CHAPTER 7

PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS OF LOW FLYING

CONTENTS

Introduction

1. Modern detection methods have necessitated the use of low flying techniques to attain tactical and strategic aims. Simply stated, the lower and faster one can fly the greater is the likelihood of reaching the target undetected and, therefore, unattacked. However, this has the disadvantage that ground information and target location become limited and difficult.

2. There are, of course, human limitations to low flying and the purpose of this chapter is to consider the factors involved. Emphasis is given to the high speed, low level case, but the factors considered apply in some degree to all low flying.

Low Flying

3. The precise definition of what constitutes low flying is laid down in Ministry of Defence (RAF) Flying Orders, which are usually amplified in Command, Group and Station Orders. These regulations are laid down to protect individuals, including aircrew, and to control aircraft movements, but have little relevance to the need to develop operational techniques.

4. In war it may be necessary to use low flying techniques to penetrate the enemy defences and also to minimize the effects of enemy attacks by missiles and guns in defended areas and by enemy fighter opposition; it is generally agreed that the upper height limit for survival in this context is of the order of 200 ft AGL. However, low flying is, in itself, potentially dangerous for obvious reasons, some of which are discussed later in this chapter, and it is considered that 100 ft AGL is the height at which continuous low flying represents about the same flight safety and operational risk.

5. The most important limitation to low flying in the operational context is the ability of the pilot to perform his task under the very exacting conditions of flight at very low levels and to continue to do so for a considerable period of time, and it is vital that the relevant human factors are fully understood so that they can be overcome or minimized.

Vision

6. The pilot of an aircraft depends on vision for the performance of his task. Vision may be defined as the sensing by the eyes of variations in brightness and/or colour and the interpretation of these variations by the brain.

7. Vision occurs in two stages:

a. The reception of light at the retina of the eyes and its conversion into nerve impulses.

b. The interpretation of these nerve impulses by the brain, a process known as perception.

8. The eye is of a spherical shape with a transparent bulge, the cornea, in front, and is located in a socket within which it moves. Light entering through the cornea passes through a lens and is focussed onto the sensitive inner layer of the eye, the retina, where conversion into nerve impulses occurs.

9. The retina is not a uniform layer since it consists of two types of light-sensitive cells, rods and cones, distributed in varying densities. The cones are responsible for colour and detailed vision, the rod cells for vision under low light intensities. The cones have their greatest concentration at the fovea which is thus the area of greatest visual acuity and the part of the retina associated with line of sight vision. The rods reach their maximum density in a zone encircling the fovea and the density then gradually decreases. Because of their structure and the way in which they are connected to nerves, rods can react to lower light intensity than cones, but are not able to appreciate details to the same extent.

Visual Acuity

10. This may be simply defined as the ability of the eye to distinguish detail. Because this ability is related to the structure of the retina, maximum visual acuity is obtained when the eye is directed so that the incoming light is focussed on the fovea. Because the fovea and para-fovea subtend a small angle (approximately 20°), objects must be brought within this projected cone for detail to be seen. The eye can accomplish this by its own movement and by movement of the head and body. Or, put very simply, this means that to see something clearly, it has to be "looked at".

Visual Field

11. From the layout of the retina it is obvious that the greater part of its area is concerned with the location of objects appearing in the visual field in order that the eye may then be moved to bring the object into the view of the fovea for detail to be seen.

Visual Problems in Low Level Flight

12. The visual process is not instantaneous—it takes time. It may be described in terms of five stages—although it is actually a smooth co-ordinated action without breaks:

		Approximate Time (Seconds)
"Pick-up"	a. Detection of an object in the visual field	0·1
	b. Ordering eye movement	0·3
Acquisition ("Lock-on")	c. Eye movement	0·3
	d. Focussing object on fovea	0·4
Recognition	e. Perception	1·0
		2·1

13. The time of 2·1 seconds is merely an estimate and may easily be shorter or longer depending on various factors including:

a. *Human Factors.*

(1) Mental alertness.

(2) Overall fitness.

(3) Experience.

b. *External Factors*

(1) Position of an object in the visual field. Broadly speaking the nearer its position to the periphery, the longer is acquisition time.

(2) Complexity of the situation, *eg* size, number, contrast or camouflage and familiarity of an object and the level of illumination.

(3) Distractions, *eg* the basic flying task, the application of *g*, the need to check aircraft instruments and the presence of enemy opposition.

The Blur Zone

14. To the pilot of an aircraft at low level, objects on the ground will have a relative angular velocity dependent on aircraft height and speed, the size and range of the object and its bearing to the line of flight. Thus, if dead ahead, it has no angular velocity, whilst to either side it has an angular velocity which is at first low but which increases to a maximum as the object comes abeam and then decreases as the object goes astern. For an object to be recognized it must be tracked by the eyes so that its image is held on the fovea. This means an object may be sensed (visually "acquired") but not recognized since the eye has not "locked on" to it; and, of course, the object's image must not just appear in the eye, it must be there long enough for the brain to appreciate its significance. The visibility of objects moving across the field of vision depends on what has been termed *dynamic visual acuity* and is a function of an individual's ability to keep the image of a moving object on or near his fovea. Thus it bears little relationship to static visual acuity measured clinically by test charts *etc*, but is more related to a skill which, like most skills, can be acquired and then improved by training and practice.

15. There is, therefore, a limit or threshold beyond which the eye cannot track a moving object and which is dependent upon visibility of the object, its angular velocity and the observer's experience. This being so, it is of interest to consider the locus of all points in space having a common angular velocity when they are seen

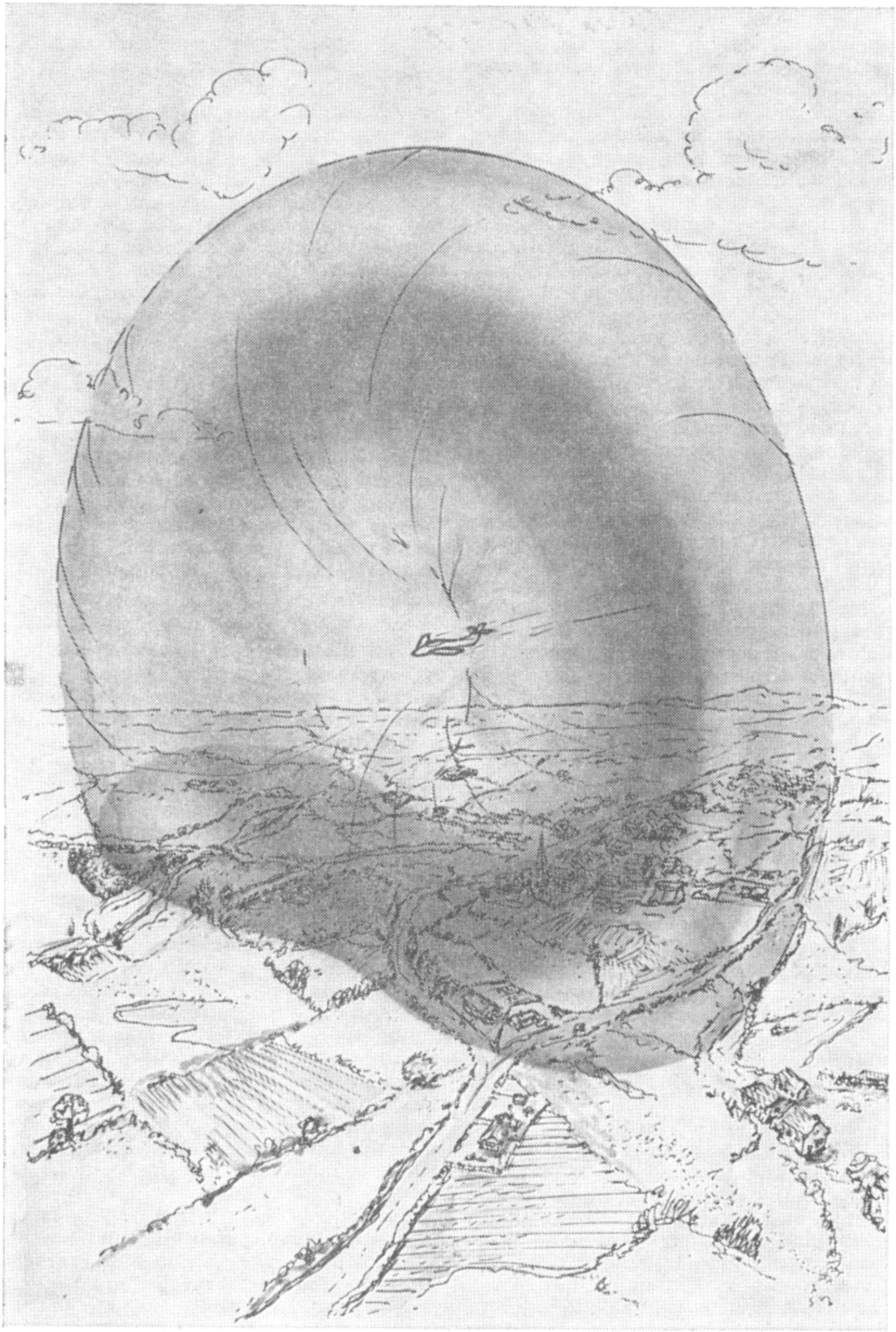

Fig 1 The Blur Zone

from an aircraft moving past them at a uniform linear velocity. Fig 1 shows diagrammatically that at a given instant of time, all points having a common angular velocity lie round about an observer and on the surface of an imaginary toroid, or doughnut shape, whose cross-section through the centre consists of two circles tangential to one another. Inside this blur zone objects are moving faster than threshold and are, therefore, not recognizable, whilst outside the blur zone they are moving slower than threshold. If one considers the aircraft flying at a theoretical zero feet altitude, the blur zone on either side is therefore represented by the section of this toroid through the observer's position, and the blur zone is then a circle on either side of the observer. With increasing height between the aircraft and the ground, the zone of blurring of ground features is represented by the section of the toroid a distance from the centre of the toroid, equal to the height of the aircraft. With increasing height, the sectional area then decreases until at a height equivalent to the diameter of the blur zone, that blur zone reduces to a geometric point. It should be noted that there is a critical height above ground at which forward visibility is maximally impaired and this is the height which is approximately equal to half the diameter of the blur zone. From an inspection of Fig 1 it will be obvious that this takes place because at this height the toroid is at its maximum thickness.

16. In fact, the toroid represented in Fig 1 is merely an approximation, for, as an object observed is nearer the observer and therefore travelling past at higher angular velocity, the angle which it subtends at the observer's eye is also greater, so that the threshold angular velocity at which it becomes no longer clearly visible, increases. As a result, the blur zone on either side of the observer changes from a circle (which applies only in the theoretical case) to a lobe, as in Fig 2. However this does not substantially alter the conclusions presented in connection with the consideration of a theoretical blur zone.

17. In addition to the distances at which it will or will not be possible to see an object because of blurring, reaction time must also be taken into account. In-flight experiments show that it takes about 0·2 seconds for the eye to catch up with and then follow a moving object. At 400 kt, an aircraft covers 133 ft in 0·2 seconds, so it would be necessary for the pilot to detect the object at least this distance ahead of the blur zone. The addition of this simple reaction time which, as seen in Fig 2, results in a forward extension of the blur zone, would allow for only an instant of clear vision before the object again moved into the blur zone. In practice, a longer reaction time must be considered and experiments and expert observations have shown that about 0·7 seconds is required to pick up and identify an object moving at this sort of speed; this, of course, may again be represented by a further forward extension of the blur zone. Pre-occupation with other aspects of the sortie, *eg* weather, navigation, enemy action, the basic flying task, *etc* can result in a significant increase in reaction time but, overall, it can be reduced by training and experience.

Coning of Vision

18. There is a great deal of visual information being presented to a pilot during low flying; moreover there is a very strong sensation of motion. The sense of motion is directly related to speed and height and, for a given speed, it can be reduced by an increase in height; or if height is held constant, by decreasing the ground speed.

19. The need for precise, accurate flying when very near the ground, together with the enhanced sensation of motion and the wealth of visual information being presented, results in the brain relieving the "pressure" by reducing the amount of visual material it will handle to manageable proportions. Thus, while the visual field is physically unaltered, there is a tendency to ignore the periphery and concentrate attention along the line of flight. In practice, the strain of coping with the flying task and the amount of visual information being presented results in general tension, a disinclination to "break lock", *eg* to look at instruments, and attention tends to become concentrated in a narrow band ahead of the aircraft. This results in what has been described as "coning of vision", or "tubular vision", but the latter expression is somewhat of a misnomer because the implication is that only objects at the end of the tube are illuminated and the rest of the field of vision is in darkness. This is not so and "coning of vision" or "tubular vision" really means that the size of the area being effectively scanned is reduced to a narrow band concentrated along the line of flight. Although there is no specific scientific evidence to support this, experience shows that the extent to which the normal visual field is narrowed under so-called "tubular vision" varies from person to person and, indeed, from time to time in the same person.

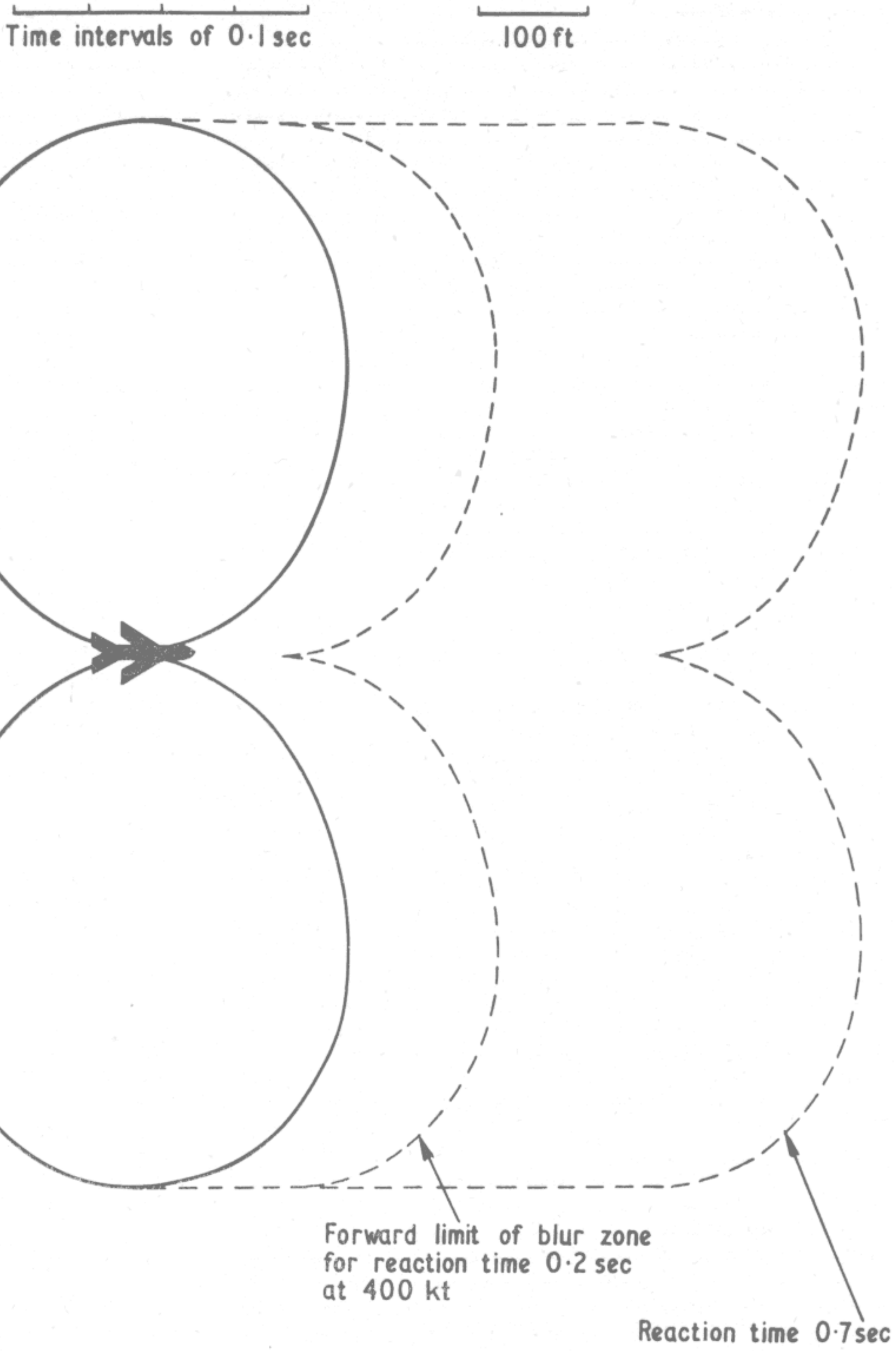

Fig 2 Blur Zone for a Black Object of 0·8 ft Diameter Seen Against a White Background

Training and Experience

20. Experience shows that there is an instinctive and largely involuntary action to relieve the pressures imposed on individual pilots or crew members by very low level flight. Such flying usually involves detailed flight planning, and accurate timing is fundamental to the task; therefore pilots are reluctant to seek respite by reducing speed and are much more likely to relieve the pressure by increasing height. This tendency must be consciously resisted, since, of course, if height is increased, detection is more likely and the chances of successfully completing the mission reduced.

21. Confidence is essential in order to maintain the necessary near-perfect performance of a difficult task for protracted periods. Training is not only essential to acquire the necessary level of skill but also to provide insight into what constitutes a serious risk and what does not. It is only when the risks are appreciated fully and accepted that true confidence is achieved. Fatigue and the length of time the pilot is required to fly to very close limits will tend to diminish the improvements resulting from practice and confidence.

22. Visual acuity under dynamic conditions can be improved by training and experience but the ability to fly to a given angular velocity is quickly lost by lack of practice. As familiarity with the low level role increases, the environment becomes less demanding and coning of vision less marked. The recognition of an object is easier if the object has familiar characteristics, emphasizing the importance of visual training in recognition. Perception time can be reduced if the flight has been so planned as to enable the pilot to visualize and memorize the dominant features and essential points of his route. Order and method are of the utmost importance in this context so as to reduce to an absolute minimum those functions of aircraft operation which distract the pilot from the actual flying task.

23. The time spent in relating objects pictured on the map to those on the ground is a vital factor in map selection and few maps are drawn with this requirement in mind. Correct map preparation can do much to improve recognition time and maps should be duplicated rather than folded. Thus a well-designed stop-watch used in conjunction with a carefully prepared map materially assists in maintaining knowledge of position, which itself reduces pressure on the pilot, maintains confidence and provides advance warning of anticipated features along the route.

24. The introduction of a second crew member, be he navigator, observer or pilot, is beneficial in that the task may be shared. This is particularly true in the case of a fully qualified second pilot. However, the time taken in communication and reaction between crew members is likely to negate at least some of the benefits, particularly in the very high speed, low level case. The importance of mutual training and practice cannot be too strongly emphasized.

Electronic Aids

25. Scientific research and development continually aims at providing the pilot with aids to alleviate some of the problems and the following are some of the most important:

a. *Instrument Head-Up Display*. This system presents all essential flight information on the windscreen, or a reflector plate, at visual infinity and so reduces the need to look inside the cockpit.

b. *Terrain Avoidance/Terrain Following Guidance Systems*. These systems relieve the pilot of much of the task of controlling the aircraft.

(1) A terrain avoidance system operates in a straight line and maintains a set ground clearance. It is thus more reliable but less flexible than a pilot who can deviate from track and follow natural features such as valleys and cliffs.

(2) A terrain following system has the reliability of terrain avoidance coupled with flexibility. Thus a terrain following system can manoeuvre an aircraft up a valley and can select a route round an obstacle.

It must be appreciated however that installation of the above facilities means that there is more equipment to be monitored and such equipment can only operate within the overall limitations of the aircraft; speed, turbulence, height AGL to fly and the rate of change of height with distance may all be limiting factors at some time or other. However, the trend is towards greater reliability and flexibility and such devices will be of increasing benefit to the pilot.

c. *Automatic Navigation Systems*. These systems provide for accurate and reliable navigation but the pilot must still use a map to ensure against malfunction, jamming and war damage; however the system does reduce the pressure because the pilot can map-read from ground to map instead of from map to ground.

Conclusion

26. Low flying techniques must take into account the limitations of the human operator. Some of these limitations are purely physical whilst others arise from the special, and often very severe, pressures that high speed, low flying imposes. These limitations can be partially overcome by training, experience and pre-flight planning, or the pilot may be aided by the use of electronic devices. However, electronic devices are complicated and susceptible to damage and/or failure and there is always the possibility that the task may fall to the aircraft's crew. Thorough training and constant practice therefore will enable the crew to acquire the necessary skill and confidence for the task.