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Neuro 430
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Writing in the Major Assignment

WHAT DO YOU SEE?
–A MODEL TO INTRODUCE VISUAL PROCESSING

Abstract

Vision is one of the most studied human senses. Visual processing occurs in two major stages. Light entering the cornea projects onto the back of the eye where it is converted into an electrical signal by photoreceptors. These electrical signals are then sent through the optic nerve to higher centers in the brain. In order to explain the two stages of visual processing to the kids, we used a projector head as eyes and a 5×5 grid screen as retina. Three groups of kids acted as the eye, ganglion cells or visual cortex. The kids acting as the eye filled the grid on a transparency in a pattern with red, green or blue colors. The kids acting as ganglion cells sent information to "visual cortex" with balls through red, green or blue pipes. The kids, acting as the visual cortex, drew a picture based on the information they received from the ganglion dells. By playing this game, the kids learned the basic components of visual processing. They also learned about the relationship between cone cells and color vision. They thought our model was funny and that we were friendly. We placed second in our competition group.

Introduction

We introduced visual processing to 5th grades because the visual system is interesting to children, and used common strategies for sensory processing. To give people the ability to see the world, the visual system contains photosensitive cells called photoreceptors to detect the light. Understanding how the visual system works can help kids understand how other senses work because visual processing shares similar strategies with other sensory systems. External stimuli are detected by the receptors and are converted into neural signals that convey information to the brain.

Visual processing begins at the eye where light from the external environment is focused on the back of the eye and activates photoreceptors. The essential structures in the eye for image formation are the lens and the retina. External light passes through and is refracted by the lens. Eventually, there is a focused image formed on the retina (1).

On the retina, the light can be detected and converted into neural signals by the photoreceptors. The retina has 6 types of cells: rods, cones, horizontal cells, bipolar cells, amacrine cells and retinal ganglion cells (2). Among them, rods and cones are the photoreceptors. The rods are sensitive to luminance. They are activated at the lowest levels of light. As illumination increases, the cones become more and more dominant in determining what is seen. The cones are responsible for color vision. They can detect color based on different wavelengths of the light. There are three types of cones that differ in the photopigment they contain. Each of these pigments has a different sensitivity to blue, green and red light (3). Thus, individual cones provide color information for the wavelength of light that excites them best. Color perception depends on how many cones in each type are activated.

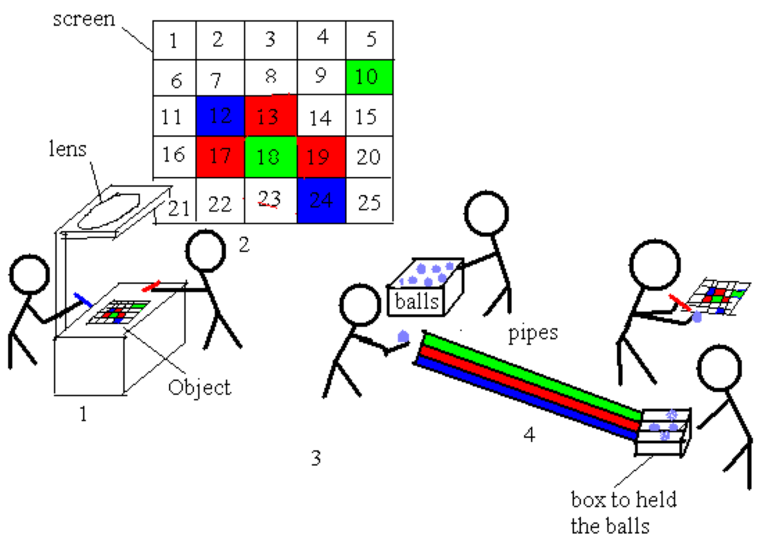
Photon absorption leads to hyperpolarization of the photoreceptors. In the dark, the photoreceptor is in a depolarized state because the Na^+ channels on the outer segment of the photoreceptors are activated by cGMP. When a photon is absorbed, cGMP levels drops and some of the channels close, leading to hyperpolarization of the outer segment membrane. Hyperpolariztion will reduce the amount of neurotransmitter release and change the excitability of post-synaptic neurons.

At the synaptic terminals of rods and cones, light-evoked signals are transferred to bipolar cells, which connect to ganglion cells. The axons of ganglion cells gather together and form the optic tract. The dendrites of ganglion cells collect the signals from the bipolar cells and the axons send the signals to different regions of the brain (2). The signals which are sent to bipolar cells by photoreceptors are modulated by horizontal cells. The information from bipolar cells to ganglion cells are regulated by the amacrine cells. Thus, the signals sent to the brain are already highly processed when they leave the retina because of the synaptic interactions between photoreceptor, horizontal cells and bipolar cells. The projection from the eye to the brain is organized into parallel routes, and the fibres of optic tract are terminated in different subcortical areas such as lateral geniculate nucleus (LGN) and pretectum. Then the LGN sends out many optic radiations to the primary visual cortex (V1) where the shape and the color are perceived. The V1 sends the information further to other areas in the cortex for object recognition and spatial perception, etc. Since there is a visual topographical projection of the retina on the primary visual cortex (4), the images formed on different positions of the retina are projected onto corresponding areas in the visual cortex. This labeled line code property is important for the spatial recognition function of the visual cortex.

Since visual processing is complex, we didn't want to introduce all the details to the kids. We only wanted them to know the basic components of this process. First, we introduced the major structures involved in the visual processing: lens, retina, ganglion cells, optic nerve, and visual cortex. Then, we showed them how the lens can refract the light and focus an image on the retina. In addition, we taught them that color information is encoded by three types of cones on the retina transferred by ganglion cells. We also showed them how the topographical projection of the retina on the visual cortex contributed to spatial perception. In order to achieve the above objects in a fun way, we made a model and designed a game for the kids. In this game, the kids were divided into 3 groups and each group acted as eyes, ganglion cells or visual cortex separately. The task for the kids was to see if the "visual cortex" could draw the same picture as "eye" without looking at it.

Methods

The set up of our model is briefly shown in the following picture.



The images drawn on the transparency represented the objective "seen" by the eye. The lens of the projector head served as the lens in the eye. When the projector head was turned on, the kids saw an image focused on the screen. The screen had a numbered 5×5 grid representing the retina and each box on the screen acted as a cone cell. In this model, there were 25 cones in different positions of the "retina". We used red, green and blue pipes to represent a bundle of optic nerves. The numbered balls rolled through the "nerve", and were information sent to the visual cortex. The visual cortex was represented by a paper which had the same grid as the screen.

During the game, the kids were divided into 3 groups of 2-3 kids. The kids in group 1 were responsible for the eye-work. They filled the boxes on the transparency with green, red or blue color. They were also in charge of focusing the projector head to get a sharp image. The kids in group 2 stood in front of the screen and acted as ganglion cells (the bipolar cells are omitted in our model). They picked up the balls containing the same numbers with the filled boxes on the screen. Then they rolled the balls through the channel which contained the same color with the boxes on the screen. Thus, the positions of the images were encoded by the number of the ball and the color information was encoded by the color of the pipes. The kids in group 3 sat on the other side of the screen and worked as the visual cortex. They picked up the balls from the channels and chose the pens which had the same color with the channels to fill the boxes contained the same numbers with the balls. This helped the kids to learn how the information is interpreted in the visual cortex. Finally, we asked the kids to compare the image drawn by the "visual cortex" with the image on the transparency to see how visual perception reflexes the real world.

Results

After we presented this model, the kids seemed to understand how visual processing took place. They asked about color blindness when we were introducing the color vision and three types of cone cells. At the end of the game, if they got different picture from the "eyes" and the "visual cortex", some of them could analyze where the problem was by the hints we gave them. By doing this, they understood that the eyes, the nerve and the visual cortex must work together during the visual processing. After the game, we asked them which part is the most important in the visual processing. Their answer was "all of them".

In the voting for the favorite model, we got 7 votes out of 25 and ranked at the second place out of 4 models.

The score of each evaluation question is shown in table 1. They also wrote some comments on the evaluation form. For example, some of the kids wrote that the most interesting part of the model was rolling the balls through the channels. Some of them thought that drawing a pattern was most interesting.

Question	Score	Ranking in the group
Understand	4.40	3
Friendly	4.96	1
Fun	4.64	2
Learn more	3.84	2

Table 1

From the written entries of the evaluation form, we saw that some of them liked learning the parts of the eye and visual processing. Some of them liked the game. They liked working with the projector head, drawing the pattern, finding the code, rolling the balls and guessing what the object was.

The kids also wrote what they learned from the model. Some of them learned that the eye has a cord that goes to the brain. Some of them got that the eye carries color back to the brain. Some of them said that the eye has different parts that can distinguish color and things. Some of them thought that all the information goes through the lens.

Discussion

By using this model, we introduced the basic components of visual processing to the kids. In the eyes, the lens refracted the light and focused an image on the retina. The information of the shape and color of the image were encoded by the positions and the types of cones and transferred to the visual cortex by the optic nerve. The topographical projection from the retina to the visual cortex was essential for the perception of the object shape.

A good model should convey accurate scientific information and help children to understand the model easily. Our model contained the information that we were trying to tell the kids. But it turned out that they did not understand as well as we expected. For the "understanding" evaluation, we only got 4.4 out of 5, ranking 3 of the 4 models in the R group. From the entries on the evaluation form, we saw that the kids understood the principles fairly well. Some of them said "the eye had different parts that can distinguish color and things". Some of them said that "the eye has a cord that goes to the brain". Some of them learned that "the eye can not send color back to the brain that sometimes nerves get damaged." When the kids were asked if they want learn more about this topic, they only gave us 3.84 out of 5. This is not a good score although it ranked 2 out of 4 models in R group. The reason that they did not want to learn more might be that they received the information passively. It might have been better if we had asked them what they were interested in before we made the model.

To make this model more understandable, we needed to reorganize our presentation of the model. On "kids judge" day, we first introduced all the visual processing using another set of eye ball, nerve and brain and then let the kids play the game. They might not have received a deep impression about each part of our model represented and the structure of the visual system. Maybe introducing the principles, showing them our game at the same time, and matching each part of the model with the structures in visual system would be more helpful for the kids to understand the model.

There might have been some inaccuracies in the model that hindered the kids' understanding of the model. For example, they only used red, green and blue in this model but there are many more colors in the environment, using combination of red, green and blue. Also the things that they drew on the transparency were too simple, and didn't look like anything in reality.

To improve out model, we can print a RGB picture in blue, red and green channel separately on transparencies, show the overlap of these three pictures, and then show them the pictures in each color. By doing this, we can show them that all the colors can be decomposed into red, blue and green. We can also show them a picture in a 200×200 grid, and tell them that we will only work on a very small part of the retina in this game.

Another important objective of our model was to let the kids have fun while learning and evoke their interest in neuroscience. Being friendly to the kids is necessary to make them enjoy learning our model. We did well in this aspect and got 4.96 out of 5, which scored highest in that category in the R group. The most effective way to attract the kids is to involve them in an active way in our model. From the writing entries of the evaluation from, we found that every part of the model had fans. They like working with the projector head, drawing the pictures, finding the code and rolling the balls. This is good, but we can still improve the model. Because the kids like competition, we can divide them into two teams and let them compete against each other. To do this, we need to add one more set of signal balls, one more set of nerves and one more box to held the falling balls. Then, for a six-kid group, we will have 2 kids working on the projector head. They will draw the pattern on the transparency. Then will turn on the projector head and begin to measure the time. The two different ganglion cell kids then send information to the corresponding visual cortex from the corresponding nerve. After each cortex-kid draws the picture, the judges record the time. The team that draws the exactly same picture faster will win.

In summary, this model illustrated the scientific process of vision and involved the kids in an active way. To improve this model, we could give a better presentation to make it easier to understand. We can also make it more interesting by introducing competition in the game.

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