It's a Confusing World Up There

The Specifics of Spatial Disorientation

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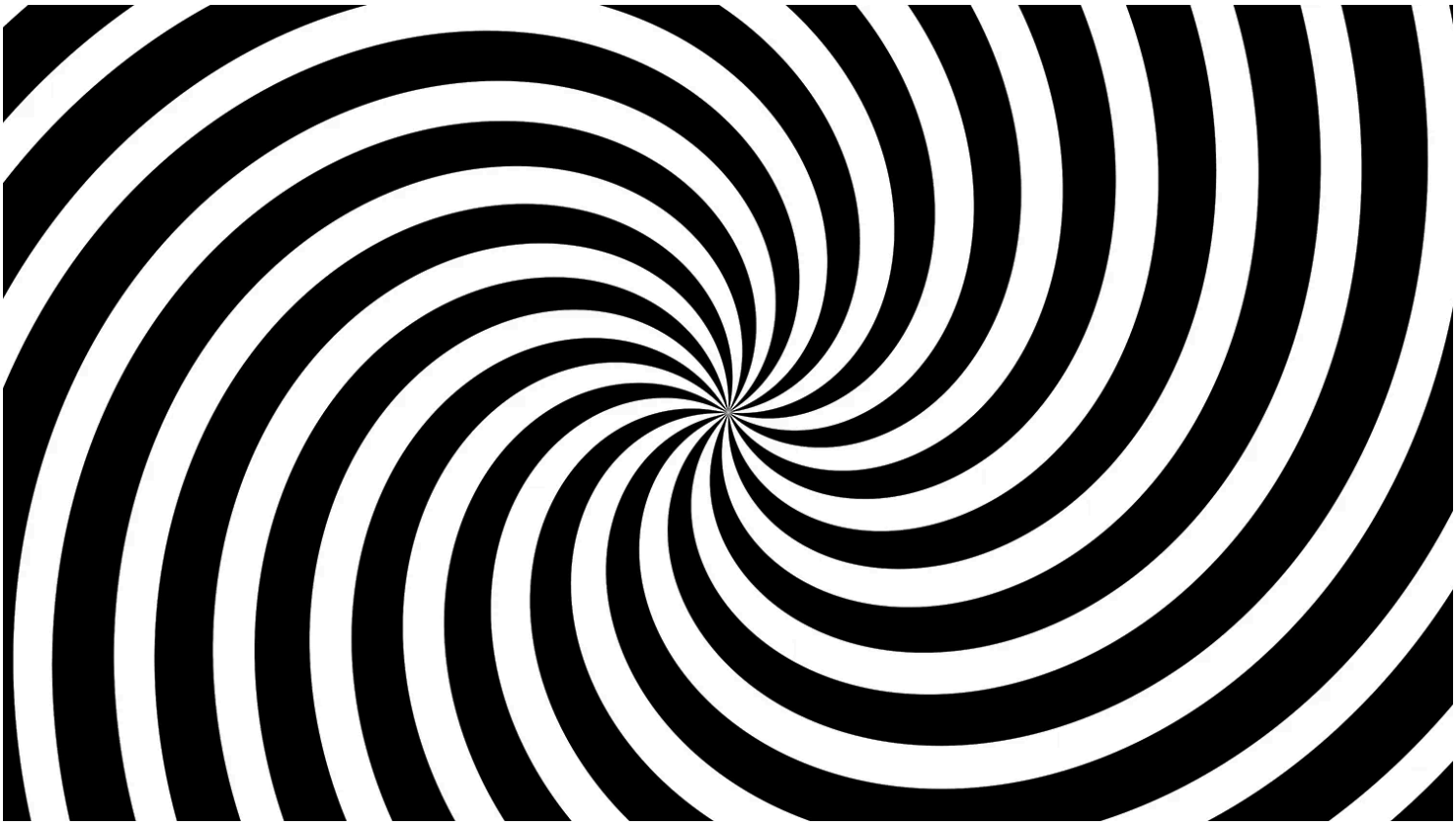
By Nicole Hartman and Rebekah Waters, FAA Safety Briefing Magazine



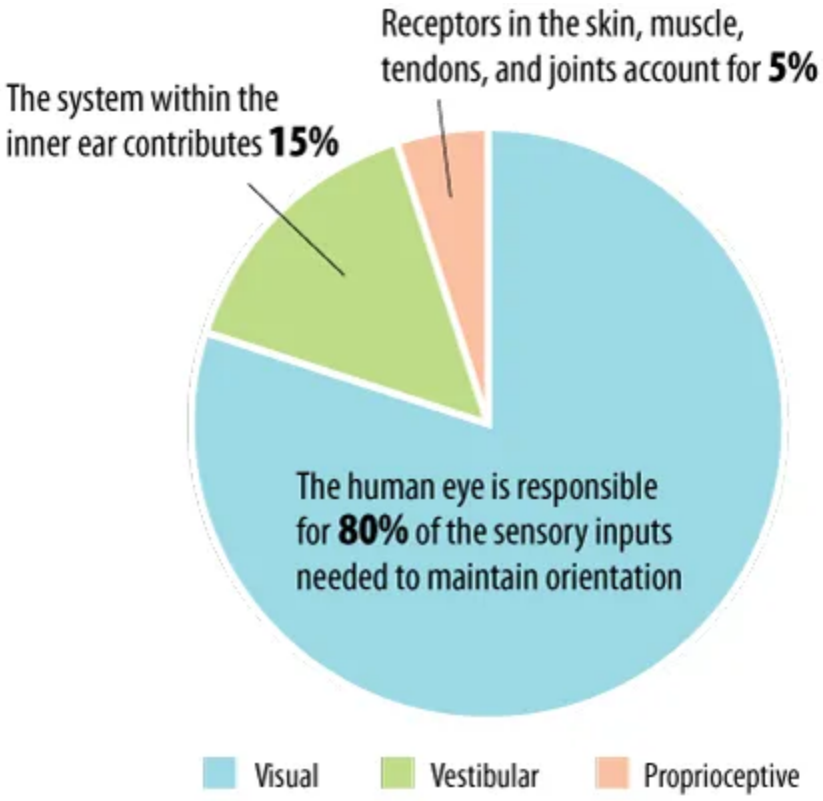
It's sobering to search the National Transportation Safety Board (NTSB) database for accidents caused by spatial disorientation, or "spatial D." The query produces page after page of accidents — hundreds of aviators have succumbed to this confusing condition. Statistics show that between 5 to 10% of all general aviation accidents are attributed to spatial disorientation, and 90% of those are fatal. NTSB data suggests that spatial D is a more common occurrence at night or in limited visibility weather conditions. All pilots are susceptible to the optical illusions that may cause loss of aircraft control at any time. Let's take a closer look at the causes of spatial disorientation, review the types, and discuss strategies for preventing this source of aviation accidents.

Seeing Isn't Always Believing

Spatial orientation is our natural ability to maintain our body's orientation and/or posture in relation to the surrounding environment (physical space) at rest and during motion. The three-dimensional environment of flight is unfamiliar to our bodies and creates sensory conflicts and illusions that make spatial orientation difficult. The numerous sensory stimuli (visual, vestibular, and proprioceptive) during flight vary in magnitude, direction,

and frequency and can lead to sensory mismatches resulting in disorientation. This condition is known as spatial disorientation — the inability of a pilot to correctly interpret aircraft attitude, altitude, or airspeed in relation to the Earth or other points of reference.

Becoming spatially disoriented is the result of a properly functioning human system, which we are hard-wired to trust, misinterpreting our actual position or orientation in space. It goes against our natural instincts to accept that our orientation isn't what it appears to be. Even a brief loss of orientation while in flight for 10–15 seconds can result in an unusual aircraft attitude putting the pilot and passengers at risk for an accident. The sensory inputs needed to maintain orientation automatically and subconsciously used to orient ourselves include visual, vestibular, and proprioceptive.



👁 The visual system includes the eye and its component parts that are necessary for visual acuity (focus), depth perception, and assessing the

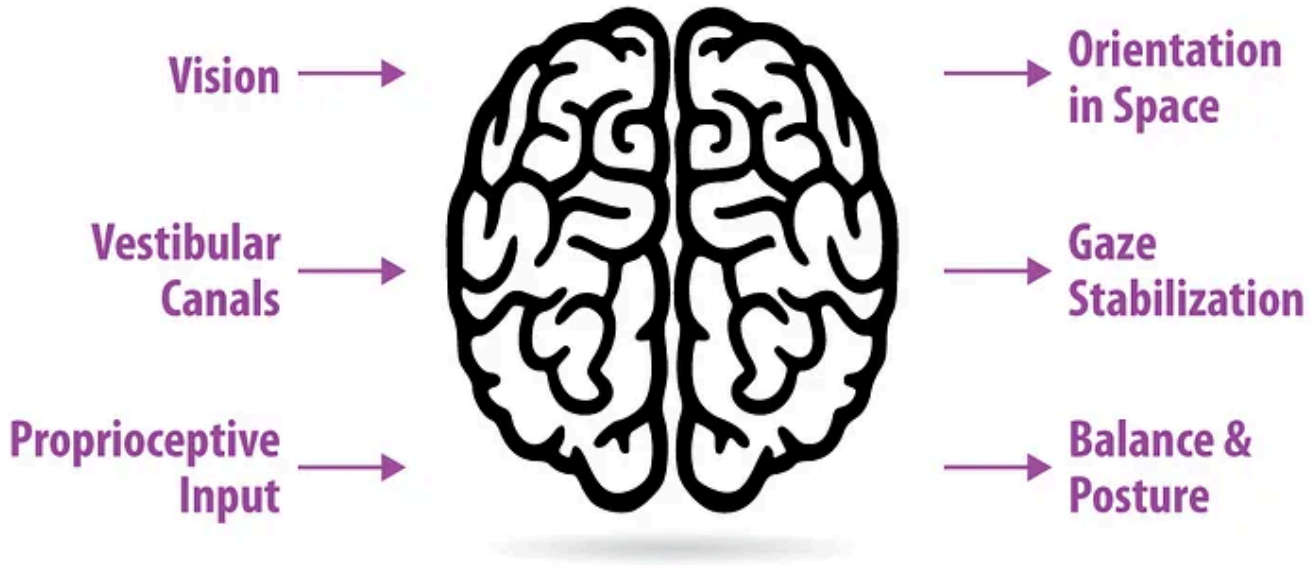
body's position in space relative to other objects both fixed and moving. During flight, visual reference is the largest contributor to accurate spatial orientation. By using visual references, the pilot can gather information about distance, speed, and depth. Any condition that deprives the pilot of natural visual references, such as clouds, fog, haze, darkness, terrain, or sky backgrounds with indistinct contrast (i.e., arctic whiteout or clear, moonless skies over water) can rapidly cause spatial D.

🦻 The vestibular system includes the sensory organs contained within the inner ear that detect relative motion of the head in space within its axes of movement. It consists of two major components: the semicircular canals that detect changes in rotational acceleration, and the otolith organs that detect linear (straight) acceleration. Your vestibular system's primary function is to detect rotational and translational movements of the head and generate a corresponding response signal. But this system was designed to function on the ground in a 1G environment (normal gravity). Accidents can occur due to a combination of vestibular illusions and poor visibility. When the body is subjected to certain forces that cause a vestibular illusion, vision is often the only sense that can contradict these false perceptions. However, in darkness or other poor visibility conditions, it is much easier to be deceived by an illusion and to ignore information provided by your instruments.

🖐 Proprioception is a term that encompasses the human sensation of the body's (trunk/limbs) position as it relates to space and forms the foundation about which the other sensory organs guide desired movements within that space. Proprioceptive sensory inputs give us a reference to posture and the relative position of our body in relation to our environment.

Prone to Puzzlement?

It is important to recognize that even when a pilot's visual, vestibular, and proprioceptive systems are working properly, associated underlying medical conditions or human factors can increase the risk for spatial D. There are both external and internal factors that will increase a pilot's susceptibility to spatial disorientation. Any visual condition that reduces a pilot's ability to maintain orientation to the horizon (i.e., clouds, haze, night conditions, terrain) will increase the risk of spatial D. Additionally, a pilot may be more vulnerable to spatial disorientation as a result of age, fatigue, stress, anxiety, or get-there-itis. Some medical conditions, medications, smoking, alcohol, and other drugs that affect the visual, vestibular, or proprioceptive sensory inputs can also increase susceptibility.



The brain combines sensory signals (left) in order to maintain control of the body.

Be sure to read the Aeromedical Advisory in this issue for examples of how certain medications can exacerbate spatial D.

Misfortune with Medications

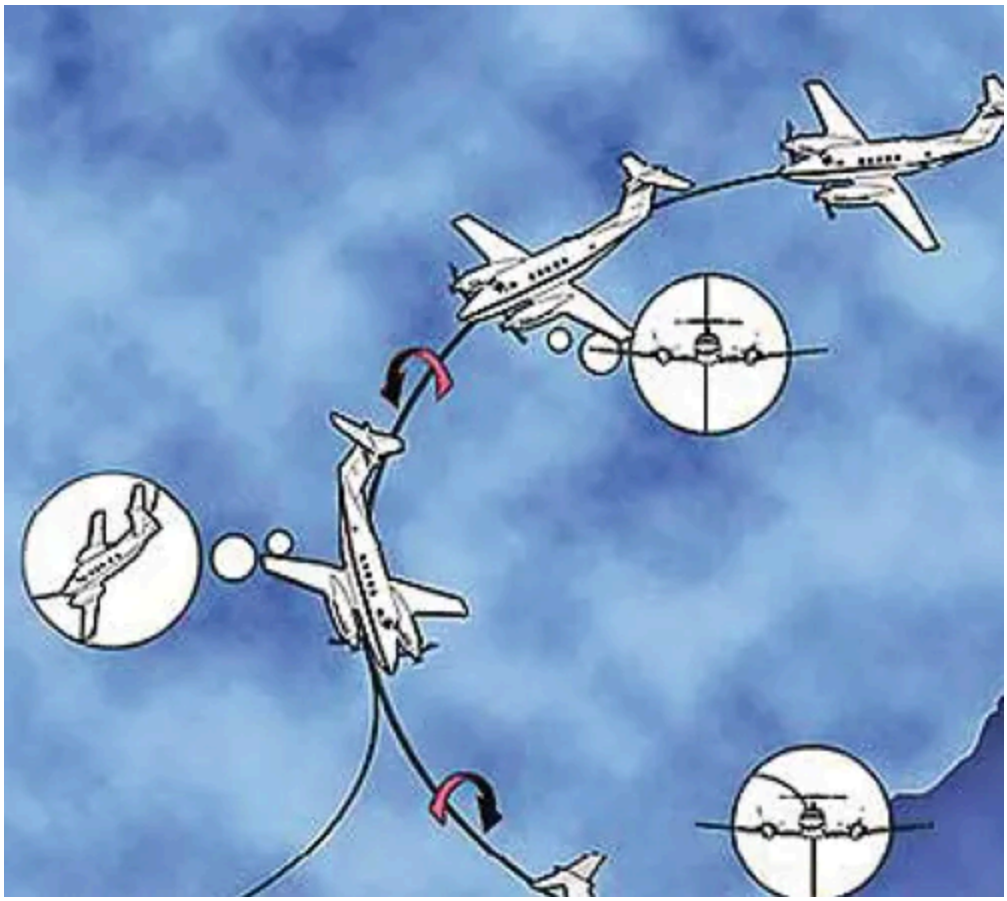
Aeromedical Advisory: a checkup on all things aeromedical

Don’t Trust Your Gut

Without visual references (e.g., VFR at night/low visibility and IFR flying), pilots can become disoriented, especially in situations like low visibility or turbulent weather, where sensory inputs can be conflicting or misleading. When visual cues are absent, your body will turn to your vestibular system for information. The vestibular system is complex and can be easily deceived in certain flight conditions. When motion makes this system unreliable, pilots experience vestibular illusions. These dangerous illusions are the most likely culprits of spatial disorientation.

There are six types of vestibular illusions you may encounter while flying IFR. The most common illusion, “the leans,” occurs after a sudden return to level flight after a gradual and prolonged turn. If the rotational acceleration of the turn is 2 degrees per second or lower, your vestibular system will not detect this movement. When you level out after a turn like this, you may experience the illusion that your aircraft is banking in the opposite direction. If you rely on what your body is telling you, you might lean in the direction of the original turn to regain what you think is the correct vertical posture.

If a pilot is in a turn long enough for the fluid in the ear canal to move at the same speed as the canal, the “Coriolis illusion” can occur — the most dangerous vestibular illusion. A sudden head movement, such as looking down at something you dropped during a prolonged turn can give you the false sensation of rotation or acceleration on an entirely different axis. When disoriented by this illusion, you might maneuver the aircraft into a dangerous attitude while trying to correct your aircraft’s perceived attitude. This is why it’s so important to practice moving your head as little as possible during instrument cross-checks or scans. Make sure you keep your head as still as possible when reaching for charts and other objects on the flight deck.



A prolonged coordinated constant-rate turn could cause the sensation of flying straight and level. This is when you are in danger of experiencing the “graveyard spiral.” Aircraft tend to lose altitude in turns unless you compensate for the loss in lift. When making a constant-rate turn, you may notice a loss of altitude, even though you aren’t experiencing the sensation of turning. This creates the illusion of being in a level descent. Your gut might tell you to pull back on the controls in an attempt to climb or stop the descent. If you listen to your gut instead of trusting your instruments, the spiral will tighten and increase the loss of altitude. This could lead to a loss of aircraft control.

The “somatogravic illusion” occurs during rapid acceleration and creates the same feeling as tilting your head backward. Pilots experiencing this feeling can mistake it for a climb, especially while flying IFR. This disorientation could make you want to push the aircraft into a nose-low or dive attitude. A

rapid deceleration could make you feel the opposite sensation and urge you to pull up, putting you in danger of a nose-up or stall attitude.

When you make a sudden return to straight and level flight after a climb, it can feel like you are tumbling backward. This is known as “inversion illusion.” The disorientation you feel from this might lead you to push your aircraft abruptly into a nose-low attitude, which can intensify the illusion.

Like the “inversion illusion,” the “elevator illusion” is also caused by an abrupt change. A sudden upward vertical acceleration, as can occur in an updraft, can stimulate your otolith organs and create the illusion of being in a climb. This could make you want to push the aircraft into a nose-low attitude. An abrupt downward vertical acceleration, usually in a downdraft, has the opposite effect making you want to pull the aircraft into a nose-up attitude.

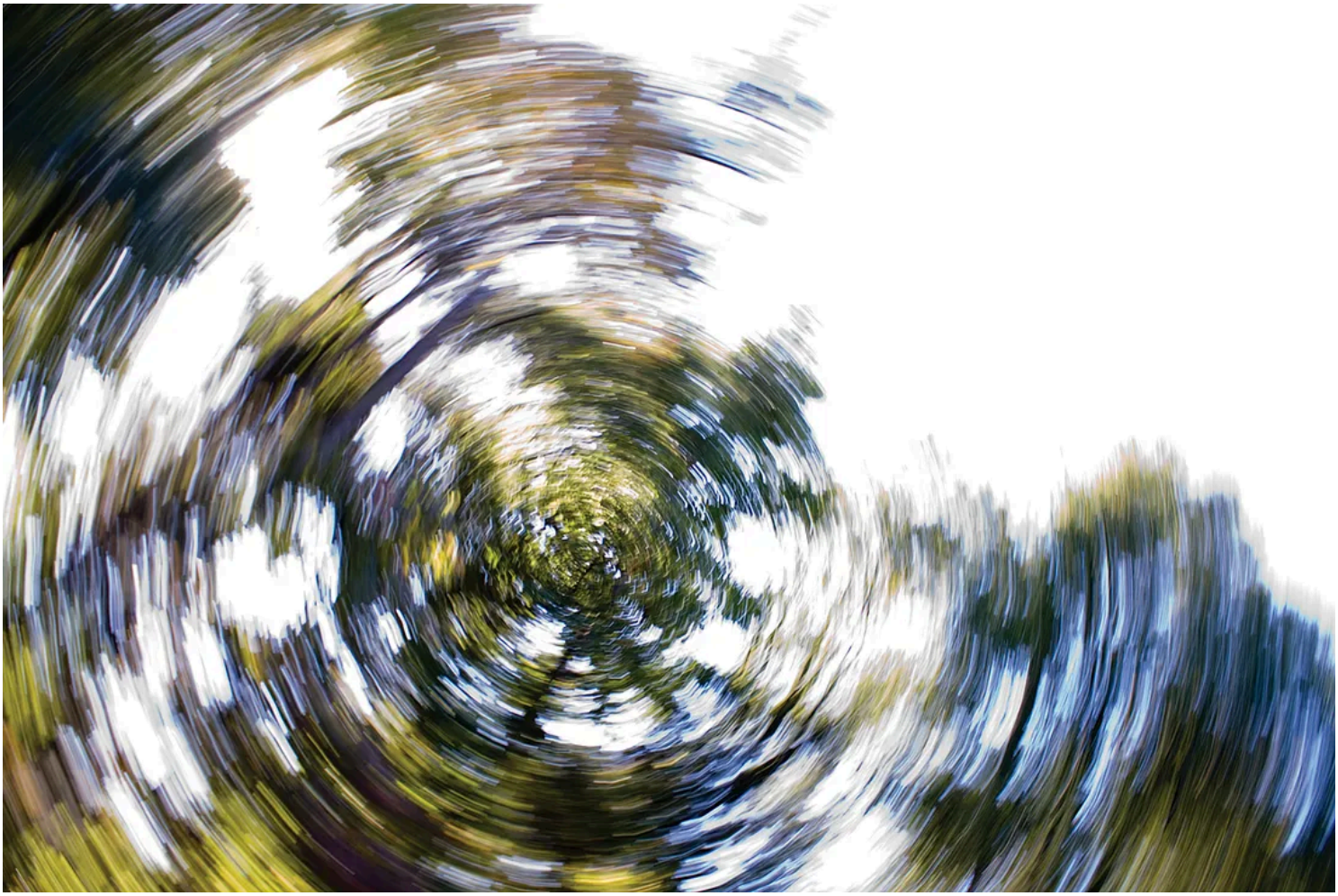
Do Your Eyes Deceive You?

Spatial disorientation can also be caused by visual illusions. Your mind believes what it sees, which can be dangerous for pilots. “False horizon” occurs when your mind uses inaccurate visual information, like a sloping cloud formation, when trying to align your aircraft with the actual horizon. This type of illusion can be disorienting and lead you to place your aircraft in a dangerous attitude. “Autokinesis” is another visual illusion that can happen when flying at night. If you are attempting to align your aircraft with a stationary light, autokinesis could create the illusion that the light is moving. When this happens, you become disoriented and could potentially lose control of your aircraft.

> It goes against our natural instincts to accept that our orientation isn’t what it appears to be.

Combating Spatial D

Reviewing the NTSB data reveals that there are many causes of spatial disorientation, but the outcome for the majority of the accidents is the same — fatality. So, what can you do to avoid these dangerous situations? “Preflight weather planning is critical to avoiding an inadvertent encounter with instrument conditions,” said Katherine Wilson, senior human performance NTSB senior human performance investigator. “But if a pilot finds themself in that situation, it is important they trust their instruments and exit the conditions as quickly and safely as possible.”



Your first line of defense against spatial D should be practice, practice, and more practice. Undergo regular training on spatial disorientation recognition and recovery techniques so you will be aware and prepared for potentially disorienting situations. Consider experiencing spatial D firsthand, either with a flight instructor or in a simulator. You could also immerse yourself in the visual and vestibular illusions that you might encounter at a spatial disorientation laboratory. Many universities and the military use labs to simulate various flight conditions and scenarios to train pilots to recognize and cope with spatial D. Experience the disorientation in a controlled environment, and practice overcoming what your body is telling you so you

can commit to trusting your instruments. To learn about training offered by the FAA go to bit.ly/FAACAMIED.

> Your first line of defense against spatial D should be practice, practice, and more practice.

Set yourself up for success — to help prevent spatial disorientation, pilots should:

- Obtain training and maintain proficiency with flying instruments before flying with less than three miles visibility.
- Use and rely on your flight instruments, especially at night, in reduced visibility, and in featureless and sloping terrain. Be sure to test your flight instruments before each flight as well as during your preflight and taxi.
- Maintain night currency if you intend to fly at night. Include cross-country and local operations at different airports.
- Do not attempt VFR flight when there is the possibility of getting trapped in deteriorating weather.
- If you are flying with another pilot and start to experience spatial D, transfer control. Pilots rarely experience visual illusions simultaneously.
- Plan your transition to instrument flying before you enter IMC. Start your instrument scan while you are still in visual conditions.
- Avoid movements in the cockpit that are prone to cause spatial disorientation when flying by reference to instruments. Sudden head movements, or the classic “reaching down to pick up a dropped pencil” may bring on sudden disorientation.

In addition to these tried-and-true methods of combating spatial D, it is also important to:

- Study and become familiar with unique geographical conditions in areas where you plan to operate.
- Check weather forecasts before departure, enroute, and at your destination. Be alert for weather deterioration.
- Consider practicing maneuvers that illicit illusions with your flight instructor to maintain proficiency.
- Contact your FSDO for opportunities to use a full motion simulator and experience the illusions you might encounter.
- Set personal minimums for VFR and IFR flight designed to minimize your exposure to conditions that increase your risks.

Remember, once you enter instrument conditions, completely commit to instrument flying. Attempting quick transitions to visual flight because you spotted a hole in the clouds or caught a glimpse of the ground below may cause spatial disorientation that could have been avoided by maintaining a proper instrument scan. Although it's tempting to reengage in visual flight when going in and out of clouds, keep the instrument scan and don't transition back to visual flying until you have the necessary visibility and visual references to do so safely. Resist this temptation, and follow the strategies mentioned above to make sure you have a safe and successful flight no matter what flying conditions you encounter!

Learn More

- Spatial Disorientation Fact Sheet
- Pilot Safety Brochure & Visual Illusions Brochure

- Aeronautical Information Manual (AIM), Chapter 8
- Instrument Flying Handbook, Chapter 3
- NTSB Visual Illusions Safety Alert (SA-052) & Reduced Visual References Safety Alert (SA-020)
- Condition Inspection, a look at specific medical conditions, *FAA Safety Briefing*, Mar/Apr 2020

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