to our pediatric low vision cabinet in »Little house« from child neurologists, ophthalmologists Type and degree of visual impairment was determined according to functional vision assessment of each child. On the bases of those assessments different kind of visual stimulations were carried out with children who have been identified to have a certain visual impairment. Through visual stimulation program some of the children were stimulated with light stimulus, some with different materials under the ultraviolet (UV) light, and some with bright color and high contrast materials. Children were also involved in program of early stimulation of overall sensory motor development. Goals and methods of therapy were determined individually, based on observation of child's possibilities and need. After one year of program, reassessment was done. Results for visual functions and functional vision were compared to evaluate the improvement of the vision development. These results have shown that there was significant improvement in functional vision, especially in visual attention and visual communication.

Key words: *cerebral visual impairment, visual stimulation, perinatal brain damage, low vision, functional vision*

Introduction

The sense of sight has remarkable influence on overall child development, through visual communication with parents, observations of environment and learning by imitation.

Cerebral visual impairment (CVI) is defined clinically as a bilateral loss of vision with normal pupillary responses and an eye examination, which shows no abnormalities[1]. Etiology of CVI is different. Most common causes of CVI are perinatal hypoxia ischemia, intracranial hemorrhage of different level, infections, hydrocephalus, intracranial cist, head trauma, and other[2–8]. Children with perinatal brain damage usually have decreased visual acuity, constricted visual field, and problems with oculomotor functions, fixation, and saccades[4,5,9–11].

In children with visual impairments it is necessary to assess functional vision. Functional vision describes person's visual skills and abilities as applied to the performance of the usual tasks of daily life. It describes the functioning of a person by using their vision.. Functional vision assessment primarily assesses how the individual applies his or her vision in real-life tasks or environments outside the clinical setting[12,13].

Functional visual assessment can be done using none standardized materials and standardized tests while playing with child. It is done through assessing visual functions and observing the ability and the manner of child's using his vision. According to this assessment, visual stimulations are planed and structured. Main goal of visual stimulations is facilitated by using of the vision in everyday situations. Also there are specific goals, focused on development of visual functions. Under term visual stimulation, it mainly refers to using visual stimuli to

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make an infant or child aware of the vision[14]. Cziker, Goetz and Gee (1987) are describing visual stimulation as the none contingent presentation of visually interesting stimulus items; which is based on the assumption that visual display will motivate a child to become visually attentive. Harrel and Akeson (1986) emphasized that productive vision stimulation goes beyond presenting a stimulus that is strong enough to assure the physical act of »seeing«[15]. The aim of this study was to identify functional vision problems in children with brain damage and the improvement of functional vision in these children, due to visual stimulations.

Subjects and Methods

In this study we assessed 30 children from birth to 3 years of age with perinatal brain damage (mainly with intraventricular hemorrhage and periventricular leukomalacia). Children were referred to day care center for pediatric low vision cabinet in »Mali dom, Zagreb« mainly from child neurologists and ophthalmologists. Children with retinopathy of prematurity grade III, IV and V were excluded from research.

Assessment

The assessment of functional vision was done by vision therapists in »Mali dom, Zagreb«.

Binocular corneal reflex was assessed using penlight on distance of 40 cm, to observe alignment of eyes.

Monocular corneal reflex was assessed using penlight on distance of 40 cm, in order to observe position and steadiness of reflex and then make a conclusion about the position and steadiness of fixation.

Following movements were assessed using interesting toys and other objects in bright color. Objects were brought to child in the center of visual field within distance of 40 cm, and moved easily in all directions (horizontal, vertical, diagonal, and in circles).

Saccades were observed as the ability of child to switch fixation from one object to another, or from one person to another. Only large saccades were assessed.

Peripheral visual field was assessed binocularly using confrontational method. Child was stimulated to look in front, by showing him/her interesting object in 40 cm distance. When child set his attention on that material, the assessor brought slowly other interesting object in visual field from different directions. We observed child's reaction in response to the new incoming object.

Visual attention was evaluated subjectively. We observed how much the child is interested in some visual objects and noticed as »very interesting in looking«, »interested in looking, but other stimulus draws his attention«, »very short attention« and »looks only at glance, does not keep attention«.

Visual communication with other people was also assessed subjectively, by observing child's behavior. It was described as »using his vision in communication« – that means that child looks at facial expressions and has a reaction as a response to that expression.; »hard to keep visual communication«; »looks through other person«; »does not look at other person at all«.

Visual acuity was assessed using Teller acuity cards or Lea Grating, following testing procedure[16,17]. This method is based on a child's preference for black and white gratings over a uniform field, depicted on cards with decreasing stripe widths. The location of the left/right position of the test stimulus varies randomly. Assessor observes child's reaction on the stimulus based on eye or head movement. While child is looking in direction of lines it is marked that he sees it. The threshold of acuity is taken as the finest stripe width for which the subject consistently responds correctly. Acuity values are expressed in cycles per degree and can be compared to normative data reported in the literature[18,19].

Contrast sensitivity was assessed with Hiding Heidi, following testing procedure[20]. Test is based on child's preference for looking at black/white faces over a uniform field, depicted on cards with decreasing contrast. The cards are presented in the order of decreasing contrast 100%, 25%, 10%, 5%, 2.5% and 1.25%[20].

Visual stimulation

Children with below-average results for visual functioning were recommended to early intervention program in Mali dom, Zagreb. Visual stimulations were carried out together with the stimulation of overall development. We divided visual stimulation methods in four major groups:

a) stimulation with everyday materials – everyday materials and familiar faces under normal lightning conditions were used to encourage child to look at them with a goal of improvement of specific visual functions and functional vision
b) stimulation with bright colors and high contrast material – using everyday materials, pictures, faces and toys in bright colors and high contrast (made especially for visual stimulation) child was also encouraged to look to achieve better visual functioning
c) stimulation with materials under the ultraviolet (UV) light – different materials in bright colors and high contrast were presented in front of black surface under the UV light that increased brightness and contrast to encourage using vision
d) stimulation with lights and lightning materials – bright and dim lights and lightning materials such as flashlights, light snakes and other were used in dark room to encourage using of the vision.

Methods of visual stimulations that will be used were determined in accordance with results of functional vision assessment of each child.

During visual stimulation program, whenever progress in functional vision was noticed, reassessments were done.

Statistical analysis

Data were described through descriptive statistics. Evaluation of developmental progress in visual functions and functional vision was calculated using Wilcoxon Signed Rank Test. Results with $p<0.05$ were considered statistically significant. Statistical analysis was conducted with significance power of 95%. Nonparametric test was used as distribution did not satisfy parametric assumptions. The analyses were done with program STATISTICA version 6.1. and Microsoft Office Excel 2007.

Results

During three-year period we assessed 30 children, 15 girls and 15 boys. All children had perinatal brain damage. Most of the children had intraventricular hemorrhage (IVH) (36.6%), than periventricular leucomalacia (PVL) (23.3%), cists (10%) and other, as shown in Table 1.

10 of this children were born prematurely, two of them had ROP I and two of them ROP II.

On he first assessment age span was 3 to 20 months (mean age 8.43 months), and on second assessment 5 to 30 months (mean age 16.93). Visual stimulation program lasted 2 to 18 months, depending on improvement of visual functions and functional vision.

Results of the first assessment

Results of the first assessment have shown that children with perinatal brain damage had most problems in alignment of eyes, where only 20% of children had normal position of both eyes, and 76.7% had some kind of

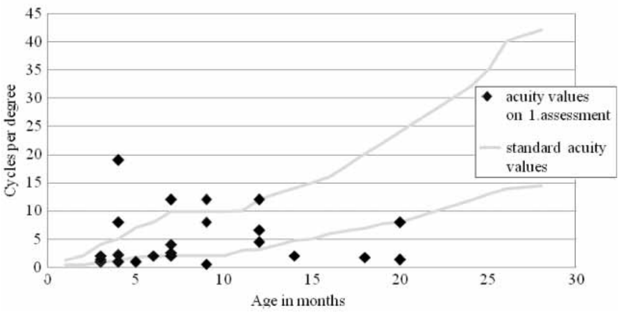

Fig. 1. Grating acuity on first assessment.

strabismus. Most of the children, who had strabismus, had esotropia. Also, they had problems in fixation (in position and steadiness of fixation). 66.7% of children could not keep steady fixation and 63.3% had eccentric fixation point. Children who had steady fixation, mainly had central fixation, and vice versa. Many children had problems in following movements (70%), while only 23.3% of assessed children had problems with saccades.

Average results of grating visual acuity, as we can see in Table 2, are mainly within the average values for age. From large values of standard deviations we can see that there are large differences between individuals. Therefore in Figure 1 are shown individual results of grating visual acuity. As we can see from that Figure 1, about half of children have visual acuity results on or under the lower boundary of standards for grating visual acuity results. Some of the children even have visual acuity result much above upper boundary. It is also easy to see (from Table 2 and Figure 1) that in children who are less than

TABLE 1
REVIEW DIAGNOSIS

	Frequency	Percent
Mild IVH (I,II)	7	23.3
Severe IVH (III,IV)	4	13.3
PVL I	2	6.7
PVL II	1	3.3
PVL III	4	13.3
Hydrocephalus	2	6.7
HIE	1	3.3
Cists	3	10.0
Infection	1	3.3
Ventriculomegalia	1	3.3
SCL	2	6.7
Corpus callosum hypoplasia	1	3.3
Microcephalia	1	3.3
Total	30	100.0

IVH – intravetricular hemorrhage
PVL – periventricular leukomalacia
HIE – hypoxic-ischemic encephalopathy
SCL – supcortical leukomalacia

TABLE 2
VISUAL ACUITY ON FIRST ASSESSMENT

Age	X	SD	Standard VA lower	Standard VA upper
3	1.4667	.50332	1.3	5
4	6.2400	7.69987	1.8	7
5	1.0000	.	1.9	8
6	2.0000	.	2.1	9.8
7	5.1250	4.66146	2.1	9.8
9	6.8333	5.83809	2.1	9.8
12	8.7500	3.84057	2.1	9.8
14	2.0000	.	3	10
18	1.7000	.	4.8	14
20	4.7000	4.66690	5	15
Total	5.1080	4.97225		

Age – age in months on first assessment
Mean – mean of visual acuity in cycles *per* degree
Standard VA lower – standard visual acuity values, lower boundary
Standard VA upper – standard visual acuity values, upper boundary

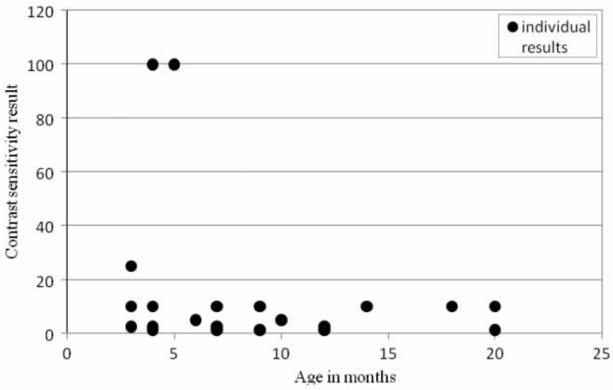

Fig. 2. Contrast sensitivity results on first assessment.

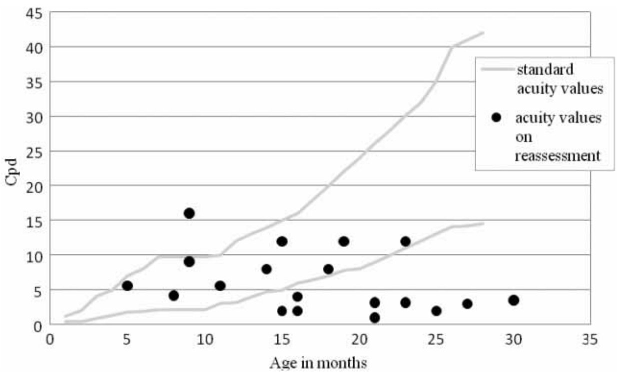

Fig. 3. Grating acuity on reassessment.

12 months old, the grating acuity results are better than in older children.

Contrast sensitivity results also are individually different, as shown in Figure 2. Yet if we take in account that normal contrast sensitivity results are less than 2.5% (tested by Hiding Heidi), we can say that 56.6% of children have problems in contrast sensitivity perception.

During the first assessment many children had problems in keeping visual attention; even 63.3% had problems in longer visual observing of objects. Mainly they had problems in keeping visual attention while other stimuli were present in surrounding. In some children inability of keeping good body posture disturbed and influence their visual attention.

Of all children that were included in the study, 60% of them had problems in sustaining good visual communication with people, and even 20% of them did not look at person in front of them at all.

Visual stimulation

Table 3 is showing how many children needed certain type of visual stimulation. As we can see most of the children (60%) were stimulated with bright colors and high contrast materials.

Results of reassessment

Results of reassessment have shown that children again had most problems in alignment of eyes. During period between two assessments two children who had Esotropia now have normal position of eyes. Therefore, on reassessment 30% of children had normal position of eyes. Again many of the children had problems in fixation (in position and steadiness of fixation). Yet on reassessment 53.3% of children could not keep steady fixation and 46.7% had eccentric fixation point. On reassessment less than half of children (46.7%) had problems in following movements and 20% of children still had problems with saccades.

Average results of grating visual acuity on reassessment are also mainly within the average values for age, as we can see in Table 4. Again from large values of standard deviations we can see that there are large differences between individuals also on reassessment. Therefore in Figure 3 are shown individual results of grating visual acuity. We can see that on reassessment more children have visual acuity results between boundaries of standards for grating visual acuity results. From this data we can also see that older children still have lower visual acuity results. It seems that older children achieved less improvement on visual acuity than younger children, who came in rehabilitation at age less than 12 months.

Contrast sensitivity is again individually different, as shown in Figure 4. Yet we can say that on reassessment 43.3% of children had problems in contrast sensitivity for functional purposes.

TABLE 3
METHOD OD VISUAL STIMULATION

Methods of visual stimulation	Number of children	Percent of children
Everyday materials	5	16.7
Bright colors and high contrast materials	18	60.0
Materials under UV light	6	20.0
Lights and lightning materials	1	3.3
Total	30	100.0

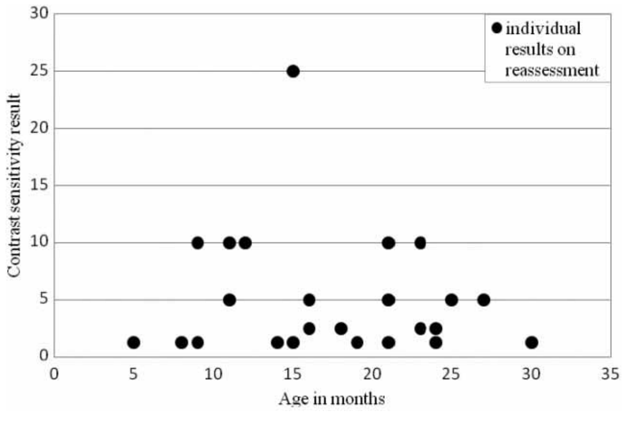

Fig. 4. Contrast sensitivity result on reassessment.

TABLE 4
VISUAL ACUITY ON SECOND ASSESSMENT

Age 2	X	SD	Standard VA lower	Standard VA upper
5	5.6000	.	1.9	8
8	4.2000	.	2.1	9.8
9	12.5500	4.87904	2.1	9.8
11	5.6000	.	2.1	9.8
14	8.0000	.	3	10
15	7.0000	7.07107	3.2	12
16	3.0000	1.41421	4	13
18	8.0000	.	4.8	14
19	12.0000	.	5	15
21	2.6000	.84853	6	16
23	7.5750	6.25790	6.5	18
25	2.0000	.	7.8	22
27	3.0000	.	8	24
30	3.5000	.	10	28
Total	6.1763	4.26739		

Age – age in months in the second assessment
Mean – mean of visual acuity in cycles *per* degree
Standard VA lower – standard visual acuity values, lower boundary
Standard VA upper – standard visual acuity values, upper boundary

On this reassessment children had shown much better results in keeping visual attention; now only 36.7% of them had problems in sustaining visual attention. In visual communication only 26.7% had problems in sustaining good visual communication with people, and only 6.7% (two of them) did not look at person in front at all.

Comparation of assessment results

As we can see there is improvement on all tested visual functions. Yet greatest improvement was on variables visual attention where difference between two assessments was statistically significant (Wilcoxon Signed Rank Test p=0.00; Z=–3.448) and visual communication, where difference was also statistically significant (Wilcoxon Signed Rank Test p=0.00; Z=–3.508), than on ability of smooth pursuit of objects (Wilcoxon Signed Rank Test p=0.00; Z=–3.502), and steadiness (Wilcoxon Signed Rank Test p=0.00; Z=–3.127) and point of fixation (Wilcoxon Signed Rank Test p=0.00; Z=–2.828). Results for contrast sensitivity from first and second assessment are also statistically significant (Wilcoxon Signed Rank Test p=0.00; Z=–2.946).

Grating visual acuity results are statistically better from the first ones and reassessment, but differences in acuity in standard results for children are also statistically different in different age, so we would prefer showing it through individual improvement in grating acuity as seen in Figure 5. Children who had only one assessment result for visual acuity are not presented in this fig-

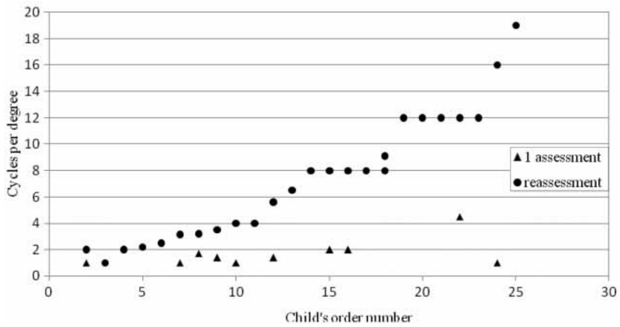

Fig. 5. Individual grating acuity results.

ure. Some children achieved e same result at the first and at the second assessment, so their result is presented only as reassessment result.

Discussion

Problems in fixation, alignment of eyes and smooth pursuit, found in this study are similar to other studies, where authors found many children with problems in keeping central and steady fixation, many children with strabismus, and with problems in smooth pursuit in children with brain damage.

Although many authors have found difficulties in coordination of saccades in these children, it is not so in this study. It can be due to differences in testing procedure of saccades, because in this study we tested mainly functional vision through observation of visual behavior. The accuracy of saccades was not relevant, it was important if child can look from one face to another or from one object to another[2,3,5,10,11,21–23].

Many authors are investigating reasons of the previously mentioned visual problems of children with brain damage. Aring et al. says that it is well known that children with lesions of central nervous system may have defective ocular motor control, which could manifest as unstable fixation[24]. It could be that the reason for eye motility disorder lies in disrupted dorsal stream pathway from occipital cortex to the parietal and frontal cortices. Salati et al. says that the smooth pursuit pathway is so complex that cause of its failure cannot be localized[23]. Lesions in both the cortex and the cerebellum affect smooth pursuit and optokinetic nystagmus[11]. When it comes to reasons for strabismus in children with perinatal brain damage, Jackobson and Dutton suggest that genetic or perinatally acquired defect of the horizontal connections in striate cortex may be one cause of infantile strabismus. Same authors consider another possible explanation that the cortical dysfunction is caused by anterograde degeneration from the primary lesion[11].

Many authors have been investigating visual acuity in children with brain damage, and found reduced grating acuity[4,11,25,26]. Due to problems in keeping steady and central fixation we found in these children, it was expected that they would have more problems in visual acuity. However visual acuity results were within the standard values for age, although a great individual difference is found. Dutton states that acuity is commonly reduced in CVI but can be normal, as we get in this study[3]. Guzzeta et. al. cites other authors, that acuity is generally normal in the infants with priventricular leukomalacia grades 1 and 2, and in our study higher grades of PVL were not so common[4].

Facial features and expressions are seen because of the faint shadows at the level of about 2.5% contrast[27]. Therefore we have taken into account how many children saw contrasts higher and how many lower than 2.5%. Not many authors have reported about problems of contrast sensitivity perception in children with perinatal brain damage. Fazzi et. al. found reduced contrast sensitivity in 58 of 121 patients, what is approximately half of the children in a sample what is similar to our study[26].

As in our study, Salati et al. found that treatment improves attention and fixation times, pursuit movements and the capacity to perform precise saccades as well as the acquisition of environment scanning strategies[23]. Also Fazzi et. al. found similar improvements of visual functions[28]. Improvement has also shown when using grating acuity tests and contrast sensitivity tests. Yet these visual functions develop very fast in these first moths of life, so it is very uncertain to draw conclusions about influence of visual stimulations on acuity improvement.

Conclusion

From this study we can conclude that children with perinatal brain damage have many visual problems, such as problems in fixation, smooth pursuit, strabismus, reduced contrast sensitivity, keeping attention and visual communication.

Treatment of visual problems, using visual stimulation individually set for each child, helps children with perinatal brain damage to improve functional vision, especially in visual attention and visual communication, but also to achieve better fixation and pursuit.

Considering the importance of visual perception in overall child development we can conclude that there is a great need for further examination of visual functions and functional vision of children with perinatal brain damage; especially if we think about brain plasticity and influence of visual stimulation on improvement of visual functioning.

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STIMULACIJA FUNKCIONALNOG VIDA KOD DJECE S PERINATALNIM OŠTEĆENJIMA MOZGA

S A Ž E T A K

Cerebralno oštećenje vida (COV) je jedno od najčešćih uzroka bilateralnog gubitka vida, koje često nastaje zbog perinatalnih oštećenja mozga. Vid u ranom životu djeteta ima veliki utjecaj na stjecanje osnovnih sposobnosti koje su osnova cjelokupnog daljnjeg razvoja. Stoga je neophodno rano otkrivanje oštećenja vida i rana intervencija. Cilj ovog istraživanja bio je utvrditi specifičnosti vizualnog funkcioniranja djece s perinatalnim oštećenjima mozga i utjecaj vidnih stimulacija na razvoj funkcionalnog vida u ranoj životnoj dobi. Procijenjeno je 30 djece s perinatalnim oštećenjem mozga dobi do 3 godine, koji su od strane neuropedijatara, oftalmologa i drugih stručnjaka upućeni u dnevni centar za rehabilitaciju djece s oštećenjem vida »Mala kuća«. Vidne stimulacije su provođene sa svom djecom koja su imala bilo kakvo oštećenje vida. Utvrđene su na osnovu procjene funkcionalnog vida, individualno za svako dijete. Neka djeca su stimulirana sa svjetlosnim efektima, neka sa različitim materijalima pod UV svjetlom, a neka sa materijalima žarkih boja i jakih kontrasta pod dnevnim svjetlom. Djeca koja su također bila uključena i u program rane stimulacije cjelokupnog senzomotoričkog razvoja. Ciljevi i metode terapije su također određeni individualno, na osnovu opservacije djetetovih sposobnosti i potreba. Nakon jedne godine programa, učinjena je ponovna procjena. Rezultati vizualnih funkcija i funkcionalnog vida su uspoređeni kako bi se evaluiralo poboljšanje razvoja vida. Ovi rezultati su pokazali da postoji značajno poboljšanje u funkcionalnom vidu, naročito u vidnoj pažnji i vidnoj komunikaciji.