Sarah Gibson
Neuro 430
April 25, 2007

For Your Eyes Only

Gibson, S*. and Jimenez, L.

Department of VCAPP, College of Veterinary Medicine, Washington State University, PO Box 646520, Pullman, WA 99163-6520, USA.

Abstract

The Kids Judge! Neuroscience Fair is an annual event at Washington State University that allows neuroscience students and faculty to present complex ideas in a simple way as a practice for real world application. The kids judge each exhibit on evaluation forms and then choose which one they liked the best overall. 'For Your eyes Only' was an exhibit to show how the oculomotor muscles mediate eye position in humans. We constructed a working model of paper machéd balls connected to bungee cords to simulate the eyes and their response to specific muscles being constricted. The exhibit was chosen as second place in its presenter group of four teams, and the kids were able to learn the six muscle names and how they moved the eyes. The kids were also able to predict what the eyes would look like when trying to look in a specific direction while one muscle was non-functional. The success of getting this information across made the exhibit and project successful as well. Two goals of the fair are to introduce neuroscience to a younger generation and to peak their interest in the science field. Another great purpose of the fair is to give future neuroscientists the practice of communicating highly scientific information in a way that any non-scientist could understand.

Introduction

Research on oculomotor muscles is done in a variety of sub-areas, for example, anatomy, function, or association. Extraocular muscles and their innervations seem to be often overlooked or oversimplified in general biology or introductory physiology textbooks, and it turns out that they provide structure in a very specific manner. They have intricate pulley systems to allow the eye to look in any direction possible. They play complicated roles in actions such as saccades or smooth pursuit, and they provide proprioceptive messages to send information back to the brain. All of these manipulations are carefully initiated by neurons in the brain that permit each role to be played. The extraocular muscles are specifically engineered to produce and maintain these actions and the specificity in which they are developed show that this is a highly adapted characteristic and that each function is related to the next. There are six oculomotor muscles within the category of extraocular muscles. These oculomotor muscles include the superior rectus, medial rectus, inferior rectus, lateral rectus, superior oblique, and the inferior oblique.

Each oculomotor muscle is held by connective tissue in a surrounding area of the eye. That connective tissue acts as a pulley to produce movement toward the area serving as a functional origin of the muscle, while the anatomical origin is in a different place (Demer et al., 2003). Because the insertion of the inferior oblique onto the sclera is closer to the lateral rectus, both the movement of the lateral rectus and the inferior rectus alter the movement that the contraction of the inferior oblique would create alone. The position of the eye is not a result of the inferior oblique's contraction alone (Demer at al., 2003). The superior oblique acts in a similar way with respect to the lateral and superior retci.

While vision and monitoring of neural outflow provide much of the information about eye positioning, the extraocular muscles also have proprioceptive properties assisting in obtaining this knowledge (Weir et al., 2000). Since eye position within their connective tissue is a requirement for coordinated eye movements, gaze shifts, and accurate oculomotor movements, that information becomes essential to making these eye movements smoothly, accurately and quickly. Studies have indicated that removing extraocular muscle afferent input decreases the ability to maintain static eye position and to generate smooth pursuit, saccades and the vestibulo-ocular reflex (Weir et al., 2000).

Exact positioning of the muscle insertions is the only way to create the correct eye movements. According to Feng et al. (2005), the distance from the lateral edge of the optic nerve to the posterior insertion of the inferior oblique is 5.6 ± 0.9 mm in humans, and the distance from the lateral rectus tendon to the anterior end of the inferior oblique's insertion is 10 ± 1.5 mm. Another measurement taken was the angle of inferior oblique insertion in the horizontal plane, recorded to be 23.7° ± 0.58°. This measurement by Feng et al. (2005) was taken from the inferior border of the inferior oblique to simulate a device that may be supported at the inferior border, as the research was being done to see if instruments could be placed next to the eye in order to make use of transscleral drug delivery without affecting the extraocular muscles.

The oculomotor muscles play a part in movements of both eyes in the same direction to track the motion of a target, termed smooth-pursuit eye movements. Robinson (1965) measured eye movements and net isometric tension in the horizontal recti in humans while tracking a moving target in order to observe these smooth pursuit eye movements. He concluded with many observations; and the four that are most relevant to the anatomy of the oculomotor muscles are discussed here. (1) For each pattern of innervation of each of the six muscles, there is only one position of gaze. This means that for each combination of muscle tension from each muscle, only one eye position results. (2) The steady-state rate of change of net muscle tension is 1.2 g/sec for each 1.0 deg/sec of eye velocity. He measured net tension of the muscles and how it changes as the eye is rotated. As the eye moves toward its resting state at 1.0 deg/sec, muscle tension is reduced

1.2g/sec. (3) The smooth pursuit system shows larger velocity changes than saccades with proportionately less additional rate of increase of muscle tension. It takes slightly longer to be accomplished and it exhibits no or less velocity overshoot than that of saccades. (4) Under conditions of visual feedback, the smooth pursuit system is shown to be capable of smooth endless pursuit under positive feedback showing a continuous control system, as opposed to a sampled system. Smooth pursuit has far less corrections and uneven tracking than that of saccades, because of the continuous tension kept in the oculomotor muscles.

We used a model of the eyes with connected oculomotor muscles to teach fifth graders at the Kids Judge! Neuroscience Fair about how eye control is accomplished. Our goal was to use the model to explain the anatomy and function of these muscles with respect to eye movement, while including what happens if there is no innervation available to the muscles. The idea of smooth pursuit was explained if time allowed and only if the students grasped the idea of muscle movement well enough to move on to explain the more complex idea of smooth pursuit. Our interactive model allowed the students to contract each muscle in either eye and observe the resulting movement in the respective eye. Our lesson plan included an explanation of the anatomy and pronunciation of the six oculomotor muscles. Through demonstration with our model, we showed how the positions of the eyes change to reflect the contraction of specific muscles. We then had the kids move the muscles to directions that they wanted the eyes to 'look.'

The main goals of the Kids Judge! Neuroscience Fair was to keep younger generations interested in science and to allow opportunities for neuroscience researchers to be able to communicate on a less technical level as most of the American population speaks and reads at a fifth or sixth grade level.

Methods

Building of the Model

The eye part of our model was made using two rubber four-square balls and attaching them to two-foot PVC pipes with hot glue and duct tape. The pipes served as the 'optic nerve' and more importantly, as a way to mount the eyeballs onto a wooden frame. The ball was fist covered in saran wrap, and then washcloths were used between the layer of saran wrap and a layer of wax paper as a spacer. The balls were wrapped in the single layer of wax paper and multiple layers of paper maché, and then spray painted white. After the paper maché was dry, the washcloths were removed to create space for rotation of the wax paper around the saran wrap. The iris was drawn on the ball to give a point of reference for the eye movements.

Between layers of the paper maché, little pieces of cardboard with a hole punched in them were placed to use as the muscle insertions. Bungee cords were then connected to the little pieces of cardboard and pulled through holes drilled through the back of big cardboard boxes acting as the eye sockets, which had been placed around the PVC pipes.

These bungee cords were labeled as the muscles on the back of the cardboard boxes. The PVC pipes were then attached via metal straps and screws to a long 2x4 that ran horizontally about 3 feet off the ground. This 2x4 was part of a wooden frame that was also constructed for the model. A poster was also created with cartoon pictures of where the muscles lay on the eyes and pictures of what muscles are used to look in each direction.

Presentation of the Model

We began our presentation by asking the kids to hold their heads still and then look in various directions. We then asked them what they thought moved their eyes. Each time at least one kid said "muscles," and at that point we went on to explain the six muscles on each eye and how they move the position of the eye. Using our model, we showed how the muscles moved each eye and explained that the muscles work together to produce a gaze in a single direction. As one muscle contracts, the opposing muscle relaxes to allow a coordinated movement. When the kids showed that they were able to complete the exercises, we asked what they eyes would look like when trying to look in a specific direction while a specific muscle doesn't work. A computer was also available with a simulation of the eye movements that can also be shown with chosen deficits, for the kids to see a more accurate picture of the eyes than our model alone.

Evaluation of the Model

The floor of Beasley Coliseum was filled with college professors, college students, and the judges, fifth grade students. Four groups of kids came to each of the four teams in our presentation group, the blue presenters group, in rotation. Each child was given a Judge Evaluation Form with seven questions for each exhibit they visited. After visiting all of the exhibits, the kids voted for their favorite.

Results

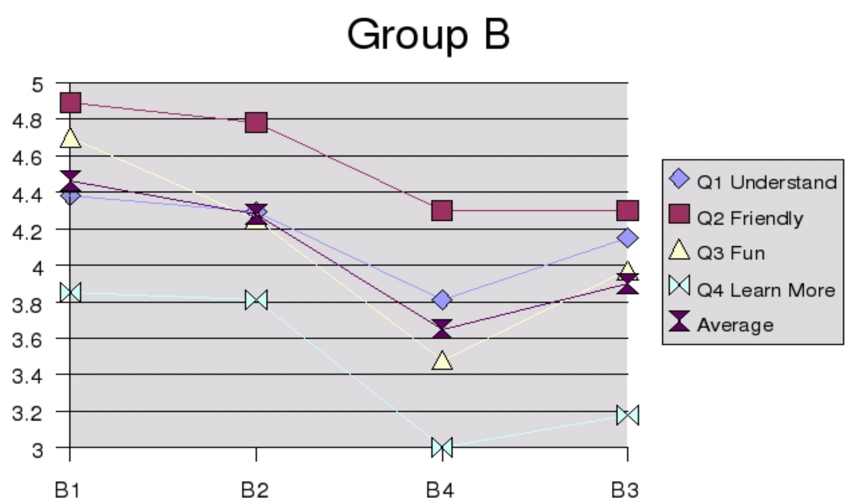
'For Your Eyes Only' placed second within their presenter group at the 'Kids Judge! Neuroscience Fair.' Our exhibit was rated by four groups of children on four questions with a scale of one to five, where a five answered most positively to the question (Table 1). Subjects of interest were understanding the material, presenter friendliness, how fun the exhibit was and future interest in topic.

Table 1. Children's Rating Questionnaire of Our Exhibit

	Avg Score
1. Could you understand what the presenters were trying to tell you?	4.36
2. Were the presenters friendly?	4.78
3. Was the exhibit fun?	4.27
4. Would you like to learn more about this topic?	3.69

Three open ended questions were also asked regarding the child's favorite part, what he or she learned and additional comments. The typical favorites were looking at the eye model, making the eyes look cross-eyed, manipulating the eye model by pulling the cords, and using the computer to simulate different deficits. The main things learned were that muscles moved the eye position, there were six oculomotor muscles, and the names of those muscles. The kids learned that there is a significant amount detail regarding eye positioning that has to do with muscles and their innervating nerves that they were unaware of previously. They learned that their bodies quickly translate a "look to the left" to the muscles that allow one to do so. Most of the additional comments were either, nothing or nice model. One child even went so far as to say that she could tell that a lot of work went into the building of the model.

Each presentation group was also ranked against the other teams in their group. Graph 1 shows the ranking as well as how well our presentation was scored as compared to the other three teams on our group. The rankings of the four groups in the blue presenter group are as follows: (1) What's in Your Nose Besides Boogers? (2) For Your Eyes Only, (3) The Brain Under the Microscope, and (4) Don't Touch That!



Graph 1. The blue presenter group's questionnaire averages showing What's in Your Nose Besides Boogers? (Group B1) For Your Eyes Only, (Group B2), The Brain Under the Microscope (Group B4) and Don't Touch That! (Group B3).

Discussion

The project was intended to show a simple version of a complex idea, and since we received a fairly high ranking from the kids for understanding the concept, our goal was essentially met. During our presentation most kids seemed alert and interested in what we were explaining, and by the end they were correctly choosing what muscles needed to be pulled to make a specific movement. The kids were also able to draw pictures of what the eyes would look like when exhibiting a non-functioning muscle. The interaction of the kids with the model may have increased the fun and the interest factors. These factors and our friendliness also contributed to the success of our project.

We placed second in our group of four presenters. We expected not to place first, as the first place group had a very fun and interactive game of tag to explain their concept of the olfactory system. During judging, many kids all over Beasley Coliseum kept expressing the desire to be at the exhibit where kids were running and playing. Because our exhibit did not have that excitement factor, we expected that presentation group to place the highest. In light of these facts, we were very pleased to come in second in the kids' minds.

To keep our presentation concept simple, many important issues were not discussed. We did mention the muscles were controlled by nerves, but the names of nerves were either said quickly or not at all, because we were already asking the kids to remember the names of each muscle. Because the emphasis was not on the nerves in our presentation, reflexes, medial longitudinal fasciculus mediation and, pupil and eye lid positioning were also not discussed. All of these aspects are important to eye movement, but are discussed after a foundation of which nerves innervate which muscles is understood.

The correct placement of muscle insertions were mentioned as necessary for correct movement of each muscle. However, our oblique insertions were not exact as they should have been. These muscles simply spun the eyes around while the position of the iris did not change. This inaccuracy was adjusted for during demonstration of the model by us using our hands to manipulate the position of the eyes. Due to this inaccurate movement, these muscles were not discussed when kids were manipulating the eye positions. The positions the kids were asked to move the eyes included up, down, left, right, and cross-eyed. If this project were to be redone, we would consider measuring the appropriate places for the insertions and pulleys in order to create the correct response for of the oblique muscles.

The majority of the kids needed the whole presentation time to grasp the idea of each muscle moving the eye in a separate direction, what that direction is, and which muscles to use in order to produce an eye position. Due to most of the presentation time being utilized for eye position, smooth pursuit and saccades were not mentioned. This may have been to our advantage because had we had more time to explain either these concepts or the concept of nerve innervation, it may have overwhelmed the kids with facts. The goal of the presentation was not to lecture information to make sure they know everything they can about eye position.

We believe the only way to make our model and presentation better would be to change the attachment of the oblique muscles to the eye. If moved to the correct place, the eye rotation due to pulling this cord would better replicate the actual movement produced in the human eye. Another way that would make it more kid-friendly is to construct a face around the eyes to make the model look more human. And lastly, if there was a way to incorporate a little more interaction between the model and each student, or more energy and activity into the presentation, the project would have had a better reception from the judges.

The goals of the presentation were to explain our experiment, to create a basic understanding of eye position, and to attempt to spark the interest of science in these fifth graders. We believe that by coming in second place, and scoring well on our Judge Evaluation Forms, that our exhibit at the Kids Judge! Neuroscience Fair was a success.

Works Cited

Demer, Joseph L., Sei Yuel Oh, Robert A Clark, and Vadims Poukens. "Evidence for a pulley of the inferior oblique muscle." Investigative Ophthalmology and Visual Science. 44 (2003): 3856-3865.

Feng, Xiao, Kristin Pilon, Yoseph Yaacobi, and Timothy W. Olsen. "Extraocular muscle insertions relative to the fovea and optic nerve: humans and rhesus macaque." Investigative Ophthalmology and Visual Science. 46 (2005): 3493-3496.

Robinson, D.A. "The mechanics of smooth pursuit eye movement." Journal of Physiology. 180 (1965): 569-591.

Weir, Clifford R, Paul C Knox, Gordon N Dutton. "Does extraocular muscle proprioception influence oculomotor control?" British Journal of Ophthalmology. 84 (2000): 1071-1074.