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Curriculum topics:

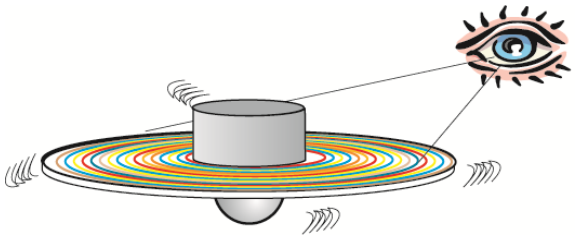
- Vision
- Color
- Light
- Perception

Subject: Life Science

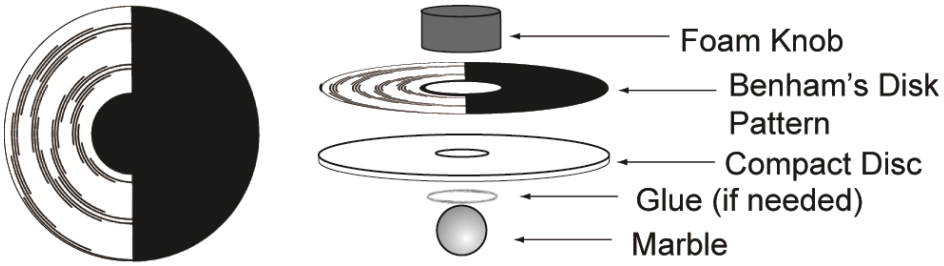
Grade range: 3 – 12

BLACK AND WHITE MAKES COLOR

The mystery of Benham's Disk



Spin a CD with a Benham's Disk pattern on top and observe an interesting optical effect. The black and white pattern on the disk creates a mysterious illusion of color! This illusion provides valuable insights into how our eyes and brain perceive color.



Who we are:

Resource Area for Teaching (RAFT) helps educators transform the learning experience through affordable "hands-on" activities that engage students and inspire the joy and discovery of learning.

For more ideas and to see RAFT Locations

www.raft.net/visit-raft-locations

Materials required

Per unit:

- CD
- Adhesive cylindrical foam piece, bottle cap, or other object to make a knob
- Benham's Disk pattern (page 4)
- Marble
- Hot glue or white glue (if needed)

How to build it

1. If using a RAFT kit, skip to step 2. If making your own disk, attach the Benham's Disk pattern (page 4) to the blank side of the CD.
2. Place the knob over the hole in the center of the CD, on the same side as the Benham's Disk pattern. (The RAFT kit includes a self-adhesive foam "knob". Peel-off the backing paper from the adhesive end of the foam, while squeezing the sides of the foam between your thumb and index finger.) A bottle cap or other knob can also be used.
3. Flip over the CD and press the marble into the hole from the opposite side of the knob. Be sure the marble contacts the adhesive on the foam. (If using another type of knob, glue as needed.) Press down hard to securely connect the knob, CD, and marble.

To do and notice

Spin the Benham's Disk and watch the pattern carefully as it spins. Look for narrow arcs of color at different distances from the center of the circle. Different people may see different colors, and some people will not notice any effect (this is normal). Do the colors observed change as the disk slows down? Reverse the direction of the spinning and see what happens.

The science behind the activity

Color sensing nerves, called cones, are located on the retina in the back of the eye. Cones come in 3 types: red-sensitive, green-sensitive, and blue-sensitive.

White light is a mix of all the colors in the visible spectrum. White light causes all three cones to fire, and our brain tells us we are seeing white. Black is the absence of color. Black causes no cones to fire, and our brain tells us we are seeing black.

It takes a small amount of time for each cone to fire. This is called "latency." After a cone fires, it takes a brief time to shut off even after the color is removed. This is known as "persistence." Each of the different types of cone (red, green and blue) may have a slightly different latency and persistence.

Notice the pattern of curved black and white lines on the Benham's Disk. Recall that white causes all 3 cones to fire, and black causes them to turn off. As you watch the pattern spin, each transition from black to white should trigger all 3 cones to fire at the same time. However, as the different cones turn on and off rapidly, their different latency and persistence responses cause them to get "out of sync." So, instead of firing together when your eye sees a transition from black to white, the cones may fire at different times. As a result, your brain interprets the information as color!

Interestingly, scientists cannot explain why only certain patterns generate the effect. Random black and white patterns do not tend to produce the illusion of color. Somehow, the length of the arcs of black and their locations around the disk are important – but the details continue to elude explanation.

Curriculum Standards:

Senses
(Next Generation Science Standards: Grade 4, Life Science 1-2; Middle School, Life Science 1-8)

Body systems
(Next Generation Science Standards Middle School, Life Science 1-3)

Science Practices
(Next Generation Science Standards Grades 3 – 12)

Additional standards at: http://www.raft.net/raft-idea?isid=305

Learn more

- Have different people observe the spinning pattern and record the colors perceived. What are the most common colors reported? What percentage of the people tested see no colors? Do family members see the same colors?

Extend this activity with the following suggestions:

- Create other black and white circular patterns and test if new colors are perceived when the pattern is spun. The bands could be made wider, less frequent, or more frequent. The solid black area could be made larger or smaller in size.
- Research other black and white patterns that have been used to create the perception of color when spun. Duplicate the patterns and see if the same or different colors are generated. See the OPL website (also referred to below) for ideas.
- Use a CD, marble and spinner knob to construct spinner wheels in the same way (see RAFT Idea Sheet ***Colors in the Mind***). Use a CD with a white label (or cover the CD with white paper) for the best effect.

  Background: Cone cells discern color and function best in bright light. In dim light, colors are greatly diminished. The three types of cone cells all send signals to our brain regarding the strength of each color (red, green, blue). Our brain then interpolates these relative strengths to mix them, giving the colors in between such as orange, yellow, indigo, and violet as well various shades of colors in between. The human eye/brain perception is capable of distinguishing several hundred hues.

Related activities: See RAFT Idea Sheets:

Colors in the Mind –
http://www.raft.net/ideas/Colors in the Mind.pdf
Eye See It! –
http://www.raft.net/ideas/Eye See It.pdf
The Light Color Wheel –
http://www.raft.net/ideas/Light Color Wheel.pdf

Resources

Visit www.raft.net/raft-idea?isid=305 for "how-to" video demos & more ideas!

See these websites for more information on the following topics:

- **Online Psychological Laboratory: other versions of Benham's Disk**– http://opl.apa.org/contributions/Lite%20Edu/Benham.htm
- **Online colorblind tests** – http://www.color-blindness.com/color-blindness-tests/
- **Online test for color blindness - shapes** – http://colorvisiontesting.com/online%20test.htm
- **Online test for color blindness - numbers** – http://colorvisiontesting.com/ishihara.htm
- **Color blindness simulator** – http://www.color-blindness.com/coblis-color-blindness-simulator/

Acknowledgements:

Adapted from "Benham's Disk", *The Exploratorium Snack Book.*