DOCUMENT
GSM-G-CPL.021

DOCUMENT TITLE
HUMAN PERFORMANCE AND LIMITATIONS

CHAPTER 12 – BALANCE, MOTION SICKNESS AND ACCELERATION

Version 2.0
October 2017

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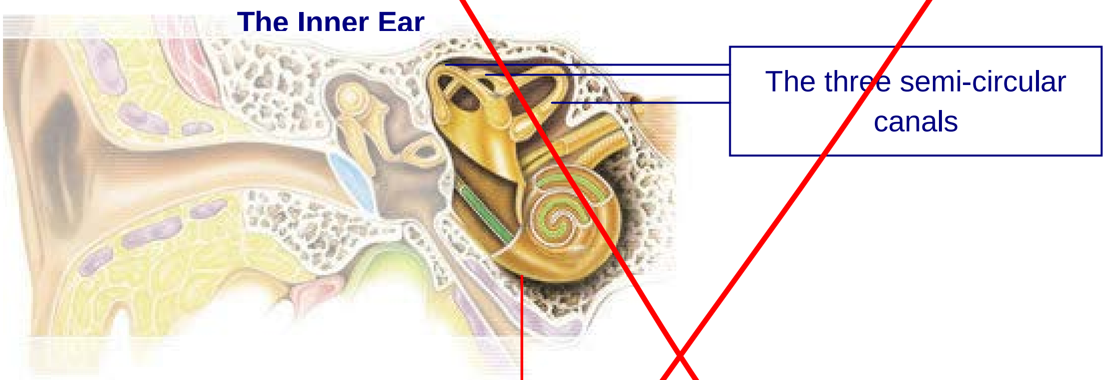
BALANCING, MOTION SICKNESS AND ACCELERATION

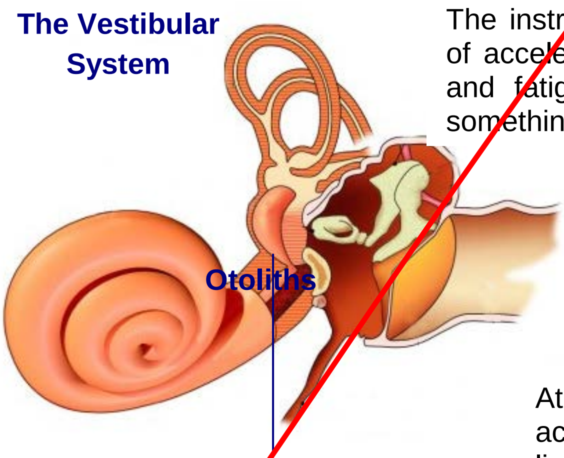
12.1 Balancing

What do you need to perform the perfect handstand? Muscles are important, of course, as well as flexible joints, strength and skill, but had you thought about ears? Along with your eyes and stretch receptors in your muscles and tendons, your inner ears also help you balance.

12.1.1 Anatomy

The balance or equilibrium function of the ear can basically be described as the detection of angular and linear accelerations of the head. The three semi-circular canals in your inner ear automatically detect these head movements and inform your brain of your position.





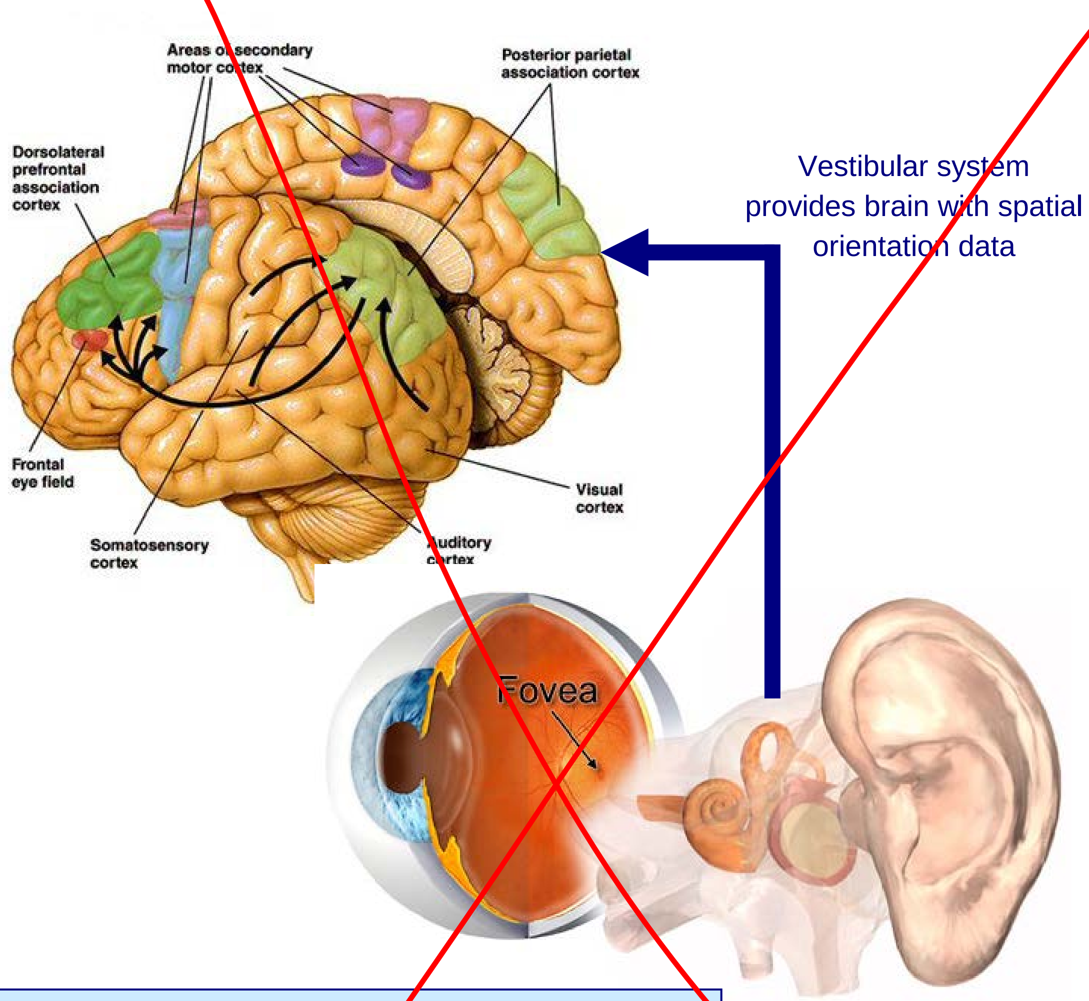
The instruments that measure the vertical components of acceleration in an aircraft are called accelerometers and fatigue meters. In the balance system we find something similar to a 'g'-meter.

At the base of these semi-circular canals we find linear accelerometers (known as the otoliths) that detect linear accelerations, whilst the canals detect angular accelerations. Together, these angular and linear accelerometers are termed the **Vestibular System.**

12.1.2

Vestibular System

The function of Vestibular System is to provide data to the brain that enables it to both maintain a model of spatial orientation as well as to control other systems that need this information.



> **Example** Information from the Vestibular System is used to control eye movements so that a stable picture of the world is maintained on your retina, even when you move your head.

There are two major problems associated with the Vestibular System:

- Firstly, it is not sufficiently reliable to maintain an accurate model of orientation without other information, mainly visual information.
- Secondly, the motion stimuli detected by this system, such as encountered during flying or sailing, can lead to nausea or motion sickness.

12.1.3 Motion Sickness

As motion sickness is such a common occurrence in humans that travel, let us examine it a bit more in-depth:

Motion sickness can occur when your **brain receives a mismatch of information**. If for example you are making a boat trip across a rough sea, your inner ears tell your brain that you are moving up and down or from side to side but your eyes and muscles send messages to say that you are standing on a solid surface (the deck of the boat).

This contradictory information can confuse your brain and lead to nausea, vomiting, hyperventilation, pallor and sweating.

It can be extremely incapacitating, but it is the body's normal response to the perceived unfamiliar stimuli. Anyone with a normal sense of balance will suffer from this if provoked enough and it can occur at sea, in the air, in space and can even be stimulated by the absence of motion when the person is expecting motion, such as when experienced aircrew are doing **simulator training**.

Although a few individuals suffer sickness on every flight, many rapidly adapt to the motion and no longer suffer any symptoms, although if a period of no exposure has passed (such as being on leave), a recurrence may occur until the person has adapted again - explaining why passengers are more prone to suffer from motion sickness than aircrew.

The incidence of motion sickness in flight varies greatly. It is influenced by:

- The form and intensity of the stimulus
- Individual susceptibility
- The nature of the work being done. Compare a competition aerobatic pilot's stimulus to a captain of a Boeing 747 on a long route.

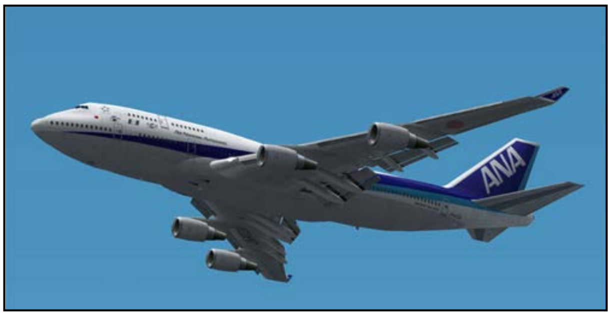
Anxiety, apprehension or fear will add to the problem. These feelings might arise from fear of the unknown – such as when an inexperienced pilot is to try an energetic manoeuvre for the first time.

There are measures other than adaptation that can be implemented to reduce motion sickness:

- The provocative stimuli can be reduced by keeping the head still, as movement further aggravates the Vestibular System.
- Visual mismatching can be reduced by closing the eyes…provided you are not the one flying!).

- Medication that alleviates symptoms is available but normally influences performance detrimentally in another area.
- Looking outside whenever possible. Minimise ‘head in the cockpit’ activities. Intersperse ‘head-down’ activity such as navigation or flight log work with frequent and regular periods of looking outside.
- Eat dry crackers, olives or suck on a lemon, to dry out the mouth, lessening nausea.
- Drinking a carbonated beverage.
- Eat lightly before a flight and limit fluid intake. (But do not fast).
- Minimise head movements.
- Ventilate the cabin with fresh air.
- Perform gentle manoeuvres only, particularly in the pitch axis.
- Talk to nervous passengers and encourage them to relax. Get them involved in mind absorbing activities that require them to look outside the aircraft.
- In an airliner, choosing seats with the smoothest ride (the seats over the wings).
- If possible, close the eyes. This may remove the conflicting input to the brain from the eyes and the vestibular apparatus.
- If nausea continues on subsequent flights, medication may be beneficial. Seek advice from a Designated Aviation Medical Examiner.
- Some alternative treatments may help, the most popular being ginger, or ginger derivatives, such as ginger tea or powdered ginger capsules.

12.2 Acceleration



Constant speed, even very high speed, has no effect on the human body, whereas acceleration or deceleration (rate of change of velocity) may result in considerable effect on the body, ranging from fatigue to collapse of the cardiovascular system. All parts of the body are affected by ‘*g*’ to varying degrees, with organs being displaced or distorted due to the apparent increase in ‘weight.’ But the component of most concern to the pilot is the blood supply.

(In aviation, acceleration is usually expressed in multiples of the acceleration due to gravity, represented by the symbol ***‘g’*.** (Note it is a lower case ‘*g*’, not upper case, and italicised)

The ability of the body to cope with the effects of acceleration depends on a number of factors including the intensity of the acceleration and the period for which that acceleration is applied.

Therefore, for convenience, acceleration is divided into sustained accelerations (more than 1 sec) and impact accelerations (which essentially relates to impact acceleration forces).

12.2.1 Sustained Acceleration

As you know the body is under the influence of the force of gravity on Earth.

Accelerations in aircraft can subject the body to forces of acceleration much greater than this, and for convenience are denoted as multiples of our 1"g" terrestrial environment.

Long duration accelerations are perceived as increases in body weight so that limbs become harder to move, the head becomes heavy, and organs are displaced from their normal positions. Since this increase in weight affects the blood, there are also changes in the circulation of the body.

When sitting upright or standing, the blood pressure measured in the upper arm closely reflects the pressure in the heart.

However, there are hydrostatic forces that act on the blood pressure so that, at head level, the blood pressure is reduced from that seen at heart level.

Similarly, the blood pressure in the lower body and legs is greater than that seen in the heart.

These hydrostatic differences are the result of the force of gravity and as applied "g" forces multiply the force of gravity, so too do they multiply the hydrostatic variation in the blood pressure

During increased '*g*' loads, all parts of the body get 'heavier'. It is therefore harder for the heart to pump the blood 'uphill' to the head and the blood tends to flow to the stomach and legs. The brain and eyes need a substantial and continuous supply of oxygen and sugar. As there is very little stored oxygen and sugar in the head, any reduction in blood flow will have an almost immediate effect on the eyes and the brain.

Any drop in oxygen level in the brain will result in the brain commanding the heart to respond to the crisis by increasing the pumping rate, but it will take several seconds for the heart rate to increase. A temporary diminution in the effect might be noticed, but even with only modest levels of sustained '*g*', the heart cannot work hard enough to return the blood supply to normal.

The first organs to show any deterioration in function are the eyes, as they have no store of blood and therefore no store of oxygen. **Colour vision** will be affected first, with all images being seen as shades of grey or white. As the level of 'g' increases the field of vision will shrink, from the outer or peripheral regions, inwards. This is known as **tunnel vision**. This phenomenon will progress until all of our field of vision is grey (the **grey out**). A further increase in 'g' will lead to a total loss of vision, or a **blackout**. It should be noted that the pilot is still conscious at this time, he just can't see!

Further increase in 'g' will inevitably lead to insufficient oxygen and sugar being supplied to the brain, resulting in a decrease in brain function and eventually loss of consciousness. This is called **'g-induced loss of consciousness'**, or **G-LOC.** This is obviously a dangerous situation, like any other form of loss-of-control it requires time and space from which to recover. At low levels, G-LOC can be fatal.

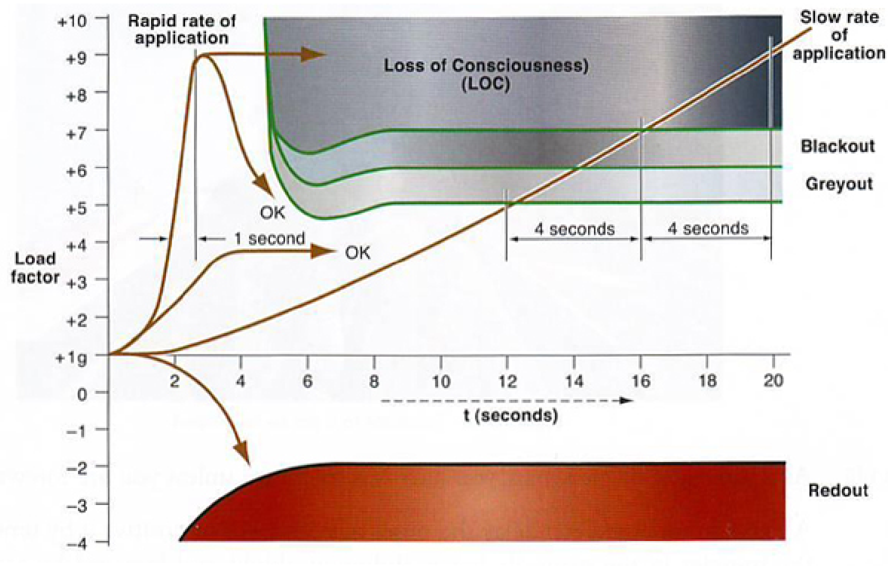
In negative *'g'* manoeuvres, large amounts of blood accumulate under pressure in the head, neck and upper areas of the body. This is both unpleasant and dangerous. The feeling of heaviness and interference with limb movement are similar to those of positive acceleration, only in the opposite direction. Exposure produces a sense of fullness and pressure in the head, which may lead to a severe throbbing headache.

Exposure for some seconds produces swelling of the eyelids and small haemorrhages in the skin of the face and neck.

Congestion of the lining of the air passages may cause difficulty in breathing and nose-bleeds may occur. The conjunctiva of the eyes become suffused and reddened and blurring of vision can occur.

Exposure exceeding 4–5 negative '*g*' for longer than 6 seconds causes mental confusion and unconsciousness. The increase in arterial pressure can cause a slowing or change in rhythm of the heart rate. Exposure to negative acceleration produces an upward displacement of the diaphragm and reduces lung volume and ventilation. **Generally accepted tolerance is about negative 3*g*.**

When talking of long duration acceleration it is also important that you take note of "g" tolerance.



"g" tolerance is reduced by a number of factors including hypoxia, hyperventilation, heat, low blood sugar, smoking, and alcohol. Fighter pilots are assisted in anti-"g" procedures by the inflation of anti-"g" suits. These also help to reduce the fatigue associated with anti-"g" straining manoeuvres.

Other devices designed to improve "g" tolerance include raising the legs of the pilot or reclining his whole seat (as used in the F-16) but such systems are difficult to incorporate in existing aircraft and even when designed in from new are not a complete solution. The most important factors for the pilot are practice and experience.

Negative "g" occurs during aircraft manoeuvres such as inverted flight, outside loops, bunting, and some forms of spinning. The consequences on the body are the opposite of those for positive "g" but are even more uncomfortable.

Symptoms include facial pain, bursting of small blood vessels in the face and eyes; the pushing-up of the lower eyelid to cause **redout** and the upward rush of blood from the lower body causes **slowing of the heart rate**. The maximum tolerable level is -3 "g", and then only for very short periods.

Grey out will be experienced during sustained load of 3.5G.
Black out and G-LOC will occur at a sustained load of about 5G.
Generally accepted safe limit for negative G is about -3G.

12.2.2 Impact Acceleration

As was said earlier, short duration acceleration refers to impact acceleration forces, and impacts are directly related to the relative strengths of various parts of the body. The human body can tolerate forces of, at most, 25 “g” in the vertical axis and 45 “g” in the fore to aft axis.

Forces above these levels will cause injury or death and it is for this reason that aircraft are designed to provide adequate protection.

Adequate restraint of the pilot in the aircraft seat is vital to prevent injury through contact with aircraft structures, and prevent him/her being thrown out of the aircraft on impact. The best form of harness is a five point system with lap, shoulder and negative "G" (crutch) strap.