SPATIAL DISORIENTATION
SENSORY ILLUSIONS OF FLIGHT
VERTIGO

The terms listed in our title are often used interchangeably even though their exact meanings differ somewhat:

SENSORY ILLUSION	A false or misinterpreted sensory impression; a false interpretation of a real sensory image.
VERTIGO	A hallucination of movement. A sensation of rotary motion of the external world or of the individual.
SPATIAL DISORIENTATION	Loss of proper bearings; state of mental confusion as to position, location, or movement relative to the position of the earth.

(TABLE 23)

Sensory receptors in various parts of the body provide the brain with information relative to your position in your environment. The eyes, vestibular apparatus, and muscle senses practically tell you *which way is up.* In flying, many conditions you encounter can cause conflicts, or illusions, in these sensory functions. Cockpit confusion might be another term for disorientation, since the information from your senses and from your instruments may be contradictory.

To understand the functions of the organs of equilibrium and how interpretations of these senses may lead to sensory illusions and spatial disorientation is a complex but rewarding undertaking.

SENSORY SYSTEMS INVOLVED IN EQUILIBRIUM

The sensory organs of the body associated primarily with maintaing body equilibrium are the eyes, semicircular canals (vestibular apparatus), and the skeletal muscles (proprioceptors).

A. THE EYES

The eye acts as the receptor organ for visual sensations. These sensations establish impulses in the cone and rod cells and the impulses travel the optic nerve to the brain for interpretation. The eye is very reliable for orientation, provided adequate reference points are available. When flying, however, you are at a disadvantage when trying to interpret visual cues. An object seen from the air often looks quite different than objects seen from the ground. Also, you are used to having the ground extend to the horizon. In the air you lack the visual cues that a continuous background provides for recognizing objects and deciding their size and distance. A very common mistake is in interpreting the lights that you see at night. Pilots can become confused about the relationship between their own motion and the false motion of fixed lights on the ground. Thus, a pilot may decide that a fixed light on the ground is another airplane traveling in the opposite direction.

If you cannot see the horizon, you may mistakenly choose some other line as a reference and, for example, may fly parallel to a tilted cloud bank instead of the ground. Consider what happens when no clouds are present and the horizon is obscured by haze or adverse lighting conditions. In such a situation you are apt to be completely without reference, which amounts to *flying blind.* In Alaska and other similar areas, this problem is particularly severe due to haze and light reflected from the snow covered ground. Under such conditions, sensory illusions in flight are only part of the problem; a noticeable loss of depth perception increases the hazard.

All these illusions are mistakes in interpretation caused by inadequate information on which to establish a reference. Your eyes are reporting correctly to your brain, but there isn't enough information for the brain to interpret.

This situation is worse at night than during the day, for your eyes are furnishing less information. Under such conditions your eyes can send false messages to the brain.

Have you ever been stopped at a traffic signal and then had another automobile pull along side? Although you were stopped, did you have the illusion your car was backing up slowly only to find that you were indeed stopped and the other car was moving up slowly? This is one simple illustration of sensory illusions. There are numerous others that can and do occur while flying aircraft in both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) conditions.

B. PERCEPTION of the SKELETAL MUSCLES

The tension of the various muscles in your body assist you in determining your position within a frame of reference, as well as any motion with respect to this reference. Compared to the eyes and vestibular apparatus, however, these muscles *(known as the proprioceptors)* play a very small role in determining orientation.

However, no matter how small a part the proprioceptors play in determining perceived direction in the air, they can give some indication of position by the pressure of your body in the seat of the aircraft and the sensation that gravity is being applied along a line from the earth passing vertically through the seat. The feeling can occur regardless of the aircraft's reference point to the earth. This means that even though the muscle sense indicates to the pilot that the aircraft is flying a straight and level course, the aircraft may actually be in a coordinated turn.

C. THE VESTIBULAR APPARATUS

The Inner Ear consist of an auditory and non-auditory portions. The latter is primarily associated with equilibrium and contains the three semicircular canals. The semicircular canals are filled with a thick fluid and each canal lies at an approximate 90 degree angle to the other.

One end of each canal is enlarged and in this area is a mound of sensory hair cells. Angular acceleration, or rotation, of the body along either the yaw, pitch, or roll axis will move the fluid in a respective canal. This movement displaces the sensory hairs and an impulse is sent to the brain to be interpreted as motion about a known axis. The hairs that project into the fluid are extremely fine, light, and sensitive. Any acceleration greater than 2 degrees per second will cause the hairs to displace and an impulse is sent to the brain that indicates which way the hairs are bent, the brain then figures out the plane of rotation. Since the canals lie in different planes, they can report movement in all three dimensions (yaw, pitch, and roll). This system works fine for sudden, short turns, but, if the turn continues at a constant rate for a period of time, (approximately 25 seconds) the motion of the fluid catches up to the speed of the canal walls, and the hairs are no longer bent. In this scenario, a pilot would initially feel a turn to the right, but, after 25 seconds, as long as the rate of the turn is constant, the pilot would feel as though the turn has stopped, when in actuality, this pilot is still turning to the right.

Once the turn to the right is detected, and the turn is stopped, the fluid in the canal will continue to move. In this situation, the hairs that were straight because the fluid and canals were moving at the same rate, would suddenly bend in the opposite direction. This would cause an opposite sensation as though one was now turning hard to the left. An untrained pilot in this situation would, more than likely, turn the aircraft back to the right to compensate for the ***perceived*** left turn. As a result, a pilot would try to counteract this imaginary motion by turning back into the original turn or spin. This is the physiology behind the classic *Graveyard Spin or Spiral.*

As angular acceleration begins, the canal(s) wall will rotate as the body rotates. The fluid in the canal will lag behind causing the sensory hairs to deviate from their normal erect position (see example A). As the rotation continues at a constant rate for approximately 25 seconds, the fluid will move at the same rate as the canal, the sensory hairs will come back to the erect position, and the sensation of turning will not be felt (see example B). If the rate of the turn decreases or if the turn stops, the fluid, due to inertia, will continue to move and will bend the sensory hairs in the opposite direction (see example C).

When the brain perceives angular motion from a canal, it will cause the eyes to react to the motion. In an attempt to keep everything in your visual field during rotation, the eyes will sweep opposite of the plane of rotation. So in the example of the person turning to the right, the eyes would sweep to the left. This system works well during the rotation. The problem is that when the angular acceleration stops, and the fluid in the canals continues to, the eyes continue the sweeping motion for up to 30 seconds of completion of rotation. This condition is called ***nystagmus***. A pilot in this situation could, for example, be turning onto a final approach. After the turn is completed, the pilot, who is trying to scan VASI bars for example, would find that the bars are sweeping side to side, making them very tough to scan.

During angular acceleration in one plane of motion, the pair of canals (one in each ear) lying in that plane will be the only ones stimulated. But if one were to deviate one's head position during angular acceleration, another canal would be stimulated. This would send two conflicting impulses to the brain. The brain would have a difficult time trying to process the information coming from the two canals, and would find a "happy medium" to accommodate the signal. This gives a person a very strong illusion called ***Coriolis.*** In this scenario a pilot would be turning to a new heading, if the pilot moves the head during this turn by looking down at an approach plate or up at a switch or toggle, this could give the pilot a sensation that the aircraft is making a violent roll or pitch. An untrained pilot may possibly put the aircraft into an unusual attitude.

If an aircraft slowly tips to one side while a pilot is distracted, the rate of the roll can be so slow that the pilot may not detect it. This is called ***Sub-Threshold Acceleration*** and can be a very dangerous illusion. Any angular acceleration greater than 2 degrees per second will be detected by the semicircular canals. If the rotation is slower than this rate, angular accelaration may go unnoticed. This is the basic physiology behind a common illusion called the ***leans***. A pilot in this situation would, as mentioned above, slowly roll to the right or left. The rotation, if less than 2 degrees per second (sub threshold), would be unnoticed. Once the pilot checks the instrument panel and detects the roll, the pilot would attempt to go straight and level. When the pilot comes about level there will be a strong sensation of rolling to the opposite side. An untrained pilot may put the aircraft back into the initial roll because that "feels normal."

FLIGHT FACTORS CONTRIBUTING TO SPATIAL DISORIENTATION

1. Changes in angular acceleration.

2. Flying in Instrument Flight Rules (IFR) conditions.

3. Low level flight over water.

4. Frequent transfer from Visual Flight Rules (VFR) to IFR conditions.

5. Unperceived changes in aircraft attitude (Sub-Threshold Acceleration)

WHAT TO DO TO BEAT SPATIAL DISORIENTATION

From all this you can see that, individually treated, each type of illusion can cause a great deal of trouble. Since this is precisely what may happen if you are not careful, let's see what you can do to beat these illusions.

First of all, you probably appreciate the fact that sensory illusions or vertigo are problems that usually show up under instrument conditions. Whenever the visibility is poor enough to prevent you from double-checking your equilibrium sense with your eyes, your equilibrium system is undependable. That is why your aircraft provides you with an artificial equilibrium system for indicating bank angle (turn & bank indicator), aircraft attitude (attitude indicator), pitch angle (VSI), and so forth. This system is much more reliable than anything you are equipped with, but it's not easy to use, primarily because you were not born with it. All your life on the ground you have been navigating by your eyes, and you are accustomed to doing what they tell you to do. Now, when you fly by instruments, you are told to ignore your senses and put your faith in dials and indicators.

1. Use Your Head.

There are several points to remember about instrument flying. The first is that you can learn to do it, but you have to use your head. Flying by instruments is a skill that can be highly developed. You have to read and interpret the instruments and act accordingly. At the same time, you must have confidence in the instruments and ignore any other signals your body gives you.

This procedure usually slows you down a bit. Tests show that flyers interpret the actual horizon about one-fifth of a second faster than they interpret instruments. Furthermore, pilots make a recovery from a dive about one and a half second faster under VFR conditions as opposed to IFR conditions. Pilots are also more susceptible than usual to the stresses of flight such as fatigue, oxygen lack, and anxiety. These stresses may reduce the pilot's ability to think straight, so there is the danger of forgetting to use instruments when things get tough. Anything that produces an emotional upset is likely to disrupt conscious mental processes and make the pilot much more susceptible to illusions or false sensation.

2. Rare Sensations

The second point to remember is that the illusions that have been described in this section are relatively rare. Believe it or not, this can actually be a disadvantage. You learn to adjust to the sensations of normal flight as you gain flying experience, but the possibility remains that you will suddenly encounter a vivid illusion you have never experienced before. If you don't know what the illusion is or how you can handle it, you are likely to get panicky and let your emotions take over. When this happens, you are putting your life in the hands of your senses, and under such conditions they may prove to be inadequate.

3. Trust Your Instruments.

Last, but not least, remember that many accidents occur as a result of indecision about going on instruments. With poor visibility you may begin to go on instruments too late and then sensory illusions can make you believe your instruments are wrong.

There is just one way to beat false interpretation of motion. Put your faith in your instruments and not your senses. Know what kind of tricks your senses can play on you, keep calm, and have confidence in your instrument panel. Once you have acquired this confidence, you can fly at night and in weather as easily as if you were following railroad tracks, two creeks, and a cornfield back to the airport. The moral is simple: The transition from VFR to IFR must be a complete and trusting transition.

CONCLUSION

Anytime there is low or no visual cue coming from the outside of the aircraft, you are a candidate for spatial disorientation. Developing the dicipline to trust your instruments is achieved through training practice. Trusting what your instruments are telling you and disreguarding what your body is telling you is the key to control disorientation and its dangerous illusions.