# Your Eyes are Deceiving You

**Session Time:** Four, 50-minute sessions

## DESIRED RESULTS

### ESSENTIAL UNDERSTANDINGS

Pilots must be aware of their physical and mental condition in order to conduct safe flights.

Geographic, atmospheric, environmental, and physiological conditions may create situations where a pilot's visual perception is inaccurate and cannot be relied upon.

Pilots must understand the types and nature of illusions and disorienting conditions they may encounter in flight and how to overcome inaccurate perceptions.

### ESSENTIAL QUESTIONS

1. How does a pilot recognize and compensate for optical illusions that may result in an unsafe flight situation?

### LEARNING GOALS

**Students Will Know**

- The basics of human eye anatomy.
- Common visual illusions that a pilot may encounter.
- Strategies for compensating for common visual illusions.

**Students Will Be Able To**

- *Describe* the cause and effect of common visual illusions. [DOK-L2]
- *Illustrate* aircraft positions given specific flight scenarios. [DOK-L1]
- *Label* an anatomical diagram of a human eye. [DOK-L1]

## ASSESSMENT EVIDENCE

**Warm-up**
Students will describe optical illusions and visual deceptions that are known to occur, and the interplay between human anatomy and environmental conditions that creates them. Next, students will observe various common optical illusions and attempt to explain what they are seeing. Finally, students will connect these illusions to situations that might be encountered by pilots.

**Formative Assessment**
Working individually, students will answer questions about the connection between the anatomy of the eyes, optical illusions, and safe piloting.

**Summative Assessment**

Students will form groups of three. Each group member will create 8–10 flashcards on an assigned topic; group members will then take turns quizzing each other.

## LESSON PREPARATION

### MATERIALS/RESOURCES

- Your Eyes Are Deceiving You Presentation
- Your Eyes Are Deceiving You Student Activity 1
- Your Eyes Are Deceiving You Student Activity 2
- Your Eyes Are Deceiving You Student Activity 3 No Photos
- Your Eyes Are Deceiving You Student Activity 3 Photos
- Your Eyes Are Deceiving You Student Activity 4
- Your Eyes Are Deceiving You Student Activity 5
- Your Eyes Are Deceiving You Teacher Notes 1
- Your Eyes Are Deceiving You Teacher Notes 2
- Your Eyes Are Deceiving You Teacher Notes 3
- Your Eyes Are Deceiving You Teacher Notes 4
- Your Eyes are Deceiving You Teacher Notes 5
- **Quarters**
- **Tape**
- **Student Activity 3: Runway Illusions (per group)**
    - Camera (cell phone camera okay)
    - Tripod
    - Set of 3 paper runways
        - You may print out the images in the PDF titled 3runwaywidths, or you may create your own.
    - Tape
    - Wedge

**Student Activity 4: Runway Illusions Simulator Scenarios**

- Computer with flight simulator software or flight simulator
- Joystick or yoke
- Optional: Throttle quadrant, rudder pedals, additional monitors

- **Student Activity 5: How Do You See It? (per student)**
    - 10 index cards
    - Pens or markers

### LESSON SUMMARY

Lesson 1: It's Getting Hard to Breathe
**Lesson 2: Your Eyes Are Deceiving You**
Lesson 3: Dizzying Heights
Lesson 4: I Have a Headache, and My Stomach Hurts

The lesson begins with a warm-up in which students describe times they have experienced visual illusions and hypothesize possible causes. Students then observe various common illusions and discuss why they might occur and how they could affect a pilot.

In Sessions 1 and 2, students learn how the anatomy of the eye enables us to see under varying conditions (e.g., during the day, at night, in color), and how visual processes can cause different illusions or problems (e.g., blind spots, color blindness). Students also learn about the three main kinds of vision, and they practice strategies—such as scanning—that will help them overcome visual illusions. Students then complete a formative assessment to demonstrate what they have learned about these topics.

Session 3 further explores illusions that can affect and threaten pilots. In particular, students learn about aerial perspective illusions, and complete an activity that explores how these illusions can pose challenges to pilots during an approach to land. After learning about additional kinds of illusions, students begin Session 4 by applying what they have learned in a flight simulator. Students then answer questions to prepare for the Private Pilot Knowledge Exam and complete a summative assessment in which they create study flashcards and quiz each other.

## BACKGROUND

The FAA emphasizes the importance of pilot vision. According to Chapter 17 of the Pilot's Handbook of Aeronautical Knowledge (PHAK),

*Of the senses, vision is the most important for safe flight. However, various terrain features and atmospheric conditions can create optical illusions. These illusions are primarily associated with landing. Since pilots must transition from reliance on instruments to visual cues outside the flight deck for landing at the end of an instrument approach, it is imperative that they be aware of the potential problems associated with these illusions and take appropriate corrective action.*

This lesson reinforces the importance of a pilot's reliance upon aircraft instrumentation. Although most visual flight rules (VFR) flying is done while looking outside, it is critical for pilots to know not to let their visual sense overrule what their cockpit instruments are telling them. A significant portion of aircraft accidents are the result of pilots trusting their eyes and other senses without cross-checking their instrumentation. Therefore, following the guidance from this lesson can literally save a pilot's life.

## MISCONCEPTIONS

Students may believe that our eyes are consistently reliable. While we have learned to trust our eyes, typically more than any other sense, it is possible for the brain's analysis of what we're perceiving to drive us to take actions that are incorrect or even dangerous while in flight. This is why it is critical for pilots to trust their instruments.

Students may believe that the best way to see a dim object at night or in very dark environments is to stare directly at it. This is actually not the case. In fact, the central part of the eye is full of cones, which are excellent for perceiving details and colors during the day but less effective at night. Rods, which are off-center in the eye (especially in the periphery) are 10,000 times more light sensitive, making them more effective for night vision.

Students may think that supplemental oxygen is only necessary above 10,000 ft. While this is true during the day, at night pilots should use supplemental oxygen above 5,000 ft cabin altitude. This is because oxygen plays a critical role in the eyes' and brain's ability to perceive correctly, especially at night.

## DIFFERENTIATION

To encourage student collaboration and motivation during the ENGAGE section of the lesson plan, have students share their ideas in pairs before bringing the class together in a class-wide discussion.

To promote working memory throughout the EXPLAIN section of the lesson plan, have students create a graphic organizer for taking notes. Section headings can include human eye anatomy, color blindness, types of vision, and types of visual illusions. Also, using a model aircraft to simulate aircraft attitudes in various scenarios can help students to visualize how illusions occur.

## LEARNING PLAN

### ENGAGE

**Teacher Material:** Your Eyes Are Deceiving You Presentation

**Session 1**

**Slides 1-3:** Introduce the topic and learning objectives of the lesson.

**Slides 4-12:** Conduct the **Warm-Up**.

**Warm-Up**

Ask students what optical illusions or visual deceptions they have experienced. Ask them to be descriptive.

- When did the illusion happen?
- What were the conditions, both internal (tired, groggy, etc.) and external (night/daytime, in the air /on the ground, light/dark, etc.)?
- How did you recognize that this was an illusion?

*Answers will vary based on student experiences. There are no right or wrong answers here.*

Consider writing student responses down on a while board. Answers will vary based on students' current knowledge and understanding. Do not attempt to correct anything; just get students pondering and discussing the elements that will be addressed in this lesson.

When students have finished discussing illusions and visual deceptions, advance to the first illusion slide.

Slides 5–11 show some common optical illusions (source: https://sciencebob.com/see-some-optical-illusions/). Tell students to take a look at each slide; for each illusion, ask:

- What do you see?
- What do you think might cause this illusion?

*Again, there is no need to correct wrong answers; the goal is to get students thinking about these issues. If students are curious, however, here are brief explanations for what is happening in each slide.*

- **Slide 5:** This image consists of black rectangles surrounded by white lines. However, students will likely see gray dots scattered among the white lines (particularly where the lines intersect, along the periphery of students' vision). These dots are imagined: patterns of alternating black and white tend to confuse the brain into combining the black and white into a new, gray pattern.

- **Slide 6:** This image consists of a multicolored "pinwheel" pattern. However, if students view the pinwheel along the peripheries of their vision, it will likely appear to move. Staring directly at the pinwheel will likely cause the "movement" to stop. Once again, this illusion is caused by a pattern; the repeating lines and contrasting colors confuse the brain as it tries to make sense of the image.

- **Slide 7:** This image appears to show an ordinary elephant, but upon closer inspection students will find that the elephant's four legs aren't actually part of its body—the legs exist in the "negative space" between what ought to be the elephant's legs. This illusion is a case of an artist playing with viewers' expectations: our brain expects to see legs in a particular position, and so it fills in gaps in the image.

- **Slide 8:** Students will likely need prompting to experience this illusion: if they lean toward and then away from the image while staring at the black dot at the center, the shapes that surround the black dot will appear to move in a circle. Once again, shifting your perspective of the image tricks your brain into imagining motion along the peripheries of your vision.

- **Slide 9:** This slide shows an example of a famous kind of illusion, in which a simple drawing appears to show multiple faces, depending on which parts of the image the viewer focuses on. This particular image can appear to be the face of an older man (his mustache is in the lower-right), the head of an older woman glancing at the viewer (the right eye of the man becomes the left eye of the woman), and the head of a young woman looking down and away from the viewer (the older woman's eye becomes the younger woman's ear).

- **Slide 10:** Ask students to raise their hand if they think this image is a spiral. Then, move your finger from one box to the next to demonstrate that the image actually consists of four concentric circles made up of little boxes. The tilt of the boxes tricks the brain into believing they form a spiral.

- **Slide 11:** This illusion consists of two groups of circles; each group consists of a central circle surrounded by four circles of different size. Ask students which central circle they think is bigger. At a glance, the circle on the right will likely appear bigger, but in fact they are the same size. The circle on the right appears bigger because it is surrounded by smaller circles, whereas the circle on the left is surrounded by larger circles.

**Slide 12:** Ask students to consider what illusions have to do with piloting. In particular, discuss how illusions or misinterpreted information could drive a pilot to react in a way that could be detrimental, or even fatal. If students have trouble thinking of any illusions related to piloting, have them consider various phases of flight: takeoff, turning, descent, final approach, landing, flying inside clouds, etc.

**Teaching Tips**

The videos on Slide 12 further explain how the brain takes in and interprets the images that the eyes perceive. This input is processed by the brain in order to help the viewer infer what is going on, but it can also fool the brain into perceiving illusory shapes, colors, and motion.

- "Brain Games - Optical Illusions from National Geographic" (Length 4:27)
  https://video.link/w/GAo1
  For teachers unable to access Safe YouTube links, the video is also available here:
  https://www.youtube.com/watch?v=w986vl6uZpU
- "How do optical illusions work?" (Length 3:22)
  https://video.link/w/XAo1
  For teachers unable to access Safe YouTube links, the video is also available here:
  https://www.youtube.com/watch?time_continue=1&v=VYIr40D7wNw&feature=emb_logo

## EXPLORE

**Teacher Materials:** Your Eyes Are Deceiving You Presentation, Your Eyes Are Deceiving You Teacher Notes 1
**Student Material:** Your Eyes Are Deceiving You Student Activity 1

**Slide 13:** According to the FAA's Safety Guidance on Pilot Vision,

*Vision is a pilot's most important sense to obtain reference information during flight. Most pilots are familiar with the optical aspects of the eye. Before we start flying, we know whether we have normal uncorrected vision, are farsighted or nearsighted, or have other visual problems. Most of us who have prescription lenses, contacts, or eyeglasses have learned to carry an extra set of glasses with us as a backup when we fly. However, vision in flight is far more than a lesson in optics.*

Students have already viewed several optical illusions in this lesson. Now, they will view an illusion that relates more explicitly to piloting.

**Slide 14:** Distribute **Your Eyes Are Deceiving You Student Activity 1** to students. Have students read all of the instructions first, then follow the directions carefully to experience their blind spot. Ensure that all students have copies of the photo used in the activity; either print the final page of the activity worksheet, or arrange for each student to view the image on a sufficiently large screen. Possible responses are provided in **Your Eyes Are Deceiving You Teacher Notes 1**.

## EXPLAIN

**Teacher Materials:** Your Eyes Are Deceiving You Presentation, Your Eyes Are Deceiving You Teacher Notes 2, Your Eyes Are Deceiving You Teacher Notes 3, 3runwaywidths.pdf
**Student Materials:** Your Eyes Are Deceiving You Student Activity 2, Your Eyes Are Deceiving You Student Activity 3 No Photos **or** Your Eyes Are Deceiving You Student Activity 3 Photos **(*decided by the teacher*)**

**Slides 15-16:** Students have learned that their brains can trick them, but what about their eyes? In fact, the eyes are responsible for causing the blind spot that students explored in the previous activity. To understand how, students must understand the anatomy of the eye. Once again, the FAA's Safety Guidance on Pilot Vision provides an excellent summary:

- When we say that we are "seeing" an object, we are really seeing light (either from the sun or from an artificial source, such as a lightbulb) that has reflected off the object. This light enters the eye through the cornea and then continues through the pupil.
- The opening (dilation) and closing (constriction) of the pupil is controlled by the iris, which is the colored part of the eye. The function of the pupil is similar to that of the diaphragm of a camera: to control the amount of light.
- The lens is located behind the pupil; its function is to focus light on the surface of the retina.
- The retina is a region of the inner layer of the eyeball. It contains two kinds of photosensitive cells, or receptors, called rods and cones. (Rods and cones are discussed in greater detail in later slides.) The function of the retina is similar to that of the film in a camera: to record an image.
- The rods and cones transform light energy into electrical signals that are carried by the optic nerve to a part of the brain called the occipital lobes. This part of the brain interprets the electrical signals and creates a mental image of the actual object that was seen by the person.

As you mention each part of the eye, point to the corresponding part of the image on Slide 16.

**Slide 17:** As noted, human eyes contain two kinds of receptors: rods and cones. According to the FAA's Safety Guidance on Pilot Vision,

- The cones are located in higher concentrations than rods in the central area of the retina known as the macula, which measures about 4.5 mm in diameter. The exact center of the macula has a very small depression called the fovea, which contains cones only. The cones are used for day or high-intensity light vision. They are involved with central vision to detect detail, perceive color, and identify far-away objects.
- The rods are located mainly in the periphery of the retina—an area that is about 10,000 times more sensitive to light than the fovea. The rods are responsible for helping a person to see in low light conditions. They are also particularly sensitive to detecting movement.
- However, they cannot be used to detect detail or to perceive color.

During the day, the greatest amount of detail will be seen when staring directly at an object, since the highest concentration of cones in the fovea is focused on the object. But at night, these cones become significantly less effective. Since the cones are less effective, depth perception, sharpness, clarity, and size judgment are also degraded at night.

**Slide 18:** This slide contains an illusion that demonstrates the difference between central and peripheral vision. Instruct students to stare at the cross in the center of the circle of purple dots—they should see a rotating green dot moving through the stationary purple dots. In fact, the green dot is an illusion—an empty space is moving through the purple dots. (You can demonstrate this by taking and showing screenshots of the animation.)

**Questions**

What does this illusion reveal about central versus peripheral vision?

*Answers may vary, but ultimately students should agree that peripheral vision is distinct from central vision, and it may not be as trustworthy.*

Why should a pilot care about the distinction between central and peripheral vision?

*Answers may vary, but students should realize that pilots who think they spot something (like an aircraft) in their peripheral vision may be mistaken: they should always try to verify their peripheral visions by refocusing their eyes to spot the perceived object in their central vision.*

**Slide 19:** Rods and cones are responsible for blind spots in human vision. Again, according to the FAA's Safety Guidance on Pilot Vision,

*. . . the area where the optic nerve connects to the retina in the back of each eye is known as the optic disk. There is a total absence of cones and rods in this area, and consequently, each eye is completely blind in this spot. As a result, it is referred to as the blind spot that everyone has in each eye. Under normal binocular vision conditions (both eyes are used together), this is not a problem because an object cannot be in the blind spot of both eyes at the same time. On the other hand, where the field of vision of one eye is obstructed by an object (windshield divider or another aircraft), a visual target could fall in the blind spot of the other eye and remain undetected.*

**Slide 20:** Optical illusions may be more prevalent at night. The previous slides have discussed the daytime blind spot, but people also have a nighttime blind spot. Pilots must educate themselves on techniques and successful practices for mitigating this blind spot. Recall that rods are the receptors responsible for night vision, and they are located primarily in the periphery of the retina; there are no rods in the centrally located fovea. According to Chapter 17 of the PHAK,

*The concentration of cones in the fovea can make a night blind spot in the center of the field of vision. To see an object clearly at night, the pilot must expose the rods to the image. This can be done by looking 5° to 10° off-center of the object to be seen. This can be tried in a darkened room. When looking directly at the light, it dims or disappears altogether. When looking slightly off center, it becomes clearer and brighter.*

**Slide 21:** To protect their night vision, pilots must understand how eyes adapt to dark environments (dark adaptation). Rods take time to "warm up" when a person moves from light to darkness, and the contrast between the two states plays a crucial role. If a person leaves a very bright area and immediately goes into a dark one, it can take up to 30 minutes for the light-sensitive rods in the eyes to fully adapt. If the person were to go from a less bright or dim area to a dark one, that adaptation time would decrease. Pilots must take extreme care to protect their night vision: even a glimpse at a bright light may force their rods to begin adapting to dim light all over again.

**Questions**

Why do you think it is a good idea to gradually dim cockpit displays and instruments as evening transitions to night?

*A gradual transition gives pilots' eyes more time to adapt to the darkness outside the aircraft, making it easier to see dimmer objects.*

**Teaching Tips**

To demonstrate dark adaptation, make the room as dark as possible. Set up a small, dim object that is very hard to see with direct vision in the dark room. (This shouldn't be too difficult if students have become accustomed to a bright classroom that is suddenly made dark.) Have students look a short distance away from the dim object (just a bit to the left or right) to demonstrate how their rods can pick up light better than the cones.

Return the lights to normal and ask if any students have had personal experience with dark adaptation, night blindness, and other optical illusions at night. Additionally, ask if any students have gone stargazing: how do dark adaptation and peripheral vs. central vision affect what you can see?

*Answers will vary based on students' experience. Explain that astronomers use their peripheral vision to see dim objects in the night sky a little better. Looking slightly to the side of a star or planet makes it appear brighter.*

How do you think pilots can spot hazards that fall within their night blind spot?

*Students essentially already answered this during Student Activity 1; however, to better drive home the importance, emphasize that pilots should develop a proper method of visually scanning the sky. Students should recall the technique of scanning the sky in segments from the first semester of this course.*

**Slides 22-23:** Color blindness may be an obstacle to becoming certificated as a pilot. Safe flight requires acute color perception. All types of signals, cues, and data come to the pilot through color. Light travels in waves, and we perceive different wavelengths of light as different colors: longer wavelengths appear as red and orange, medium wavelengths appear as yellow and green, and shorter wavelengths appear as blue and violet. The human eye contains three types of cones that work together to help us see color. Some people have problems with—or even lack—one or more of these cone types; these people are unable to see or distinguish between certain colors: they are color blind.

According to the National Institutes of Health (NIH), the most common form of color blindness is red-green. Some people with this deficiency struggle to distinguish between red and green, while others cannot see either color at all.

Males are subject to this deficiency more often than females, and people with northern European ancestry are more likely to have it than people from other populations. Another form of color blindness, blue-yellow, is less common but affects males and females equally. The least common form of color blindness is called blue cone monochromacy; people with this deficiency have only one functioning type of cone for sensing color.

The slides show examples from common tests for color blindness:

- For Slide 22, people with normally functioning cones should be able to see the numbers or letters within each square (clockwise from top-left: 58, 18, 17, E). People with a color deficiency will be unable to see at least some of these characters.
- For Slide 23, people with normally functioning cones should be able to trace each narrow, curving "path" through the surrounding circle. This test forces the eyes to focus more closely as the subject follows the variously colored dots from start to finish.

**Teaching Tips**

If a student struggles to identify the characters or paths in either of the slides, emphasize that these are only examples, and that color blindness should be diagnosed only by a trained professional; individuals should not attempt to diagnose themselves.

Remind all students that color blindness is not a weakness but simply something to be aware of and adapt to. It is genetic; between 6 and 8 percent of all males have some degree of color blindness. Students wishing to learn more can go to the NIH's web page on color blindness, which includes links to information about testing:

- https://ghr.nlm.nih.gov/condition/color-vision-deficiency

**Session 2**

**Slide 24:** Now that students have learned about eye anatomy, they are prepared to understand and contrast the three types of vision. According to the FAA's Safety Guidance on Pilot Vision, these three types are:

- Photopic Vision
  - *During daytime or high-intensity artificial illumination conditions, the eyes rely on central vision (foveal cones) to perceive and interpret sharp images and color of objects.*
- Mesopic Vision
  - *Occurs at dawn, dusk, or under full moonlight levels and is characterized by decreasing visual acuity and color vision. Under these conditions, a combination of central (foveal cones) and peripheral (rods) vision is required to maintain appropriate visual performance.*
- Scotopic Vision
  - *During nighttime, partial moonlight, or low-intensity artificial illumination conditions, central vision (foveal cones) becomes ineffective to maintain visual acuity and color perception. Under these conditions, if you look directly at an object for more than a few seconds, the image of the object fades away completely (night blind spot). Peripheral vision (off-center scanning) provides the only means of seeing very dim objects in the dark.*

**Slide 25:** Visual scanning is a critical habit when flying—it is a technique that should be used during every flight. Without a proper scan pattern, the risk of collision or other mishap during flight increases significantly. According to the FAA's Safety Guidance on Pilot Vision,

*The probability of spotting a potential collision threat increases with the time spent looking outside, but certain techniques may be used to increase the effectiveness of the scan time. Effective scanning is accomplished with a series of short, regularly-spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10 degrees, and each area should be observed for at least 1 second to enable detection. Although horizontal eye movements seem preferred by most pilots, each pilot should develop a scanning pattern that is most comfortable and adhere to it to assure optimum scanning.*

*The human eyes tend to focus somewhere, even in a featureless sky. If there is nothing specific on which to focus, your eyes revert to a relaxed intermediate focal distance (10 to 30 feet). This means that you are looking without actually seeing anything, which is dangerous. In order to be most effective, the pilot should shift glances and refocus at intervals. Shifting the area of focus, at regular intervals, between the instrument panel and then refocusing outside of the aircraft helps to alleviate this problem.*

The graphic on the slide illustrates this process. Point out that the pilot scans from left to right in the distance (points 1 and 2), and then from right to left closer to the aircraft (points 3 and 4). This is only one possible (simplified) pattern: the important thing is for the pilot to make their pattern habitual.

**Teaching Tips**

Have students take a moment to practice this scan pattern while looking at the front of the classroom. Remind them that, to be effective, their eye movements should be short, regularly-spaced, and not exceed 10 degrees, and should last at least one second at a time.

After a few moments, have students pretend to incorporate their "instrument panel" into their scans. They can simulate this with a piece of paper that contains text or pictures; students should alternate between scanning "outside" the aircraft and reading a sentence or examining a picture on their paper. Allow students about a minute to practice this.

Remind students that the more they practice their scan pattern, the more habitual and second nature it will become. The goal is to do it automatically without having to think about it.

**Slide 26:** Emphasize that whereas nighttime scanning should bring objects into the peripheries of the field of vision (i.e., off-center), daytime scanning should bring objects into the central vision field. Why is this form of scanning effective during the day? The answer has to do with the fovea, which students learned about in the previous session.

Remind students that the fovea is a tiny depression in the center of the macula; it contains a concentrated number of cones but no rods, which explains why vision is sharpest when a person focuses the center of their gaze on an object. A person's total field of vision is approximately 135 degrees vertically and 160 degrees horizontally. However, the foveal field of vision, which produces the sharpest and clearest images, makes up only 1 degree of this total.

**Teaching Tips**

Have students complete the following short activity to demonstrate the 1-degree foveal field. You will need one or more quarters and some tape.

1. Tape each quarter to a wall or window.
2. Have each student stand between 4 and 5 feet from a quarter and close or cover one eye.

3. The quarter makes up approximately 1 degree of this field of vision, so this is the small area on which the fovea is able to focus.

**Slide 27:** In a 10-degree circular area surrounding the foveal view, images are still quite clear and sharp in daylight. Outside of that 10-degree circle, however, only a meager 10 percent of the fovea's visual acuity is perceived.

To relate these facts to practical flight, have students imagine an oncoming aircraft from the perspective of a pilot in the cockpit. If the oncoming aircraft is in the pilot's central, foveal field of vision, it could be perceived approximately 5,000 feet away. If the aircraft is in the pilot's peripheral vision, however, it would not be visible until it is only 500 feet away. Again, this is why flight instructors typically tell students to "keep your head on a swivel" and keep scanning the sky.

**Slide 28:** In addition to those factors already discussed, other significant factors affect human vision. The FAA's Safety Guidance on Pilot Vision describes some of these factors:

- *During the day, objects can be identified more easily at a great distance with good detail resolution. At night, the identification range of dim objects is limited and the detail resolution is poor.*
- *Flying at night under clear skies with ground lights below can result in situations where it is difficult to distinguish the ground lights from the stars. A similar problem is encountered during certain daylight operations over large bodies of water. Various atmospheric and water conditions can create a visual scene with no discernible horizon.*
- *Excessive ambient illumination, especially from light reflected off the canopy, surfaces inside the aircraft, clouds, water, snow, and desert terrain can produce glare that may cause uncomfortable squinting, eye tearing, and even temporary blindness.*
- *Self-imposed stresses such as self-medication, alcohol consumption (including hangover effects), tobacco use (including withdrawal), hypoglycemia, and sleep deprivation/fatigue can seriously impair your vision.*
- *Other factors that may have an adverse effect on visual performance include windscreen haze, improper illumination of the cockpit and/or instruments, scratched and/or dirty instrumentation, use of cockpit red lighting, inadequate cockpit environmental control (temperature and humidity), inappropriate sunglasses and/or prescription glasses/contact lenses, and sustained visual workload during flight.*

Hypoxia also impairs night vision. Because the rod cells in the eye, which give us night vision, require a lot of oxygen, a lack of oxygen causes visual impairment. One FAA reference suggests that without oxygen, a pilot flying at night is 24 percent blind at 8,000 feet, and 50 percent blind at 12,000 feet. The FAA recommends that pilots use supplemental oxygen above 5,000 feet MSL at night and above 10,000 feet MSL during the day to maintain visual acuity.

**Slide 29:** The following additional reminders and tips apply to pilots in general:

- Vision acuity drops 90 percent outside of the 10-degree circle at the center of one's field of view.
- Most midair collisions occur in day visual meteorological conditions—the times of best visibility—within five miles of an airport.
- Avoid self-medicating, drinking alcohol, and smoking. Beware of being sleep deprived, hypoglycemic, and fatigued. All of these lower visual acuity.
- Do not fly while wearing monovision contact lenses. (People with monovision lenses wear one lens for seeing far away and another lens, with a different prescription, for seeing close up.)
- All pilots can be subject to visual illusions; therefore, all pilots should rely on their instrumentation.

**Slide 30:** Have students watch the following video segment about eye anatomy, scanning, and impairments. This is an excellent synopsis of what they have learned, with bits of new information as well.

- "Aeromedical Factors" (Length 4:30)
  https://video.link/w/Stp1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/xK44nFczul0?start=1190&end=1323

**Slide 31:** Conduct the **Formative Assessment**.

**Formative Assessment**

Distribute **Your Eyes Are Deceiving You Student Activity 2**. Instruct students to answer the questions on their own. Correct responses are available in **Your Eyes Are Deceiving You Teacher Notes 2**.

[DOK-L2; *describe*] [DOK-L1; *illustrate*]

**Session 3**

**Slides 32-34:** Pilots must also know to anticipate and correct for illusions due solely to perspective. These aerial perspective illusions may cause pilots to misjudge the distance between the aircraft and the ground—errors that can be particularly dangerous as the aircraft approaches the runway, descends, and lands. Sloping runways, sloping terrain, and runways with varying widths and lengths can cause these illusions, as described on the following slides.

**Slide 32:** According to the FAA's Guidance on Spatial Disorientation and Visual Illusions,

*Pilots learn to recognize a normal final approach by developing and recalling a mental image of the expected relationship between the length and the width of an average runway.*

*A final approach to an* ***upsloping runway*** *may produce the visual illusion of a high-altitude final approach. If you believe this illusion, you may respond by pitching the aircraft nose down to decrease the altitude, which, if performed too close to the ground, may result in an accident.*

*A final approach to a* ***downsloping runway*** *may produce the visual illusion of a low-altitude final approach. If you believe this illusion, you may respond by pitching the aircraft nose up to increase the altitude, which may result in a low-altitude stall or require a go-around.*

**Slide 33:** According to the FAA's Guidance on Spatial Disorientation and Visual Illusions,

*A final approach over* ***upsloping terrain*** *with a flat runway may produce the visual illusion that the aircraft is higher than it actually is. If you believe this illusion, you may respond by pitching the aircraft nose-down to decrease the altitude, resulting in a lower approach. This may result in landing short or flaring short of the runway and risking a low-altitude stall.*

*A final approach over a* ***downsloping terrain*** *with a flat runway may produce the visual illusion that the aircraft is lower than it actually is. If you believe this illusion, you may respond by pitching the aircraft's nose up to gain altitude. If this happens, you will land further down the runway than you intended.*

**Slide 34:** According to the FAA's Guidance on Spatial Disorientation and Visual Illusions,

*A final approach to an unusually* ***narrow runway*** *or an unusually* ***long runway*** *may produce the visual illusion of being too high. If you believe this illusion, you may pitch the aircraft's nose down to lose altitude. If this happens too close to the ground, you may land short of the runway.*

*A final approach to an unusually* ***wide runway*** *may produce the visual illusion of being lower than you actually are. If you believe this illusion, you may respond by pitching the aircraft's nose up to gain altitude, which may result in a low-altitude stall or require a go-around (bottom images).*

**Slide 35:** With this activity, students can see for themselves the effects of runway slope and width on their visual perception of an aircraft's height above the runway. Divide students into small groups; distribute **Your Eyes Are**

**Deceiving You Student Activity 3 No Photos** and a set of runway images from the file titled **3runwaywidths.pdf** to each group. Instruct students to read all activity instructions before starting, then follow the directions carefully and answer the questions for each part. Potential answers to questions are available in **Your Eyes Are Deceiving You Teacher Notes 3.**

**Teaching Tips**

If space or time is limited, modify the procedure to conduct the activity as a teacher demonstration. You'll need to set up one camera and tripod and take the pictures yourself to show the class. If possible, project the images from the camera to a large screen so the entire class can see "in real time" as you set up each runway.

Note: **Student Activity 3 Photos** is provided as a resource if taking photos in class is not practicable. The document provides students with photos taken from the appropriate perspectives so they may answer the questions.

The following short video should help to further drive home what students just experienced in the activity.

- "Aeromedical Factors" (Length 0:36)
  https://video.link/w/7up1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/xK44nFczul0?start=1154&end=1190

**Slides 36-37:** Now that students understand how and why runway illusions occur, they need to understand how to prevent the errors that runway illusions can cause. Chapter 17 of the PHAK suggests the following strategies for preventing potentially hazardous consequences of runway illusions:

1. *Anticipate the possibility of visual illusions during approaches to unfamiliar airports, particularly at night or in adverse weather conditions. Consult airport diagrams and the Chart Supplement U.S. for information on runway slope, terrain, and lighting.*
2. *Make frequent reference to the altimeter, especially during all approaches, day and night.*
3. *If possible, conduct an aerial visual inspection of unfamiliar airports before landing.*
4. *Use Visual Approach Slope Indicator (VASI) or Precision Approach Path Indicator (PAPI) systems for a visual reference, or an electronic glideslope, whenever they are available.*
5. *Utilize the visual descent point (VDP) found on many non precision instrument approach procedure charts.*
6. *Recognize that the chances of being involved in an approach accident increase when an emergency or other activity distracts from usual procedures.*
7. *Maintain optimum proficiency in landing procedures.*

The image on Slide 37 shows how different systems, including PAPI and VASI, use lights to signal runway information to pilots.

Slide 38: The following video segment from AOPA's Air Safety Institute reveals a real-world approach to a challenging runway environment. Instruct students to take notes, writing down any tips that might benefit them as future pilots.

- "Beyond Proficient: Flying to Catalina Island" (Length 3:04)
  https://video.link/w/m2p1

For teachers unable to access Safe YouTube links, the video is also available here: https://www.youtube.com/embed/SKxe3C5-15A?start=387&end=571

**Slides 39–44** describe additional illusions that can fool and endanger pilots.

**Slide 39:** The FAA's Guidance on Spatial Disorientation and Visual Illusions describes the **black-hole approach illusion** (also known as a **featureless terrain illusion**):

*A black-hole approach illusion can happen during a final approach at night (no stars or moonlight) over water or unlighted terrain to a lighted runway beyond which the horizon is not visible. In the example shown in Figure 9, when peripheral visual cues are not available to help you orient yourself relative to the earth, you may have the illusion of being upright and may perceive the runway to be tilted left and upsloping. However, with the horizon visible (Figure 10) you can easily orient yourself correctly using your central vision.*

*A particularly hazardous black-hole illusion involves approaching a runway under conditions with no lights before the runway and with city lights or rising terrain beyond the runway. Those conditions may produce the visual illusion of a high-altitude final approach. If you believe this illusion you may respond by lowering your approach slope (Figure 11).*

**Questions**

What can a pilot do to avoid falling victim to this second scenario and lowering the aircraft's approach slope?

*following the PAPIs, VASIs, or other approach lighting*

**Slide 40:** Chapter 17 of the PHAK describes several other illusions related to ground lighting:

*Lights along a straight path, such as a road or lights on moving trains, can be mistaken for runway and approach lights. Bright runway and approach lighting systems, especially where few lights illuminate the surrounding terrain, may create the illusion of less distance to the runway. The pilot who does not recognize this illusion will often fly a higher approach.*

***Autokinesis** is caused by staring at a single point of light against a dark background for more than a few seconds. After a few moments, the light appears to move on its own. Apparent movement of the light source will begin in about 8 to 10 seconds. To prevent this illusion, focus the eyes on objects at varying distances and avoid fixating on one source of light. This illusion can be eliminated or reduced by visual scanning, by increasing the number of lights, or by varying the light intensity. The most important of the three solutions is visual scanning. A light or lights should not be stared at for more than 10 seconds.*

**Slide 41:** Chapter 17 of the PHAK describes another illusion related to the horizon:

*A **false horizon** can occur when the natural horizon is obscured or not readily apparent. It can be generated by confusing bright stars and city lights. It can also occur while flying toward the shore of an ocean or large lake. Because of the relative darkness of the water, the lights along the shoreline can be mistaken for stars in the sky.*

Furthermore, according to the FAA's Guidance on Spatial Disorientation and Visual Illusions,

***False Visual Reference Illusions** may cause you to orient your aircraft in relation to a false horizon; these illusions are caused by flying over a banked cloud, night flying over featureless terrain with ground lights that are indistinguishable from a dark sky with stars, or night flying over a featureless terrain with a clearly defined pattern of ground lights and a dark, starless sky.*

**Slide 42:** Chapter 17 of the PHAK describes an illusion called **empty-field myopia**:

*Empty-field myopia is a condition that usually occurs when flying above the clouds or in a haze layer that provides nothing specific to focus on outside the aircraft. This causes the eyes to relax and seek a comfortable focal distance that may range from 10 to 30 feet. For the pilot, this means looking without seeing, which is dangerous. Searching out and focusing on distant light sources, no matter how dim, helps prevent the onset of empty-field myopia.*

**Slide 43:** Chapter 17 of the PHAK describes an unpleasant sensation called **flicker vertigo**:

*A light flickering at a rate between 4 and 20 cycles per second can produce unpleasant and dangerous reactions including nausea and vomiting. On rare occasions, convulsions and unconsciousness may also occur. Proper scanning techniques at night can prevent pilots from getting flicker vertigo.*

**Slide 44:** Chapter 17 of the PHAK describes several illusions caused by weather:

***Water Refraction**: Rain on the windscreen can create an illusion of being at a higher altitude because it makes the horizon appear lower than it is. This can result in the pilot flying a lower approach.*

***Atmospheric haze** can create an illusion of being at a greater distance and height from the runway.*

*As a result, the pilot has a tendency to be low on the approach. To understand this illusion better, recall the runway width illusions; in this case, the fact that a narrow runway makes a pilot think they are higher than they actually are.*

*Because haze makes things appear farther than they actually are, the runway may seem narrower than it actually is. Seeing a narrow runway, the pilot may think the aircraft is too high and descend. This would put the aircraft at a lower-than-appropriate altitude for the approach.*

*Conversely, extremely clear air (clear bright conditions of a high altitude airport) can give the pilot the illusion of being closer than he or she actually is, resulting in a high approach that may result in an overshoot or go around.*

*Because bright conditions and clear air make things appear closer than they actually are, the runway may seem wider than it actually is. Seeing a wide runway, the pilot may think the aircraft is too low and climb. This would put the aircraft at a higher-than-appropriate altitude for the approach.*

*The diffusion of light due to water particles on the windshield can adversely affect depth perception. The lights and terrain features normally used to gauge height during landing become less effective for the pilot.*

*Flying into fog can create an illusion of pitching up. Pilots who do not recognize this illusion often steepen the approach abruptly.*

Finally, the FAA's Guidance on Spatial Disorientation and Visual Illusions describes an illusion caused by perceived motion: the **vection illusion**:

*A common example is when you are stopped at a traffic light in your car and the car next to you edges forward. Your brain interprets this peripheral visual information as though you are moving backwards and makes you apply additional pressure to the brakes. A similar illusion can happen while taxiing an aircraft.*

**Slide 45:** Enhanced Night Vision Systems include both Synthetic Vision Systems (SVS) and Enhanced Flight Vision Systems (EFVS). These are both examples of electronic systems that improve flight safety, both in poor weather conditions and at night. These technologies are being incorporated into civil, commercial, and military aircraft at an increasing rate. They produce digital images to enhance the surrounding environment. However, due to the cost, these systems are still uncommon in small aircraft such as those used for flight training.

## EXTEND

**Teacher Materials:** Your Eyes Are Deceiving You Presentation, Your Eyes Are Deceiving You Teacher Notes 4
**Student Materials:** Your Eyes Are Deceiving You Student Activity 4**, computer with flight simulator software or flight simulator, joystick or yoke, Optional: throttle quadrant, rudder pedals, additional monitors**

**Session 4**

**Slide 46:** Distribute **Your Eyes Are Deceiving You Student Activity 4** and have students complete the simulator activity. This will help to further demonstrate the effects of varying runway slopes, widths, lengths, lighting, and the black-hole effect. Instruct students to complete the listed scenarios in order because each demonstrates a different illusion, as previously discussed in the lesson. Ensure that different students get to answer the questions following each scenario to allow for critical thinking and application to real-life flying. Sample responses to questions are in **Your Eyes Are Deceiving You Teacher Notes 4**.

**Teaching Tips**

**Student Activity 4** has seven flight simulator scenarios. Depending on the time available, you may choose to have students perform all scenarios, or only scenarios you choose. After performing the scenarios, discuss the results of the various flights as a class.

Some key questions may include:

- Did all students feel the aircraft was too low at the beginning of Scenario 2 (Denver, KDEN)?
- Did all students feel the aircraft was too high at the beginning of Scenario 4 (Richmond, 08R)?

## EVALUATE

**Teacher Materials:** Your Eyes Are Deceiving You Presentation, Your Eyes Are Deceiving You Teacher Notes 5
**Student Material:** Your Eyes Are Deceiving You Student Activity 5

**Slides 47-56:** FAA Private Pilot Knowledge Test practice questions.

**Slide 57:** Conduct the **Summative Assessment**. Students quiz each other on questions developed from content on this lesson's slides.

**Summative Assessment**

Divide students into groups of three. (If the class cannot be divided evenly into groups of three, allow one or more groups of two, combining the second and third topics into a single topic: in-flight and landing illusions, and piloting strategies and techniques for preventing and adapting to illusions.)

Provide each group with a copy of **Your Eyes Are Deceiving You Student Activity 5**, as well as index cards and pens or markers. Have students follow the directions to complete the assessment. Additional tips for teachers are provided in **Your Eyes Are Deceiving You Teacher Notes 5**.

[DOK-L2; *describe,* DOK-L1; *illustrate, label*]

**Summative Assessment Scoring Rubric**

- Follows assignment instructions
- Postings show evidence of one or more of the following:
  - Knowledge of visual physiology and common illusions in flight.
  - Knowledge of the factors that affect pilot visuals and requirements for operations.
  - Ability to explain actions that pilots can take to account for changing visual conditions.
- Contributions show understanding of the concepts covered in the lesson
- Contributions show in-depth thinking including analysis or synthesis of lesson objectives

| Points | Performance Levels |
|---|---|
| 9-10 | Demonstrates thorough knowledge of human eye anatomy and function; Identifies all visual illusions that a pilot may encounter; effectively strategies for compensating for visual illusions |
| 7-8 | Demonstrates sufficient knowledge of human eye anatomy and function; Identifies most visual illusions that a pilot may encounter; provides sufficient strategies for compensating for visual illusions |
| 5-6 | Demonstrates poor knowledge of human eye anatomy and function; Identifies some visual illusions that a pilot may encounter; provides vague strategies for compensating for visual illusions |
| 0-4 | Demonstrates little or no knowledge of human eye anatomy and function, visual illusions that a pilot may encounter, and strategies for compensating for visual illusions |

## GOING FURTHER

As time allows, have students utilize www.skyvector.com (aeronautical charts) and www.airnav.com (airport information) to further explore other airports with narrow, wide, or sloping runways, and then use the simulator to practice landing at these airports during the day and at night. As a class, discuss the various challenges for each airport /runway environment.

## STANDARDS ALIGNMENT

## NGSS STANDARDS

**Three-Dimensional Learning**

- **HS-ETS1-4** - Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
  - Science and Engineering Practices
    - Using Mathematics and Computational Thinking
  - Disciplinary Core Ideas

        - ETS1.B: Developing Possible Solutions
    - Crosscutting Concepts
        - Systems and System Models

## COMMON CORE STATE STANDARDS

- **RST.11-12.2** - Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- **RST.11-12.4** - Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
- **WHST.11-12.6** - Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
- **WHST.11-12.8** - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
- **WHST.11-12.9** - Draw evidence from informational texts to support analysis, reflection, and research

## FAA AIRMAN CERTIFICATION STANDARDS

### PRIVATE PILOT

**I. Preflight Preparation**
**Task H. Human Factors**

- Knowledge The applicant demonstrates understanding of:
    - **PA.I.H.K1** The symptoms (as applicable), recognition, causes, effects, and corrective actions associated with aeromedical and physiological issues including:
        - **PA.I.H.K1a** Hypoxia
        - **PA.I.H.K1b** Hyperventilation
        - **PA.I.H.K1f** Carbon monoxide poisoning
        - **PA.I.H.K1g** Stress
        - **PA.I.H.K1h** Fatigue
        - **PA.I.H.K1k** Optical illusions
    - **PA.I.H.K2** Regulations regarding use of alcohol and drugs.
    - **PA.I.H.K3** Effects of alcohol, drugs, and over-the-counter medications.
    - **PA.I.H.K4** Aeronautical Decision-Making (ADM).
- Risk Management The applicant demonstrates the ability to identify, assess and mitigate risks encompassing:
    - **PA.I.H.R1** Aeromedical and physiological issues.
    - **PA.I.H.R2** Hazardous attitudes.
    - **PA.I.H.R3** Distractions, loss of situational awareness, or improper task management.

- Skills The applicant demonstrates the ability to:
    - **PA.I.H.S1** Associate the symptoms and effects for at least three of the conditions listed in K1a through K1l above with the cause(s) and corrective action(s).
    - **PA.I.H.S2** Perform self-assessment, including fitness for flight and personal minimums, for actual flight or a scenario given by the evaluator.

## REFERENCES


Pilot's Handbook of Aeronautical Knowledge, Chapter 17
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/media/19_phak_ch17.pdf

Aeronautical Information Manual 8-1-6
https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap8_section_1.htm

FAA Vision Fact Sheet
https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/pilot_vision.pdf

FAA Spatial Disorientation and Visual Illusions Fact Sheet
https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/spatiald_visillus.pdf

Common Optical Illusions
https://sciencebob.com/see-some-optical-illusions/