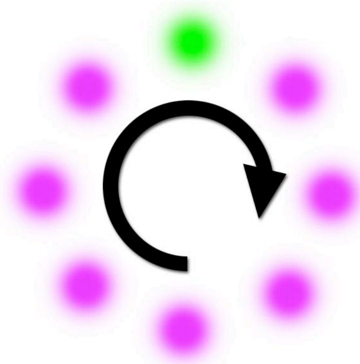
Optical Illusions

"What you see is not what you get"

The purpose of this lesson is to introduce students to basic principles of visual processing. Much of the lesson revolves around the use of visual illusions and interactive demonstrations with the students. *The overarching theme of this lesson is that perception and sensation are not necessarily the same, and that optical illusions are a way for us to study the way that our visual system works. Furthermore, there are cells in the visual system that specifically respond to particular aspects of visual stimuli, and these cells can become fatigued.*

Grade Level: 3-12

Presentation time: 15-30 minutes, depending on which activities are chosen



Lesson plan organization:

Each lesson plan is divided into three sections: *Introducing the lesson*, *Conducting the lesson*, and *Concluding the lesson*. Each lesson has specific principles with associated figures, class discussion (D), and learning activities (A).

This lesson plan is provided by the Neurobiology and Behavior Community Outreach Team at the University of Washington: http://students.washington.edu/watari/neuroscience/k12/LessonPlans.html

Materials:

Computer to display some optical illusions (optional)
Checkerboard illusion:
Provided on page 8 or available online with explanation at
http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html
Lilac chaser movie:
http://www.scientificpsychic.com/graphics/ as an animated gif or
http://www.michaelbach.de/ot/col_lilacChaser/index.html as Adobe Flash and including scientific explanation of the illusion
Waterfall effect video with explanation:
http://www.lifesci.sussex.ac.uk/home/George_Mather/Motion/MAE.HTML
Spiral effect:
http://chiron.valdosta.edu/mawhatley/2500/spiral.htm as animated gif
http://www.michaelbach.de/ot/mot_adaptSpiral/index.html as Flash
http://www.michaelbach.de/ot/mot_adapt/index.html as Flash, different version

Introducing the lesson

D: Visual sensation & perception using the checkerboard illusion
Explain that today you will be talking about vision and learning how our eyes and brain allow us to see what's going on in the world around us. The following sequence is a guide:

1. Explain that we will be talking about two different ideas- sensation and perception. Ask students to describe the difference between the two *(sensation is what our eyes see, perception is what our brain sees; sensation is the same for everyone, while perception is different for everyone; sensation doesn't change based on past experience, while perception can)*.

2. Use the checkerboard illusion to reinforce this point and help students understand that what we sense and what we perceive are not always the same.

    a. Ask students if squares A and B are the same shade of grey or different shades of grey *(They will usually say that they are different shades of grey)*.

    b. Show students the squares without the rest of the image (if done on paper, two holes corresponding to the squares can be cut out of a second paper and laid over the image) and ask them again to again compare them *(they now look the same)*.

    c. Explain to students that the colors are actually the same- the sensation of color doesn't change, but our perception of the color is different depending on the context. That is, our brain makes the color appear different than it really is.

d. Ask students why they think their brain makes the shades of grey look different in the complete picture, or what cues their brain is picking up on to change their perception *(your brain thinks that it is in the shadow, so it interprets it as being lighter than it really is, your brain recognizes the checkerboard pattern and knows that it goes dark-light-dark, so it assumes that square B should be lighter than it really is).*

e. Explain to students that your visual system often changes what we see so that our perception is different from our sensation. Optical illusions are ways to trick our visual system and therefore discover how our brain processes information. Explain that we are going to look at several different optical illusions to try to understand how our brain understands the world, but first we need to identify different things in our world that our brain is paying attention to.

D: Aspects of vision

1. Ask students if they have ever watched a basketball (or other sport) game. Ask students how they were able to tell which team each player was on *(the color of their jersey)*. Follow-up by asking what it would have been like if they weren't able to see color *(they wouldn't be able to tell the teams apart very easily).*

2. Ask students to describe some of the other things their eyes had to pay attention to while watching the game *(the movement of the players, where the ball was, etc).*

3. Explain that there are many different things that their eyes and brain are paying attention to whenever they look at something, including: color, faces, movement, size, depth (3D), background, length, brightness, patterns, and shadows. List these on the board as students suggest them. Explain that with the checkerboard illusion we've already seen how the brain uses shadows and patterns to create perception from our sensation, and that we'll look at a few others, including color and movement.

Conducting the lesson

Note: Depending on time and attention of your students you can do as many or as few of the following activities as you wish.

Principle 1: (Color) **Photoreceptors in our eyes fatigue**

D: After-images

1. Ask students if they have ever had their picture taken with a flash. Ask them what they saw afterwards if they were looking directly at the flash *(a dark spot in their vision)*. Explain to them that this black spot is called an "after-image." Ask students how they think this black dot relates to the difference between sensation and

perception *(the black dot really isn't there, so our perception of it is different from the actual sensation).*

2. Explain to students that you are going to look at some other examples of after-images to try to understand why they appear and what they teach us about how the visual system works.

A: Lilac chaser

1. Explain to students that they are going to see a movie with a circle of dots, with a gap in the dots rotating around the circle. Ask them to tell you the color of the dots immediately after you pull up the lilac chaser movie *(pink, lilac, purple)*. Using a laptop, display the lilac chaser optical illusion. Ask students to stare directly at the center of the image, trying not to move their eyes from the center.

2. Ask students what they begin to see if they don't move their eyes. *(A moving green dot appears, the purple dots disappears)*

3. Explain to students that just like the dark dot after a flash is an "after-image", the green dot they see is an "after-image." Challenge students to follow the green dot with their eyes to confirm this. Just like the dark dot wasn't really there (we didn't sense it, but we perceived it), the green dot isn't really there, but something that our eyes and brain make us think is there.

4. Ask students why they think that the dot that they see is green rather than some other color *(it is the complimentary color of lilac).*

5. Using the color wheel found on page 9 explain that green is the opposite color of the lilac, and that this illusion helps us understand how our brain sees color.

D: Photoreceptor fatigue

1. Ask students what happens if they try to lift something heavy like a weight over and over again repeatedly, or if they run for a long time *(they get tired, they can't lift it or run any more).* Explain that when you do something hard your muscles can get tired or 'fatigued' and they have a hard time doing the same thing until they get some rest.

2. Explain to students that there are special cells in our eyes called photoreceptors that 'see' light- that is, when light hits them, they send a signal to our brain. Just like muscles get fatigued when they do the same things over and over again, the photoreceptors in our eyes can get fatigued if they see the same thing for a long time (like the purple dots) or if they see something really bright (just like our muscles can get tired really quickly if we lift something really heavy). Explain that this is what causes the 'after-image.'

D: Opposite colors

1. Ask students if they have ever played tug-of-war. Ask them what would happen if one team suddenly got really tired *(the other team would be pulling more strongly and would fall over backwards)*. Explain that this is sort of what happens with fatigue in our eyes. Every time we look at a color, our eyes are sending two opposite signals to the brain, like two teams pulling on the same rope, but in different directions. In the case of the example, it's a lilac signal and a green signal (or teams). When we first look at the image, the lilac signal is winning, so that's what we see, but if we stare at it long enough, the photoreceptors that tell us that it is lilac get fatigued, and can't send as strong of a signal (don't pull on the rope as hard). That means that the green signal (team) begins to win instead, and our brain thinks that we are seeing green instead of lilac. Our perception and our sensation are not the same- we are sensing purple, but perceiving green.

2. Ask students to predict what they would see if the dots were blue instead of lilac *(yellow).* Note: with the Flash version of the effect, you can change the colors of the dots to test this hypothesis.

A: Inverse-flag effect
Note: If a computer is not available, this activity could be done with an overhead projector in place of the lilac chaser, modifying the discussion where relevant.

1. Show students that flag on page 9. Using the color wheel, ask them to predict what they will see as an 'after-image' of the flag if they stare at it for a long time. *(The American flag).*
2. Have students stare directly at the center of the flag without moving their eyes while you count down from 20. Then have them stare at a blank screen, wall, or paper and say what they see *(the American flag).* If students do not see it immediately, have them blink a few times, or try the effect again.
3. To reinforce the previous discussion, ask students to turn to their neighbor and explain why they see an after-image that looks like the American flag. Ask students if they have any questions.

***Principle 2: (Movement)* Cells in our brain help us perceive movement**

D: Movement

1. Explain that another important thing that our brain pays attention to in everything that we see is movement. Ask students to hypothesize what life would be like if we couldn't see movement *(this may be hard for students to conceptualize, but they might say that things that move disappear, or everything might be a still frame).* Explain that there are examples of people with certain brain damage who cannot see movement.

2. Read or ask a student to read the following description of such a patient (from HHMI website, http://www.hhmi.org/senses/b210.html):

“The patient had great difficulty pouring coffee into a cup. She could clearly see the cup's shape, color, and position on the table, she told her doctor. She was able to pour the coffee from the pot.

“But the column of fluid flowing from the spout appeared frozen, like a waterfall turned to ice. She could not see its motion. So the coffee would rise in the cup and spill over the sides.

“More dangerous problems arose when she went outdoors. She could not cross a street, for instance, because the motion of cars was invisible to her: a car was up the street and then upon her, without ever seeming to occupy the intervening space.

“Even people milling through a room made her feel very uneasy, she complained to Josef Zihl, a neuropsychologist who saw her at the Max Planck Institute for Psychiatry in Munich, Germany, in 1980, because "the people were suddenly here or there but I did not see them moving.”

3. Explain to students that there are specific areas in the brain that are responsible for seeing movement. In the case of this patient, these areas of the brain were damaged, and she was no longer able to see movement.

4. Explain that one of the ways by which we can learn how these areas of the brain help us perceive motion is by using optical illusions.

A: Waterfall effect

1. Load the waterfall effect movie and tell students to stare at the center of the waterfall while you count down from 20.

2. Pause the movie and ask students to describe what they see *(the waterfall looks like it’s going upwards instead of downwards)*.

3. Ask students if they think that the movie is actually moving backwards (sensation) or that it is in their brain (perception). Explain that the movement is something that they perceive that isn’t really there.

D: Motion sensitive cells

1. If you have already used the tug-of-war example in Principle 1, help students understand that the explanation for this motion after-effect is similar to that of the color after-image. Explain that just like there are cells in our eyes that send opposite color signals to the brain, and that they get fatigued over time, there are cells in our brain that turn on when they see movement in different directions- up, down, left, right.

2. Explain that you could imagine that these cells represent different teams in tug of war, and that the up and down teams are pulling on the same rope, and whichever one tugs harder tells us if we are seeing something move up or down.

3. Explain that in the case of the waterfall effect, the down cells turn on when they see movement going downwards (they pull harder on the rope). At the same time, the up cells turn off (they don't pull very hard on the rope). It looks like the waterfall is moving because the down cells are winning. But because you stare at the movement for a long time, the down cells get fatigued and they can't send as strong of a signal (they can't pull on the rope as well). When you look at something that isn't moving, for a brief moment the up cells are sending a stronger signal (pulling harder on the rope), so your brain perceives upward motion.

A: Spiral effect

1. An even more compelling version of this effect is the spiral image effect. However, this one should not be used if students may be prone to inducible seizures, and may make some students feel sick.

2. To reinforce the difference between sensation and perception in movement, show students the spiral image effect for 20 seconds and have them look at their hand or an object afterwards. Ask them to turn to a neighboring student and explain what causes the effect based on what they have learned.

Concluding the lesson

D: Sensation vs. Perception

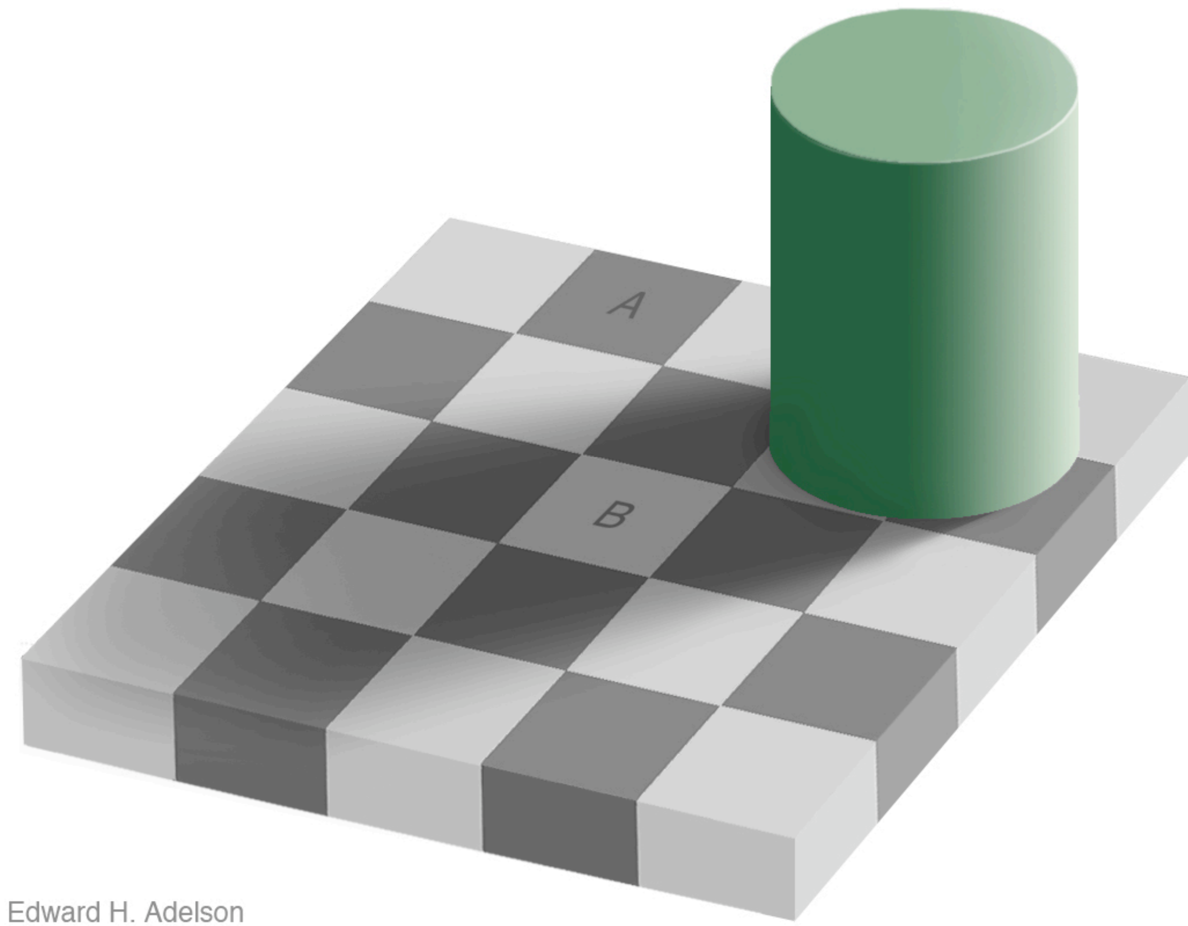
1. Ask students to describe what they have learned about the difference between sensation and perception.

D: Fatigue

1. Ask students to describe what fatigue is *(when neurons fire a lot they get fatigued)*

2. Ask students to describe which cells get fatigued in the optical illusions that we saw *(photoreceptors for the inverse color illusions, cells in the brain for the motion illusions)*

3. Reinforce the idea that particular cells in the visual system respond to particular parts of a visual scene.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Edward H. Adelson