Seeing is Believing?

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ABSTRACT

Vision allows us to encode information about the outside world, and visual processing must therefore include a mechanism for interpretation of this coding. The mechanism is both complex and not very well understood and is termed the binding problem. Despite its complexity, vision is one of our most important senses, so for Brain Awareness Day, we attempted to explain basic visual processing to fifth-grade students. We used a poster with simplified diagrams to detail the first concept: how the visual system perceives pieces of our environment and must integrate them into a meaningful whole. In addition, two small racecar Lego sets were given to groups of students to build, but they were not allowed to see a picture of how the car should look. Students were able to act as visual processing pathways by putting together pieces of a whole into an object that they could understand. To demonstrate a second concept, we used a poster of visual illusions. We explained that vision is an interpretation of how our senses perceive the outside world, and therefore it is not always accurate. Students were asked to rate the presentation on a number of levels, and we based our success on this evaluation and their reactions during our presentation. Our model tied for third (last) place in Group A and had the lowest combined average score. However students generally appeared to grasp one or both of the main concepts and said they very much enjoyed building the cars. We might have improved our scores and increased student interest by further simplifying the concepts and clarifying the two main points.

INTRODUCTION

All animals depend on their senses to comprehend the environment; for most animals senses are essential for finding food and alerting to danger. As humans, most of us rely heavily on sight, as evidenced by the large amount of the brain devoted to vision. Visual processing begins in the retina, where photoreceptors detect light. Information about light is transmitted to retinal ganglion cells, which subsequently form the optic nerve, chiasm, and tract. In visual processing that leads to conscious perception, the optic tract synapses in the lateral geniculate nucleus (LGN) of the thalamus and projects to the primary visual cortex (V1) (Kandel, et. al., 2000). Visual field information is preserved retinotopically and, once it reaches V1, certain pathways have been shown to respond preferentially to certain features of an object. Areas V4 and V5, for example, are linked with color and motion, respectively. Additional features may include contour and depth as well as more complex visual distinctions of object identity and location (Kandel, et. al., 2000; Tsunoda, et. al., 2001).

The ability of the brain to rapidly integrate both object identity and location suggests that a process or mechanism “binds” together related stimuli. Binding different information levels may begin with receptive fields, such as ON center/OFF surrounds, which occur in the retina, LGN, and V1. In V1 simple cells integrate information from receptive fields of the retina and LGN. Complex cells in V1 receive and integrate signals from simple cells and then project to higher order processing areas (Kandel, et. al., 2000). Horizontal connections can modify such parallel pathways. Furthermore, complexity of a bound object may depend on whether the contributing pathways have been previously stimulated (Gilbert, et. al., 1996).

Different theories have arisen to explain exactly how the brain binds these features into a coherent object. One theory states that binding depends on spatial and temporal frequencies, or the tendency of certain features to group together over space and time (Kandel, et. al., 2000). It is suggested that patterns over time are more easily detected if that pattern relates spatially into a recognizable object. According to some studies, temporal relationships between features are not found to completely bind them, but changing temporal frequency does influence spatial binding. Unfortunately, difficulties with experimentally testing these hypotheses have prevented more definitive characterization of the relationship between spatial and temporal frequency and binding (Alais, et. al., 1998; Gray, 1999; Usher & Donnelly, 1998). Even if it can be shown that neurons fire synchronously to related spatial stimuli, there must still be a link between the synchronicity and coherent perception of an object (Blake & Yang, 1997). Singer (2003) discussed the relationship between synchronicity and binding as well. He described the concept of assembly coding, in which a neuronal network response is synchronized when each cell or group of cells in the network responds to a specific stimulus. He suggested that these networks are capable of evaluating synchrony in both space and time, and this is the mechanism underlying binding in the visual system.

Visual processing is a complex subject and still not very well understood, so we used a much simplified and loosely applied model to demonstrate binding to younger students in an understandable format. Processing can essentially be explained as a series of parallel pathways that condense information so the brain may understand or perceive a whole object. A poster illustrated the general principles of segmentation into features and binding of those features into an object. Students were then instructed to build Lego racecars without seeing a picture of the car's intended form. Building the models quickly and accurately parallels the efficiency with which the brain integrates features into an understandable whole. A further point is that the brain may not be entirely accurate in its representation of an object (seen in the differences between the two Lego models within one group). Even if assembled correctly, the coherent object may not make sense, as in a visual illusion. Several visual illusions were presented to exemplify how this happens. The fundamental concept we attempted to convey is that the brain is adept at assembling a coherent form for an organism to perceive consciously. The misjudgments the brain can make are usually minor and can be observed using visual illusions.

MATERIALS AND METHODS

For each rotation group, we began by presenting a poster that illustrated how features of the environment are perceived and integrated by the visual system. We explained how color, line orientation, depth, and texture are taken in by the retina, encoded into parallel visual pathways, and integrated back into a coherent picture of the world. The image of a 'T' was used to exemplify each feature.

The second part of the presentation included two Lego racecars that the kids were instructed to assemble. Certain pieces of the racecars had been previously glued together to save time, but we left enough pieces to ensure variability between the two assembled racecars. Each rotation group was split into two groups of three or four that each assembled one car. Students were not shown a picture of the intended form of the Lego set, but were instead instructed to build it based on how they thought it should look. We gave them five minutes to complete this task. The kids were then shown the difference between their models and the intended racecar.

When the car exercise was complete, we showed them a poster of visual illusions. Students were instructed to figure out what was wrong with them and why they did not make sense. We explained that common visual illusions demonstrate how the brain can misinterpret certain images due to their context.

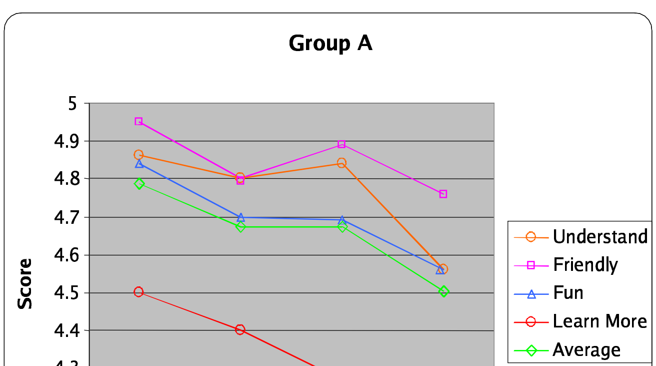
Finally, we summarized the main points from both posters. We reiterated that seeing is a matter of putting all the pieces together, and the brain 'binds' quite a few pieces of information together every second so that we can understand what we see. Furthermore, the brain is great at binding, but it can make mistakes.

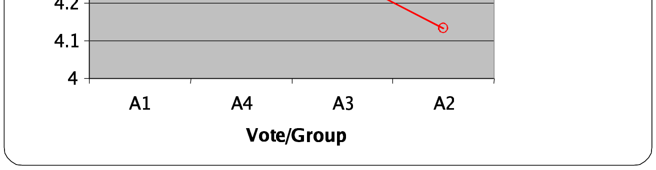
At the end of the presentation, students were instructed to fill out a quick survey of the models. They were asked to rate the models based on how well the presenters helped them understand the topic, if the presenters were friendly, whether they had fun, and whether they would like to learn more about the topic. Each category was rated on a scale of 1 to 5, with 1 being the lowest score and 5 the highest. Additional space was provided for the kids to write what they learned, what their favorite part of the model was, and any other comments or suggestions.

RESULTS

The students seemed to be a bit overwhelmed by the amount of information on the first poster, as they did not ask many questions during this part. We explained it as clearly as we could, but tried to also move through it quickly to keep their attention. As we moved to the second part, where they assembled the Lego racecars, the students became much more enthusiastic. They worked together very well to assemble the cars and most groups finished building them within five minutes. The students were also excited to see the intended racecar, and some of them even wanted to try to build the cars again. The illusions poster also seemed to interest the kids, as they spent a long time at the end of the presentations looking at the poster.

Figure 1 shows the comparison of our scores (A2) to those of other presenters in Group A. Our combined average was the lowest out of the four groups (4.50) and the individual average scores for each category were also the lowest. Nevertheless, we tied for third place with group A3. Most kids wrote that building the cars was their favorite part of our model. A few wrote that they liked the illusions the best and that being able to see the intended racecar was the most exciting part. The evaluation question for what the kids learned yielded many different answers. Some of them included that the brain puts together information from our eyes, the eyes turn things into tiny particles, the brain can make mistakes, and different brains interpret things differently. Unfortunately, we also received a few answers that were blank, or the student had written "nothing" or "lots." Other comments were "well planned," "awesome," "I loved it," "it was my favorite," and "you were good presenters." We received very few suggestions, but one student wrote that it would be a good idea to have a race between groups to build the cars the fastest.





Question	Average responses for **A2**
1: Did you understand the explanations of the presenters?	4.56
2: Were the presenters friendly?	4.76
3: Did you have fun at this exhibit?	4.56
4: Would you like to learn more about this topic?	4.13
Combined Average:	4.5025

Figure 1. Trends between the presenters of Group A and individual ratings for Group A2.

DISCUSSION

Posters were used so the students had a concrete visual aid to help them understand the visual system. The first poster illustrated how the brain assembles a coherent picture by encoding and interpreting certain features of the environment. Color, line orientation, depth, and texture all depend on various pathways and cells within the visual system, but ultimately they are bound into a single percept to facilitate comprehension. As we explained this to the younger students, they seemed to grasp that the brain must put all the pieces together, but the rest of the information might have overwhelmed them and confused this point. We received the lowest average score for the 'understanding' category in Group A, a 4.56, but I believe that the main points were generally understood. We gave them an opportunity to ask questions, but in most cases they did not have any. This may have been due to the kids not understanding the details.

In the illusions poster, we demonstrated that the brain can make mistakes in binding. Not only does the brain interpret what we see using prior experience, but it can reflect artifacts of the visual system. For example, vision may prevent us from seeing certain features that are present in the environment (the blind spot). What one sees in the illusions is a complete picture that must involve binding, yet upon careful inspection, it does not make coherent sense. The kids seemed fascinated by the poster of illusions, and they seemed to understand that they were the result of the brain misinterpreting the image.

The Lego sets allowed students to become parallel neuron pathways, each in charge of certain features (pieces). They worked together assemble a whole object, which represented how the brain, with the right pieces, is quite accurate at binding features into an understandable whole. When finished, the two models looked a little different, some radically so when the students decided to think creatively. None of the models matched the intended racecar exactly, and this demonstrated how the visual system does not represent the environment in its exact proportions.

The model's limitations include, of course, that the concept of visual integration is greatly oversimplified and thus not as accurate as it could be. The synchrony theory explains how binding occurs and why we see what we do by analysis of frequency information. This is something that is extremely difficult to model in an interactive and understandable format. Lego models seemed ideal to illustrate just that the brain does bind to help us understand the features of a whole object in our environment.

A few of the students wrote down and seemed to understand our take-home message, but not as many as we would like. A clearer statement of the main points would have helped. Also, it may have been better to have a simpler poster, without as many details, because I believe it was distracting for them to have so much information at once. This would mean sacrificing some accuracy in an attempt to make a stronger point, but the kids might have had more fun by and wanted to learn more about the topic if we had not tried to present as much information. In addition, I would suggest having more questions at the end of the presentation. Asking them questions would have been another way to evaluate how well they understood the model, but our explanations took most of our allotted time.

Overall, I believe the model was well received but we could have more clearly explained the main points. Our first poster probably contained too much information, but our illusions poster held the kids' attention well. More time with each rotation group would have been helpful for this concept, as it is complex and was difficult to explain. At the same time, it is one of our most important senses and I believe kids can benefit from learning more about the basic concepts of visual processing even if they do not understand its complex nuances.

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