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IMPROVING EYE GAZE COMMUNICATION THROUGH OCULAR MOVEMENT EXERCISES

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Abstract

A thirteen year old girl with severe athetoid cerebral palsy, visual and intellectual disabilities was given a series of exercises in maintenance of fixation and saccadic and smooth pursuit eye movements. The aim of the exercises was to give her improved control of eye movements to enable her to access an eye gaze communication board. The exercises were performed daily as part of her school programme with measurements of fixation and refixation time being taken twice weekly. Results showed an improvement in both measurements, however fluctuations were obvious with fatigue, illness and varying levels of co-operation.

Key Words: *saccades, smooth pursuit, cerebral palsy.*

INTRODUCTION

The saccadic and smooth pursuit eye movement systems have been clearly defined as to their pathways, characteristics and function[1]. It has also been determined that developmental changes can be plotted in the saccadic and smooth pursuit systems and in fixational control[2]. The literature clearly defines the different types of cerebral palsy, methods of treatment and the type and extent of improvement that can be expected from that treatment[3,4]. Whether the child with athetoid cerebral palsy can be taught to control eye movements is yet to be determined.

The eye movement systems are represented in the frontal lobes for the saccadic system and the occipitoparietal lobes for smooth pursuit. The saccadic system is responsible for refixation movements, fast phases of vestibular nystagmus, optokinetic nystagmus and microsaccades. The smooth pursuit system is responsible for following or tracking a slowly and smoothly moving target once the saccadic system has placed it on the fovea. The position maintenance system is a non optic reflex system. Its function is to maintain an object of interest on the fovea or to maintain a specific gaze position. Cortical representation is in the frontal and occipitoparietal areas[1].

Development changes occur in the eye movement and position maintenance systems. The velocity of smooth pursuit movements improves

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with age as does the ability to change direction when visually pursuing an object. The saccadic system is thought to be the first well co-ordinated motor system in humans with attention and arousal being the determining factors in how well a saccadic oscillation is performed. Position maintenance or fixational control has been found to improve with instruction and practice[2].

Cerebral palsy has been defined as "a disorder of movement and posture due to a defect or lesion in the immature brain"[3]. Athetoid cerebral palsy results from damage to the extrapyramidal pathways or basal ganglia due primarily to perinatal insults[5]. Children with athetoid cerebral palsy show an unsteady and fluctuating type of postural tone, all movements are jerky, uncontrolled and extreme in range with the uncontrolled movements being increased when the child tries to perform a purposeful movement. The involuntary movements that are seen in the athetoid child consist of intermittent tonic spasms and mobile spasms where the limbs are involved in rhythmic alternating movements of pronation and supination, flexion and extension. Head control is often poor and is frequently associated with disturbances of eye control, speech and hearing[3].

The disturbance of postural tone and difficulty with purposeful movement in these children can result in unintelligible speech. This necessitates the use of an augmentative communication system, where an alternative communication system is used to either complement existing speech or provide the child with a sole means of communication. When developing a communication system for the child with athetosis, direct selection may be used where the alphabet or a series of pictorial representations are pointed to using any part of the body for example a finger, foot or the eyes. Because of the eyes' physical and neural relationship to the brain they are often the last system to be impaired. Eye movements are also low energy movements and are largely independent of postural and other body movement systems[6]. These advantages apply particularly to the child with athetoid cerebral palsy due to the difficulties with controlling movement whilst maintaining a normal background posture.

The relationship between visual and ocular motor disorders and cerebral palsy has been well documented, with there being a high incidence of strabismus and nystagmus[8,9]. Research has also been conducted into eye movements in children with cerebral palsy with results showing that smooth pursuit and saccadic movements tend to be irregular with jerky pursuit movements and slow saccadic movements being described[10,11,12]. It should be noted however that similar irregularities were also observed in children with learning disabilities[11] indicating that the irregularities are not con-fined to cerebral palsy. Whilst the type of cerebral palsy was mentioned in each case, the subjects were thereafter considered as a group with no distinction being made between eye movements in the different types of cerebral palsy, the application of these observations to a child with athetoid cerebral palsy is therefore limited. Whilst the irregularities were identified, there was no attempt to improve these eye movements through any form of exercise in any of the aforementioned studies. The slower saccadic movements have been linked to poor reading and writing skills, motor achievement and visuo-spatial abilities[12].

The relationship between ocular motor disorders and cerebral palsy has been established, but as previously mentioned, it has not been determined whether exercises in these areas will lead to any improvement in the saccadic or smooth pursuit systems. Erhardt (1987)[13] has used smooth pursuit exercises to increase visual awareness and Waters (1987)[14] advocates the "training of visual pursuits and saccades" in children with cerebral palsy as part of their Occupational Therapy programme. both of these authors aim for an improvement in the subject's visual awareness, with the eye movement training being part of an overall stimulation programme. Whilst awareness is stated to improve the authors fail to indicate whether there is any observable change in the subject's ability to perform smooth pursuit or saccadic movements.

Treatment techniques that are specific to athetosis include developing cognitive control to overcome deficits in specific areas and applying the principle of repetition to "strengthen and consolidate" normal movement patterns[15]. The child with athetosis does not have a problem with initiating movement but rather with controlling that movement and maintaining a normal background posture[5]. Due to these problems the principles of repetition and cognition would need to be applied consistently in all aspects of the child's disabilities. Whilst these techniques have been applied to the general treatment athetosis it has not been determined whether the same principles will apply to control of the ocular motor system.

The purpose of this study was to determine whether visual fixation time and refixation time would be improved through exercises in maintenance of fixation, saccadic and smooth pursuit eye movements. A thirteen year old girl with athetoid cerebral palsy was the subject for the study and the exercises were included as part of her I.E.P. The purpose of the exercises was to improve control of visual fixation and refixation movements and ultimately provide the subject with a means of accessing an eye gaze communication system (figure 1).

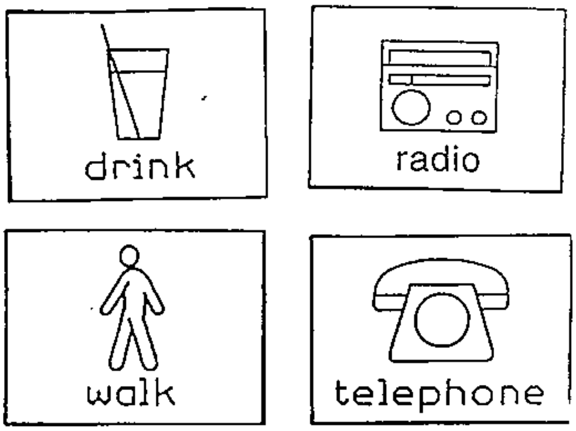

Figure 1. Example of an eye gaze communication system using a perspex card with pictorial representations of activities.

The type and extent of improvement that was recorded is discussed including the effect the exercises had on other aspects of the subject's I.E.P. Possible limitations to the method of measurement and how this project was influenced by other factors apart from eye movement exercises is included.

METHOD

This project was based on a single subject. The subject being a thirteen year old girl with severe athetoid cerebral palsy, a moderate intellectual impairment, optic atrophy, myopia and a left ptosis. Prior to commencing any exercises a baseline measurement was taken of the subject's ability to take up fixation, and then maintain fixation for as long as possible. Both tasks were timed using separate stop watches with the measurements being taken in four positions of gaze to correspond with an eye gaze communication system that was to be introduced (figure 1). The baseline was taken over a two week period with the measurements being taken in the morning prior to the subject commencing school and at the end of the school day.

Having established a baseline the subject was given a series of exercises to be done twice daily five times a week. The exercises are outlined in Table 1.

Table 1:
Orthoptic programme for the classroom

1. Saccades – horizontal-four horizontal eye movements including initial take up of fixation. The two targets to be held at eye level approximately 15 cms apart.

   – vertical-four vertical eye movements including initial take up of fixation. The two targets to be held on the midline, the upper target at eye level with the other target approximately 10 cms below.

2. Smooth Pursuit - visually follow a slowly moving target firstly on the horizontal plane twice then twice on the vertical plane.

3. Maintenance of Fixation - maintain fixation on a centrally held target for as long as possible.

The exercises were included in the subject's classroom programme with the teacher supervising. This involved an initial demonstration of the exercises by the Orthoptist and then the teacher carried out the programme holding all fixation targets as the subject was unable to do so due to the nature of her disability. Twice weekly the subject was seen for an individual orthoptic treatment session, a measurement of fixation and refixation times was taken at the commencement of each session, this was then followed by a number of exercises based on the programme in Table 1. Measurements were taken in four different sequences, one sequence per session, to take into consideration fatigue and difficulty maintaining fixation in different positions of gaze. (see figure 2)

Figure 2
Sequences used for measurement

1	2
3	4

A

4	1
2	3

B

3	4
1	2

C

2	3
4	1

D

Coloured discs were used to mark each position with the subject being requested to look at a nominated colour and to maintain fixation for as long as possible. Once fixation was lost, the subject was told how many seconds she had maintained fixation then after approximately one minute she was requested to look at the next colour in the sequence. The position of the colours was kept constant, only the order in which the subject looked at them was changed.

RESULTS

Results are presented in the form of line graphs. Figures 3 and 4 show an average of the measurements taken over a morning and afternoon session on the same day for the baseline period and then an average of the four positions of gaze from each measurement session thereafter.

Figure 3 shows an average of the time to take up fixation for each measurement session. As can be seen, measurements over the two week baseline period are erratic with the majority of measurements being over 15 seconds. Once the ocular movement exercises commenced there was an initial peak measurement of 28.5 seconds. Results then show a rapid reduction so that the measurements of time to take up fixation all fall below 10 seconds. The 2 week holiday period resulted in an initial increase in time to take up fixation but this was then followed by a rapid reduction in times which was sustained until the end of the project.

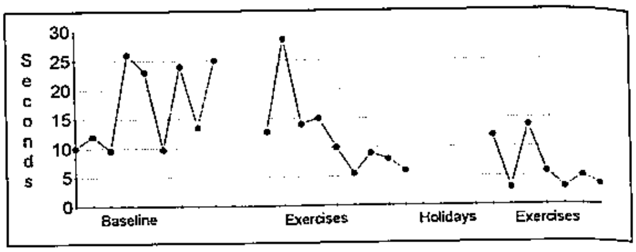

Figure 3. Time to take up fixation - Averages

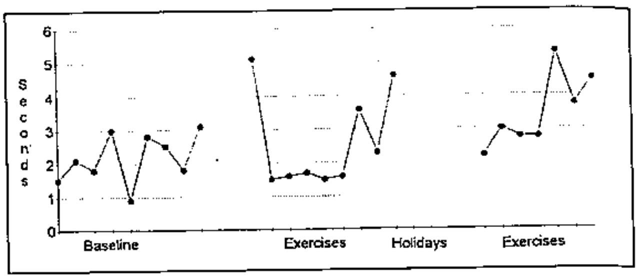

Figure 4. Fixation maintained - Average measures.

Figure 4 demonstrates an average of the time that fixation was maintained for each measurement session. Predictably the baseline period was again somewhat erratic with all measurements falling below 3 seconds. Once the eye movement exercises were commenced there was an initial reduction in fixation time with the average measurement falling below 2 seconds. After 3 weeks of exercises an improvement is evident. The 2 week holiday break was followed by a reduction in fixation time for a further 2 weeks with improvement then becoming evident for the remainder of the project.

It is worth noting that the lower left position of gaze gave the most variable results of the four positions, with both time to take up fixation, and fixation maintenance being longer in this position.

DISCUSSION

The aim of this project was to determine if a subject with athetoid cerebral palsy could improve in her control of eye movements in order to use eye gaze to access a pictorial communication system. No mention in the literature was found as to whether exercises in ocular movements will result in any improvement however, it has been found that the principles of repetition and cognition when applied to the physical management of athetosis will "strengthen and consolidate" normal movement patterns[15]. These principles plus the statement by Johnston and Pirozzolo (1988)[2] that position maintenance and fixational control have been found to improve with instruction and practice were applied as a basis for this project.

When the results were analysed some improvement was evident in that there was both a reduction in time to take up fixation and a slight increase in the time that fixation was maintained. This improvement was shown in figures 3 and 4 where an average of the measurements from the 4 positions of gaze was taken. It would appear from these two graphs that a greater improvement was achieved in the time to take up fixation. This may reflect an improvement in saccadic eye movements or a combination of the saccades and improved head control.

When the 4 positions of gaze were compared graphically it was found that the lower left position of gaze was the most difficult position for the subject to firstly gain fixation on and then maintain it. This difficulty was particularly evident over the baseline period, with an improvement being evident once the exercises were being done consistently.

Some of the variation in results can be explained by the subject's mood, state of health and level of fatigue on individual days. It was found that fatigue particularly influenced results with time to take up fixation being the most affected. If the subject was very tired, this particularly being evident after she had been involved in a physical activity such as swimming, time to take up fixation was noted to increase, on 3 occasions taking over 1 minute. These longer periods only occurred on the third and fourth measurements taken regardless of position or gaze. It was also found that if the subject was tired or unwell she could frequently maintain fixation for longer perhaps owing to the fact of her being able to "lock" her head into position. All of the subject's random body movements decrease significantly when she is very tired or unwell, this is reflected in her ability to maintain fixation for longer probably due to the fact that random head movements also decrease. Results were also noted to be affected if the subject was in a good mood with laughter tending to influence results by increasing the subject's random body movements. This produced the effect of time to take up fixation increasing markedly and fixation being maintained for shorter periods. This occasionally necessitated taking a second series of measurements after the subject's full co-operation was sought.

Once an improvement in the measurements became obvious it was found that this improvement was reflected in other aspects of the subject's I.E.P. As her understanding of the purpose of the exercises became evident this was reflected in her being more willing to cooperate. The subject's classroom teacher was then able to use eye gaze for choice making in a number of situations throughout the school day. For example: providing the option of the choice of a drink for morning tea by holding up a carton of milk and one of fruit juice and asking the subject to look at her preference. Once the subject had successfully utilised eye gaze for selection on several occasions she became more interested in the project and more eager to participate in the exercises as she could see the positive benefits of gaining control over her eye movements.

The fact that the subject had a ptosis made it easier for people involved in her I.E.P. to interpret her requests. Once it had been explained that she was only using her right eye and that the person who was interpreting her request should disregard the eye with the ptosis, it was found that people were more willing to use the eye gaze communication system.

The introduction of 4 positions of gaze for this project was made to give the subject a wider variety of choices. It was found however that the 2 lower positions were more difficult for the subject to fix upon thus leading to frequent misinterpretation of her choice if the person interpreting her choice was not familiar with the subject. The choice could be confirmed by asking the subject if she was looking at the interpreted selection, which she could confirm by using her YES/NO response (lips pursed for no, smile and "ah" for yes). Due to this difficulty, people who were not familiar with the subject were advised to provide her with 2 choices which allowed for a more rapid selection by the subject and a more accurate interpretation by the person she was communicating with.

CONCLUSIONS

The use of exercises that involve repetitive saccadic and smooth pursuit movements and the training of maintenance of fixation was found to be beneficial in teaching a subject with athetoid cerebral palsy to control her eye movements. This was reflected in a reduction in time to take up fixation and a slight increase in the time that fixation was maintained. It was found that a corresponding use of eye gaze for communication in all aspects of the subject's I.E.P. increased the subject's motivation to co-operate as she could see the positive benefits of the programme. It is felt that the eye movement exercises assisted in the measured improvement but it cannot be ascertained whether this improvement was also brought about by the increased use of eye gaze for communication. The subject's motivation and understanding of the project were key factors in gaining a reliable response and by providing her with feedback on how results were showing an improvement, both within a treatment session and over a period of time, her enthusiasm for the project was maintained.

The principle of repetition and the use of cognitive skills in the general management of athetoid cerebral palsy have been found to be effective[15]. By using exercises that are based on repetitive eye movements and by seeking the full co-operation of the subject these principles were applied for the purposes of this project. It would appear from the positive results that were achieved, that a person with athetoid cerebral palsy can be taught to control eye movements as well as learning to control postural tone and general body movements. The results gained in this project are based on observation, and a number of factors need to be taken into consideration when accounting for the improvement. These factors include the exercises in saccadic and smooth pursuit eye movements, the increasing use of eye gaze throughout the subject's school programme, the subject's motivation and her degree of co-operation.

In order to determine whether the eye exercises resulted in an improvement in saccadic or smooth pursuit eye movements a more accurate measurement system would be necessary to record any change to the eye movements than the method used in this study. The electro-oculogram has been used to record saccadic and pursuit movements in children with cerebral palsy[10]. It is suggested that this would provide the means to determine whether saccadic and smooth pursuit movements can improve with practice. Physical restrictions on this project meant that this form of measurement was not possible. The fact that this project was conducted within a school meant that the use of the eye exercises and their application could be constantly monitored, however the disadvantage was that the abovementioned clinical measurements were not possible. One other means of determining if the eye movements could be improved would be to limit the use of eye gaze to the exercises and measurement sessions avoiding the use of eye gaze for choice making. If these restrictions were applied it would be difficult to maintain the motivation and co-operation of the subject, however it would provide a more "pure" set of measurements.

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