Information Assimilation and Processing

2

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2.1 Introduction

Try, if you will, to teach a computer how to play tennis. It would be impossible, of course. Yet, the proposition alone points to just what outstanding levels of performance a human being is capable of achieving. A person's intelligence, his sensory skills and his motor skills are enormous.

It was through the human capacity to work with tools that he ultimately learned how to build aircraft, with which acceleration forces and speeds have been reached that man, himself, wasn't "built" for. Naturally, because this development has taken place over just a few generations, it has not been possible for him to genetically adapt, either.

This chapter will initially describe the mechanisms enhancing man's enormous capacity, what his limits are and what problems he must deal with, especially with regard to flying.

The section addressing "Information assimilation" describes the physiological principles of sight and hearing—particularly important senses for flying an aircraft.

In order to be able to process information once it has been taken in, or assimilated, it must be compared with information already stored in memory. Old information must be modified and new information added. This process requires various types of memory, as described in the section on "Information processing", in which their potential and their limitations are explained.

Two well-established models dealing with the processing of information stored in memory have been proposed in psychological literature. Both encompass only one part of "reality" yet, notwithstanding, are capable of describing the problems

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associated with information processing and decision making in complex situations (e.g. in an aircraft).

All explanations and examples herein have been chosen so as to find application in the commercial airline industry. They have been drawn from the literature referenced, yet have been modified in part to facilitate better comprehension.

Overall, the fundamentals of information assimilation and processing as presented in this chapter will apply to most chapters in this book, and particularly the chapters dealing with “Human error” and “Decision making”, as well as those dealing with “Communication”, “Leadership and team behaviour” and “Stress” in a broader sense.

2.2 Information Assimilation: The Human Senses

2.2.1 General Considerations

The most important senses for flying are those of sight and hearing. Virtually all relevant information is taken in via these two senses and they are the primary focus of this chapter for this reason. In addition, the sense of equilibrium must also be considered. This sense may play a subordinate role in the conduct of a flight, but the information it provides inside the aircraft is easily and oftentimes misinterpreted. Problems associated with it are addressed in this discussion, as well.

Naturally, there are other helpful senses available to the pilot. A pilot will sense the aroma of a meal if the aircraft is equipped with an on-board galley. He will sense odours coming from the air conditioning system or the smell of smoke. Yet, as a rule, these senses are not important for carrying out a routine flight. If they do take on importance at some point, however, they will function just as they do on the ground. Deceptions to the sense of smell have, to date, only very rarely resulted in a wrong decision being made during flight. Similarly, this also applies to the perception of pressure, pain and temperature. For this reason, we have abstained from going into detail about these senses in this chapter.

2.2.2 The Human Eye

Most pilots have above average eyesight when compared to the rest of the population. Nevertheless, there are deceptions to perception related to the function of the sight organ, against which even good eyes cannot defend.

The following section addresses the healthy functioning of the eye, along with possible optical illusions and their related consequences for flying activities.

Functional Principle

Humans perceive light through the eye (see Fig. 2.1). Light initially penetrates the cornea, then passes through the iris and is refracted by the lens. An ingenious interplay between the iris and the lens ensures that objects perceived are clearly

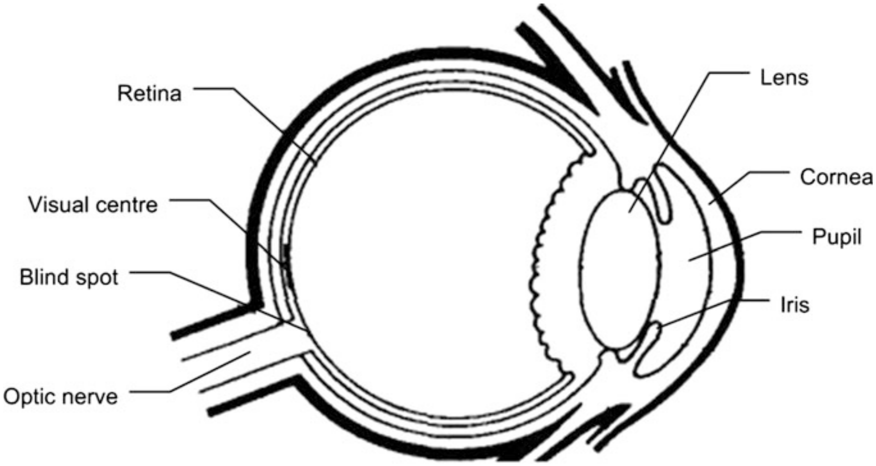

Fig. 2.1 The human eye

reproduced on the retina with optimal light intensity. This interplay takes place automatically for the most part and, therefore, can be influenced consciously only to a limited extent. For example purposes, just try to view an object with blurred focus. If you haven't attempted this before, you'll find it's possible only for short intervals and with a great deal of effort.

The retina is covered with four types of receptors capable of transforming light into electric signals. They differ in the wavelength of light that causes their maximum stimulation and in the intensity required for stimulation.

Three types are referred to as cones, which react particularly intensively to blue (445 nm), yellow-green (535 nm) and yellow–red (570 nm). They have a very dense arrangement with each being tied to a nerve fibre, enabling visual acuity. Cones require a relatively large amount of light in order to relay the respective colour impression to the brain, however, meaning that they function only in daylight or with sufficient lighting.

The fourth type of receptor is referred to as a rod, which reacts particularly intensively to green light (500 nm). As opposed to the cones, rods require very little light to stimulate a reaction and are arranged further apart from each other than are the cones. Moreover, a sole nerve cell may oftentimes be stimulated by multiple rods (see Fig. 2.2).

Cones (totalling approx. 6 million) and rods (approx. 120 million) are distributed non-uniformly over the retina. In fact, cones, alone, are located in the visual centre (approx. 400,000 per mm^2), while rods, alone, are located in the fringe area of the retina. This arrangement ensures that objects observed especially in natural light will be clearly distinguished with an accurate representation of colour.

The contrast-enhancing interconnection of the rods with one another ensures that the effects of brightness and darkness in the fringe area of the visual field are very clearly distinguished. In addition, rods also specialize in the perception of

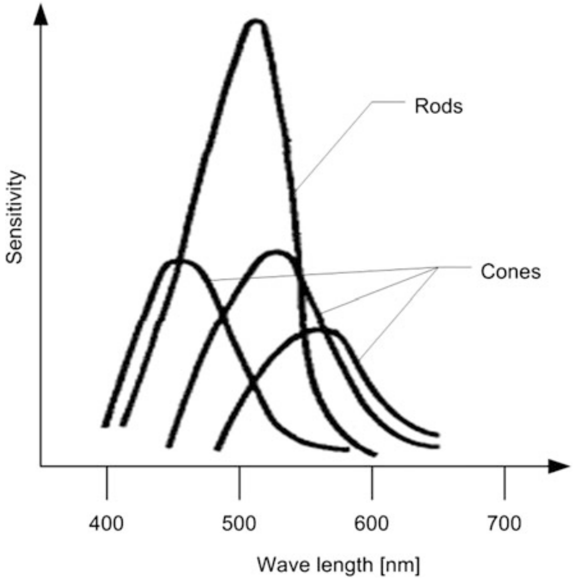

Fig. 2.2 Wavelength-related excitability per receptor-type

movement. If something moves in the fringe area of the visual field, it will be detected extremely quickly. Special processing within the brain is not required for this. On the other hand, sharp vision is not possible in the area. As viewed in evolutionary terms, this feature of the eye enables very quick reactions when being attacked from the side. In the event of an attack, however, sharp vision in the fringe areas would be counterproductive because the comparatively high volume of data would prolong the reaction time and consequently lower the chances of survival.

This retina "data" must be relayed to the brain via the nerve fibres for further processing. This is facilitated by the optic nerve, which emerges from the eye with a slight inward offset from the visual centre. This part of the eye is referred to as the blind spot because there are no receptors located there.

As long as sight is available in both eyes, these blind spots play an insignificant role because they are located at non-corresponding retinal points in the individual eyes. Corresponding retinal points in this context are understood to be points on the retina in the right and left eyes where one and the same perception is reproduced.

Humans also require the use of both eyes for distance perception. In order to reproduce objects on corresponding retinal points at distances less than 12 m, the eyes must be rotated towards each other at ever increasing angles as the object is positioned closer to the eyes. The brain "calculates" the distance between the object being observed and the eyes based on this rotation angle. At greater distances, the angular difference when focusing into infinity is so small that a precise estimation of distance with the given resolution of the eye is no longer possible.

In order to process the information taken in by the eyes, it must be relayed to the "proper" locations in the brain. But what are the proper locations? A person's

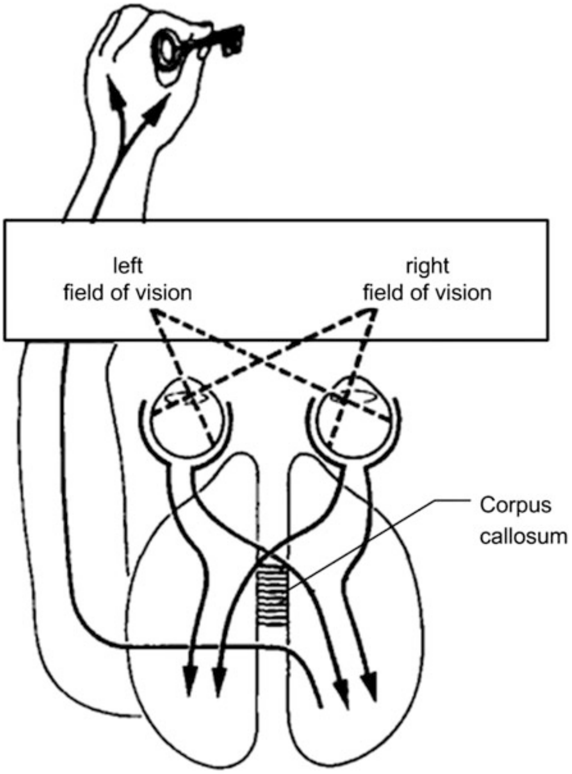

Fig. 2.3 Interconnection between the optic nerve and the brain

left arm, for example, is controlled by the right side of his brain, just as is the left leg. All motor functions and the overall sensory system (pressure, pain and temperature perceptions) on the left side of the body are governed by the right side of the brain. Correspondingly, the right side of the body is governed by the left side of the brain.

This “distribution of tasks” between the right and left sides of the brain with respect to the sensory and motor functions of the two body halves applies in principle to the eyes, as well (see Fig. 2.3). Everything seen on the left side (with either the right or the left eye) will be processed on the right side of the brain and vice versa.

Because of the division of the optic nerves into right and left visual fields, it is possible, for example, to leave control of the left arm through the eyes completely up to the right side of the brain. This “design” has a hidden benefit in that a transfer of data between the right and left sides of the brain is not necessary. Such a transfer of data would be possible via the so-called corpus callosum, which represents the only interconnection between the two halves of the cerebral cortex and, as such, represents a bottleneck factor, as well. If a related transfer of data were necessary, then control of the motor functions would become too time consuming and error-prone.

For processing optical information, an image of what is perceived is initially generated in the so-called “Area 17” in the rear section of the brain. Nerve cells capable or recognizing certain patterns, such as lines, circles or other simple figures, have access to this image. Additionally, there are nerve cells in the cerebral cortex that are specialised in higher-level processing (e.g. the reading of instrument indications). They access both the nerve cells in which the image is stored, as well as the nerve cells responsible for pattern recognition.

Processing in the brain takes place extremely rapidly because the brain works in parallel to a great degree. A pilot knows immediately when he observes a bar at a certain position within an arc on the display screen or instrument panel that he is dealing with a rotary speed indicator. All memorized information is available immediately once this observation is made. In contrast, a computer must be queried sequentially. The capacity of the human brain may be relatively low but, with the speeds that can be reached thanks to its parallelism during processing, it is still very impressive when compared to a computer.

Optical Illusions

The brain’s high degree of efficiency when processing optical stimuli is possible only because of the parallel processing described above, as well as because of a systematic reduction of data. On the one hand, hardly any information from the periphery of the viewing area is consciously perceived. Processing of this data takes place only subconsciously, if at all.

On the other hand, the information consciously perceived is processed in a simplified manner. Psychologists were already trying to determine the rules applicable to this simplification process in the mid-19th Century.

Several examples of optical illusions presented in this section will demonstrate that not everything is as it appears to be when viewed. The optical illusions described herein have been taken from testing directives and, for this reason, may not always adapt to everyday application. The impact that even “minute” optical illusions can have during flight will be discussed in the next section (see Fig. 2.4).

In illusion (a), the right horizontal section appears longer than the left section. In illusion (b), the upper horizontal bar appears longer than the lower bar. Both can be described as illusions due to the addition of a third dimension. If, in the case of illusion (a), the horizontal lines are viewed as wall edges, then left section is seen as an advancing edge while the left is seen as a receding edge. The advancing edge must appear to be closer to the observer than it actually is because it jumps out of the image plane. Because it is apparently closer to the observer (and should actually be larger because of this proximity), it subjectively appears to be smaller.

The slanted lines in illusion (b) can be envisioned as being train tracks with the horizontal lines as railway ties. The upper tie is then farther away and, because it almost touches the tracks, must therefore be wider.

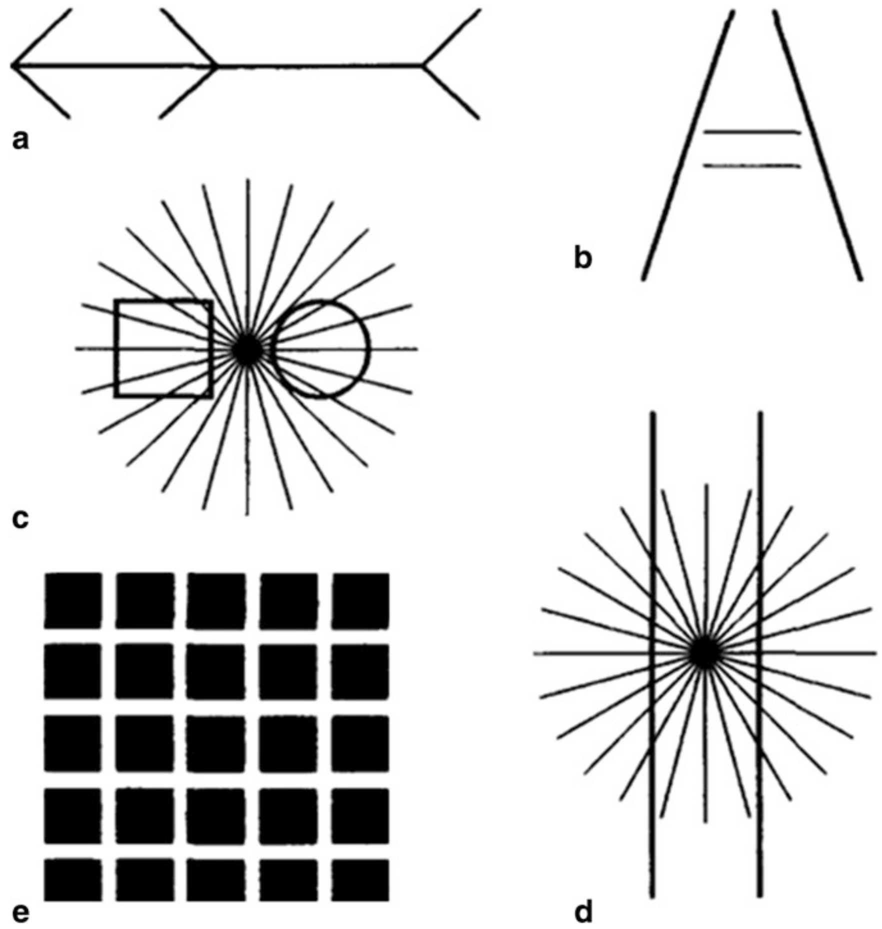

Fig. 2.4 Optical illusions. **a** Müller Lyer: The *right section* appears longer. **b** Ponzo: The *upper horizontal line* appears longer. **c** Orbison: The *square* and *circle* appear distorted. **d** Hering: The *parallel lines* appear warped. **e** Hering: The intersecting points of the *white bars* appear *grey*.

The deformation in illusion (c) or (d) is not due to the spatial interpretation of a two-dimensional figure, but rather due to varying information densities at different locations on the image. If numerous other lines are located between two lines at one location, then it follows that there must be more space between those lines at that location, otherwise the numerous lines could not fit between them. This applies to the circle or square, as well, which are segmented on one side by numerous lines. The respective segmented sides must be larger, because otherwise they could not have been divided so many times.

As seen in the contrast illusion (e), the ability of the eye to distinguish contrasts in a contrast-weak environment can, in a contrast-rich environment, lead to the illusion that the lighter sections of a picture appear darker.

Despite the obvious weaknesses of the sight organ, the eye is the dominant perceptive organ for determining the bodily position. Just about everyone has been on a train thinking it has departed the station, when actually it was a train on the neighboring platform that departed.

Impact on Flying

The processes described in the two previous sections play a role, virtually throughout the entire flight. An "estimation error" of merely half a degree during final approach can determine whether a landing will be hard or soft, whether touch-down will be at the 1,000 foot mark or somewhere else, or whether the aircraft will come to a stop by the end of the runway or not.

In the aircraft parking position, for instance, a passenger boarding bridge, a passenger bus or another vehicle in the vicinity can move in a way that creates an impression that the aircraft, itself, is moving. The natural reaction would be to immediately apply the brakes. It becomes critical when one knows about this "perceptual disorder" and, therefore, does not react. If the aircraft really is moving, then failing to respond can result in serious damage.

A similar situation can arise while taxiing. "Drifting snow" can create the impression that the aircraft is being taxied in a curve when it is actually rolling straight ahead or vice versa.

A special problem commonly related to upgrade training from smaller to larger aircraft involves excessive taxi speeds. The speed appears to be less than it actually is because of the increased distance to the ground, resulting in the urge to taxi faster.

Another problem related to directional control can occur during takeoff due to precipitation. Additional flight attitude-related illusions can be anticipated when flying through hilly and mountainous terrain or clouds, which can arouse the perception of a false horizon.

A collision hazard exists on takeoff and during cruise flight because our eyes specialise in perceiving motion in the peripheral areas. The risk of an in-flight collision is particularly great when the position of another aircraft does not change with relation to one's own position (related to direction), meaning a so-called fixed bearing exists (see Fig. 2.5).

In Fig. 2.5, the position of your aircraft relative to the positions of various other aircraft at the same points in time is depicted at times t-4 through t. A mid-air collision will occur at time-point t.

Common throughout is that a fixed bearing existed at each position. If such a situation exists, then a mid-air collision is likely. If this is not the case, then a collision is not possible as long as the direction and speed of the respective aircraft do not change.

Another difficulty exists particularly during cruise flight, when the eye automatically focuses on what is being seen through its lens. First of all, it should be noted that the eye accomplishes its task very effectively during daylight. But problems can occur when it gets dark or when the contrasts begin to weaken.

If the eye does not detect a contrast sharp enough to orient upon, most people will align their focus to a distance just short of one metre (about the distance to the

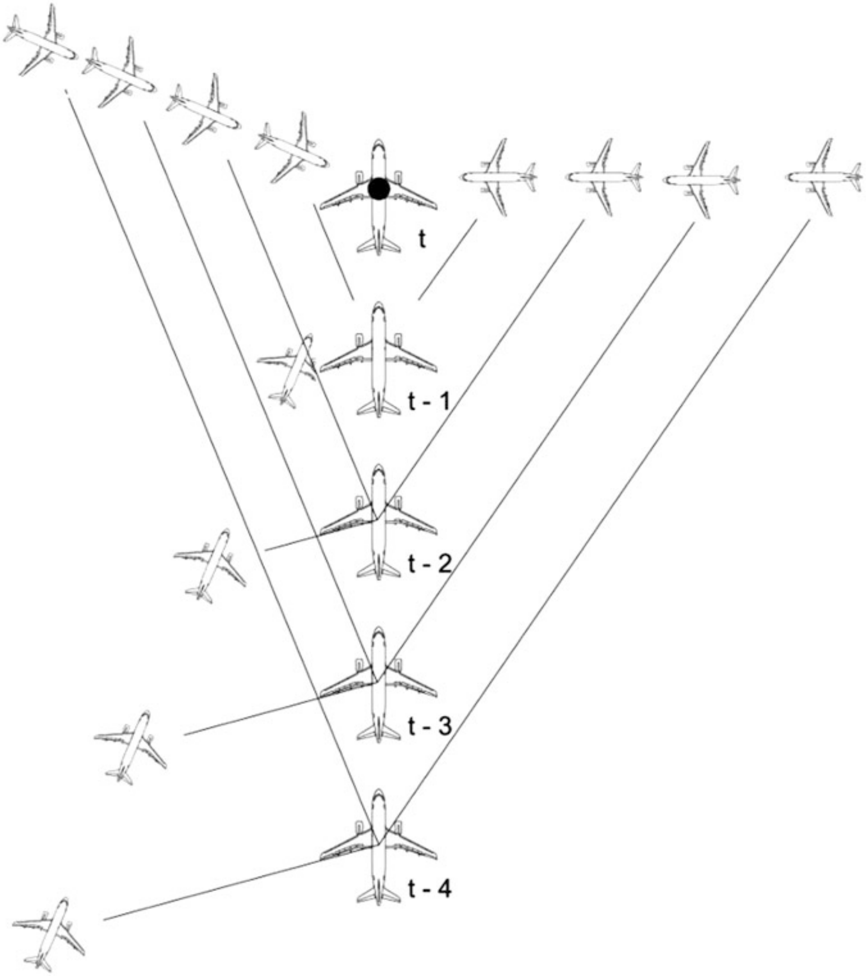

Fig. 2.5 Relative aircraft positions

cockpit windshield). When a pilot stares into the blue and frequently contrast-weak sky, his eyes, under some conditions, may focus more readily on the greater contrast provided by the potentially scratched, dirty or wet windscreens. The consequence can be another aircraft not being discovered due to an inadequate depth of field. This problem also occurs at night because the luminous intensity may not be sufficient enough to produce distinct contrasts. Moreover, if the blood circulation to the eyes is reduced (e.g. due to smoking in the cockpit), then its automatic focusing function will be additionally impaired. The aging process of the eyes, normally after 40 years of age, also plays a part.

The blind spot does not normally play a significant role. It becomes a factor only when sight in one of the eyes is impaired while the other is free. The chance of this happening in the cockpit increases with wider posts between the windshield panels.

The "interconnection" between the eyes normally presents no problem, meaning that everything seen in the right visual field will be stored in the left half of the brain and vice versa. Everyone having undergone upgrade training in the same aircraft type from copilot to captain or from captain to training captain, and who must now fly from the other seat, is familiar with the phenomenon that more time will be required to find a respective switch. It is possible that the corresponding information is stored on the "wrong" side of the brain. As soon as it is stored on both sides, however, the seat-change will no longer present a problem—as long as positions are switched on a regular basis.

The function and distribution of the rods and cones on the retina is optimized for use during daylight conditions. In contrast, difficulties can arise at night, when the cones are "blind" in the darkness. At the location where humans have the sharpest visual acuity during daylight conditions, namely at the visual centre, they don't see a thing there at night. The reflex action of looking towards a object when it moves or towards something of interest is, at the very least, useless at night, if not outright damaging. The act of looking to the side of the position one actually wants to observe is difficult to train and helpful only to a limited degree because focused vision and colour acuity are not possible.

Another factor to be considered at night is the so-called autokinetic effect where a single stationary light in an otherwise dark environment appears to move. There are essentially two factors that can cause this phenomenon. First, the eye requires the ear's vestibular system for stabilization of its viewing direction. This is not sufficiently precise enough to hold the eyes completely stable on its own, however. Secondly, the eyes move autonomously in order to keep from always stimulating the same receptors with the same information. This would lead very quickly to fatigue or even to the short-term "blindness" of the respective receptors. Both effects together will cause an object at rest to appear to be moving, especially at night. During the day, this effect is completely compensated for through experience. Every pilot knows that a runway does not move during approach, so this knowledge will stabilize his perception. At night, in contrast, it may not be possible under certain conditions to identify an unlit runway, so that the place where it is located appears to move.

Other problems can arise during approach, particularly in poor weather conditions.

It is common with *good visibility* to underestimate distances while they are overestimated with *poor visibility*. This is because, under poor conditions, objects being viewed are less easily identifiable, conveying the impression that they are farther away. The consequence for flight is that an approach may be flown at too low of an angle. A similar situation occurs at night when flying over unlit areas (water, desert, etc.). The pilot imagines himself to be higher than he actually is and will be tempted to fly lower in this case, as well.

Another possible interpretation for flying too low during poor weather conditions or at night assumes that, during a visual approach, the pilot normally

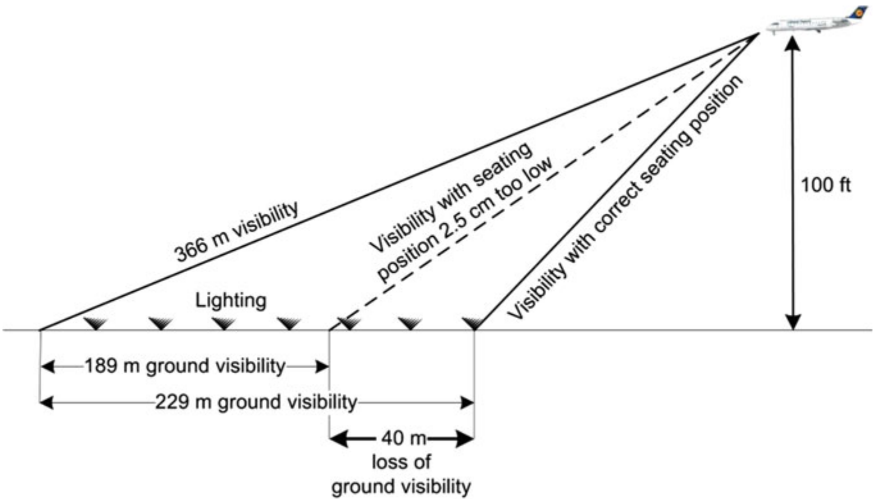

Fig. 2.6 Visibility loss due to incorrect seat position

maintains the angle between the natural horizon and the touchdown point, resulting in a constant approach angle. If the horizon is not visible, however, the eye will use the furthest point that may still be visible (e.g. the end of the runway) as a substitute horizon. Holding a constant angle between the substitute horizon and the touchdown point will automatically result in a downward arched approach profile.

Another problem can be related to the pilot's seat position during poor weather approaches, as illustrated in Fig. 2.6. If the pilot is seated just a bit too low, he will sacrifice a portion of his forward visibility. While the distinguishable lights located the farthest away will indeed be perceived, those lights located closer in will be blocked by the aircraft. This unnecessarily complicates the alignment with the runway.

Different approach angles due to varying approach speeds or flap settings can also have an effect similar to that of an incorrect seat position. The horizon will be located at a different position on the windscreen, meaning that the approach angle will be perceived differently, resulting in a potentially inaccurate flight path correction.

Runway gradients and sloping terrain can also lead to an incorrect estimation of altitude. Figure 2.7 illustrates four examples of possible altitude-related illusions. Mixed combinations of terrain and runway sloping are also possible.

If, in addition, the runway gradient is not constant but has "hills" or "valleys", then the length of the runway can be either under- or overestimated. Unusual runway dimensions (in length or width) can have a similar effect. Under certain circumstances, unnecessarily heavy braking may be used on a runway assumed to be too short, while insufficient braking may be used on a runway assumed to be too long. Both possibilities can have dangerous consequences.

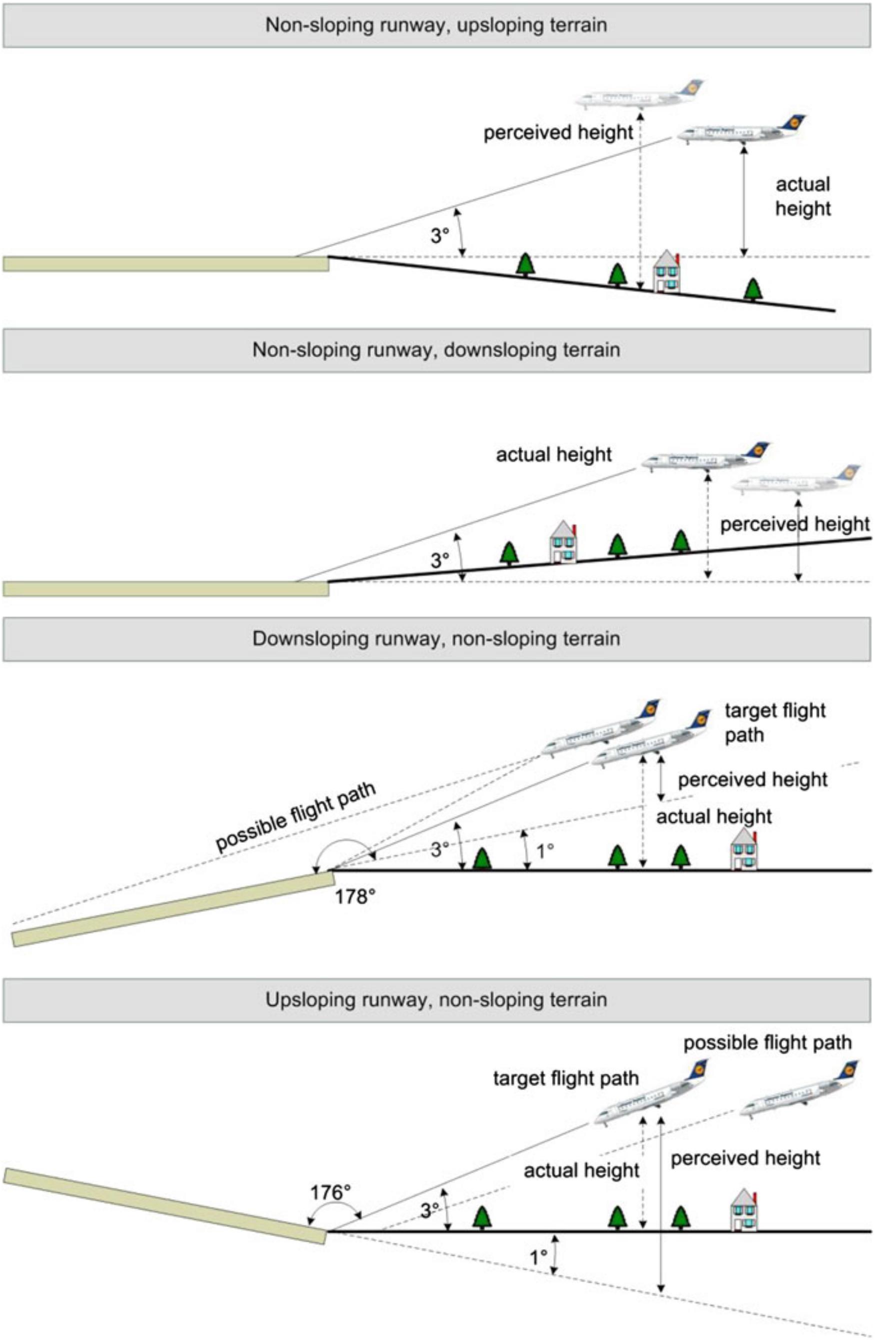

Fig. 2.7 Altitude illusion due to runway and terrain gradient

(No) Protection Against Optical Illusions

A method for protecting oneself against optical illusion does not exist. It is a phenomenon that everyone is susceptible to. It is human nature that the sight organ is subject to illusion. A training program applicable for all situations where illusions can occur cannot be developed. There are simply too many types.

Nevertheless, possibilities do exist for protecting oneself against the consequences of these illusions. First of all, illusions should be seen as being natural phenomena. Every person should become familiar with the situations conducive to prompting illusions and take advantage of all the materials available to help avoid them.

Cockpit windscreens should be cleaned prior to departure while seat positioning is clearly defined in transport aircraft. Using his knowledge of blind spots, a pilot can shift his position a bit to keep from impairing his forward visibility due to the cockpit windscreen posts. If it is known that aircraft appearing stationary in the sky can be dangerous, then a determined scan for their presence can be undertaken. The attitude that a plane will be spotted out of the corner of the eye, anyway, when the situation becomes critical is very risky. Just the opposite is the case. Aircraft will first become recognizable when they appear significantly larger, which, at the speeds commonly flown, will probably be too late.

A PAPI (or perhaps a VASIS) is frequently available as an aid to help stabilize an approach. As a rule, the ILS should be used when it is available, even during a visual approach. The crew member not flying should be tasked to take over altitude monitoring via DME or GPS and to call out any deviations, especially during non-precision approaches. Smoking prior to nighttime approaches to airports with poor lighting should be abstained from.

Moreover, authorities and employers should be tasked to establish procedures aimed at eliminating the consequences of the illusion phenomena.

2.2.3 The Human Ear

The human ear fulfils two functions. First, it facilitates hearing and, secondly, it serves the determination of position in space and, as such, facilitates balance. Both functions will be described in the following sections.

Because aviation-related disorders in the hearing process are relatively rare and can be traced back to either an overload of the working memory or the consequences of noise stressors (see the related chapter on “Stress”), this chapter will offer merely a short, simplified description of the process.

In contrast, the function of the ear as an equilibrium organ (vestibular system) for the flight activity has proven to be very prone to disorder. Similar to the eye, the ear was “conceived” for slow movements at ground level. The accelerations and the motion related to flight may be perceived, but may not always be correctly processed. The consequences range from discomfort and nausea to spatial disorientation. For this reason, we have dedicated an entire section to equilibrium organ-related disorders.

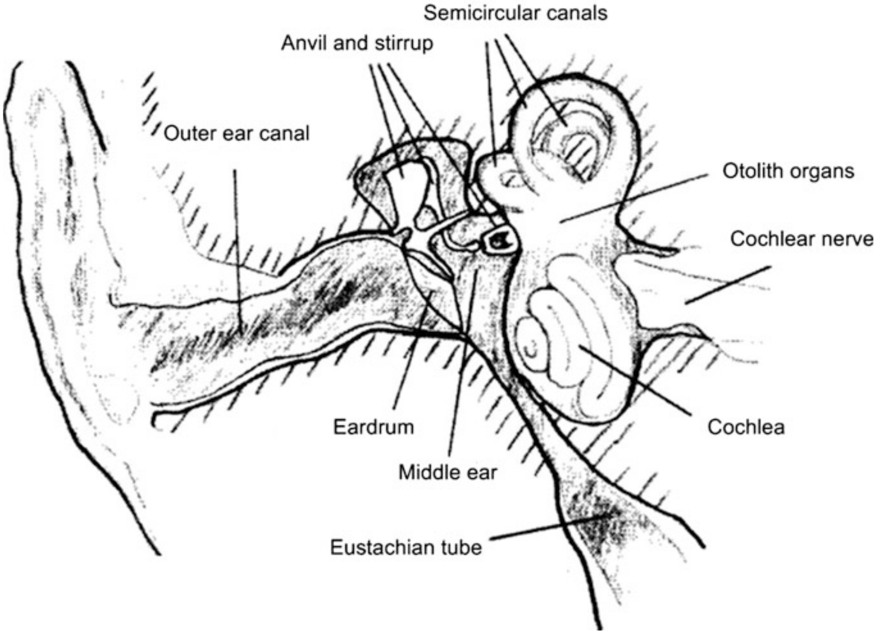

Fig. 2.8 The human ear

The Inner Ear

Sound waves penetrate the inner ear through the outer ear canal, the eardrum and the auditory ossicles (hammer, anvil and stirrup), causing the fluid in the cochlea to oscillate. These oscillations are picked up by extremely minute hair cell fibres and transferred via the auditory, or cochlear, nerve to the brain for processing (see Fig. 2.8).

Frequencies ranging from around 20 to 16,000 Hz are processed in the cochlea, whereby the human ear is particularly sensitive to the frequencies between approximately 1,000 and 4,000 Hz. This also happens to be the frequency range for human speech. Unlike the optical nerve, however, which is divided into the right and left visual fields, the auditory nerves in both ears provide both halves of the brain with their information.

A separate analysis of the information from the individual ears takes place merely with respect to directional hearing. For this, the time difference between a sound wave occurrence in the right and the left ear is measured and evaluated on the one hand, while a precise frequency analysis is carried out on the other. A noise that acts upon one ear directly and upon the other ear indirectly (passing by the facial area or the back of the head), or that simply contacts the two ears (auricles) from different angles, has its frequency distribution altered in a characteristic manner. An analysis of this distribution is performed in the brain with a bandpass filtering function that can distinguish clearly between tones as close together as 1,000 and 1,002 Hz, for example, thus enabling the direction of a noise source to be determined.

The Vestibular System

For determining position in space, the ear has three vertically stacked, so-called semicircular canals available for ascertaining rotational motion, as well as two areas comprised of so-called statoliths, which register the direction of the resulting forces imposed upon the body (see Fig. 2.8). The semicircular canals and the statoliths combine to make up the vestibular system.

The semicircular canals are filled with a fluid, whereby, if the head is swivelled in a direction on a plane with a semicircular canal, the fluid initially remains at rest. A relative motion then ensues between the fluid and the hair cells in the semicircular canal, with the stimulation of the hair cells being transmitted to the brain as a rotational motion in the respective plane. This principle works very nicely as long as the rotational motion does not continue for a prolonged period of time. There is absolutely no problem in rotating the body at a defined angle and being at risk of losing the sense of orientation. Similarly, a person will have little difficulty fixing his eyes on an object and simultaneously moving his head and/or body.

If the rotational motion continues for a prolonged period of time, however, then the fluid in the respective semicircular canal will come to a rest relative to that canal due to friction (similar to a glass being rotated over time, whose fluid takes on the rotational speed and comes to rest relative to the glass). The hair cells will then no longer report any motion in this plane. Once the rotation stops, a sense of rotating bodily motion will be induced in the opposite direction due to the inertia of the fluid, triggering corresponding reflexes. Everyone should know the phenomenon from their childhood, where someone is spun around a number of times, stopped and let loose. His body has the sensation of turning in the opposite direction, triggering related reflexes that will keep him from standing on his own legs for some time.

Statoliths also function very well on the ground. They make it possible to determine the direction of gravity, which is practically the only constant force exerted on a body under natural motion. Hair cells located in a calcite crystalline enriched gelatine layer stimulate their assigned sensory cells uniformly if the body is in a vertical attitude, or more or less one-sidedly if it is in a tilted attitude.

In an aircraft, however, statoliths interpret both the resultant of centrifugal force and of gravitational force as being gravity. The resulting misinterpretation can be compensated for only by means of the eye's monitoring function.

Disorders Related to the Equilibrium Organ in Flight

Disorders related to the sense of equilibrium in flight result from the design of the vestibular system. With an introduction of curved flight, the nerve fibres inside the semicircular canals sense the rotational motion that is actually taking place. Yet, the statoliths register a resultant vector that doesn't accurately reflect the rotational movement being carried out. Similar rotational motion on the ground would be accompanied by the risk of falling, so that any related reflexes must be suppressed.

If the rotational motion continues, the fluid in the semicircular canals will come to rest due to friction. The statoliths register the resultant vector so that the equilibrium organ assumes an unaccelerated horizontal flight attitude.

When recovering from curved flight, the equilibrium organ induces a sense of rotational motion in the opposite direction. This situation is accompanied by the related risk of a false reaction.

All intermediary states of a body in rotational motion and fluid rotating through the semicircular canals are possible. For this reason, an estimation of flight attitude based on the human sense of equilibrium is impossible. This is also the fundamental reason why VFR pilots have so many accidents when flying into IFR weather. They have greater trust in their sense of equilibrium than in their instruments.

Once an aircraft enters a spin condition, the same effects are greatly increased because all rotational axes are affected. A potential reaction when recovering from a spin could be to inadvertently enter a spin in the opposite direction.

Signals sent by the equilibrium organ are natural and should not be suppressed. The only thing a pilot can do to stave off their effects is to avoid head movements during instrument flight and to trust his instruments implicitly.

Even if a pilot has been trained to trust only what he can see, he will nevertheless be subject to the optical illusions described herein. In addition, there are also illusions associated with the interaction between the eyes and ears. Strobe lights, windshield wipers and propellers can induce an impression of motion that is not actually taking place or is taking place in a manner other than perceived. Because responses to such illusions are not uniform, however, it is advised in this case, as well, that the pilot should trust his instruments. If the pilot is unsure of himself, then he should switch on his autopilot (if available). In any case, it is easier to monitor the autopilot than to try to overcome a perceptual illusion while flying the aircraft at the same time.

2.3 Information Processing

The previous sections discussed how information is taken in by the eyes and the ears. Those sections described in part just how the first steps are taken in processing information and what system-related errors (can) occur thereby.

Once the effort is made to delve into a discussion of the higher, cognitive human processes, there is no way around dealing with the memory. Without memory, every piece of information taken in would be "new". Our condition would be similar to that of an infant's—a being without any prior experience whatsoever.

As long-term memory plays a particularly significant role in decision making on the flight deck, two related conceptions commonly held today will be described at length.

The potential for, and the limits of human information processing related to flight will be subsequently addressed. Limitations to this potential due of special situations can be found in practically every chapter in this book. This includes the chapters on Human error, Communication, Decision making and Stress.

2.3.1 The Human Memory

There are two different conception models commonly accepted today. The one differentiates between sensory memory, short-term memory and long-term memory. This relates closely to the experience that not all information is available all the time ("What was Peter's friend's name again?") and that not all available information can be taken in or processed simultaneously at all times. This multi-store memory model corresponds to the concept of information processing with the help of schemata or scripts.

The other memory-related conception model assumes one individual storage facility, yet with different conditions within this store.

While the multi-store model referred to above concentrates more intently on the aspect of the information being processed, the single-store model places the actual processing methods as the focus of consideration. Mental models for the processing of information fit more appropriately in the later conception about memory.

The question, as to which of these conception models is "appropriate" for aviation, is irrelevant. Of much greater significance is that the perspectives gained from either conception model can contribute to an understanding of the flight-related problems associated with information processing.

The Multi-Store Memory Model

The information taken in by the sensory organs initially accesses the so-called sensory memory. This has practically unlimited capacity with respect to volume. Yet, the information stored there exhibits an approximate half-life value of merely 100–150 ms. After this period, half of the information has already been lost.

The sensory memory is used to provide sufficient time for arriving information to be processed. This processing takes place in the short-term or working memory. Besides the information from the sensory memory, the working memory also accesses information from the long-term memory which has already been stored there. The working memory's storage capacity is relatively limited, however, so that if one's attention is drawn away from an object or a problem, the information in the working memory will be lost after only a few seconds. The working memory can process only 7 ± 2 units of information simultaneously. This processing principle applies to motoric areas, as well. Good jugglers can juggle up to a maximum of nine objects at the same time.

The respective capacity limit is dependent upon the person and his condition at the time.

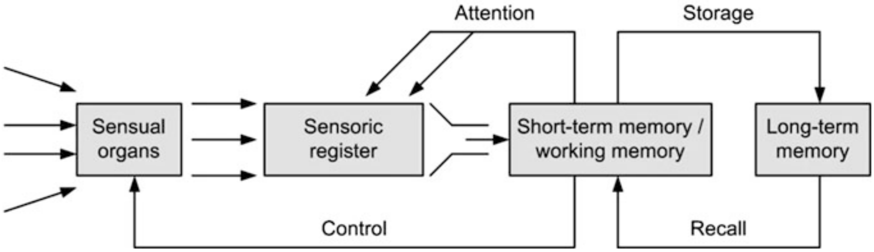

Fig. 2.9 Multi-store memory model

An overload of the working memory can occur if the approximate 7 units are exceeded. Additional units of information will be blocked and tunnel vision will ensue. Now, at the very latest, is the time to substantially reduce the load (with delay vectors, autopilot usage, etc.). Moreover, errors will also begin to occur within the approximate 7 units: A person who can memorize a 7-digit number without difficulty will most likely only be able to retain fewer than 7 digits when trying to memorize an 8-digit number.

Despite the limitation of approximately 7 units, the working memory has enormous capacity because it has access to the long-term memory (see Fig. 2.9). From this location, for example, experiences can be activated and combined with information within the working memory.

Information can enter into long-term memory from the working memory either consciously or unconsciously. Long-term memory is practically unlimited and comprises what the respective person knows about the world. Knowledge that hasn't been used for some time may not be easily recalled but, as a rule, is not lost. Even knowledge that a person can't remember despite lengthy deliberation can be recalled under hypnosis; an admittedly impractical technique for application in the daily flight routine, however.

Learning, with respect to this model, is the transfer of information into long-term memory by means of processing in the working memory. If the information to be learned remains active in the working memory long enough, it will then be permanently stored in long-term memory. This takes place, for example, through continuous repetition, through the linkage to a preferably large volume of content already stored in memory or through the active search for new information that can be linked to the content being learned.

The Single-Store Memory Model

The single-store memory model assumes merely one storage facility. All information coming in from the outside is either immediately processed in this memory or is lost. A personal long-term memory is not incorporated into this model. Moreover, the single-store model assumes that working memory is actually only one state of arousal within the memory.

If a portion of the newly arriving stimuli is recorded because of the state of arousal in a section of this memory, then it can be stored. The high degree of loss during information acquisition is explained in this model by a shallow depth of processing. Not all incoming information can be processed because the overall memory cannot be active at all times. For this reason, the unprocessed information is lost.

2.3.2 Schemata and Scripts

The terms schema and script play a large role in the theories dealing with knowledge stored in long-term memory. Both terms deal with knowledge correlations stored there. While schema describes knowledge through terms and definitions, script describes knowledge through action processes.

An example of schema can be found in the notion of a bird. A bird can fly, has wings, lays eggs, etc. A typical representative of this species would be a robin, while the features of a chicken or an ostrich diverge significantly from the schema drawn up by our conception of what a bird is.

Scripts represent stored information related to action processes. An example of a script can be found in a visit to a restaurant. The visit is comprised of: entering, being escorted to a table, reading the menu, ordering, eating, paying and leaving.

Schemata and scripts, each in their own right, can vary significantly. It’s heavily dependent on the experience of the individual. This can mean, for example, that the script of being escorted to a table in a restaurant may have been stored differently by Americans than it might have been by Europeans. While almost all American restaurants will provide an escort to a table, this is rather the exception in Europe.

Schemata and scripts can greatly simplify human action. One will know how to behave if the corresponding script has been committed to memory. Yet, similar to how the simplification of information acquisition can cause problems in borderline situations, the simplification through the use of schemata or scripts can conceal the risk of falsification. If test persons are informed about, or see a film about a short story having to do with a restaurant visit, and are subsequently asked whether the customer paid or not, many of them will confirm that they heard or saw this take place, even if it didn’t actually take place in the story.

Schemata and scripts play a similar role in flight. Power plant schema certainly appears differently to a jet pilot than it does to a sport pilot, while an engineer will see it differently than pilots altogether. Similarly, the script related to a flight sequence will differ significantly between an air transport pilot and an aerobatic pilot.

The problems that can arise when the schemata or scripts are stored incorrectly or when different members of the cockpit crew possess divergent schemata or scripts will be addressed in a later section.

2.3.3 Mental Models

If one assumes there is only one store for the entire memory, then the concept of a large network with many nodes, in which each node would compose a unit of knowledge, would seem likely. Each node can, in turn, then be linked to a differing number of other nodes. This network can be elevated through attentiveness. The respective information will then be available once a certain level has been reached. Likewise, new information will be introduced into this network when attention is paid to it. Such a network can be referred to as a "mental model".

Example: A colleague named Peter has a wife and three children. The last time I flew with him was on a trip to Rome two months ago. If I try to recall the weather conditions on that day, meaning to access a special node in my knowledge network, then I have the option of trying to do this directly. If that doesn't work, then I can attempt to remember through neighboring nodes. If one node in a network is elevated, then the neighboring nodes will also be elevated to a certain degree. I may recall that we had a slight slot delay, that Peter's two daughters are named Julia and Andrea, that Peter told me this during the flight to Rome and that we were looking forward to the pleasant day there!

This conception of memory as a network is generally helpful when trying to remember something not easily recalled. One simply attempts to elevate the network closest to the content trying to be remembered, then, at some point, the information will be activated to a degree that it can actually be recalled. This process requires some time, but functions very reliably.

2.3.4 Information Processing in Aviation

Several problem areas can be derived from the conception of memory and how it works that apply to the flying activity, as well.

Diverse aspects to consider can be drawn immediately from the working memory limitation of 7 ± 2 units.

First, burdens brought into the cockpit from the outside will limit the available working memory. Individual units may be "occupied" by a personal situation, such as home construction or some other issue, to a degree that only a residual number of units remain available for the actual flight operation (refer to the chapter on Stress).

Secondly, poor flight preparation is necessarily accompanied by smaller knowledge units. Under certain conditions, some information may have to be reworked during flight, which can significantly limit working memory capacity.

Thirdly, pilot training that is too accelerated or of insufficient quality can also result in the size of the units to be processed being smaller than their potential or less than what is needed. In this case, the working memory may be functioning at the extent of its capacity already during normal flight operations. Related errors during critical flight situations are that much more likely to occur.

The working memory limitations depicted above fundamentally reduce "situational awareness".

Fatigue, awkwardly designed cockpits, etc., contribute in part to a pilot not being totally aware of his situation, as well. Although cockpit safety can be enhanced by favourable ancillary conditions, such as through a reasonable presentation on the navigation display or with thorough briefing habits, the overall benefit to safety is nullified, however, if the pilot's capacity is limited because to the factors mentioned above.

It goes without saying that the responsibility for adequate flight preparation rests with the flight crew. It is also the pilot's responsibility to restrain from flying when a difficult situation may limit his flying fitness. What does not fall under his responsibility is the design of the flight deck and the establishment of training guidelines.

When crew members with different flying backgrounds occupy the same cockpit, there is always the risk and there is always the opportunity associated with their distinct insights into flight-related correlations. Scripts, schemata and mental models can diverge significantly from one another. One example might be the military pilot flying with a retrained flight engineer. Pilots coming from the business aviation environment will also possess different flying experiences than airline pilots.

A particular risk of misunderstanding always exists with such crew configurations. Yet, conversely, there also exists the chance that one crew member will more readily recognize an error made by the other crew member precisely because his correlated insight is different. It is possible to exploit the overall knowledge possessed by the crew through skilful communication, thereby realizing beneficial synergies. Helpful information related to this subject can be found in the chapters "Communication" and "Leadership and team behaviour". One such synergy, or complement to the different areas of knowledge, can be seen in the following example:

A captain, new to the aircraft type, is flying with a copilot who already has extensive experience in it. Even though the captain possesses the greater overall flight experience, the copilot may possess better experience when it comes to individual aspects of the operation. The captain should consciously put this to good use. Both crew members working together will conduct the flight more effectively than either one could do on their own.

For clarification: Despite the limitations that every pilot, every aircraft manufacturer, every employer and every aeronautical authority should be aware of, it is the human being, alone, who is sufficiently adaptable to, and capable of safely handling the complex environment found in today's cockpit.

Naturally, humans have their limitations; they make mistakes. They have not developed into beings capable of processing of large quantities of data in parallel. Every party involved should be reminded of this time and again in order to keep pilots from being put into situations that are conducive to error.

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Further Reading

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