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## **Crazy Eyes!**

### Abstract:

The vestibulo-ocular reflex helps us stabilize the visual world around us. It is this reflex that allows our eyes to track objects smoothly as well as allow our eyes to remain fixed in a particular direction despite our head movements. For this to be possible, the semicircular canals within our inner ear send signals regarding the movement of fluid upon hair cells. These signals act upon the muscles that control eye movement and, based on the direction of fluid movement detected by the vestibular system, the eyes compensate by moving in the proper direction. We designed a model to demonstrate the importance of this reflex as well what life might be like without such a system. Our model allowed the kids to manipulate their own vestibulo-ocular reflex which they enjoyed and maintained important concepts from.

### Introduction:

The vestibulo-ocular reflex (VOR), an immensely important aspect of the central vestibular system, assists in the ability of keeping one's eyes pointed in a particular direction regardless of the actions of the body. In essence, this reflex allows for stabilization of the visual field despite head movements in horizontal, vertical, or torsional directions (Clarke, 2001). In order to accomplish this and thereby produce accurate vision, it is crucial that the image remains stable on the retinas. On each side of the head, deep within the inner ear, are housed the otolith organs as well as three semicircular canals which are oriented in three distinct directions. These organs, namely the utricle and saccule, are able to detect changes in linear acceleration and the angle of the head. The canals, on the other hand, serve to detect angular acceleration which can result from sudden rotational movements of the head (Bear, 2001). Each canal contains a bulging region known as the ampulla and is filled with fluid called endolymph. The ampulla houses a gelatinous cap, the cupula, into which the cilia of hair cells within the canal project. Rotation of a canal in the direction to which it is receptive, such as a horizontal rotation, causes the endolymph within to remain relatively stable, an act of inertia, and thereby exerts directional force on the cupula. The movement of the cupula bends the residing cilia and either an excitatory or inhibitory signal results. If the signal is excitatory, the hair cells connected to the cilia release neurotransmitters onto the

vestibular nerve axons below. These axons, derived from cranial nerve VIII, project to the medial vestibular nucleus and onto the medial longitudinal fasciculus. Axons from here reach to nuclei such as the abducens nucleus and the oculomotor nucleus. The signal, upon arriving at this point in the pathway, activates either the lateral rectus or medial rectus muscles of the eyes to create a joint directional movement which is opposite to that of the head's rotation (Bear, 2001).

When broken down, the VOR has two main components which are referred to as the rotational VOR (RVOR) and the translational VOR (TVOR). The sensory signals originating from both the semicircular canals and the otolith organs drive the TVOR, thereby assisting in the ability of this reflex to function properly (Angelaki, 2004). Amazingly enough, this reflex works in a similar fashion even when the eyes are closed or when one is in complete darkness. For example, the ability of a subject to focus on an imaginary target while in the dark is provided by the fact that a stimulus such as a moving sound source, or any perceptual information for that matter, has the potential of eliciting the same smooth pursuit eye movements as long as it represents the target's motion (Hashiba, 2001).

Overall, considering that slight movements of the head occur constantly, the preservation of this reflex can be viewed as extremely valuable. The purpose of this particular investigation is to explore different aspects which give rise to as well as modulate the VOR. Through a series of interactive models and thought-provoking questions, we will delve into the underlying mechanism of the VOR, the components and pathways involved in the response, and possible situations which can affect proper functioning of each aspect. As impressive as the reflex is, this incredible symphony of so many vestibular aspects also raises the notion that perhaps such a variety of components presents an even greater potential for manipulation of the system, involuntary or otherwise. Such manipulation, which could alter the proper functioning of areas from the cerebellum to the workings of the inner ear, could easily affect the compensatory response ability of the VOR.

In order to further explore this concept, manipulation of this reflex will be administered via an interactive model. The children will be taught the pertinent information, in a simplified way, so that they may later be asked to derive their own hypotheses. Each child will be allowed to manipulate a model of a semicircular canal to further demonstrate the information we are trying to present. They will have an opportunity to test these hypotheses by manipulating their own VOR through spinning their entire bodies. The children will be able to see the actual reflex at work as a result of their own actions and, as we will be asking them for their conclusions, will be able to connect what we have told them with their own experiences. Based on what they view as their results, we will be able to better judge whether or not they were able to truly grasp the concept of this particular reflex. On the whole, we hope the children we present to

will be able to take home with them a greater understanding of and appreciation for a reflex that is vital to our ability to accurately view the world around us.

*Materials and Methods:*

In order for the children to adequately grasp the concept of the experiment, we will begin by presenting a poster highlighting the production of signals, the pathway they follow, and, in the interest of time, the main components of those discussed previously. Throughout the presentation and following activities, we will be welcoming any questions the children might have and answering them to the best of our ability. After the poster's pictures and concepts have been discussed, we will present the children with a model of the fluid within the canals and the affect its movement has upon the cilia of the hair cells. This model will be made using a petri dish filled with water and a magnetic stirring rod to help move the water in a specific direction. Paint brush hairs will be placed in the water and the children will be able to witness how the movement of the water affects the movement of the hairs. To test understanding of the concept, we will inquire, once the children have witnessed the direction of hair movement as the water is in motion, which direction they believe the hairs will travel once the water is no longer being stirred.

Next, the children will be presented with a large model of the semicircular canals constructed with large rubber pipes connected together. This three-dimensional visual aid will contain small metal balls within each tube which are free to roll around inside. As a result, since the children will be allowed to manipulate these "canals" in whichever direction they please and through the movement of the balls inside, a greater understanding will be gained of the affect a certain type of rotation has on each specific canal orientation. We will ask for the children to give us examples, using the model, of what horizontal and vertical movements of the head would look like. Since we will be focusing primarily on horizontal rotation for our final model, we will encourage the children to rotate the canals in this way so that they witness the effects this has on the movements of the metal balls and are able to draw conclusions from what they observe as well as give us examples of when horizontal rotation might occur. At this point we will also touch once again on how the movement of these canals, a result of head movement, affects the actions of the eyes.

Once we have explained all of the aspects important to our experiment, we will ask four children to each sit in a chair and stare at an object which will be placed in front of them. Four more children will be selected and, after being paired up, will be asked to fully spin their partners around in the chairs ten times. Prior to the actual spinning, we will encourage the children doing the spinning to race to be the first to complete this task and tell us what they witness when they observe their partner's eyes. We will ask the children to form a hypothesis, based on the information they have been presented with, as

to what they believe will happen to the movement of the eyes following a horizontal rotation of the semicircular canals. After the experiment, we will hear what the children witnessed and explore why this was the case with regard to the VOR. To determine the amount of information the children were able to retain from our presentation, we will inquire as to how many of them have ever experienced an ear infection and ask them to describe their symptoms. Based on what we have previously explained, we will ask them to hypothesize how an ear infection could affect this reflex as well as suggest possible other situations where alteration could occur, such as while one is in space.

Results:

We found that the children involved in the Kid’s Judge Neuroscience Fair who took part in our Crazy Eyes exhibit learned from as well as responded with enthusiasm to it. The children gave us, for the most part, positive remarks on the questionnaire forms and we placed second in the yellow group. This reflected their willingness and eagerness to participate in the spinning experiment as well as in answering questions and forming their own hypotheses. The judges in the yellow group were instructed to fill out a questionnaire which ranked our performance on several different levels. The ranking was conducted on a one to five scale with five representing the answer of yes and a one representing a response of no. For each question asked on the questionnaire, the votes were added and then averaged to determine how the judges viewed our performance. The questions asked included whether or not the kids could understand what we were trying to tell them, if we were friendly, if they found the exhibit fun, We then compared our rankings to those received by other exhibits in the yellow group (table 1).

Table 1

<b>Exhibit</b>	<b>Q1 Understand</b>	<b>Q2 Friendly</b>	<b>Q3 Fun</b>	<b>Q4 Learn More</b>	<b>Average</b>	<b>Place Vote</b>
<i>Putt-Putt Pathways</i>	4.56	4.85	4.67	3.63	4.43	1
<i>Crazy Eyes!</i>	4.64	4.72	4.38	3.80	4.39	2
<i>Marvelous Myelin</i>	4.60	4.56	4.60	3.92	4.42	3
<i>The Stroop Fluke</i>	4.23	4.35	3.92	2.96	3.87	4

The responses from the children when asked towards the end of the questionnaire what they learned from the exhibit were very similar. The most common responses had to do with either the affect semicircular canal signals had on the eyes or the movement of hair cells and the resulting eye movement. Despite the fact that these responses varied slightly from child to child, the answers were all related to the vestibulo-ocular reflex. These similar responses revealed that we were successful in teaching the children about our topic. However, two of the children stated in the questionnaire that they did not learn

anything new from our presentation. On the other hand, when asked which part of the exhibit they enjoyed the most, the overwhelming response by the children was the spinning in the chairs.

*Discussion:*

Overall, Crazy Eyes ended up a success. The comments we received from the children regarding our presentation supported our hope that we would be able to teach them the important aspect of the vestibulo-ocular reflex while at the same time maintaining their interest and level of excitement. However, in order to do this, we were required to simplify our lesson slightly when presenting it to the 5<sup>th</sup> graders. Although we discussed the primary structures involved in the reflex such as the hair cells, semicircular canals, and eye muscles, we omitted several of the more involved details. These included choosing not to confuse the children with information regarding the different ions such as sodium, potassium and calcium that are involved in the transduction of signals needed for this reflex to function properly. Also, although we touched briefly on the importance and major mechanism of tip links, we did not delve into the entire process involved between the movement of kinocilium and the connected hairs. Instead, we simply recognized that they were present. We also did not discuss the specific pathways involved in the reflex, but informed the children that there was a connection nonetheless between the inner ear and the eye muscles. We feel that it was necessary to omit these details in order for the children to better understand the basic concept we were striving to teach them without having it clouded by pathways and words they would most likely be unable to recall later. We found, as we altered each presentation based on the one before, that the children were much more engaged if we would explain a portion of the reflex and then ask them a question about what the importance of having that particular structure or function would be. The children were all extremely eager to answer as well as ask questions throughout our exhibit. We were truly surprised as the kids began to answer their own questions as we presented them with more information and active models with which they could test their own ideas.

Unfortunately, the models we used did not always perfectly represent the structure they were intended to mimic. The model we used for our semicircular canal occasionally had some of the “hair cells” detach from the walls of the tubes and freely float within the tube. This made it slightly more difficult for the children to see which direction the remaining hair cells were bending as the water moved over them. The spinning experiment, which was the most enjoyed portion of our exhibit according to the responses made by the children, appeared to produce a result most of the children had never seen before. The model of having the children spin in the chairs and visualize the results the VOR had on their eyes was chosen by us to demonstrate the manner in which one can manipulate a reflex as well as see what life might be like in the absence of that

reflex. As we were not certain that all the children in each group would be able to see the eye movement after the spinning had ceased, since this reflex seems to respond with varying degrees based on the individual, we had a backup plan. If the children were unable to see any movement of their classmates' eyes, I would spin myself in the chair and allow them to look at the results of manipulating my VOR. I knew from prior experience that I would have a very pronounced response to the spinning and the children responded to what they witnessed with many excited remarks. I believe this was partially due to the fact that they were not aware that spinning would result in such strange eye movement, and partially due to the realization that their hypotheses decided upon before the spinning were supported by what they observed.

Crazy Eyes, despite its weaknesses, turned out to be an enjoyable and informative exhibit for the children participating in Kids Judge. The children demonstrated through their comments that they were able to retain the important information regarding the VOR just as we had hoped they would. Our award of second place in our group suggested to us that they also remained interested and perhaps even excited about our topic and the models we offered. I believe for the next Kids Judge, however, I would suggest using a base model that did not take a lot of time to explain for the children to understand what would be happening. The children seemed to enjoy our exhibit quite a bit during the organized judging session, but it was less popular during the open browsing section. This was due to the fact that our models took a bit of background information disclosure before the kids could truly understand the point of performing their own experiment. Unfortunately, this caused many children to lose interest quickly and move onto another exhibit with more interactive aspects involved. Overall, our exhibit received relatively high scores from the children as well as placing second in our group. This information was encouraging to us as it suggested that we were in fact able to teach the children adequately about our topic while providing them with interactive models they could enjoy. I believe Crazy Eyes met its purpose at Kids Judge and was indeed a triumph.

Works Cited:

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