Aviation Medicine

Aviation psychology

I: Human errors and warning systems

ROGER GREEN

"I am a brother to dragons and a companion to owls."¹

In research into the human factors in aviation the respective roles of the psychologist and doctor are not well demarcated. It is in recognition of this indistinct borderline that this and the following article on aviation psychology appear as one of a series on aviation medicine. To some extent, however, aviation psychology is an entire and separate pursuit, so what follows can provide the reader with only an impression of the scope and nature of the subject.

Perceptual limitations

Many psychological problems have already been referred to in previous articles (28 May, p 1726, and 4 June, p 1807)—for example, vestibular illusions and communication in noise, both of which are as much of psychological as of medical interest. A further problem is the way in which pilots use visual cues, particularly in the approach to land. If pilots are asked to describe the cues which they use during the approach (fig 1) they are likely to be unable to identify them since, as with many skills, it is not necessary to be able to describe the components of that skill in order to possess it. Nevertheless, with thought and

FIG 1—Schematic representation of runway shape, visual angle, and streaming cues.

experiment the possible cues available to the pilot may be identified—namely, the way in which the world appears to stream past the viewer, the textural gradient in the terrain, the visual angle between the horizon and the touchdown point—that is, the angle of approach—the projected shape of the runway on the retina, and possibly some others.^{2,3} Individual pilots probably do not use all available cues but unconsciously attend to only

FIG 2—Constancy of relative bearings for aircraft on collision courses.

an idiosyncratic subset which is found to be adequate during training.¹ Thus if on an approach where special circumstances have removed or altered a cue which is important to a particular pilot—for example, if snow cover has hidden the texture of the terrain—he may have difficulty when another pilot does not. The shape of the runway may present a similar problem. A pilot who relies on the perceived shape of the runway may be misled by an abnormally long runway which will appear to be the same shape as a shorter one viewed from a shallower angle of approach. Errors such as these may induce the pilot either to land long (some distance down the runway from its threshold)

or short (before the runway threshold); the latter is normally the less desirable.

Mid-air collisions are also of interest to the psychologist of vision.⁵ If two aircraft at constant speeds and on constant headings are going to collide then they maintain constant relative bearings to one another (fig 2). All other aircraft will possess some relative motion. This means that the aircraft which it is most important for the pilot to detect appears stationary on his windscreen, and the small amount of movement—to which the peripheral retina is so sensitive—is completely absent. The aircraft is also unlikely to be detected because its size stays very small on the retina until shortly before collision (fig 3), and detection thus relies on efficient visual search by the pilot. The small size of the target requires that it must be detected foveally or near foveally and the discontinuous saccadic nature of visual search makes detection only probable.⁶ Thus, unfortunately, the combination of physical, physiological, and psychological circumstances makes the detection of an aircraft on a collision course less likely than that of an aircraft which poses no such threat.

FIG 3—Relation of time to impact to angular size of oncoming aircraft.

If a pilot detects an aircraft shortly before a potential collision he may avoid it if he can react quickly enough. Despite the fact that much is made by the layman of the quick reactions of pilots, fast responses are rarely required in flight. The pilot is almost always best advised to consider a decision rather than to respond in haste. Two specific accidents in which fast responses were required⁷⁻⁸ have, however, led to experimental work in simulators, which indicates that the sort of simple response times found in the psychological laboratory⁹ give little guidance to the applied psychologist. When pilots are presented with unexpected emergencies their response times are long and variable, from two to perhaps seven seconds.⁷ Clearly such long response times are determined not by the time required to make the response but by the time which is required for the

pilot to grasp an unusual, unexpected, or complex event—the so called cognition time. To the designer of a terrain following autopilot who relies on the pilot to intervene and prevent the aircraft striking the ground in the event of a system failure, this fact may be unpalatable but it is inescapable. Thus this is one respect in which the design must accommodate the man rather than vice versa—a principle which is central to the specialty known as engineering psychology or, more broadly, ergonomics.

Problems of equipment

DISPLAYS

Reference to the increasing complexity of aircraft instrument displays since the first world war has become an aviation cliché. Interpreting apparently complicated instrument arrays is, however, not as difficult as first appears, because only a limited subset of instruments requires constant or regular attention and many need monitoring only in certain phases of flight. The experienced pilot is also accustomed to the patterns of display presented by instruments (their arrangement being designed to facilitate this) and should quickly be able to identify a deviation from normal. Despite this, problems with displays and controls arise with depressing regularity.

The best known problem is that of the “three pointer altimeter.” Aircraft instruments have traditionally been designed as circular dials with indicator needles, and some early altimeters resembled clocks in having a stubby needle which indicated thousands of feet and a slim needle which indicated the remaining hundreds of feet. As aircraft flew higher the display of tens of thousands of feet was needed, and a new, very stubby, needle was added (fig 4). The unwitting lethality incorporated

FIG 4—A three pointer altimeter.

in such instruments was highlighted in 1958, when in two separate incidents Viscount and Britannia airliners flew into the ground after their pilots had reported their altitudes to air traffic controllers as being 10 000 ft (3048 m) higher than they actually were.¹⁰⁻¹¹ It is easy to misread instruments designed like this, for the most important pointer is the smallest and hence the easiest to misapprehend.¹² This particular problem is easily solved by the provision of a counter, or digital readout, on the altimeter (although many aircraft flying today still have three pointer instruments), yet this does not represent a general case for greater use of digital instruments. Many displays, such as fuel gauges, are best presented with an analogue component to the display. It is much easier for a busy pilot to assess his fuel state by looking at the position of a needle on a gauge than by reading the number of remaining kilos; since for the

latter he must mentally refer the observed digital value to the memorised values of maximum capacity and minimum permissible level.

The invasion of the modern cockpit by electronic displays^{13 14} has placed enormous demands on the engineering psychologist. In aircraft such as the Panavia Tornado and the European Airbus multifunction cathode ray tubes have replaced many of the conventional instruments. The potential of these displays to present information only when it is required and in colour—to overlay radar returns on a moving map and display check lists and lists of emergency actions—is enormous. This is new ground, and all of these possibilities must be carefully evaluated to ensure that some reincarnated form of three pointer altimeter is not being unintentionally designed into these systems. Perhaps the main difference between electronic displays and traditional instruments is the capacity of the former to present widely differing information on the same display surface. The consequence of this is that unlike conventional instrumentation not all information is displayed constantly. Heavy reliance must be placed on the computers, which decide when the pilot needs to be warned of an incipient or actual system failure. This, in turn, places an onerous load on the designer to anticipate all possible combinations of such failure.

WARNING SYSTEMS

With a wide variety of possible failures but a low actual incidence there is a temptation to warn the pilot by associating each fault with an auditory signal. The hazards of such practice are illustrated by the apocryphal story of the pilot who landed without lowering his undercarriage, although air traffic control was warning him by radio. He later explained that he could not hear them because his aircraft had been fitted with a klaxon to warn that the undercarriage had not been lowered. The problem of abstract tones having no inherent meaning is exacerbated in modern aircraft, in which navigational and warning tones are numerous. Recommendations are being made on how best to use the auditory channel with synthesised speech and abstract audio displays.¹⁵

Warning displays must, of course, be reliable. All large British commercial aircraft are fitted with a ground proximity warning system. The difficulty of triggering such a warning system reliably resulted in frequent false alarms, and pilots became familiar with the noise—a familiarity which bred sufficient contempt for several aircraft to have been flown into the ground with the warning sounding. Of accidents to world-wide passenger carrying commercial aircraft between 1976 and 1982, about a quarter were categorised as “controlled flight into the ground.”¹⁶

CONTROLS

Displays represent only one half of the pilot's interface with his machine: he must also control it, and this represents another rapidly changing topic of interest for the engineering psychologist. Although the control column and throttle controls of many current aircraft are still recognisable, some new factors are dictating the necessity for change. Reclined seats to improve the pilot's G tolerance (see previous article, 21 May, p 1630) mean that the control column cannot remain between the pilot's legs; in the F16 aircraft a force sensitive joystick, which does not move at all, is located on the right of the pilot's seat. The next generation of fighter aircraft will include highly advanced computer controlled aerodynamic surfaces. The pilot will not demand a control surface deflection but a manoeuvre; the computer then will decide how best to produce that manoeuvre given the existing state of many variables including speed, angle of attack, weight, centre of gravity, and altitude. With such sophistication new types of canard control can be contemplated that will allow direct horizontal and vertical

translational forces to be developed on the airframe so that, for example, the aircraft may gain height without any rotation in pitch. Precisely how the pilot will demand these extra dimensions of control remains to be discovered.

Next week's article covers the psychological factors in assessing workload and selecting pilots.

References

- 1 Job XXX, 29. *Holy Bible*, King James version.
- 2 Gibson JJ. *The perception of the visual world*. London: Allen and Unwin, 1952.
- 3 Mertens HW. Perception of runway image shape and approach angle magnitude by pilots in simulated night landing approaches. *Aviat Space Environ Med* 1981;**52**:373-86.
- 4 Chappelow JW, Smart JA. Putting texture in perspective. *Proceedings of the Royal Aeronautical Society's two day flight simulation symposium*. London: April 6-7 1982. Royal Aeronautical Society, 1982:1-6.
- 5 Green RG. Mid air collisions—how to avoid them. *Air Clues* 1982 July: 260-2.
- 6 Harris JL. Visual aspects of air collision. In: *Visual search—proceedings of the 1970 annual symposium of the committee on vision*. Washington DC: National Academy of Sciences, 1973:26-50.
- 7 Green RG, Skinner R. Response times to locked controls at rotation. In: *Report on the accident to BAe HS 748 G-BEKF at Sumburgh Airport, Shetland Islands on 31 July 1979*. London: Department of Trade, 1981. (Department of Trade Accidents Investigation Branch Report 1/81.)
- 8 Chappelow JW. An investigation of the time taken to respond to total engine failure. In: *Report on the accident to Wessex 60 GAS WI at 52° 56'N 01° 46'E*. London: Department of Trade (in press).
- 9 Kling JW, Riggs LA. *Woodworth and Schlosberg's experimental psychology*. New York: Holt, Rinehart & Winston, 1971.
- 10 Civil Aviation Authority. *Report on the accident to Viscount type 802 G-AORC which occurred on 28th April 1958, at Tarbolton, Ayrshire*. London: Civil Aviation Authority 1959:CAP 154. (Civil Accident Report C 679.)
- 11 Civil Aviation Authority. *Report on the accident to Britannia G-AOVD which occurred on 24th December 1958, at Sopley Park, Christchurch, Hants*. London: Civil Aviation Authority 1960: CAP 164. (Civil Accident Report C693.)
- 12 Rolfe JM. Human factors and the display of height information. *App Ergonomics* 1969;**1**:70.
- 13 Stonehouse D. Evolution of the airborne display. *Electronic Eng* 1980;**52**: 29-45.
- 14 Howell GC. The modern military aircraft cockpit. *Electronic Eng* 1980; **52**:47-55.
- 15 Wheale JL. Decrements in performance on a primary task associated with the reaction to voice warning messages. *Br J Audiol* 1982;**16**: 265-72.
- 16 Civil Aviation Authority. *Memo report*. London: Civil Aviation Authority 1982;CARDPB/P(82)173.

A woman in her early 60s suffers from intractable pruritus vulvae. Would superficial x ray treatment be of value?

Superficial x ray treatment has been widely used for treating all sorts of benign skin conditions. Some radiotherapists and dermatologists consider that with the advent of, for example, the stronger topical corticosteroids there is now no place for radiotherapy in treating benign skin diseases. Nevertheless, there may still be occasional indications although very rarely on the vulva. Radiotherapy should never be suggested as treatment for pruritus vulvae without a more precise diagnosis. It would not be suitable for such non-specific changes as those of intertrigo or seborrhoeic dermatitis nor is it usually considered suitable for the treatment of what dermatologists call lichen sclerosus and gynaecologists may call hypoplastic vulval dystrophy. The premalignant change of vulval leukoplakia is best treated by other means. A possible indication for radiotherapy is lichenification (lichen simplex—the thickening response of the skin to prolonged rubbing). Lichenification will usually respond to appropriate topical treatment, however, and radiotherapy could be contemplated only in those few patients who have failed to respond to other measures. Even then it is unlikely to be dramatically successful. In brief, neither gynaecologists, radiotherapists, nor dermatologists recommend radiotherapy for pruritus vulvae.—R H CHAMPION, consultant dermatologist, Cambridge.