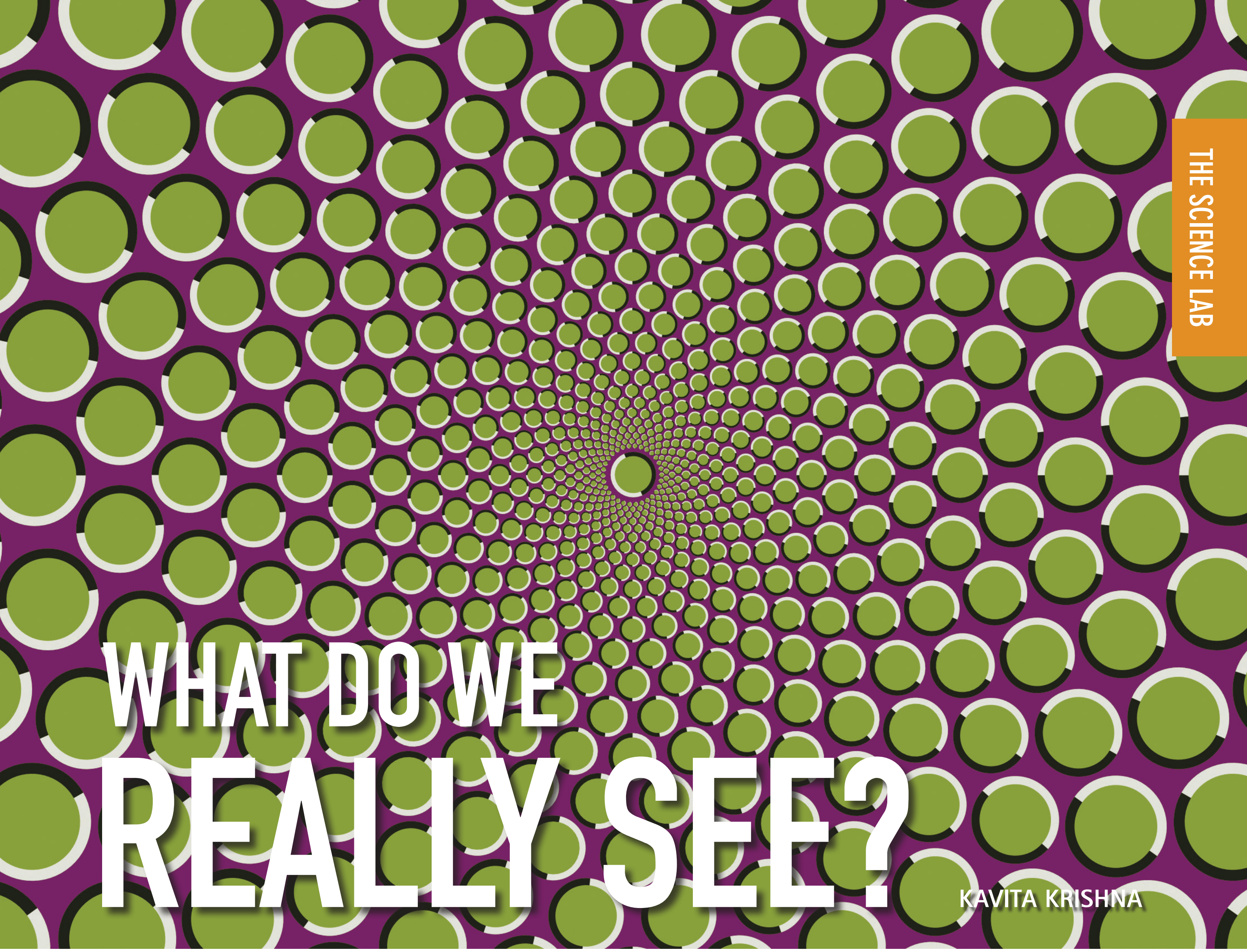


WHAT DO WE REALLY SEE?

KAVITA KRISHNA

This article presents a few simple activities, with handmade toys and optical illusions, that explore ways in which our brain and eyes work together to perceive the world.

Our ability to see is fascinating, yet something that we usually take for granted. Young children spontaneously experiment with the way they see — looking at objects with one eye closed, spinning a sparkler to see a ring of light, or looking through a grandparent's spectacles. Middle school students ask questions like, '*Why do we need two eyes?*' and '*Why does a ceiling fan moving at full speed look blurry?*'. These early experiments and questions invite an exploration of human vision. This article (and the accompanying activity sheets) looks at some aspects of human sight that students can discover through simple, yet interesting, activities.

Depth perception

The left and right eye are in different locations, about 6.5 cm apart. Each eye receives a slightly different two-dimensional image onto its retina. Both these images are sent to the brain. The brain uses both to generate a single three-dimensional interpretation. This results in our capacity for **stereopsis** or depth perception as demonstrated in Activity I (see **Activity Sheet: Are two eyes better than one?**).[1] The ability to perceive depth is one of the advantages of having binocular vision (using two eyes to see one image).

The blind spot

We tend to believe that what we perceive is exactly what our eyes see. However, this isn't always true and parts of what we see are 'made up' by the brain!

Each eye has a blind spot — a small part of the visual field of each eye where there are no photoreceptors (rods or cones) on the retina (see **Fig. 1**). This is the region where the optic nerve enters the eye. As demonstrated in Activity II (see **Activity Sheet: Finding your blind spot**), you are unable to see the black dot when the paper is held at a particular distance from you because the image of the dot falls on the blind spot on your retina.[1]

Why don't we notice the blind spot more often? This is because the brain compensates for the blind spot by adding in the missing information. This phenomena is called **visual filling in.**[2] Notice that in Activity III (see **Activity Sheet: Filling in**), your brain fills in the image even when your other eye is closed. This is an example of how your brain doesn't rely only on the images it receives from the retina. It 'predicts' what it is likely to see. The predictions that the brain makes are so convincing that we often 'see' things that don't exist! This is the basis for many optical illusions.

Moving images

Optical illusions can also arise because of another physiological limitation of the visual system — the speed at which it can process images that fall on the retina.

One application of this is in the Thaumatrope — a popular optical toy in the 19^{th} century. As seen in Activity IV (see **Activity Sheet: Using a Thaumatrope**), the two images on either side of the disk appear to merge into a single image when the disk is twirled quickly.[3] This is because of the time that our visual system takes to process the images that fall on the retina.

The visual system retains an image for about a 15^{th} of a second. When a different image falls on the retina within this time period, the two images are perceived as a single one. This phenomena is called the **persistence of vision.**

When our visual system sees a series of 10-12 distinct images in a second, they are perceived as a single continuous moving image. This optical illusion is called **beta movement**, and is the basis for animations and films. The Phenakistoscope, that you build in Activity V (see **Activity Sheet: Using a Phenakistoscope**), was the first popular animation device to be built. Invented in 1832, this device was an early precursor to modern day animations (see **Fig. 2**) A flip book is another simple toy that you can make based on the same principle (see **Fig. 3**)[4]

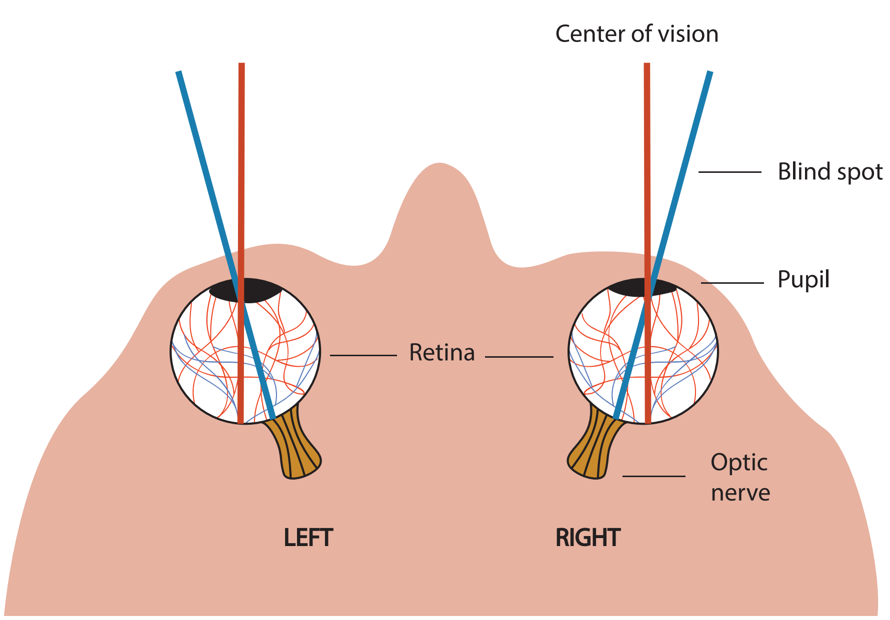


Fig. 1. The blind spot is an area on the retina that has no photoreceptors.

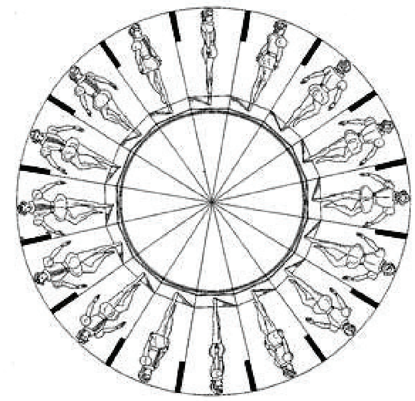


Fig. 2. The phenakisticope was invented by the Belgian physicist Joseph Plateau and the Austrian mathematician Simon Stampfer, working independently.

Credits: depuis Joseph Plateau, Corresp.Math.Phys. 1832, VII, p. 291, Wikimedia Commons. URL: https://en.wikipedia.org/wiki/File:Phenakistiscope.jpg. License: CC-BY.

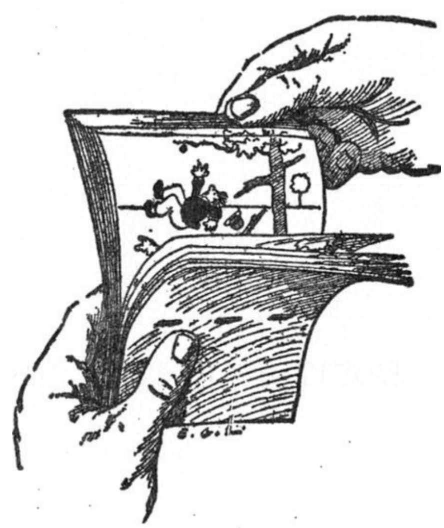


Fig. 3. A flip book is an animation toy in which several distinct images appear to be a single continuous moving image.

Credits: John Barnes Linnet, Zeitgenössische Illustration (1886), Wikimedia Commons. URL: https://en.wikipedia.org/wiki/File:Linnet_kineograph_1886.jpg. License: CC-BY.

Optical illusions

Optical illusions are perplexing, fascinating, and fun. They occur when what we perceive appears different from what is actually present, because of the interaction between the images the eye receives and the interpretations that the brain makes (see **Fig. 4**).

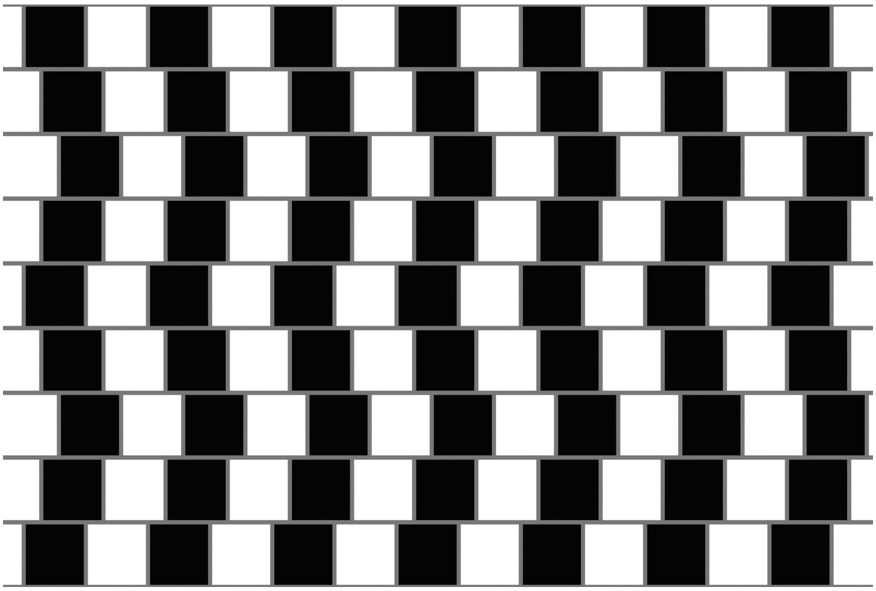


Fig. 4. The café wall illusion. This is a geometrical optical illusion in which the parallel dividing lines between staggered rows with alternating black and white "bricks" appear to be sloped although they are straight.

Credits: Fibonacci, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Caf%C3%A9_wall.svg. License: CC-BY-SA.

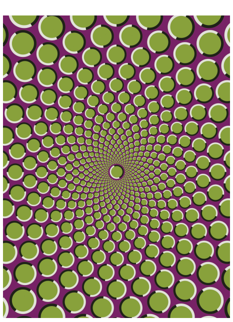
To conclude

There are hundreds of optical illusions like the ones in the activities discussed here. Each of these illusions reveal different aspects of human vision and its limitations (see **Box 1**). Many of them are the subject of ongoing scientific research in human physiology, psychology and neuroscience.

Box 1. You can learn more about optical illusions here:

1. Chudler, Eric H. 'The Blind Spot'. Neuroscience for Kids – Vision Exp. URL: http://faculty.washington.edu/chudler/chvision.html.
2. Bach, Michael. '134 Optical Illusions & Visual Phenomena'. URL: www.michaelbach.de/ot/.
3. Lotto, Beau. 'Optical illusions show how we see'. TED Global, July 2009. URL: www.ted.com/talks/beau_lotto_optical_illusions_show_how_we_see.
4. The Optical Society (OSA). 'Optical illusions'. Optics4kids. URL: https://www.optics4kids.org/illusions. Accessed 18 Apr. 2019.

Key takeaways

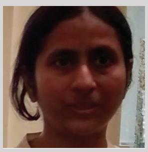


- Sight is inherently intriguing to young children, and they often spontaneously experiment with the way they see.
- What we see is a result of interactions between our eyes and our brain.
- We can explore vision to introduce students to related scientific concepts and their practical implications.
- Our ability to perceive depth is a result of our brain's ability to combine two-dimensional images from both our eyes.
- Each of our eyes has a blind spot where the optic nerve enters it. We don't notice the blind spot because our brain fills in the missing information.
- When two or more images fall on the retina within the 15th of a second, they are perceived as single image.
- Optical illusions occur when our brain's perception of images is different from what is actually present.

Note: Image used in the background of the article title – An optical illusion. Credits: Fiestoforo, Wikimedia Commons. URL: https://en.wikipedia.org/wiki/File:Motion_illusion_in_star_arrangement.png. License: CC-BY.

References:

1. 'The Blind Spot'. Chudler, Eric H., Neuroscience for Kids – Vision Exp. URL: http://faculty.washington.edu/chudler/chvision.html.
2. 'Filling-In'. Wikipedia, Wikimedia Foundation. 18 Apr., 2018. URL: https://en.wikipedia.org/wiki/Filling-in.
3. 'The Historians Toy box – Children's toys from the past you can make yourself'. Provenzo Jr, Eugene F, et al. Prentice Hall, 1979. Retrieved from the URL: https://archive.org/details/TheHistoriansToyBox/page/n55.
4. 'How to make a flipbook'. Andymation, YouTube. Uploaded on 19 Jan., 2018. URL: https://www.youtube.com/watch?v=Un-BdBSOGKY.



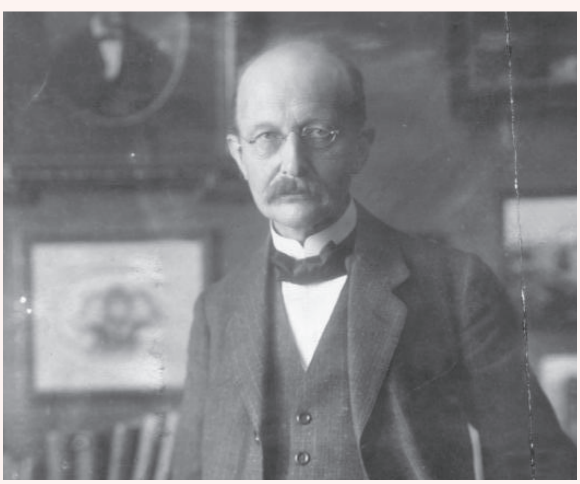
Kavita Krishna graduated from IIT Madras and worked as an engineer for 10 years. She retrained as a teacher and has over 15 years of experience in teaching, curriculum development, and teacher education in rural and urban schools. She can be reached at kavitak2006@gmail.com.

SNIPPETS

THE EXACT MASS OF A KILOGRAM: PLANCK'S CONSTANT

In 2011, the International Committee for Weights and Measures formalized an approach to redefine the International Prototype of the Kilogram (IPK) in terms of Planck's constant.

The Planck's constant (denoted as *h*) is named after Karl Ernst Ludwig Max Planck – a German theoretical physicist who was awarded the 1918 Nobel Prize for physics for his contributions to quantum theory.



The Planck's constant is named after the theoretical physicist Max Planck.

Credits: Bundesarchiv, Bild 183-R0116-504, Wikimedia Commons. URL:https://commons.wikimedia.org/wiki/File:Bundesarchiv_Bild_183-R0116-504,_Max_Planck.jpg. License: CC-BY-SA.

This constant is related to the kilogram through two very famous equations:

- According to the Planck-Einstein relation, the Planck's constant relates a photon's energy (E) with the frequency of its electromagnetic oscillation (ν): $E = h\nu$
- According to Einstein's mass-energy equivalence, any object with mass (m) has an equivalent amount of energy (E) through the speed of light in a vacuum (c): $E = mc^2$

Viewing the two relationships together:

$$h\nu = mc^2$$

Max Planck used experimental data on black body radiation to calculate the value of Planck's constant to be = 6.55×10^{-34} J/s. We also know that if the energy of a photon with a frequency of 1 Hertz (Hz) were to be transformed into matter (mass), the amount of mass that could be recovered = 7.375×10^{-31} kg.

Is this enough to redefine the kilogram? Not really. The Planck's constant is such a small value that it is often described as being 'the zero of classical physics'. Consequently, it has been difficult to measure this constant with the precision required to redefine the kilogram.

Is this the only constant that could be used to redefine the kilogram? Find out on page 87.

Siddharth Setlur is a Grade XII student & founder of the non-profit peer-to-peer learning platform (www.vlearn.xyz) who aims to pursue an academic career in theoretical physics and mathematics. He can be contacted at: siddharth.setlur@gmail.com.

Chitra Ravi works at Azim Premji University, Bengaluru.

The Science Lab

ARE TWO EYES BETTER THAN ONE?

You will need:

Two pencils or straight sticks.

What to do:

1. Hold a pencil lengthwise in each hand a couple of feet in front of your face.
2. Close one eye. Try to touch the ends of the pencils to each other.
3. Try it again, this time with the other eye closed.
4. Now do the same with both your eyes open.

Observations:

What did you observe?

Discuss:

- What is different in our image of an object when we see it with both our eyes from when we see the object with only one of them?
- Does this difference depend upon the distance of the object from us?
- Can you think of a situation where:
  a. 'seeing with both eyes' may offer you an advantage?
  b. 'seeing with one eye' may offer you an advantage?

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Contributed by:
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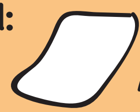
Azim Premji University

FINDING YOUR BLIND SPOT

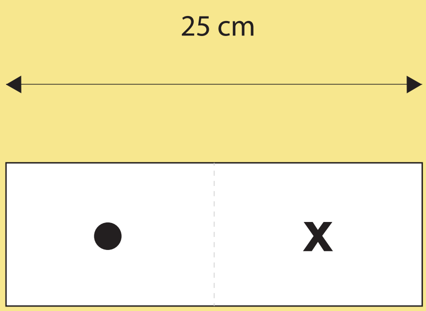
You will need:

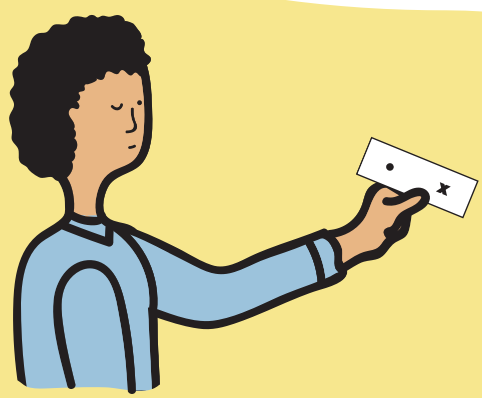

A blank sheet of paper (A4 size)


A black pen

What to do:

1. Cut the paper into half along its length to get a strip of about 25 cm length.
2. Locate the centre of the strip along its length by folding it in half.
3. Mark a black dot about 3.5 cm from the centre line to the left and a black cross about 3.5 cm to the right of the centre line.





4. Hold the strip at arm's length in front of your eyes.
5. Close your left eye and look at the black dot on the paper with your right eye. Can you see the black cross as well?
6. Move the paper towards you slowly, keeping your right eye on the black dot. Does the cross seem to disappear at some point?
7. Now repeat with your right eye closed, looking at the black cross with your left eye. Does the black dot disappear at some point?

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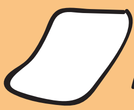
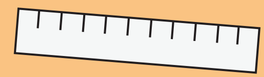
The Science Lab

VISUAL FILLING IN

You will need:

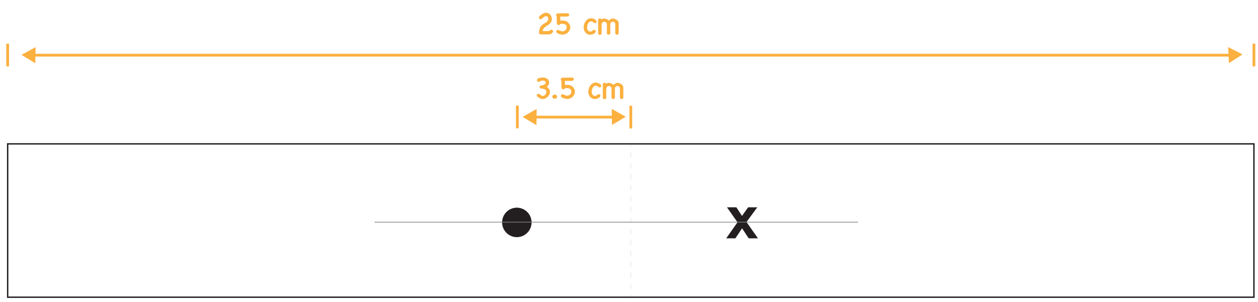

A blank sheet of paper (A4 size)


A black pen


A ruler

What to do:

1. Cut the paper into half along its length to get a strip of about 25 cm length.
2. Locate the centre of the strip along its length by folding it in half.
3. Mark a black dot about 3.5 cm from the centre line to the left and a black cross about 3.5 cm to the right of the centre line.
4. Draw a line through the centre of the cross and the circle.



5. Repeat the activity you did earlier.
6. Does the line seem continuous or do you see a break?

Observations:

What did you observe?

Discuss:

- Does the line seem continuous or do you see a break?
- Why do you think this happens?

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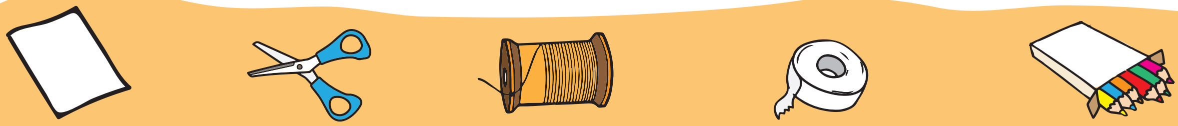
USING A THAUMATROPE

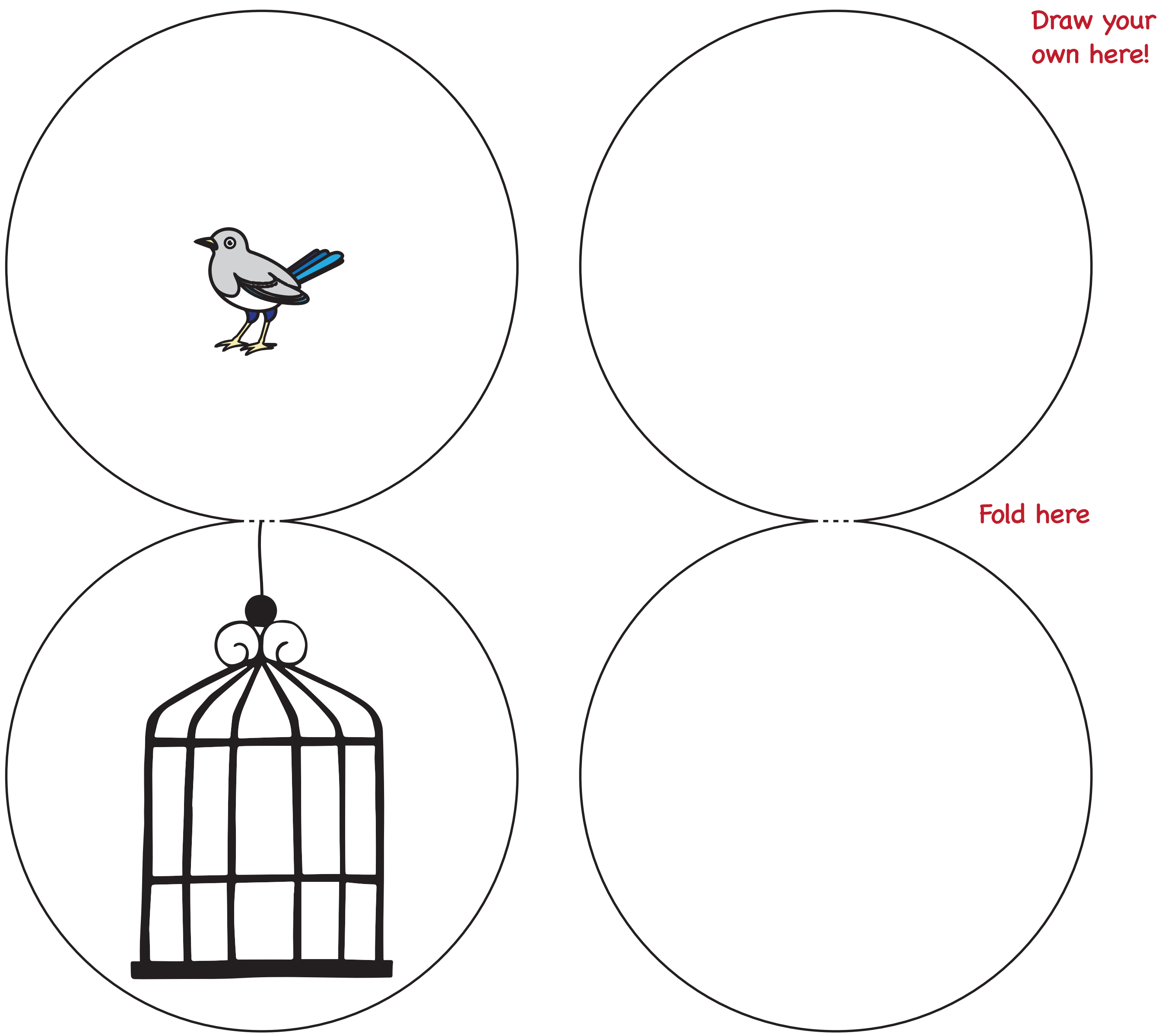
You will need:



Thick white card | Scissors | String | Cellotape | Coloured pens or pencils

What to do:

1. Cut out two identical circles joined along one side from a thick white card. Each circle should be about 3 inches in diameter.



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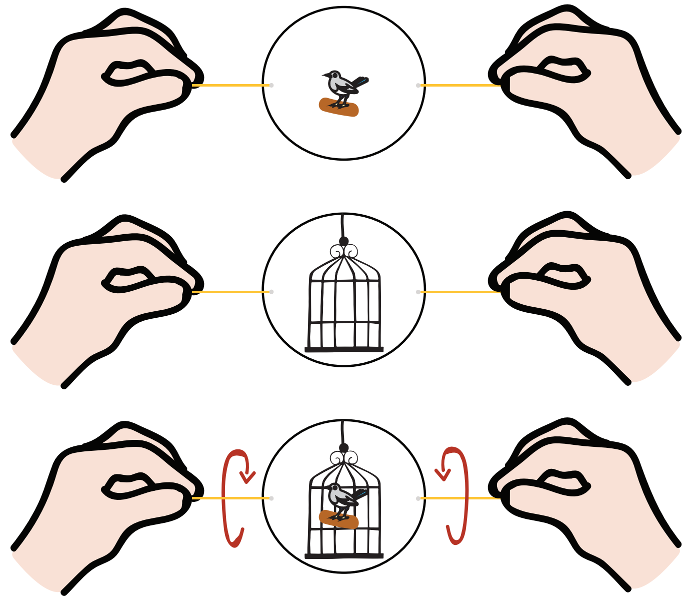
Azim Premji University

USING A THAUMATROPE



2. Draw a picture of a bird on one circle and a cage on the other. Make sure the pictures are in the centre of the circle and the size of cage is big enough to fit in the bird!
3. Lay the circles down with their blank sides facing upwards.
4. Lay the string across the centre of one circle making sure there is about 15 cm string on either side. Tape the string in place.
5. Stick the circles to each other with the string between them. The pictures should be facing outwards. The picture of the cage will now be upside down while the picture of the bird is the right way up.
6. Hold the ends of the string between your thumb and forefinger on each hand so that the disc is hanging in front of you with the picture of the bird the right way up.
7. Twist the string several times and release it to spin the disc. What do you see?

Observations:

What did you observe?

Discuss:

- What can you see when you spin the thaumatrope?
- What happens to the picture you see when you spin the thaumatrope slowly? Does this change if you spin it faster? Why do you think this happens?
- Can you see the bird in the cage when the thaumatrope is spinning really fast?
- Have you noticed what the blades of a ceiling or table fan look like when they are rotating very fast or very slowly? In what way is this similar or different to what you saw in the thaumatrope?

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The Science Lab

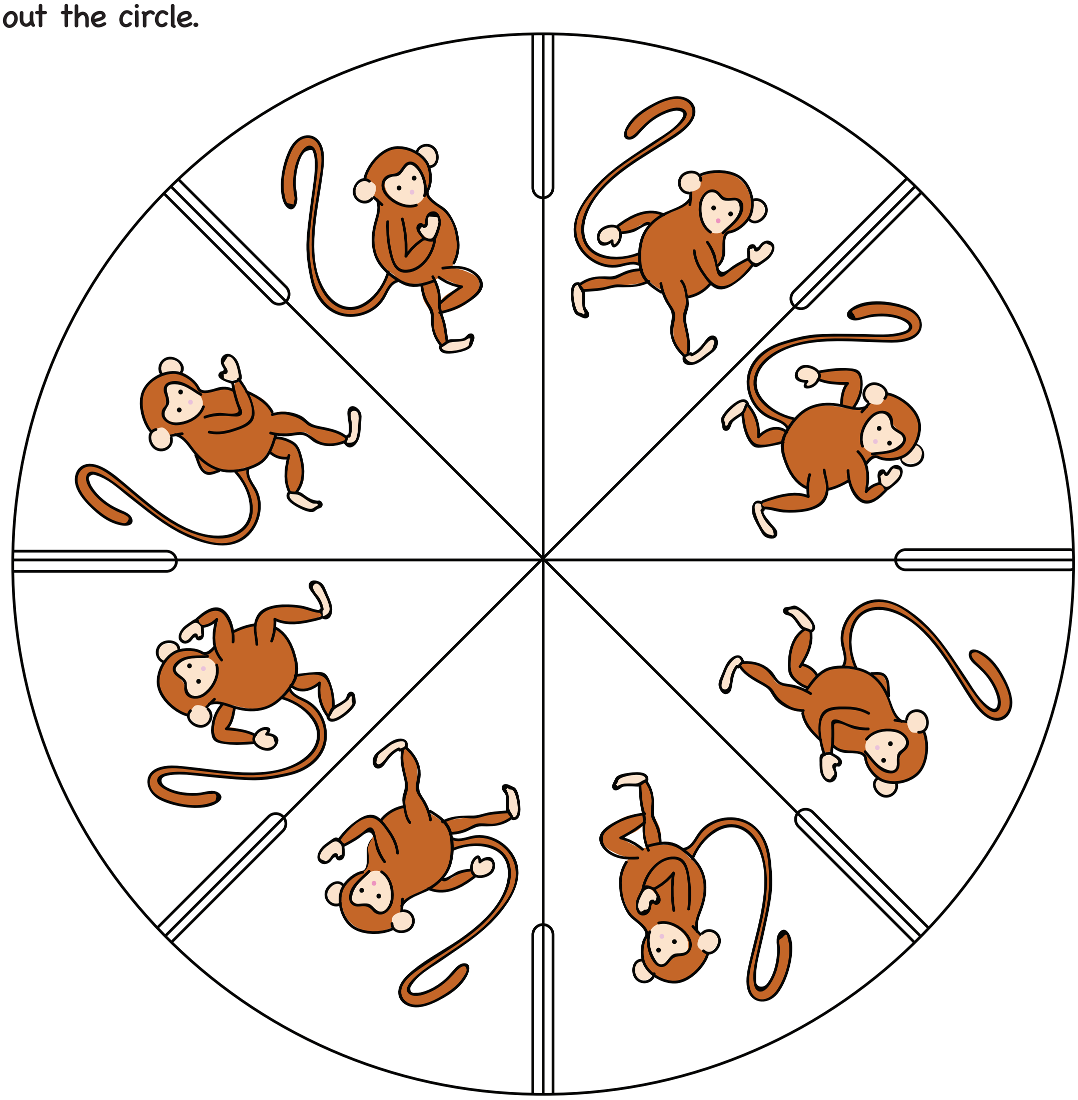
MAKING A PHENAKISTOSCOPE

You will need:

- Thick white card & cardboard
- Scissors
- String
- Cellotape
- Glue
- Thumb tack
- Coloured pens or pencils
- Craft knife
- Stick

What to do:

1. Make a copy of the pattern onto a white paper or card and paste it onto a stiff cardboard.
2. Cut out the circle.



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