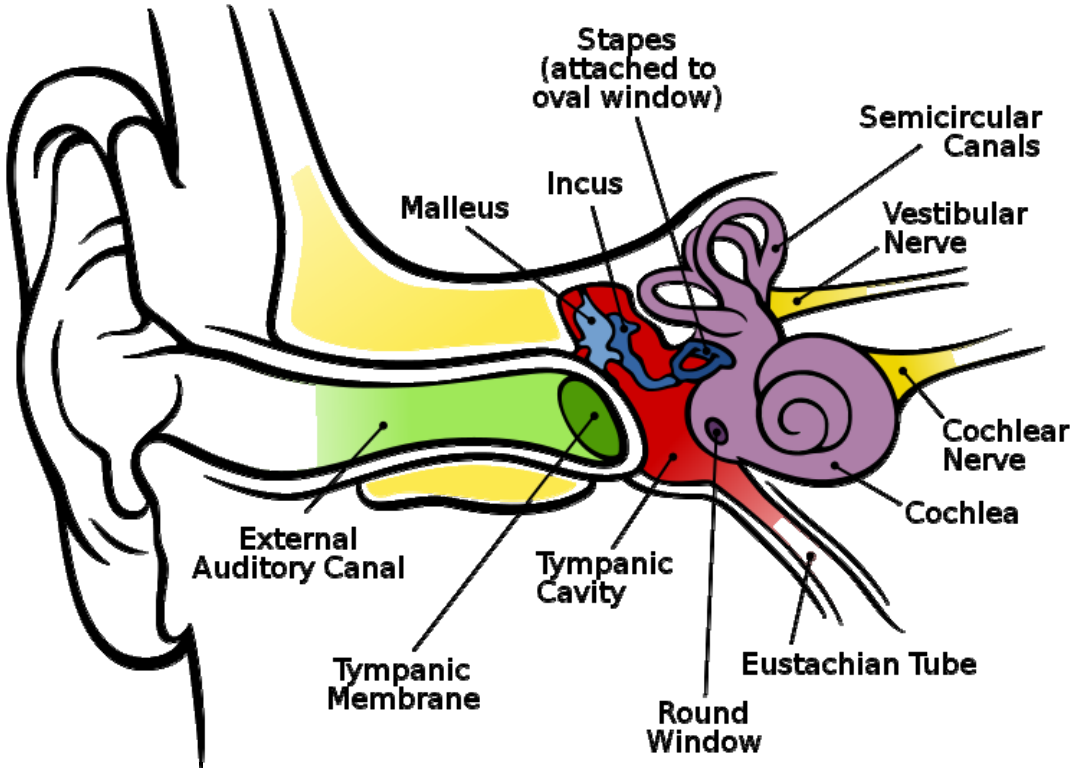
Flight Advisor Corner by Hobie Tomlinson

January 2011 **Human Factors, Part II**

Last month we started a series on **Human Factors** which we will continue this month. We outlined the areas of discussion and started covering the Sensory Systems which humans use for orientation. We were only able to get as far as the ***Eyes***, so this month we will continue with ***Sensory Systems for Orientation*** and cover the additional two systems, the ***Ears*** and the ***Nerves.***

The Ears (***Vestibular System***) have two major parts which are used for orientation, the ***Semicircular Canals*** and the ***Otolith Organs.*** The function of the semicircular canals is to detect angular acceleration of the body, while the function of the Otolith organs (located on top of the Cupola – a gelatinous structure attached to the end of the Vestibular Nerve where it enters the semicircular canals) is to detect linear acceleration and gravity.



The Human Ear ~ A Wikipedia Image by Chittka L. Brockmann

The Semicircular Canals consist of three tubes which are all located at right angles to each other. Each semicircular canal is located in one of the three axis of aircraft movement, one in the pitch axis, one in the roll axis and one in the yaw axis. Each canal is filled with a fluid which is called endolymph fluid. In the center of each canal is a gelatinous structure (called the Cupola) which rests upon sensory hairs located at the end

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of the vestibular nerve. It is the movement of these sensory hairs within the endolymph fluid which causes the sensations of motion.

Because of the friction between the fluid and the canal, it takes about 15 to 20 seconds for the fluid in the ear canal to reach the same speed as the canal's motion.

When an aircraft is in straight-and-level flight (with no acceleration of the aircraft) the hair cells are upright and the body senses that no motion is occurring. This is because the position of the hair cells and the actual sensation experienced correspond.

When an aircraft enters a turn, both the semicircular canals and the endolymph fluid within the canals are placed in motion. Because the endolymph fluid within the semicircular canal lags behind the accelerated canal walls, a relative movement is created between the fluid inside the canal and the canal wall. The canal wall and the cupola now move in a direction which is opposite from the motion of the endolymph fluid. This then causes the sensory hairs cells at the end of the vestibular nerve to be deflected from their normal, upright position.

The movement of the sensory hairs is interpreted by the brain to be a motion in the same direction as the canal wall is moving. This allows the brain to correctly sense that a turn is being made. However, if the turn continues at a constant rate for several seconds, or longer, the motion of the endolymph fluid in the semicircular canals catches up with the canal walls. As the relative motion between the fluid and the canal walls ceases, the sensory hairs return to their normal upright position. Because the sensory hairs are no longer deflected, the brain now receives a false signal that the turning motion has stopped, even though it is actually continuing at a constant rate. Thus a prolonged constant rate turn in either direction will allow the sensory hair cells to return to their normal upright position and produce the false sensation that the turn has stopped.

When the aircraft's turn is actually stopped, by returning to straight-and-level flight, the semicircular canals and endolymph fluid are again placed into motion – but now in the opposite direction. This causes the sensory hairs at the end of the vestibular nerve to again deflect, sending a false signal to the brain that a turn is starting in the opposite direction. In an attempt to correct this false perception of a turn, the pilot may reenter the original turn. It is this reentering of the original turn which is the beginning of a graveyard spiral and will rapidly place the aircraft in an out of control situation.

This false turn sensation is why flight without a visual horizon was not possible until the aircraft directional gyro was invented by Sperry Corporation. The directional gyro gave pilots a means to overcome this false turning sensation which the brain receives whenever a turn is stopped. It is this false turning sensation which makes flight without a visual horizon impossible unless the aircraft is kept from turning by the flight instruments (directional gyro). Even though we have moved from "needle, ball, & airspeed" to glass panels, the principle is the same. It is the "needle" (i.e. Directional Gyro – aka Heading Indicator) which makes it possible to keep the aircraft from turning when in instrument

meteorological conditions (IMC). ***Without the instruments (and the training required to use and trust the instruments) the eventual result is always the same – a graveyard spiral!***

The Otolith Organs detect both linear acceleration and gravity in much the same way. Instead of being filled with fluid, a gelatinous membrane containing chalk-like crystals covers the sensory hairs. When you tip your head, the weight of these crystals causes the membrane to shift due to gravity and the sensory hairs detect this shift. The brain then orients this new position to what it perceives as vertical. Acceleration and deceleration also cause the membrane to shift in a similar manner and thus give the brain a false perception of where vertical is located. Forward acceleration produces the false sensation of the head tilting backward. This particular false sensation is the reason why you sense a steeper than normal climb immediately after takeoff. This false sense of a steeper than normal climb has caused many a pilot to lower the aircraft's nose excessively and fly right back into the ground immediately after a night takeoff over an unlighted area (black hole departure) or during an instrument departure in low visibility.

The Nerves (***Postural System***) in the body's skin, muscles, and joints constantly send signals to the brain, which converts these signals into information about the body's position relative to gravity. Acceleration forces, which are felt as the pilot is pushed back into the seat, as well as the centrifugal forces created in turns can both lead to false sensations about the true direction of gravity. It is these false sensations which can easily give a pilot an untrue sense of which way is up.

The Postural System sends signals from the skin, joints, and muscles to the brain which is interpreted in relation to the Earth's gravitational pull. These signals' primary purpose is to determine posture. Inputs from each movement update your body's position to the brain on a real time basis. These signals are what "seat of the pants" flying is all about and they are what make "seat of the pants" flying possible. When these signals are used in conjunction with visual and vestibular clues, these sensations can be quite reliable. However, because of the forces acting upon the body in many flight situations, false sensations can occur. This is because either acceleration forces, centrifugal forces or both are acting to overpower gravity. Some situations which cause this to occur include uncoordinated turns, climbing turns and turbulence.

Uncoordinated turns, especially climbing turns, can cause misleading signals to be sent to the brain. Skids and slips give the sensation of banking or tilting. Turbulence can also create motions which will confuse the brain as well. ***You need to be aware of the fact that fatigue or illness can exacerbate these sensations and ultimately lead to a subtle incapacitation.***

Vestibular Illusions include the following illusions:

- ***The Leans***
- ***Coriolis Illusion***
- ***Graveyard spiral***

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- ***Somatogravic Illusion***
- ***Inversion Illusion***
- ***Elevator Illusion***

The Leans is a condition which can result when a banked attitude is entered into too slowly to set in motion the endolymph fluid in the "roll" semicircular canal. An abrupt correction of this banked attitude then sets the fluid in motion, creating the illusion of a banked attitude in the opposite direction. The pilot can then become disoriented and make the error of rolling the aircraft into the original banked attitude. If level flight is nevertheless maintained by reference to the flight instruments, the pilot will subsequently feel compelled to lean into the perceived false vertical plane until this illusion subsides.

The Coriolis Illusion occurs when a pilot has been in a turn long enough for the endolymph fluid in the canal to move at the same speed as the canal. A subsequent movement of the head in a different plane, such a looking at something in a remote part of the cockpit, will set the fluid in motion again and create the illusion of turning or accelerating in an entirely different axis. This action causes the pilot to think the aircraft is performing some maneuver – which it is not. The disoriented pilot may then maneuver the aircraft into a dangerous attitude while attempting to correct the aircraft's falsely perceived "phantom" attitude.

The Graveyard Spiral starts when a pilot in a prolonged, coordinated constant rate turn looses the illusion of turning because the fluid in the semicircular canal stabilizes. The pilot will then experience the sensation of turning in the opposite direction when a recovery to level flight is made. This usually disorients a pilot who is not instrument proficient and causes them to return the aircraft to its original banked turn condition. Due to the fact the pilot now thinks they are in straight-and-level flight (instead of returned to their initial banked turn condition) the pilot will not put any back-pressure on the elevator control. Because an aircraft will lose altitude in a turn unless back pressure is applied to the elevator control, the pilot will notice a loss of altitude occurring. The pilot now falsely believes they are in a wings-level descent, due to the absence of any turning sensation; they will thus apply back-pressure to the elevator control in an attempt to stop the descent. Because of the steepening banked turn which is actually occurring, this action only serves to tighten the spiral even more and increase both the airspeed and the rate of descent. As these two reinforcing trends keep reoccurring, the aircraft actually flies an ever tightening, descending spiral path, such as would be simulated by a marble making a circular descent inside of a funnel. As the pilot gradually looses total control of the aircraft, the airspeed and G load keeps on increasing until the aircraft either suffers a catastrophic structural failure or impacts the ground. Sometimes the pilot exits the clouds in a tight high speed spiral only to massively over-G the aircraft in one frantic, last minute attempt to recover.

The Somatogravic Illusion is caused by a rapid acceleration, such as experienced during takeoff, go-around, or missed approach. This rapid acceleration simulates the Otolith organs in the same way as tilting the head backwards. This action thus creates the

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somatogravic illusion of being in an excessively nose-high attitude, especially in any situation where there is little or no visual reference, such as "black hole" night conditions or Instrument Meteorological Conditions (IMC). This somatogravic illusion is the explanation why a pilot occasionally flies a perfectly good airplane right back into the ground immediately after taking off in these type of conditions. The reason that this happens is because the pilot lowers the nose excessively, immediately after takeoff, in response to the false "high nose attitude" sensation produced by a somatogravic illusion. A rapid deceleration caused by the quick reduction of engine power can have the opposite effect. The disorientated pilot now falsely thinks the aircraft nose has become too low and pulls the aircraft into an excessively nose-high or even stall attitude.

The Inversion Illusion is caused by an abrupt change from climb to straight-and-level flight. This maneuver can stimulate the Otolith organs enough to create the illusion of tumbling backwards (inversion illusion). This may cause a disoriented pilot to abruptly push the aircraft into an excessively nose-low attitude which will only intensity this illusion.

The Elevator Illusion is caused by an abrupt upward vertical acceleration, such as one caused by a strong updraft. This will stimulate the Otolith organs and create the false sensation of being in a climb (elevator illusion) and will cause a disorientated pilot to push the aircraft into an excessively nose-low attitude. The opposite effect would be created by an abrupt downward vertical acceleration, such as one caused by a strong downdraft. This will stimulate the Otolith organs and create the false impression of being in a dive (the same elevator illusion), thus causing a disorientated pilot to pull the aircraft into an excessively nose-high attitude.

Visual Illusions are especially hazardous because pilots rely on their eyes for so much correct information. The two illusions which can directly lead to spatial disorientation (***false horizon*** and ***autokinesis***) are only concerned with the eyes.

> **A False Horizon** can be created by a sloping cloud formation, an obscured horizon, high, close-in mountain ridges, an aurora borealis, a dark scene spread with a combination of ground lights and stars, and/or certain geometric patterns of ground lights. These all have the potential to provide inaccurate visual information (a false horizon reference) for aligning the aircraft correctly with the actual horizon. This may cause a disorientated pilot to place the aircraft in a dangerous attitude.
>
> **Autokinesis** is the term used to describe the apparent movement displayed by a stationary light at night when it is stared at for many seconds. This happens as the light's image moves back and forth across the area of cones in our eyes' retina (night blind spot). This causes the light to appear to move as it alternately disappears, then reappears in a different spot of the eyes' retina. This may cause a disorientated pilot to loose control of the aircraft when attempting to align it with the false movements of this light.

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Well that is a good stopping point for this month. Next month we will look at some ***demonstrations of spatial disorientation*** as well as ***spatial disorientation coping strategies*** and a more in-depth look at some ***other visual illusions***.

The thought for this month is: ***"If you shut up truth and bury it under the ground, it will but grow, and gather to itself such explosive power that the day it bursts through it will blow up everything in its way." ~ Emile Zola, French Novelist.*** So, until next month, be sure to **Think Right to FliRite!**

It's 2011 ~ Happy New Year!

Hobie

The "Old Days" ~ Cessna 140 on Short Final to Rwy 19 at KBTV ~ Winter of 1962

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