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ORIENTATION/DISORIENTATION TRAINING OF FLYING PERSONNEL: A WORKING GROUP REPORT

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Advisory Group for Aerospace Research and
Development
Paris, France

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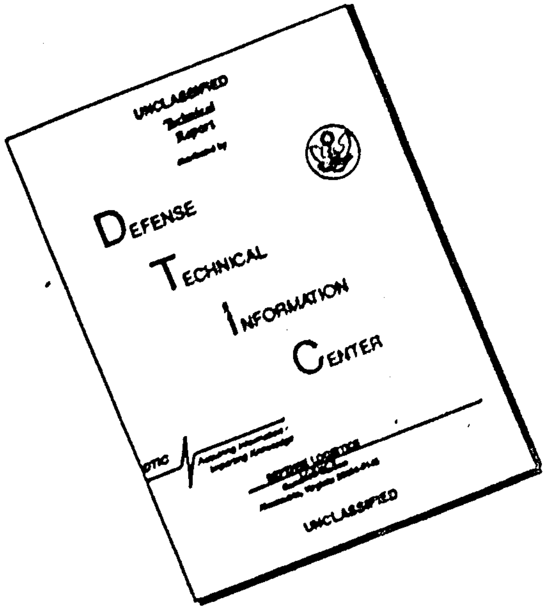

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15. Abstract

The report of an ASMP Working Group reviews orientation/disorientation training of military and civilian aircrew in NATO countries. Deficiencies in current programmes are discussed and 24 recommendations made for improvement of ground and in-flight training. Sections of the report review ground based training techniques, the use of familiarisation devices, more complex trainers, and aspects of in-flight training. Descriptions of the conduct of ground and in-flight demonstrations, a specimen lecture syllabus, and a specification for a familiarisation device, are given. Topics requiring further research or development are identified.

Manoeuvre No 4 was discontinued after the first sortie as erroneous sensations were not induced.

Manoeuvre No 5 in each version was performed twice. At no time was any type of vertigo encountered.

DISCUSSION

The test manoeuvres were chosen in an attempt to reproduce commonly reported types of spatial disorientation, such as occur during typical movements of the aircraft in Instrument Meteorological Conditions. Spatial disorientation attributable to the false perception of external visual cues is not covered by this paper and must be a subject for further study.

Theoretically, the disorientating sensations which should be evoked by the five manoeuvres are:

- i Leans combined with oculogravic illusion
- ii Somatogravic illusion
- iii Leans
- iv G-force induced illusion
- v Cross-coupled or Coriolis responses

As it is necessary to assess the reliability of the manoeuvres as an effective demonstration of typical types of disorientation, a greater number of test-persons will have to be flown. Nevertheless, these preliminary experiments lead to some tentative conclusions.

1. Only the leans and the somatogravic illusion seem to be suitable for an effective in-flight demonstration. Each of these two types of spatial disorientation, where there is a false perception of attitude, can be induced by more than one manoeuvre, or alternatively both may be elicited in a single manoeuvre.

2. In spite of the limitations in the selection of the manoeuvres imposed by general instrument flight conditions, there are several typical situations common to almost every instrument flight mission, which are able to, or even do, produce disorientation.

3. No cross-coupled or Coriolis effect was produced, not even when large head movements were made during rapid roll-out movements of the aircraft. However, the test was carried out during a standard rate turn where the angular velocity was only 3°/sec, a value which is very close to the sensory threshold for the semicircular canals. In addition, the resultant force vector was only 1.16 G, so it was also unlikely that head movements would induce a false perception of attitude attributable to the 'G excess illusion'.

CONCLUSION

Provided disorientation danger only means spatial disorientation arising from normal regular flying in Instrument Meteorological Conditions (with the exception of those escapades where pilots fail to observe the rules) one should hope that the in-flight demonstration of the leans and the somatogravic illusion will be able to reduce flight accidents due to spatial disorientation. Further tests with a greater number of subjects in order to get a statistical base and more information are recommended and should be arranged.

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD REPORT No.625

ORIENTATION/DISORIENTATION TRAINING OF FLYING PERSONNEL: A WORKING GROUP REPORT

Edited by

A.J.Benson

This Report has been prepared at the request of the Aerospace Material Panel of AGARD.

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- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
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PREFACE TO RECOMMENDATIONS

The AGARD Working Group on Orientation/Disorientation Training have produced the following recommendations for the improvement of aircrew training which, if implemented, should reduce the incidence of orientation error accidents. The Group is aware that no *a priori* cost-benefit figures may be cited to prove that the thoughtful institution of a set of training procedures is a worthwhile approach to take to reduce orientation-error accidents. However, it is clear that disorientation incidents and accidents continue to occur and that their frequency has not diminished over the years. It is also clear that a fundamental, time-tested approach to the reduction of accidents involves safety programmes and training. Industries, which are concerned with profit, make use of such programmes.

In the opinion of the Working Group, the likely alternative to the recommendations noted below is to do nothing about disorientation; indeed, this laissez-faire approach is one which some members of the Group have encountered on the part of aviation officials who are in a position to make decisions regarding programmes, but who do not have specialized training in areas of spatial orientation. We suggest instead that something be done - specifically, what we have outlined below - and that its effectiveness be tested by comparing annual disorientation statistics for a 5-year period prior to institution of the programme with disorientation statistics for the 5-year period following the start of the programme. Disorientation accidents in the US Air Force during 1972 cost the government $20,200,000 in air frames alone, not to mention the inestimable value of the aircrew killed. If our proposals prevented just one such accident per year, it would more than pay for the training programme.

We feel that the undertaking of a comprehensive orientation training programme is a reasonable approach to the problem of reducing disorientation accidents; we do not feel that it is reasonable to do nothing about such accidents on the implication that there is no before-the-fact proof that the programme will work. The latter view involves a circular argument; if a programme is not tried out, one can never demonstrate that it works.

RECOMMENDATIONS

GENERAL

1. Orientation/disorientation training should be given both on the ground and in the air. In each Service or Organisation those responsible for the ground school phase of training should discuss the overall programme with those responsible for flying training and together they should develop an integrated syllabus appropriate to the needs of the flying personnel for whom they are responsible. (5:1)*

2. Orientation/disorientation training should not be restricted to student aircrew. Experienced aircrew also suffer orientation error accidents and hence should be given regular refresher training about the hazards of disorientation. (3:1)

3. Aircrew should never hear about disorientation without being given instruction on how to deal with the problem in flight. (6:4)

4. The time devoted to orientation/disorientation training of aircrew during the basic and advanced phases of flying training should be in accord with the recommendations made in Table 5. Refresher training should be given at intervals of not more than 3 yr. (10:1)

GROUND TRAINING

5. Instruction on spatial disorientation should be included in the syllabus of basic aeromedical training of all student aircrew, both in military and civil aviation. The opinion that adequate knowledge of this topic will be gained during normal flight training is not justified. (6:1)

6. Lectures and lecture/demonstrations on orientation and disorientation in flight should endeavour to cover the specimen syllabus detailed in Annex C.2. (6:2)

7. When the time available for instruction is limited, it is better to emphasise the practical implications and causes of spatial disorientation than to describe vestibular and other sensory mechanisms. (6:3)

8. Those engaged in the orientation/disorientation training of aircrew should themselves be well informed on the topic and be capable of answering relevant questions posed by the students. AGARDograph 170 'Spatial Disorientation in Flight' is recommended as a source book. (6:5)

9. Visual aids should be employed. The FAA slide set 'Vertigo' and the film 'Perception of Orientation' (RCAF 22025) are recommended for English speaking aircrew. (6:6)

10. Some form of rotational device should be employed for the familiarisation training of aircrew in ground schools. Preferably the device should be used in conjunction with lectures. All members of the group under instruction should have experience in the device. (7:1)

11. A device with rotational freedom about a vertical (yaw) axis is adequate for familiarisation training. The provision of rotation in roll and/or pitch is not considered to be cost-effective. (7:2)

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* Figures in parentheses indicate section and number of recommendation in text.

12. The ability to rotate the subject at a distance from the axis of rotation sufficient to generate a radial acceleration of 0.2 - 0.5 G is advantageous and allows somatogravic and allied illusions to be demonstrated. (7:3)

13. The performance and facilities of the familiarisation device should be in accord with the specifications given in Section 7e. (7:4)

TRAINING IN FLIGHT

14. All student pilots, both military and civilian, should be given an in-flight demonstration of spatial disorientation preferably before being allowed to fly 'solo'. (9:1)

15. Further demonstrations should be given during the early phases of instrument flying training. (9:2)

16. Civilian private pilots should be encouraged to obtain an instrument flying rating. (9:3)

17. As skill is acquired during instrument flying training the student should be required to fly the aircraft and recover satisfactorily from unusual attitudes in the presence of disorientation and other stresses. (9:5)

18. Senior students should be allowed to do instrument flying in real, rather than simulated, Instrument Meteorological Conditions, and should be introduced to operational manoeuvres during flying training, whenever possible. (9:6)

19. Examination of the pilot's ability to recover on instruments from disorientating unusual positions should be a regular feature of flying proficiency tests. (9:7).

RESEARCH AND DEVELOPMENT

20. Consideration should be given to the development of a programmed text on spatial disorientation for aircrew training which is factually accurate. Audiovisual techniques or a printed text could be employed. (6:7)

21. New films, film strips or slide-sets are required to supplement the restricted number of accurate and acceptable visual aids currently available. (6:8)

22. A distinction should be made between motion devices used for familiarisation training, which in general operate in an 'open-loop' mode (i.e. the man on the device does not directly control its motion) and those devices which operate in a 'closed-loop' mode (such as an aircraft simulator with a motion platform) and are employed to modify the perceptual and motor responses of the aviator.

Research should continue on the evaluation and development of ground-based procedures which might favourably influence the perceptual and motor responses of the aviator in the flight environment when exposed to disorientation stress. Consideration should be given to the cost-effectiveness of such training as well as to the selective use of the procedure in th aircrew population. (8:1)

23. Flight trials should be conducted in order to establish and develop manoeuvres which reliably induce disorientating sensations in aircrew to whom a demonstration is being given. (9:7)

24. Research and development should be undertaken to make the airborne simulation of instrument flight more realistic by the introduction of an element of external visual search, as when flying in real Instrument Meteorological Conditions. (9:4)

Sect. 1. INTRODUCTION

Part of the meeting of the Aerospace Medical Panel of AGARD in September 1971 was devoted to the topic of spatial disorientation in flight. The importance of training both on the ground and in flight in reducing the incidence of spatial disorientation and orientation error accidents was emphasised by many participants and as a result it was recommended that a Working Group be set up which would prepare an advisory report on orientation training (AGARD CP-95, 1971). Accordingly a Working Group was established whose objective was 'To make recommendations for training procedures which would minimise spatial disorientation in flight and thereby optimise mission effectiveness' (ASMP/SR/28). The members of the Working Group are named in Annex A.

The first meeting of the Working Group was held on 29th September 1971, with subsequent meetings on 10th May 1972, 4th September 1972, 16th May 1973 and 4-5th May 1974.

This report summarises the work carried out and decisions made by the Working Group; it is intended, primarily, as guidance for those responsible for the training of aircrew rather than as an exegesis of spatial disorientation for flying personnel.

Sect. 2. SPATIAL DISORIENTATION - THE PRACTICAL PROBLEM

Adequate spatial orientation in flight occurs when the aviator has a correct (veridical) perception of his attitude, motion and position relative to the surface of the earth. Spatial disorientation is a term used to describe incidents in which the aviator fails to sense correctly his position, motion or attitude, or that of his aircraft, relative to the surface of the earth and to the gravitational vertical. Apart from false sensations, or more precisely perceptions, of aircraft orientation there are also incidents where the aviator has an erroneous or disordered perception of his own orientation relative to the aircraft and these too may be embraced within a broader definition of "spatial disorientation in flight".

Although spatial disorientation, according to the definition given above, includes errors in the perception of aircraft position, such incidents are more accurately described by the term geographical disorientation. Errors in the determination of position with respect to fixed co-ordinates on the surface of the earth are thus problems of aerial navigation, a task requiring different skills from those involved in the perception of aircraft attitude and motion. For this reason the topics of geographical orientation and disorientation are not discussed further in this report.

Spatial disorientation is not a new problem in aviation, for early in the history of powered flight it was found that when the pilot was deprived of external visual cues, as when flying in dense cloud, control of the aircraft was soon lost because he was unable to sense correctly the attitude or motion of his aircraft. In the ensuing half century much has been done to supplement the sensory system of the aviator by aircraft instruments and other aids. Yet the fact remains that in the unnatural environment of flight man, the aviator, is exposed to motion with concomitant linear and angular accelerations which differ in intensity, magnitude, and duration from those to which he is normally exposed during natural activity on the ground. Thus in flight, sensory systems, which are functionally adapted to transduce correctly the linear and angular motion stimuli of the terrestrial environment, can engender false or inadequate percepts of spatial orientation.

Despite a wide understanding of the various causes and manifestations of spatial disorientation in flight, the problem is not yet solved. Each year aircraft crash and aircrew are killed because the pilot failed to detect the onset of disorientation, and based his control of the aircraft on an erroneous perception of its spatial orientation. Much more common than the 'orientation error' accident are those incidents in which the aviator has to resolve sensory conflict (e.g. he may feel that he is flying in a wing low attitude, but instruments tell him that he is wings level). Commonly, the conflict between correct and false information is resolved and control of the aircraft is not impaired in any way. Nevertheless, it is known from anecdotal reports that conscious attention to conflicting sensations definitely degrades the aviator's ability to deal efficiently with other aspects of the flying task.

All aircrew have spatial disorientation at some time or other during their career. Indeed, the presence of a sensation which is in conflict with the true orientation of the aircraft is a quite normal, physiological response to particular aircraft motions. However, the nature of the false sensation, its intensity, and the ease with which orientational conflict is resolved do, of course, differ widely, as does the frequency of occurrence of incidents (Clark, 1971). Some pilots may be aware of disorientating sensations on almost every flight, others may be troubled only once in every 50 or even 100 sorties (Aitken, 1962).

A good deal less frequent are those incidents in which the pilot has allowed his control of the aircraft to be based entirely on a false perception of aircraft orientation. Fortunately, the pilot usually detects the disorientation on checking instruments, and re-establishes appropriate control once the conflict between erroneous and correct cues has been reconciled. However, situations do occur in which the pilot fails to realise that control is based on false cues, or finds out too late to take corrective action. Such is the orientation error accident. Available figures suggest that in military aviation some 5-10% of all accidents are caused by spatial disorientation and these make up 5-20% of all fatal accidents (Moser, 1969; Barnum & Bonner, 1971; Lofting, 1971; Hixon et al, 1971). In private flying, excluding commercial flying, spatial disorientation probably accounts for a considerably greater proportion of the aircraft accidents. For example, US general aviation accident statistics, 1964-72, show that the three categories: 'became lost/disorientated', 'spatial disorientation' and 'continued flight into weather' accounted for 37% of all fatal accidents. It is also worthy of note that in both military and private aviation the proportion of accidents attributed to spatial disorientation has remained relatively constant over the past decade. Disorientation also features in other accidents which have, as a prime cause, some other factor, such as the failure of an aircraft system or the impairment of the pilot by alcohol or hypoxia.

Although loss of control and an aircraft accident are the most serious consequences of a false or inadequate perception, it is recognised that the existence of a conflict, commonly between false sensations and correct cues from aircraft instruments, requires the aviator to resolve this conflict and in so doing direct his attention away from other aspects of the flying task. Performance can also be degraded by high arousal and anxiety engendered by perceptual conflict and, in particular, by unexpected and unfamiliar sensations (Benson, 1973). In addition to the false sensations evoked by vestibular stimulation there can be concomitant involuntary movements of the eyes, limbs, and body which may impair vision or more directly interfere with the pilot's control of the aircraft. The importance of such reflex motor responses in the disorganisation of control is at present largely conjectural though gross disturbances of muscular activity, graphically named the 'Giant Hand' phenomenon, have been described (Malcom & Money, 1971).

Apart from the immediate effects of disorientating and dissociative sensations which more or less directly impair flight safety, in a small number of aircrew such perceptual disturbances are the precipitant of anxiety reactions and subsequent loss of confidence by the aviator in his flying ability (O'Connor, 1967; Benson, 1973). The afflicted individual has to be withdrawn from active flying duties, at least for a period, and the service of a highly trained aviator is lost.

Sect. 3. ETIOLOGY OF SPATIAL DISORIENTATION

Over the years, many differing manifestations of spatial disorientation have been reported by aircrew and likewise, the number of factors which are considered to be of etiological significance have proliferated. It is outside the scope of this report to make a detailed analysis of all the causes of spatial disorientation, but it is relevant to consider those aspects of the problem where the training and experience of the aviator have been shown to be, or were thought to be, important.

A general outline of the etiology of spatial disorientation is given in a proposed syllabus of lectures to aircrew in Annex C.2. As may be seen, this is divided into four groups, namely:

i The flight environment

ii Flight manoeuvres

iii Aircraft factors

iv Aircrew factors

These are not mutually exclusive; for example, the 'training, experience and proficiency' of the aviator which appears as a factor in Group iv, will materially influence the probability of occurrence of spatial disorientation in a particular flight environment or manoeuvre. Thus a pilot who rarely flies other than in good weather, when external visual cues are unambiguous (Visual Meteorological Conditions (VMC) syn. Visual Flight Rules (VFR)) is more likely to suffer from disorientation when he encounters adverse weather conditions than the pilot who is in current instrument flying practice (Collins, 1970).

The ability of aircrew to cope with conflicting orientation cues, or what may be termed disorientation stress, is dependent upon many factors. If inter-subject differences, attributable to personality and psychological factors are for the moment laid aside, then the one which is the most important is the training and experience gained by the aviator in the flight environment. There he learns to make use of those cues which are reliable and to disregard, or at least not be aware of, those cues which are erroneous or inadequate.

Part of this learning process is the selective adaptation or habituation to the inappropriate sensations evoked by linear and angular accelerations peculiar to flight. At a higher level is the acquisition of perceptual skill in the interpretation of visual cues, especially the symbolic orientational cues provided by aircraft instruments. These skills are acquired primarily by experience in flight conditions where the aviator is exposed to disorientation stress; if he never has to resolve conflicting cues then he is unlikely to be able to deal effectively with this problem when it arises. Furthermore it should be emphasised that the perceptual skills which minimise the aviator's susceptibility to disorientation once 'learned' are also 'forgotten' if proficiency is not maintained by repeated practice. Aircrew have consistently reported that they were more likely to suffer from spatial disorientation, expressed as a heightened awareness of illusory sensations, when they returned to flying duties after a few weeks on the ground (Aitken, 1962). There is some evidence that this is caused by a loss of habituation (Aschan, 1955) though it is likely that changes in attentional and cognitive mechanism also occur during the period away from flying. In contrast, the occurrence of an orientation error <u>accident</u> does not appear to be related to recent flying experience (Barnum & Bonner, 1971).

Whereas training, experience and proficiency in flight play a dominant role in determining how the aviator will respond to disorientation stress, the fact remains that the perceptual disturbances, embraced by the term spatial disorientation, are protean. Some types of disorientation occur only rarely (e.g. pressure vertigo*), yet can cause a severe impairment of control because of their intensity, unexpected occurrence or unfamiliar nature. Even highly trained aviators who have not had personal experience of certain types of disorientation can also succumb in the same manner as their less experienced brethren.

So far consideration has been given only to the training received by aircrew in flight, but knowledge gained from ground based instruction can materially influence the probability of occurrence of spatial disorientation and the ability of the aviator to recognise and cope with the problem should it arise. It is considered to be of particular importance that the student aviator should appreciate the limitations of sensory function that cause disorientation and the flight conditions and manoeuvres which are likely to reveal the perceptual fallability of the aviator. To be forewarned is to be forearmed. With appropriate instruction the student aviator is less likely to be jeopardised because of his limited skill.

Instruction can also help the aviator to recognise disorientation if and when it occurs in flight, so that correct procedures are followed in order to resolve conflicting cues and to ensure that control is not based on incorrect or inadequate information. Admittedly the pilot with many flying hours will have learned about some of the manifestations of disorientation and their cause from his own practical experience, but because of the protean nature of the condition he is unlikely to have personal experience of every type of illusory perception that aircrew have reported. For example: the pilot who has flown on

* Also called alternobaric vertigo.

operational duties for several years may have had 'the leans' many times and be quite familiar with the disorientation on breaking formation in cloud, yet even such a highly trained and experienced aviator can be acutely disturbed by the sudden and unexpected occurrence of the unfamiliar sensations of, say, the 'Break-off phenomenon'.

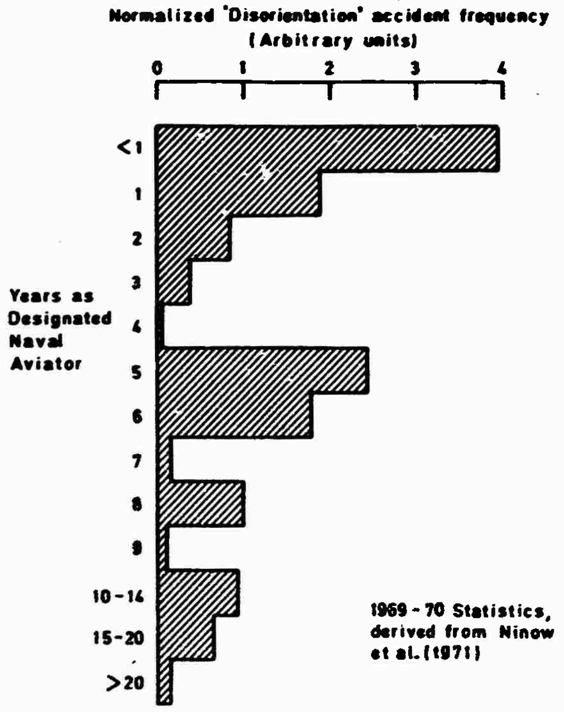

Fig. 1 Effects of flying experience on 'disorientation' accident rate in USN Fighter-attack pilots

There is thus a need for the more experienced aviator as well as the student pilot to be informed and to be kept informed about the problem of spatial disorientation in flight. The necessity for refresher training is substantiated by fig. 1, which shows the frequency of disorientation 'mishaps', normalised for population exposure, plotted against flying experience. The incidence falls rapidly in the first 4 years, but rises again in the 5 and 6 year groups, and subsequently stabilises at about 25% of the initial level. These and USAF statistics (Moser, 1969) support the generalisation that the probability of an aviator suffering an orientation error accident decreases with flight experience, but also emphasise the fact that even highly experienced aircrew are at risk. Some aircrew claim that flight experience gives them first hand knowledge of the problem and that they have learned how to overcome disorientation, accordingly they conclude that they do not require further training or education about the hazards of disorientation. However, it is a belief such as this which can induce a false sense of security and obscure the fact that flight experience does not give immunity from orientation error accidents.

RECOMMENDATION (3:1). Orientation/disorientation training should not be restricted to student aircrew. Experienced aircrew also suffer orientation error accidents and hence should be given regular refresher training about the hazards of disorientation. (p. 8)

Sect. 4. REVIEW OF ORIENTATION/DISORIENTATION TRAINING IN NATO COUNTRIES

Members of the Working Group had personal opinions on the merits and deficiencies of the training received by aircrew in their parent organisations, but no overall view of the policies and practices throughout the NATO alliance was available. Accordingly, in the first quarter of 1977, all member countries were sent a questionnaire which attempted to determine the type and duration of instruction given to aircrew and which solicited comments on the adequacy of the training received. Copies of the questionnaire were also sent to civil aviation authorities in the USA and Europe.

The form of the questionnaire is shown in Annex B. Most of the questions required answers which were statements of facts relating to:-

The formal instruction of aircrew about problems of orientation and disorientation in flight.

The topics covered in lectures.

The duration of such lectures and the phases of flight training in which the training is given.

The use of disorientation demonstrations or familiarisation devices.

The use of visual aids.

The demonstration of disorientation in the air during flying training, and subsequent refresher training.

Instrument flying experience during training and requirements for maintenance of instrument flying rating.

In addition, open ended questions requiring value judgements on the adequacy of current training procedures were asked which permitted the 'official' position, as well as the personal opinion of the respondent to be given.

Twenty-six completed questionnaires were returned from nine European countries, from Canada and from the USA. These revealed the training policy in military aviation of ten countries and in civil aviation in three countries.

A summary of the responses to the questionnaire is assembled in Table 1.

The most notable feature to emerge from an analysis of the completed questionnaires was the absence of any common standard in the orientation/disorientation training of aircrew. Even in the training of military aircrew the hours devoted to this aspect of the ground school instruction of student pilots ranged from 0-8 hr (mean 2.3 hr), while the time allotted in refresher training programmes ranged from 0-6 hr (mean 1.7 hr). Similarly, in civil aviation some organisations gave no instruction on the topic, others devoted 3 hr to the problem during basic training. The disparity between nations and organisations is hardly surprising, though it also became apparent that considerable differences in the duration of training occurred within an individual Service, both in basic flying schools and refresher courses.

Although all but one military organisation devoted some time to ground school lectures, the use of disorientation familiarisation devices was far from universal. This type of training aid was employed by 11 out of 15 service respondents, though in at least three and probably more, not all student aircrew had the benefit of ground based familiarisation training. Five of the military ground schools did not use training films.

In-flight demonstrations of disorientation were employed by only 7 of the 15 Service organisations who returned the questionnaire, all but 2 repeating the demonstration in refresher training programmes. In contrast, the majority of the civil transport organisations, other than in the USA, made use of flight demonstrations in the basic programmes.

TABLE Ia

Responses to Items
in the
Questionnaire on Orientation/Disorientation Training

Responding Organisation	1. Formal Instruction	2a. & b. Lectures with Standard Topics	2c. & d. Hours Allotted	2e. Trained Aircrew	2f. When	3a. Ground Demos	3b. Form of Demo: Standard	3b. Form of Demo: Other	3c. All Students	3d. Repeated	3e. When	4a. Films	4b. Film Titles	4c. With Lectures
U. S. Navy	Yes	Yes	Basic: 3 Refresh: 1	Yes	3 yrs.	Yes	When Available	Vision & Lighting	Yes	Yes	3 yrs.	Yes	1-7	Yes
U. S. Army	Yes	Yes	Basic: 1 Specialty: 1	Yes	Conversion	Yes	Yes		No	Yes	Conversion	No	---	---
U. S. Air Force	Yes	Yes	1-4	Yes	3 yrs.	Yes	Yes		Yes	Yes	3 yrs.	Yes	7, 8	Yes
7 Major U. S. Airlines	1: Yes 6: No	1: Aircraft operating procedures 6: None	1: 3 6: None	1: Yes 6: No	1. Refresher; conversion 6: No	1: Yes 6: No	None	Operating procedures	1: Yes 6: No	1: Yes 6: No	1: Semi-annual proficiency checks 6: No	Yes	1: 10, 11 6: 9	1: Sometimes 6: No
RCAF Canada	Yes	Yes	Basic: 2	Yes	3 yrs.	Yes	Yes		Yes	Yes	3 yrs.	Yes	7, 8	Yes
Italy	No	None	None	No	No	No	None	None	No	No	No	No	---	---
Lufthansa	Yes	Maps & Weather	Many on Navigation	Yes	?	Yes		Mapwork & Navigation	Yes	Yes	Check Flights	No	---	---
Luftwaffe	Mil: Yes Civ: No	Yes	Basic: 3 Refresh: 1½-3	Yes	3 yrs.	Yes	Yes		Yes	Yes	3 yrs.	Yes	6, 7	Yes
Royal AF Netherlands	Yes	Yes	Basic: 2 Adv: 2	Yes	1½ yrs.	Yes	Yes	Centrifuge	Yes	Mostly	1½ yrs.	Yes	7	Yes
Middle Wallop (Army)	Yes	Yes	Basic: 1½	Yes	Not Routine	Yes	Yes		No	No	Not Routine	No	---	---
U. K. Prof. Pilots	Yes	Yes	Basic: 1	No	No	No	None	None	No	No	No	Yes	7, 8	Yes
BEAI & BOAC Pilots	Yes	Yes	Basic: 2	Yes	Initial Type; Conversion	No	None at Present		No	No	No	Yes	6, 8	Yes
U. K. Private	Little	Yes	Basic: 1 (if at all)	Some	Rarely	No	None		No	No	No	Some	7, 8	Yes
R. N. Air Med. School	Yes	Yes	Basic: 3	Yes	4 yrs.	Yes	Under development		Yes	Yes	4 yrs.	Yes	7, 8	Yes
RAF Brampton	Yes	Yes	Basic: 2 Refresh: 1	Rarely	Basic: Refresher	Yes	Yes		No	No	No	Yes	8	Yes
Armee de l'Air	Yes	Yes	Basic: 1 Adv: 10 min. Op Units: periodically	No	No	No		Photos	No	No	No	No	---	---
Portugal	Yes	Yes	Course: 2	Yes	During Courses	No	None		No	No	No	No	---	---
Denmark	Yes	STANAG 3114	Basic: In Canada Adv: 2	Yes	3 yrs.	No	None		No	No	No	Yes	Several U. S.	Yes
Norway	Yes	STANAG 3114	Basic: 1 (USAF) Adv: 2	Yes	3 yrs.	Yes		Simulator	Yes	Yes	1 yr.	Yes	7, 8	Yes
Turkey	Yes	Yes	Basic: 6-8 Adv: 3-6	Yes	3 yrs.	Yes	Yes		Yes	If Needed	3 yrs.	Yes	6, 8	Yes

TABLE Ib

**Responses to Items
in the
Questionnaire on Orientation/Disorientation Training**

Responding Organization	6a. Flying Practice Instrument	6b. IFR Trained Aircrew
U. S. Navy	Basic & Advanced (actual airborne instrument flight) Student Heli: 69.3 hr. Student Prop: 72.8 hr. Student Jet: 74.1-74.5 hr.	Instrument Rating: 12 hr./yr. Night Proficiency: 12 hr./yr. (can be combined)
U. S. Army	Basic Rotary Wing Instrument and hood: 42.5 hr. Simulator: 7.5 hr.	Annual Instrument Flight Examination
U. S. Air Force	Simulator: 20 hr. Instrument training: 100 hr.	Instrument: 10 hr./6 mos. minimum Also certain instrument approaches
7 Major U. S. Airlines	3: All as considered 1: 4-10 hr. depending on aptitude 1: 18 hr simulator & aircraft 1: 12 hr. simulator & 4 hr. aircraft 1: 4 hr.	4: No minimum specified 1: 8 hr./yr. 1: Captains--3.5 hr. simulator & 1 hr. aircraft; First Officers--2.25 hr. total simulator and aircraft 1: Captains--6 hr. simulator & 1 hr. aircraft Co-Pilots--4 hr. simulator & 1 hr. aircraft
RCAF Canada	Approximately 45 hr.	20 hr./yr. minimum
Italy	None	None
Luft-hansa	PPL: 5 hr. & 10-15 hr. Link CPL: 20 hr. Link IFR: 60-65 hr. flight & 20 hr. Link	Nearly all flights are IFR
Luft-waffe	Same as USAF	20 hr./yr. (10 hr./last 6 mos.), at least 4 hr. at night with 3 hr./last 6 mos.
Royal AF Netherlands	Basic: 30 hr. under hood; 30 hr. simulator Adv.: .5 hr. under hood; 20 hr. simulator	2 sorties each 1 hr./month under hood 1.5 hr./mo. simulator 2 hr. actual & 8 hr. simulated/6 mos for maintaining instrument rating
Middle Wallop (Army)	Rotary: 10-15 hr. Basic Fixed: 4-5 hr. Adv. Fixed: 50-65 hr.	Rotary & Fixed: 5 hr./6 mos. actual or simulated; 6 instrument approaches and at least 50 hr. of first pilot time
U. K. Prof. Pilots	Commercial: 10 hr. Instrument: 40 hr.	No specific (line flying)
BEA & BOAC Pilots	Basic: 100 hr. Trained Pilots: Varies with legislation	No specific
U. K. Private	None for PPL	None
R. N. Air Med. School	---	---
RAF Brampton	Instrument flying: 26 hr.	1 hr./month for last 6 mos.
Armée de l'Air	Basic: 5 hr. actual; 2 hr. IFR nav.; 28 hr. under hood Adv.: 25 hr. (incl. 2 hr. actual)	100 hr. on type At least 10% night flying/yr.
Portugal	---	---
Denmark	Airborne instrument flying: 94 hr.	8-12 hr./mo.
Norway	Basic: USAF Initial Norway & yearly continuation	20 hr./yr.
Turkey	Dual command: 4 hr. under hood Dual or single: 3 hr. in clouds + 3 hr. IFR	Transport: 20 hr./yr. (10 hr./last 6 mos.) Jet: 14 hr./yr. (includes [illegible] hr. GCA and 7 hr./last 6 mos.)

NOTES:

Responding Organization. Lufthansa interpreted disorientation to be "getting lost" and emphasized navigational instruction.

Items 2a & b. Standard Topics refers to anatomy and physiology of the equilibrium organs, specific sensory illusions, and causes and effects of disorientation.

3b. Standard Ground Demonstration refers to a vertical axis rotation device (usually a chair or table) which is used to provide accelerations and decelerations; head movements of a subject are made during rotation of the device or following rotation.

4b. Numbers indicate the following films:

1. Vision in Military Aviation (USN: MN9480B)
2. Vision in Military Aviation--Sense of Sight (USN: MN9480A)
3. Vision in Military Aviation--In Flight Recognition and Closure (USN: MN9480C)
4. Vision in Military Aviation--Errors in Vision (USN: MN9480D)
5. Disorientation Crashes (USN: MN4353C)
6. Spatial Disorientation in Flight (USAF: MV9604)
7. Perception of Orientation (RCAF)
8. Pilot Vertigo (USAF: FLC-22-0033)
9. Upset (FAA). Note: This film deals primarily with problems associated with aerodynamics of flight, high altitudes, and high and low speed buffets.
10. Attitude Flying (TWA)
11. The Visual Approach (TWA)

5b. Standard In-Flight Demonstration usually refers to exposing the student to an unusual attitude of the aircraft (or to disorientation) while the student's eyes are closed; the student is then required to open his eyes and recover by using instruments (or to simply perceive the illusion).

TABLE Ic

Responses to Items
in the
Questionnaire on Orientation/Disorientation Training

Responding Organisation	5a. Flight Demos	5b. Form of Demo: Standard	5b. Form of Demo: Other	5c. Trained Aircrew	5d. Form of Demo	7a. Adequate Program	7b. Inadequate How	8a. Personal Opinion Same	8b. How Opinion Differs	9a. & b. Additional Comments
U. S. Navy	Yes	Yes	Mask Instruments	Yes	Same as 5b.	No	Poor classroom demo techniques	Mostly	Chair demos are inadequate	There is need for a superior type of training device.
U. S. Army	Yes	Yes	Leans	No	----	No	Insufficient demos; no continued training	Yes	----	Need to know illusions which apply to rotary-wing aircraft.
U. S. Air Force	Yes	Yes		Yes	Same as 5b.	Yes	Need simulator with fly-out controls	Mostly	There is no standardization of training	Too much effort in basic research, not enough applied.
7 Major U. S. Airlines	6: No 1: Yes	---	Instrument Practice	6: No 1: Yes	Same as 5b.	Yes	----	Yes	----	Pilots employed are all highly experienced. All En Route flying is done on instruments.
RCAF Canada	Yes	Yes	---	Some	Same as 5b.	Flying: Yes Academic: ?	Academic not sufficiently up-to-date or operationally oriented	No	Needed: Academic updating, flight orientation to teaching, program of demos and flight sequences	Flying-oriented simulator needed (for both fixed and rotary wing).
Italy	No	---	---	No	----	No	Problem not yet solved	Yes	----	Currently planning a program and film.
Lufthansa	Yes	Navigational Tracking		Some	Same as 5b.	Yes	----	No	----	Good training will eliminate any problem of orientation.
Luftwaffe	Yes	Yes		No	----	No	Civilian not same as military	Yes	More emphasis needed on training	None.
Royal AF Netherlands	No	---	---	No	----	No	Demonstrations are limited	No	----	None.
Middle Wallop (Army)	No	Yes		Some	Same as 5b.	No	Need general approval that training is necessary	No	----	Need greater overall awareness that training is necessary for **all** aircrew.
U. K. Prof. Pilots	Yes	Yes		Only one illusion	Dutch roll	Yes	----	Yes	Too little lecture and airtime	Medical Branch publishes a circular on disorientation.
BEAI & BOAC Pilots	Yes	Yes	Limited Acrobatics	No	----	Yes (but)	Wish to use demonstrators	No	----	None.
U. K. Private	Some	Occasional		No	----	Yes for PPL	----	Yes	Should require some IP & 1 lecture for PPL	DTI publishes a disorientation information circular.
R. N. Air Med. School	No	---	---	No	----	Yes	----	No	----	Advice Service (training) is provided to all crews.
RAF Brampton	Yes	Yes		No	----	Yes	----	No	----	Lack of teaching aids/demos and films makes explaining illusions difficult.
Armée de l'Air	No	---	---	No	----	Yes	----	---	----	FAF thinks that line training is better than any instructional device.
Portugal	No	---	---	No	----	No	It is only theoretical	---	----	None.
Denmark	No	---	---	No	----	Yes	----	Yes	Need more lectures and inflight demos	None.
Norway	Yes	Yes		Yes	Same	Yes	----	No	----	After USA training, all pilots must pass Operational Training Unit Course.
Turkey	Yes	Yes		Yes	In flight for ratings	No	Need demonstrators	No	Need demonstrators	None.

Eight returns from organisations concerned with the training of military aviators expressed the opinion that inadequacies existed in their orientation/disorientation training. In contrast, all the civil organisations questioned considered their training programmes to be adequate, though 3 out of the 5 implied that improvements could be made by the introduction of familiarisation training or by devoting more time to the topic in lectures. The need for demonstration devices or improvement of existing demonstrations was also expressed by 6 of the military respondees.

Overall, all but 9 of the 26 questionnaires returned contained comments which indicated that deficiencies existed, or were thought to exist, in current training programmes. Surprisingly, these all related to the ground school phase of training; there was no criticism of instrument flying training despite the widely differing standards and experience required during basic training and for the maintenance of an instrument rating. It was however worthy of note that one Service organisation placed more emphasis on in-flight experience acquired during normal flying training and line duties than on ground school instruction, although not to the complete neglect of the latter.

Replies to the questionnaire thus substantiated the opinions expressed by members of the Working Group during the first meeting, namely: that deficiencies existed in the orientation/disorientation training of aircrew and that improvements could, and should, be made to the instruction received during basic training and subsequent refresher courses, both in the air and on the ground.

Sect. 5. OBJECTIVES OF ORIENTATION/DISORIENTATION TRAINING

(a) Basic Objectives

The objective of training procedures in this field is to prevent or at least reduce the impairment of operational efficiency consequent to spatial disorientation in flight. The deleterious effects of illusory perceptions on aircraft control and aircrew health have been discussed in Section 2 so the basic objectives of training may be summarised:

i To reduce, and ideally prevent, orientation error accidents.

ii To reduce the frequency of incidents in which control of the aircraft is degraded as a result of disorientating perceptions or reflex interference with neuromuscular control.

iii To reduce the frequency with which the mental and physical health of aircrew is impaired by exposure to disorientation stress or unusual perceptual experiences and thereby reduce attrition of flight personnel from these causes.

(b) Specific Objectives

The importance of flying personnel having adequate knowledge about the etiology and manifestations of spatial disorientation and adequate skill to cope with the disability in flight, were mentioned in Section 3. Hence the specific objectives of training may be summarised:

i To familiarise the aviator with those factors which contribute to effective spatial orientation in the flight environment.

ii To familiarise the aviator with the various conditions and flight operations which may lead to spatial disorientation.

iii To inform the aviator about different manifestations of spatial disorientation, and how to detect the onset or existence of spatial disorientation.

iv To explain the mechanisms by which spatial disorientation is produced and to discuss normal limitations of sensory functions.

v To inform the aviator how disorientation may be overcome and to develop the necessary skill so that he can cope with disorientation when it occurs in flight, even when he is subjected to mental and physical stress.

(c) Training Methods

Aircrew usually receive instruction about spatial disorientation both on the ground and in the air. Ground based training falls within the general area of aeromedical education and is commonly the responsibility of Medical Service personnel. In contrast, training in flight is performed by flying instructors and is integrated into the instrument flying training programme. Although this is a convenient and in some respects logical dichotomy, in the past there has been little communication between the two groups responsible for aircrew orientation/disorientation training and hence a lack of an integrated approach to the problem. While accepting the premise that training on the ground should complement that received in the air (and vice versa) and that they have common objectives, the techniques employed, the knowledge imparted, and the skills acquired in these two phases are different and hence require separate assessment.

RECOMMENDATION (5:1). Orientation/disorientation training should be given both on the ground and in the air. In each Service or Organisation those responsible for the ground school phase of training should discuss the overall programme with those responsible for flying training and together they should develop an integrated syllabus appropriate to the needs of the flying personnel for whom they are responsible. (p.14)

Sect. 6. GROUND BASED TRAINING

In this phase of instruction the emphasis is upon aircrew receiving factual knowledge about differing types of illusory perceptions occurring in flight, the etiology of spatial disorientation, and how to cope with the problem in flight. In addition, it is important that didactic information about disorientation is put in proper perspective and related to the mechanism of correct spatial orientation in the flight environment.

The Working Group is aware of the opinion, expressed by some personnel concerned with the aircrew training, that specific instruction about spatial disorientation should not be given to student aircrew. They argue that the trainee pilot will find out all that he needs to know about the problem during the course of in-flight training and that he will learn to deal with it by good airmanship. Furthermore, classroom lectures and demonstrations only serve to make the student more likely to attend to illusory sensations during flight training and for him to become preoccupied with the sensory disturbances.

There is an element of validity in this point of view, especially if lecture material on the topic is presented in an alarmist manner and not put in the proper context of 'normal limitations of sensory function', (a not uncommon failing of some lecturers). However, the members of the Working Group are, for reasons already adduced, unanimous in their opinion that aircrew should be informed, and kept informed, about the potential dangers of disorientating perceptions, if orientation error accidents and incidents are to be minimised.

(a) Instructional syllabus

A detailed syllabus of the factual knowledge about spatial disorientation which, the Working Group consider should be taught to aircrew is given in Annex CII. The topic is divided into seven main headings:-

i Introduction.

ii Mechanism of spatial orientation in flight.

iii Mechanism of spatial disorientation in flight.

iv Commonly described illusions.

v Causal factors (etiology).

vi Practical advice on the prevention of disorientation in flight.

vii Procedures to be followed in flight when afflicted by disorientation.

The syllabus is only a guide, for the emphasis placed on each topic will obviously vary according to the experience of the personnel under instruction, the uature of their operational duties and the time available. However, it is the opinion of the Working Group that the primary need of aircrew is to know:-

i The types of illusory perceptions occurring in flight.

ii The flight conditions and manoeuvres likely to induce spatial disorientation.

iii How to cope with disorientation if and when it occurs.

It is, of course, sound practice to develop the topic upon a scientific basis of sensory physiology, but where time is limited it is better to emphasise the practical implications of the problems, as outlined above, than to give a detailed description of the anatomy and physiology of the vestibular receptors. However, it is important to emphasise the fact that illusory sensations are common and quite normal responses to the motion stimuli and sensory environment of flight, even though the perceptual disturbance may be of a bizarre and quite unexpected form. In addition, it should be pointed out that some illusions occur because of the lack of information from sensory receptors and, frequently, disorientation is not characterised by sensory conflict and strong misleading vestibular cues.

Aircrew should never hear about the illusions occurring in flight and the consequences of disorientation without hearing also the instructions for how to deal with the problem in flight. This aphorism should be remembered by all responsible for the disorientation training of aircrew.

(b) Teaching Techniques

A number of educational methods are suitable for imparting knowledge about spatial disorientation to aircrew. They are:-

Group Instruction

i The formal lecture.

ii The lesson (with student/teacher interaction).

iii The discussion group.

iv Projected transparencies with:-

1. Commentary spoken by instructor.
2. Commentary on tape (tape/slide presentation)

v Videotape with commentary.

vi Cine film.

Individual Instruction

i Written information (books, pamphlets etc).

ii Written information with self assessment.

iii Programmed information, either written or in slide format with recurrent self-assessment.

The pedagogic and economic advantages and disadvantages of these various methods are well known to educationalists hence a detailed assessment is not presented here. However, certain points were considered in detail by the Working Group and opinions expressed which are reflected in this report.

(c) Instructor Competence

The effectiveness of teaching by lecture, lesson, group discussion, or live commentary is vitally dependent upon the competence of the instructor. Apart from clarity of expression he should have an adequate depth of knowledge to understand and answer correctly and effectively the student's questions. Not only is it important for him to have rapport with his students but also an appreciation of the practical problems sufficient to preserve credibility with his aircrew audience. The ability of the instructor to 'put over' his subject is a necessity irrespective of the subject being taught. Yet in aeromedical training, the Working Group are aware of the deficiencies of certain instructors, whether they be medical officers, physiological training officers, or others without medical qualifications, when attempting to teach aircrew about orientation and disorientation in flight. One defect, a lack of adequate and correct factual knowledge, probably reflects the lack of text-book material on the topic. Another is the absence of 'hardware' to provide a tangible expression of the subject material, a deficiency which does not exist when instructing on the environmental stresses of flight where personal and safety equipment can be demonstrated.

(d) Visual Aids

Whenever possible the spoken word should be complemented by appropriate visual material. This may be in the form of:-

i Wall charts.

ii Projected images from:-

Overhead projector transparencies (Viewgraph)
Slides
Film Strips
Cine film

Transparencies and slides are usually prepared at a local level and vary in quality with the skill and resources available. Many centres have slides and transparencies which are used by their training officers, but there are few sets of slides which have been developed as an 'educational package' suitable for more general use. Two sets of slides available for review by the Working Group had been prepared by the USAF, and one set by the American FAA. It was concluded (see Annex D) that the FAA set called 'Vertigo' was the most suitable for instructing aircrew. The need for a competent commentator capable of understanding and answering the students' questions is not abrogated by good visual material.

To date the potential of the overhead projector has not apparently been developed as an 'instructional package' on spatial disorientation. Overlap techniques permit the progressive synthesis of the more complex topics, while simple animations are of value to explaining the dynamics of receptor mechanisms and the development of illusions in response to angular and linear motion stimuli.

Similar comments can also be made about the use of video tape, which apart from initial cost, offers a flexible and fairly cheap instructional medium for use with small to large groups of students. It can be viewed in an illuminated room, has stop motion facilities, and can be replayed without difficulty.

Motion pictures are well established both as an adjunct to an instructional lecture and as a basic means of education. Members of the Working Group viewed fourteen films and assessed their effectiveness in teaching military pilots to cope with disorientation problems (Annex D). In their opinion none of the films laid sufficient emphasis on what the pilot should do when he recognises or suspects disorientation, though a number gave a reasonably clear accurate description of the more common illusions experienced by pilots. They reported that two films 'Perception of Orientation' (RCAF 22C25) and 'Upset' (FAA.FA611) are the most suitable for the training of military aircrew). Some members of the Working Group expressed reservation about the general use of the FAA film about Jet Upset in aircrew training. Though a well made film, with high interest and acceptability to aircrew, it is long (45 min) and devotes only a few minutes to the problems of disorientation in rather specific flight conditions.

None of the films reviewed were without defect, hence there is a need for a better film (or films) to be made. It is arguable that an improved film would significantly increase the effectiveness of training of student aircrew, in comparison with the use of those already available. However, the relative paucity of good material presents a severe limitation on the use of films as an effective tool for the refresher training of more experienced flying personnel.

(e) Individual Instruction

The basic means of individual instruction is by the written word, assembled in the form of a pamphlet, report or book. Yet despite a fairly large literature on spatial disorientation and relevant aspects of sensory function, this information is mainly to be found in scientific journals and research reports. There are few succinct reviews of the topic and even fewer written primarily for aircrew. The needs of the aviator are nominally catered for in aeromedical training notes, but in the opinion of the Working Group these were generally inadequate because of the superficial treatment of the topic and lack of positive practical information on how to recognise and cope with disorientation in the air. In addition, many contained errors of scientific fact and did not reflect current informed opinion about the problem.

An attempt has been made to redress this deficiency through the publication by AGARD of 'Spatial Disorientation in Flight: A Handbook for Aircrew' (Benson & Burchard, 1973). This is probably too detailed for casual reading though it should prove useful as a source book for instructors and those aircrew who wish to explore the topic in greater depth

The use of programmed learning techniques has attracted considerable attention in recent years. The method is certainly applicable to orientation/disorientation training, though it has not yet found a place in routine training, despite its being a relatively inexpensive addition to the pedagogical armamentarium. The Working Group is aware of the assay of such techniques by two Services in the USA. Both programmed texts, allegedly, were inadequate because they contained errors and ommissions, directly attributable to a lack of factual knowledge and understanding of the problem by those responsible for the preparation of the texts. There is thus a need for collaboration of those with specialist knowledge about spatial disorientation with educationalists, who have experience of programmed learning and teaching, in order to produce effective texts for use in both basic and refresher training.

RECOMMENDATION (6:1). Instruction on spatial disorientation should be included in the syllabus of basic aeromedical training of all student aircrew, both in military and civil aviation. The opinion that adequate knowledge on this topic will be gained during flight training is not justified. (p.14)

RECOMMENDATION (6:2). Lectures and lecture/demonstrations on orientation and disorientation in flight should endeavour to cover the specimen syllabus detailed in Annex CII. (p.14)

RECOMMENDATION (6:3). When the time available for instruction is limited it is better to emphasise the practical implications of spatial disorientation than to describe vestibular and other sensory mechanisms. (p.15)

RECOMMENDATION (6:4). Aircrew should never hear about disorientation without being given instruction on how to deal with the problem in flight. (p.15)

RECOMMENDATION (6:5). **Those engaged in the orientation/disorientation training of aircrew should themselves be well informed on the topic and be capable of answering relevant questions posed by their students. AGARDograph 170 'Spatial Disorientation in Flight' is recommended as a source book. (p.17)**

RECOMMENDATION (6:6). **Visual aids should be employed. The FAA slide set "Vertigo" and the film 'Perception of Orientation' (RCAF 22025) are recommended for English speaking aircrew. (p.16)**

RECOMMENDATION (6:7). **Consideration should be given to the development of a programmed text on spatial disorientation for aircrew training which is factually accurate. Audiovisual techniques or a printed text could be employed. (p.17)**

Sect. 7. SPATIAL DISORIENTATION FAMILIARISATION

(a) Benefits of Familiarisation Training

One of the problems in disorientation training is that the topic is a psychological one, in so far as it describes aspects of human perception in the aviation environment. It lacks the immediate relevance of topics such as hypoxia or the effect of sustained linear accelerations, because there is no hardware, e.g. oxygen masks, anti-g suits, etc, which the student is obliged to understand if his safety in flight is not to be impaired. At the end of a 'traditional' lecture on spatial disorientation it is known (Collins, 1970) that a proportion of the audience is likely to feel that the topic is not of personal consequence in flight. No doubt they accept that some accidents are caused by illusory perceptions, but that this is something which weaker or less able aviators suffer, not themselves.

Strong or persuasive verbal instruction can instil, to some extent, a more realistic attitude to the problem, but it is the experience of the Working Group that practical experience and demonstration of illusory perceptions in the teaching situation is a more powerful technique. The student can discover for himself that errors of perception are a quite normal response to certain motion stimuli, while the comments and experiences of colleagues reinforces the generality of these perceptual limitations. In addition, a demonstration gives the instructor more tangible evidence of man's perceptual limitations which he can use to draw attention to the significance of spatial disorientation in the flight environment. Accordingly, it is argued that the use of a device which allows students to be familiarised with some aspects of disorientation, without the distractions associated with flying an aircraft, is a most useful adjunct to training. Disorientation familiarisation devices of one type or another have been employed in the instruction of aircrew and medical personnel by the majority of the members of the Working Group who have found that this form of teaching demonstration was enthusiastically accepted by students and instructors alike (Collins, 1970; Dowd et al, 1970). The demonstration need not be time consuming; a quite adequate familiarisation experience can be given in 10-15 min.

(b) Cost-effectiveness of Familiarisation Demonstration

Before discussing in detail the advantages and disadvantages of the various familiarisation devices employed, which range from a simple rotating chair (of the Bárány type) at one end of the cost/complexity scale to a centrifuge with fully gimballed cab at the other, it is necessary to consider the various types of disorientating perceptions reported by pilots and the feasibility of reproducing these illusions in the laboratory or classroom.

Table 2 summarises the opinions of the Working Group and indicates the basic equipment required to produce relevant illusions on the ground, the consistency or reliability of evoking the false perception in student aircrew, and the cost/effectiveness of the demonstration. The value judgements implicit in the assessments of cost/effectiveness relate primarily to the effectiveness of the demonstration, in so far as the majority of the students will experience and be made aware of the illusory perception, rather than to

TABLE 2

FEASIBILITY OF REPRODUCING FLIGHT ILLUSIONS ON THE GROUND

Category of illusion	Basic feature of illusion	Elicitability of illusion	Basic equipment required	Cost and complexity	Cost/effectiveness
Visual					
Autokinesis	Movement of isolated light or of observer.	High	Isolated light in dark room.	Low	High
Autorotation (flicker vertigo or circular vection).	Rotation of observer in plane of visual stimulus.	High	Large field opto-kinetic stimulus.	Low → Mod	High
Cloud leans, lean on the sun & related illusions.	Body attitude related to false visual reference	Zero → Low	Large field horizon and rotation in roll.	Mod	Low
Misinterpretation of ext. visual cues, esp. lights at night.	False perception of attitude.	Zero → Low	Synthetic night V.F.A.	High	Low
Vestibular (Angular)					
Subthreshold stimuli.	Failure to perceive motion.	High	Smooth turntable with controlled angular acceleration.	Mod → High	Mod
Somatogyral illusions.	False perception of angular motion.	High	Variable speed turntable.	Low → Mod	High
Oculogyral illusions.	Apparent displacement & motion of fixed light source.	High	Variable speed turntable and simple visual display.	Low → Mod	High
Impairment of vision by nystagmus (and effect of alcohol).	Blurring of vision as in spin and on recovery.	High	Variable speed turntable and simple visual display.	Low → Mod	High
Cross-coupled stimulation (Coriolis).	False perception of angular motion and attitude.	High	Turntable with constant speed.	Low → Mod	High
Pressure vertigo	Vertigo on change in ambient pressure.	Zero → Low	Decompression or compression chamber.	Mod → High	Low
Vestibular (Linear)					
Somatogravic illusions.	False perception of attitude, in pitch or roll.	High	Turntable with subject >1m from centre or centrifuge.	Mod → High	Mod → High
Oculogravic illusions.	False perception of motion & position of light source.	High	Turntable with subject >1m from centre or centrifuge.	Mod → High	Mod → High
Elevator illusion.	False perception of motion & position of light source with vertical acceleration.	High	Vertical motion device.	High → V. High	Low → Mod
'Jet upset'	Pitch attitude change - inversion.	Mod	Centrifuge & control of tangential acceleration & cab. position.	V. High	Low → Mod
'G' excess illusions.	False perception of attitude on head movement.	High Confounded with cross-coupled effects	Turntable with radius arm or centrifuge.	Low → Mod	Mod → High
Leans	False perception of roll attitude.	Low → Mod	Device to give smooth rotation in roll and visual display.	Mod → High	Low → Mod
Leans	Adaptation to changed attitude to gravity vector.	High	Chair with controlled rotation in roll.	Mod → High	Mod → High
Central					
Dissociative sensations.	Break-off phenomenon.	Zero → Low	Sensory isolation and restraint.	Low	Low
'Fascination'	Alteration of direction of attention with task load.	Zero → Low	Psychomotor task with complex display and task loading.	Mod → High	Low
Modification of perception by arousal	Heightened awareness of sensory conflict and impaired resolution of conflict.	Zero → Low	Psychomotor task with complex display and task loading + motion cues.	Mod → High	Low

a specific evaluation of the value of the demonstrations to the operational needs of particular aircrew.

Some illusions can be generated with modest equipment and are experienced by the majority, if not all subjects, hence the cost/effectiveness of the demonstration is high. Most of the 'vestibular' illusions fall into this category with the exception of pressure vertigo and some of the more complex forms of the somatogravic and oculogravic illusions (e.g. 'Jet upset'). Unfortunately, perceptual errors attributable to changes in behavioural state and brain mechanisms, rather than peripheral sensory mechanisms (e.g. Break-off), cannot be reproduced with any certainty in the laboratory especially in the short time available for the demonstration. Likewise perceptual errors in which there is a misinterpretation of visual cues, a common enough occurrence in flight yet inconsistent in a classroom situation, have also to be given a low cost/effectiveness rating. Visual autokinesis and vertigo induced by visual stimuli are relatively simple and reliable demonstrations and can readily be incorporated in the demonstration of vestibular illusions.

(c) Equipment for Familiarisation Training

Over the years rotational devices have been constructed which are suitable for the familiarisation training of aircrew. Some have been used solely for this purpose, others were built primarily for research but have also been employed in training programmes. A detailed description of the machines, purpose built for training, has recently been prepared by Gillingham (1974). A classification of the different types of rotational devices considered to be of utility for familiarisation training is presented in Table 3.

TABLE 3

ROTATIONAL DEVICES WITH UTILITY FOR FAMILIARISATION TRAINING

1. Spin-tables: rotation in one axis only. Subject at or close to axis of rotation

   i Turntable, manually operated

      e.g. Bárány chair
      FAA converted kitchen stool.

   ii Turntable, electrically driven with speed control

      e.g. CAMI Disorientation Familiarisation Device (converted Stille Werner RS.3 rotation device)
      Vertigon (Flight Products Inc)
      Modified Link Trainer
      Research turntables, with precision velocity servos.

2. Rotational devices with more than one degree of rotational freedom
   Subject at or close to axis of rotation

      e.g. USN Human Disorientation Device (HDD)
      USAF SAM Biaxial stimulator
      RAF Desensitisation spin table
      Flight simulators with motion platforms. (Most have limited rotational freedom in all axes, though the GAT I series (Singer & Co) and the old Link Trainers have full rotation in yaw.)

3. Rotational devices with subject at end of radius arm (centrifuge)

   i Subject position fixed

      e.g. USN Slow Rotation Room (SRR)
      USN Coriolis Acceleration Platform (CAP)
      RAF Spatial Disorientation Familiarisation Device (SDFD)
      Research Centrifuge (e.g. Stille Werner CF 10).

   ii Subject aligned to the resultant force vector

      e.g. Research centrifuges.

   iii Subject with rotational freedom relative to centrifuge rotation

      e.g. USAF SAM Spatial Disorientation Demonstrator (SDD)
      USAF SAM Spatial Orientation Trainer (SOT)
      Research Centrifuges and Advanced Flight Simulators (USN Johnsville Centrifuge, NASA Ames Centrifuge S09).

(d) Familiarisation Potential of Training Device

The ability of a particular device to evoke disorientating perceptions depends inter alia upon the degree of rotational freedom, the distance of the subject from a centre of rotation, and the precision of control of the angular motion. A consideration of the several categories of machines which may be used for familiarisation training and the illusions which have a good cost/effectiveness index (as formulated in Table 2) led to the construction of Table 4 where the 'familiarisation potential' of each type of machine is assessed.

i Devices with subject near axis of rotation

The majority of sensory illusions brought about by stimulation of the semicircular canals can be demonstrated by a very simple turntable of the Bárány chair type. However, the introduction of speed control and a powered drive enhances the quality of the demonstration. Sustained rotation at constant speed followed by a stopping stimulus is more easily achieved and the decay of pre- and post-rotational effects can be more reliably shown. In addition, controlled acceleration can be made during rotation and the role of the semi-circular canals as sensors of the change in velocity convincingly demonstrated.

TABLE 4

FAMILIARISATION POTENTIAL OF ROTATIONAL DEVICES

	Subject at centre			Subject at end of radius arm		
	Rotation in yaw only		Rotation in Yaw + rotation in orthogonal axis	Fixed seat	Seat aligned with resultant	Seat with rotation in pitch and/or roll
	Manual spin table	Velocity controlled spin table				
ILLUSION						
Vestibular (Angular)						
a) Sub-threshold stimuli	0	+ (1)	+ (1)	+ (1)	± (1)	+ (1)
b) Somatogyral	+	+	+	± (2)	± (2)	± (2)
c) Oculogyral	+	+	+	± (3)	± (3)	± (3)
d) Nystagmus on vision	+	+	+	+	+	+
e) Cross-coupled stimuli	+	+	+ (4)	+ (5)	+ (5)	+ (4,5)
Vestibular (Linear)						
a) Somatogravic	0	0	0	+	0	+
b) Oculogravic	0	0	0	+	0	+
c) 'G' excess	0	0	0	± (5)	± (5)	± (5)
d) Leans	0	0	+ (1)	±	0	+ (6)
Visual						
a) Autokinesis	+ (7)	+ (7)	+ (7)	+ (7)	+ (7)	+ (7)
b) Auto-rotation (Circular vection)	+ (8)	+ (8)	+ (8)	± (9)	± (9)	± (9)

Key: 0 Illusion cannot be demonstrated; ± Demonstration uncertain or confused;
+ Illusion produced consistently.

Notes

1. Device to have good control of angular acceleration and negligible mechanical cues of rotation.
2. Perception of angular motion confounded by changing force vector.
3. Oculogyral and oculogravic illusions confounded.
4. Cross-coupled stimuli not dependent on volitional head movement.
5. Cross-coupled effects confounded with 'G' excess effects.
6. Note 1. applies to roll motion.
7. Demonstration of autokinesis does not require a rotational device; can be combined with demonstration of vestibular illusions.
8. Requires a simple visual motion display.
9. As 8. but more difficult on a centrifuge.

A manually driven chair must, of necessity, be of light construction and cannot easily be provided with a visual display for the demonstration of visual illusions of vestibular origin or the effect of inappropriate nystagmus on vision. Furthermore, weight restrictions preclude the housing of the subject in an analogue 'cockpit' and hence makes it more difficult for the student and instructor to relate experience in the familiarisation device with that in the flight environment.

In order to produce sub-threshold stimuli without mechanical or auditory cues of motion, greater demands are made on the quality of construction of the device and the precision of control, factors which undoubtedly increase the cost of the familiarisation device. However, the ability to rotate and accelerate subjects without their reporting any sensation of angular movement is a powerful demonstration of the inadequacy of the vestibular system. It can be used to impress upon the student that disorientation, in which there is a failure to detect a change in aircraft attitude, can be as disturbing and disruptive as those more commonly described incidents in which inappropriate sensations are engendered by supra-threshold stimuli. Unfortunately, the exhibition of sub-threshold angular acceleration does tend to be time consuming and hence may have to be omitted from the familiarisation training programme.

The introduction of controlled motion of the subject about roll or pitch axes considerably increases the complexity and cost of the familiarisation device without a commensurate extension of demonstration potential. Admittedly the ability to rotate in roll does allow the 'leans' to be induced by sub-threshold movements and adaptive adjustments of the subject's perception of orientation to the gravitational vertical to be demonstrated, but in order to generate appropriate stimuli a high quality motion system is required. The presence of a second rotational axis also allows cross-coupled stimuli to be generated in a controlled manner, but the dependence of the sensation on head movement is less obvious than when the student has to move his head volitionally. It may be argued (Dowd, 1973b) that the use of a familiarisation device with more than one degree of angular freedom increases the acceptability of the demonstration to aircrew. Undoubtedly, the motion is a little more like that of the real aircraft, but it is incapable of adequate simulation of aircraft motion.

In view of the limited extension of the type of illusion which can be induced by the provision of a second rotational axis, and the fall in cost effectiveness, it was the opinion of the Working Group that for the routine instruction of aircrew a familiarisation device with one axis of rotation was adequate.

ii <u>Devices with subject at end of a radius arm (centrifuges)</u>

The deficiency of familiarisation devices in which the subject is situated close to the axis of rotation is that illusions associated with an abnormal force environment (such as the somatogravic and oculogravic illusions) cannot be evoked. On the ground, the only realistic means of generating a sustained force vector which differs in direction from the gravitational vertical is a centrifuge. The magnitude of the radial acceleration required can be quite low, 0.2-0.5 G being quite sufficient to demonstrate a shift in the perceived vertical. The demonstration device need not be a large and expensive structure such as the human centrifuges found in many research laboratories; a relatively simple device with the subject placed 1-2 m from the centre of rotation will suffice. The seat or cab holding the subject should be fixed with respect to the arm of the centrifuge. A suspended cab which aligns with the resultant is unsuitable for the demonstration of somatogravic and oculogravic illusions, although the complex vestibular stimulus on starting and stopping can generate significant and disturbing sensations as well as motion sickness.

Unfortunately no ground based centrifuge permits of an unambiguous demonstration of the illusions induced by head movements in an abnormal force environment (the 'G excess' illusions) for the presence of angular motion ensures that cross-coupled stimulation of the semicircular canals will occur when the subject moves his head out of the plane of rotation. Nevertheless, despite this compounding of 'G excess' and cross-coupled effects, a device in which the subject is not seated close to the axis of rotation still provides a good demonstration of the disorientation produced by head movement in an aircraft executing angular motion.

Provision of motion in pitch or roll to the subject at the end of the centrifuge arm does not, for reasons already adduced, significantly advance the familiarisation potential of the device. Likewise, the ability to alter the distance of the subject from the centre of rotation while the device is in motion (as in CAP) increases the cost and complexity of the equipment without commensurate enhancement of its utility for aircrew training.

(e) Recommended Characteristics of a Familiarisation Device

From the preceding review of the types of illusions which may effectively be demonstrated to student aircrew and of the equipment required, it is apparent that no one rotational device is ideal for familiarisation training. Nevertheless, there are desirable characteristics for such a training device which, in the opinion of the Working Group, have the following priority:-

Rotation Device

i There should be one degree of angular freedom with rotation about a vertical axis.

ii The device should have a powered drive to give rotational speeds of up to $120^{\circ}/sec$ controlled to an accuracy of approximately 5% of indicated speed.

iii Acceleration and deceleration to be achieved in a reproducible manner without jerks, with maximum and minimum rates of approximately $15^{\circ}/sec^2$ and $\frac{1}{2}^{\circ}/sec^2$ respectively.*

iv Rotation to be as free as possible from mechanical and auditory cues of motion, with no jolt on stopping; auditory masking can be employed if necessary.

v Device to be fitted with emergency brake and circuits to ensure safety of occupant(s).

Subject Compartment

i The device may carry one or more subjects in an enclosed compartment.

ii Each subject to be provided with a visual display, inside the compartment (capsule or cabin), having some similarity to aircraft instruments. The display should have a luminous line which the subject can adjust to apparent vertical or horizontal and an indicator of control stick position.

iii Lighting within the capsule to be controlled externally.

iv Windows in the compartment should permit the subject(s) to see the room in which the device is housed.

v The compartment should be of sufficient size to allow the subject(s) to be seated at a distance of 1 m or more from the rotation axis so that he (they) may experience a radial acceleration of 0.2-0.5 G at the head when the device is rotating at maximum speed. If possible the facility to seat subject(s) close to the axis of rotation should be preserved.

vi Subject(s) to be provided with a safety harness but should have sufficient mobility to make voluntary head movements in pitch and roll planes. Monitoring of head movement (e.g. by closed circuit television (CCTV) or a position indicating device) is desirable.

vii Two way voice communication between instructor and student(s) should be provided.

Demonstration Room

i The room housing the familiarisation device should be capable of being blacked out.

ii It should have on the walls, or on a circular screen surrounding the device, a painted 'horizon' slightly below the subject's eye level. Small light sources which may be seen by the subject(s) from the device should also be provided.

iii If the device holds only one subject, observers in the demonstration room should be able to see, either by direct vision or CCTV, the motion of the rotation device and the movements of the subject within. They should also be able to hear conversation between instructor and student and the verbal reports of sensed motion by the subject.

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* If acceleration is not adjustable it should be approx. $15^{\circ}/sec^2 \pm 2^{\circ}/sec^2$.

(f) Conduct of Demonstration

The procedure to be followed during a demonstration intended to familiarise aircrew with some of the sensory illusions responsible for spatial disorientation will depend upon a number of factors, namely: the type of rotational device employed, the number of students to be instructed, and the time available. Detailed accounts of the procedure followed within the CAMI Disorientation Device (Collins, 1970) and the USAF, SOT (Dowd et al, 1970) have been published; a schedule describing the use of a proposed USN multi-seat demonstrator is given in Annex E of this report. From these accounts several features emerge which are common to most demonstrations and illustrate the manner in which the various illusions may be generated.

The description which follows is fairly detailed, but its length should not be allowed to obscure the fact that the components of the demonstration may be performed sequentially and that the whole procedure need not take more than 15 min.

i Autokinetic phenomena

The subject is put in the cab (or 'cockpit') of the device and all lights, room and cab, extinguished with the exception of a small isolated fixed light, preferably at a distance greater than 2 m from the subject. Subjective reports of apparent motion, either of the target light (visual autokinesis) or of the subject (subjective autokinesis) should be reported within 60 sec. Autokinesis develops more rapidly if the light is turned on and off at about 1 sec intervals, and subjects are made aware before the demonstration begins that the device can rotate.

ii Somatogyral and oculogyral illusions

Effect of angular acceleration. With room lights off and cockpit illuminated the subject is asked to report sensations of movement.

If the machine has good velocity control and negligible mechanical and auditory cues when turning, it is possible to accelerate the device at $0.5^{\circ}/sec^{2}$ up to say $30-40^{\circ}/sec$ without any sensation of turning being aroused. More commonly, a modest (say $5^{\circ}/sec^{2}$) acceleration can be employed to bring the subject to a fixed speed, when the initial angular motion is correctly sensed and may be accompanied by some apparent movement and displacement of target lights or other visual display which rotates with the subject (oculogyral illusion).

Once a constant speed of rotation has been reached the sensation of turning decays as the cupulae of the stimulated canals return to their neutral position. This response can be used, along with the effect of sub-threshold stimuli to illustrate how the semicircular canals provide inadequate or no information during prolonged rotation. When the subject has stabilised at constant speed a short deceleration at $10-15^{\circ}/sec^{2}$ to a lower velocity may be introduced to illustrate how the vestibular system senses the change in angular velocity. The subject will report rotation in the opposite direction to that in which he is still turning. This is apparent to the observers, though room lights have to be switched on to show the subject the erroneous nature of his perception of rotation.

With room lights off, the speed of rotation is increased to $90-120^{\circ}/sec$ at a supra-threshold rate and the opportunity taken to illustrate again the oculogyral illusion. When at steady speed, head movements can be made and the responses to cross-coupled stimulation (vide infra) elicited.

Deceleration of the turntable to rest within a few seconds simulates (in part) the stimulus on recovery from a spin and evokes a strong vertigo with rotation in the opposite direction to the original motion. Characteristic visual disturbances are also produced with initial blurring of vision and then apparent motion and displacement of instruments within the cockpit. The blurring of vision and inability to read a numerical display during the immediate post-rotational period provide a clear demonstration of vestibular control of the eye movements and allows the instructor to talk about the deleterious effect of alcohol on the voluntary suppression of these inappropriate eye movements (Collins et al, 1971).

In the post-rotational period the room may be kept darkened and the duration of the sensation, typically 20 sec or longer, observed. Alternatively, room lights may be switched on to show how unambiguous visual cues suppress or at least shorten the illusory sensation.

iii Cross-Coupled (Coriolis) Stimulation

The sensations produced by cross-coupled stimulation of the semi-circular canals is best demonstrated when the turntable is rotating at constant velocity and all sensations caused by the preceding acceleration or deceleration stimuli have died away. The speed of rotation should be between 60°-90°/sec, at higher velocity the responses can be too severe and may bring on undesirable symptoms of motion sickness before a simple sequence of head movements is completed; though the involuntary movement of the subject's trunk and limbs, which frequently accompanies the evoked sensation are less dramatic at the lower speeds.

With cockpit lights on and room lights off the subject is instructed to tilt his head, fairly briskly from the normal position to the right ear down position and to keep his head in that tilted position. If the device is rotating in a clockwise direction, the subject should report a sensation of pitch-up with perhaps a yawing component to the left. The more experienced aircrew sometimes describe the sensation to be like that of a spiral climb, especially when the head movement is not purely in the roll axis. The other important feature of the illusion to be elicited is the apparent pitch-up change in attitude of the whole cabin and the brief (1-2 sec) blurring of vision immediately following the head movement. The sensations die away in about 10-15 sec and the subject feels that he is slowly returning to the straight and level position.

At least 30 sec should elapse before the subject is told to move his head briskly to the normal upright position. The sensations are the reverse of those on tilting the head to the right, with pitching nose down, or diving, with a less obvious yawing motion to the right. It should be noted that the illusion engendered by the head movement is not simply one of a change of attitude in the pitch plane, but also of angular motion of the whole environment in the nose-up or nose-down direction.

The demonstration continues with movement of the head in pitch. On moving the head forward to the nose-down position the dominant sensation is of bank and roll to the right; the converse sensation is experienced upon returning the head to the vertical position. As before, 30 sec or more should elapse between each head movement. If time permits, head movements from the normal vertical position to the tilt back or tilt left positions may be assayed, as well as head movements from right ear down to left ear down. The latter manoeuvre evokes particularly strong sensations.

Repetition of one or more of these stimulus patterns with the room lights on should bring about an attenuation of the intensity of the illusory sensations and a shortening of their duration. This feature of the demonstration illustrates the strength of external visual cues in suppressing false vestibular sensations and how such veridical cues allow the aviator to resolve the perceptual conflict which is a common feature of most spatial disorientation incidents in flight.

Subjects should be monitored for the signs and symptoms of motion sickness during this demonstration (Money, 1970); if any are present, no further head movements should be requested and rotation should be stopped by a gentle deceleration.

iv Somatogravic and oculogravic illusions

Demonstration of these illusions required the subject to be off-set from the axis of rotation by at least 1 m, preferably at a greater radius. The subject's seat should be fixed so that he is either facing along the radius or, alternatively, at right angles to the radius. It is desirable that he should have adequate view of the room when it is suitably lit.

With room and cabin lights off, the rotation device is accelerated at 10-$15^{\circ}/sec^2$ to a velocity which gives a radial acceleration of about 0.2-0.5 G at the subject's head. During this phase the subject will sense the rotation, a sensation which decays once the device has achieved a constant speed, as already described.

After 30 sec at constant speed, the subject is asked to report his attitude relative to the vertical and to set a visual marker. If he faces along a radius, he should be provided with a luminous horizontal bar which can be set in elevation to indicate pitch attitude, or with a vertical array of small lights one of which can be selectively illuminated to indicate the horizontal. Alternatively, if he faces along the tangent, the luminous bar should rotate in the roll axis and be used to indicate the subjective vertical. During the ensuing 60 sec most subjects will report an apparent change of attitude in which the subjective vertical becomes approximately aligned with the resultant force vector. Thus if the subject faces the axis of rotation he will sense a pitch-up change in attitude and set the horizon bar low; his sensation and setting will be the converse if he faces outward. If he faces along the tangent, then the somatogravic illusion is a false perception of roll attitude in which the subject feels that he and the cab lean outwards.

In the demonstration of this type of illusion it is important to show the subject that his perception of the vertical or horizontal is false. This may be done by illuminating the 'cockpit' instruments and pointing out that fiducial markers on the display indicate the true attitudes. Alternatively, the room lights may be switched on so that the subject may see a real horizontal reference. A weighted needle or plumb line in the cab can be used to show the direction of the resultant force vector.

On deceleration at $10\text{-}15^{\circ}/sec^2$, the subject experiences the usual post-rotary sensations of angular motion. If asked to continue adjustment of the luminous bar or other attitude indicator after stopping, commonly 40-60 sec are required before the indicated attitude corresponds to the true vertical. The revelation, some 20-30 sec after stopping, of correct attitude should effectively demonstrate the shift, which is of an adaptive nature, of the perceived vertical in the direction of the sustained vector. This phenomenon may be employed to discuss one very common type of spatial disorientation, namely 'the leans', though care should be taken to distinguish between somatogravic illusions and 'the leans' and to point out that the former is not the cause of the latter.

<u>RECOMMENDATION</u> (7:1). Some form of rotational device should be employed for the familiarisation training of aircrew in ground schools. Preferably the device should be used in conjunction with lectures.

All members of the group under instruction should have experience in the device (p.18).

<u>RECOMMENDATION</u> (7:2). A device with rotational freedom about a vertical (yaw) axis is adequate for familiarisation training. The provision of rotation in roll and/or pitch is not considered to be cost-effective. (p. 22)

<u>RECOMMENDATION</u> (7:3). The ability to rotate the subject at a distance from the axis of rotation sufficient to generate a radial acceleration of 0.2-0.5 G is advantageous and allows somatogravic and allied illusions to be demonstrated. (p. 22)

<u>RECOMMENDATION</u> (7:4). The performance and facilities of the familiarisation device should be in accord with the specifications given (Sect. 7e). (p.23)

Sect. 8. GROUND BASED MOTION DEVICES TO MODIFY PERCEPTUAL-MOTOR RESPONSES TO DISORIENTATING STIMULI

In the preceding section consideration was given to the use of demonstration or familiarisation devices as a component in the aeromedical training of aircrew. The Working Group was unanimous in its opinion that equipment of the type described enhances the effectiveness of other instructional material (lecture, film, etc) and reinforces the student's awareness that disorientation in flight is a problem that he himself may have to cope with in the flight environment. The student is thus more likely to take note of and remember instruction on why and when disorientation occurs in flight and, of even greater importance, what to do about disorientation when it occurs in flight.

The influence of such a demonstration is thus primarily at the cognitive level. However, the opinion has been expressed (Dowd et al, 1970; Dowd, 1974) that experience gained in a more elaborate ground-based training device may positively influence the perceptual and motor responses of the aviator in a way which improves his ability to control an aircraft in the presence of disorientation stress. Such a ground-based training device is thus invested with the mantle of a surrogate aircraft and becomes an aircraft simulator in which the student, putatively, acquires skill in the recognition and identification of inappropriate sensory cues, learns how to resolve disorientational conflict, and develops optimum control strategies for recovery from unusual attitudes.

The assumption with this type of simulator training, as indeed with all other simulators, is that there is a positive transfer from the ground to the air; skill acquired in the simulator is of positive value to the aviator in the real aircraft. Thus, as a result, the time required to train a pilot in the air can be reduced because skill is acquired, at lower cost and with greater safety, on the ground.

The use of simulators in which there is a high degree of realism in the behaviour of visual displays (instruments and external visual world) and cockpit configuration, have a proven role in the training of aircrew, particularly in procedural and instrument flying. However, the use of 'man in the loop' simulators which have motion systems systems capable of generating conflicting sensory cues, commensurate with the disorientation suffered in real flight, has yet to be justified in the training situation.

(a) A Decision on Motion Simulators for Response Modification

Many experienced pilots, as a result of exposure to the motion stimuli of the flight environment, appear to develop changes in their perceptual-motor responses to disorienting stimuli which are beneficial in flight. Likewise, similar but not identical response changes have been demonstrated in laboratory subjects after repeated exposure to unusual motion conditions (Guedry, 1965). However, many instances of disorientation in flight come from the absence of sensory information rather than from visual or vestibular misinformation. Furthermore, many visual-vestibular conditioning or habituation experiments indicate some specificity of habituation to the particular test situation (Collins, 1973).

An additional problem which raises doubts about the positive transfer of training from a simulator/ trainer of the SOT type (USAF Brooks AFB) is that the motion of the device is very different from that of the real aircraft. By necessity, linear accelerations have to be generated by rotation of the device at a substantially higher angular rate than occurs in the flight situation. Hence changes in the simulator force environment will be accompanied by angular stimuli which are not typical of those in the flight environment. Techniques for, say, recovery from unusual attitudes developed by the student during a period of 'training' on the device will not, arguably, be appropriate to the real aircraft; certainly the sensory input to the aviator will be significantly different in the two situations.

It is perhaps not generally recognised that any flight simulator with a motion base or large visual display to simulate aircraft motion represents a potential negative transfer of training problem because the pattern of sensory feedback differs from that produced by the same control action in flight. The flight simulator, which includes simulated motion, presumes to condition the man to the motion environment while at the same time familiarising him with the cockpit and training him to use the controls and flight instruments. Potential realism, added by a motion base and/or simulated external visual reference, may be beneficial, but it may become detrimental if the sensory feedback is too dissimilar from that commonly encountered in flight when similar control actions are made. Because there is a range of detectable motion cues which would produce essentially equivalent perceptual motor responses, it might be well for the motion to be restricted to the range which minimises disorienting cues. The range can be partially specified from current knowledge, but additional knowledge could certainly be acquired as part of simulator development and evaluation. Recent information on the dependence of central visual-vestibular interactions on the size of moving visual fields is undoubtedly highly relevant to simulation (Dichgans, 1974).

Thus, as one progresses from a fixed-base internal cockpit simulator, to a simulator which introduces only gentle manoeuvres in which sensory feedback is not too different from that encountered in flight, to a motion base simulator which introduces bizarre sensory mismatches for the same command actions, one progresses along a continuum of no concern to considerable concern about negative transfer of training. Simulator sickness, the tendency to turn off the motion base by flight students, and the history of discarded expensive flight simulators all testify to the practical nature of this problem.

The introduction of illusory sensations during cockpit familiarisation training as a means of training individuals to fly in spite of disorientation has also been suggested (Malcik, 1968). This could be an 'open-loop' system (less expensive than 'closed-loop' simulators), in which disorienting vestibular signals are introduced randomly so that a particular control action would not be associated with a particular motion cue. Although this would eliminate one kind of negative transfer effect, there remains the potential problem of generating anxiety and perhaps hyperarousal which would not optimise the learning of the main task. Because of such questions, this is clearly a matter for research, perhaps involving some of the more cost-effective groups indicated below.

(b) Cost-Effectiveness of Research on Conditioning Procedures

The Working Group considers this to be an important area of research for three reasons:-

i Such procedures may eventually prove to be a desirable inexpensive part of flight training. It is possible that group conditioning can be developed, possibly even by exercise programmes, without the need for complicated devices.

ii Cost-effectiveness is considerably enhanced if procedures involving special devices are applied only to special cases such as experienced aviators with presenting symptoms of disorientation, flying phobia, or airsickness.

iii This area of research is directly related to problems encountered in flight simulators.

In regard to point (ii), cost-effectiveness would improve progressively with application of special training methods to the following groups:-

i All flight students.

ii Beginning flight students in whom special problems have been detected.

iii Advanced students in whom special problems have been detected.

iv Experienced aviators in whom special problems have been detected.

Research has indicated a fair degree of success in the treatment of Group (iv) with procedures which seem to involve elements of behaviour modification with 'motion conditioning' (Dobie, 1974).

RECOMMENDATION (8:1). A distinction should be made between motion devices used for familiarisation training which, in general, operate in an 'open-loop' mode (i.e. the man on the device does not directly control its motion) and those devices which operate in a 'closed-loop' mode (such as an aircraft simulator with a motion platform) and are employed to modify the perceptual and motor responses of the aviator.

Research should continue on the evaluation and development of ground-based procedures which might favourably influence the perceptual and motor responses of the aviator in the flight environment when exposed to disorientation stress. Consideration should be given to the cost-effectiveness of such training as well as to the selective use of the procedure in the aircrew population. (p.28)

Sect. 9. IN-FLIGHT TRAINING

Preceding sections of this report have been concerned with the ground based instruction and training of aircrew, but it is in the flight environment that the aviator experiences disorientating perceptions and it is in this environment that errors or impairment of control engendered by spatial disorientation threaten the safety of aircraft and occupants. Although it is our opinion that improvements in the quality of ground training can help to reduce the incidence of orientation error accidents and incidents in flight, there is no clear evidence, at the present time, that ground based simulator training (of the type discussed in section 8) can inculcate behavioural responses comparable to those achieved through experience in the real aircraft. Thus, at present, it is only in the real aircraft that the aviator learns to resolve sensory conflict and to maintain control in the presence of disorientation stress.

The acquisition of flying skill, of learning to fly, is a broad topic outside the scope of this report. However, in the context of disorientation training in flight, two facets of the problem were considered by the Working Group: one, the demonstration of sensory fallability in flight, and two, learning to cope with disorientation in flight.

Before entering a detailed discussion of these two problems, the importance of making an unified approach to ground based and airborne phases of disorientation training should be reiterated. The significance of instrument flying as a prime etiological factor in spatial disorientation should be, and commonly is, adequately emphasised during aeromedical training. But, in the experience of the Working Group, problems of disorientation tend to be dealt with in a cursory manner, if at all, by those responsible for teaching students basic instrument flying theory. Likewise, the demonstration and discussion of disorientation by the flying instructor is usually quite divorced from that given by ground school lecturers and at best lacks the integrated approach which this report attempts to foster.

Regrettably, the impression gained by the Working Group was that the in-flight demonstration of spatial disorientation was given a low priority by those responsible for this phase of flying training. Lip-service is paid to the problem, but in practice the topic is neglected. A number of factors contribute to this neglect, namely: pressure to reduce flying hours, inadequate training of instructors in flight manoeuvres which induce disorientation, a lack of consistency in the elicitation of illusory sensations, the possibility of loss of control and consequent impairment of flight safety, and the absence of 'disorientation' as an assessed topic in qualifying examinations.

(a) In-Flight Demonstration of Spatial Disorientation

The need to persuade aircrew, particularly the student pilot, about the inadequacy of non-visual sensory cues for flight control was made earlier in this report and was used to justify the use of demonstration or familiarisation devices in the educational programme at ground schools. In the classroom, stimulus-response relationships can be analysed and basic mechanisms of some of the common illusions explained, but the extrapolation of these experience to the flight environment must, of necessity, be by means of the spoken word. In the aircraft the student can be given the opportunity to discover for himself, that his sensory system is fallable and, in the air, is inadequate to maintain correct orientation when deprived of visual cues.

Part of the in-flight demonstration should aim to show the student that, without vision, his senses frequently provide him with no information about aircraft attitude or motion, and lead insidiously to misorientation without strong conflicting perceptions, rather than to disorientation with illusory sensations of the type commonly described in aeromedical texts. False sensations caused by abnormal sustained force vectors can also be convincingly demonstrated in the air. Somatogravic illusions associated with changes in aircraft acceleration in the line of flight can be elicited as can the sensations induced by a head movement made during a sustained turn when pulling 'G' ('G' excess and cross-coupled stimulation). Likewise the 'Leans' and other illusory perceptions associated with adaptive changes and sub-threshold stimuli can, we believe, be quite simply and consistently produced by a specially trained instructor.

The aircraft manoeuvres required to elicit disorientation will, of course, vary with the type and performance of the training aircraft, and the time which may be devoted to in-flight demonstrations will depend upon the pressure of the flying training programme. It is customary in many centres engaged in flight training, for demonstrations of the inadequacy and 'seat of the pants' cues to be made only at the beginning of instrument flying practice. At some establishments the demonstration follows a prescribed form, at others it is left to the discretion of the individual instructor. As a result, some students receive an adequate demonstration, others none at all.

In the opinion of the Working Group, an in-flight demonstration of spatial disorientation should be given to all student pilots. An introduction to instrument flying and a simple demonstration of the unreliability of sensory mechanisms should be experienced by all pilots before they go 'solo' so that they are made aware of the ease with which control may be lost if undue reliance is placed on bodily sensations when flight has to be made in the absence of external visual cues. This is a salutary experience for Service pilots; it is even more important for the 'private' pilot whose activities are less supervised than those of a Service pilot with comparable flying experience.

Further demonstrations should be given before beginning night flying and in the early phases of instrument flying training when the pilot, under the hood with eyes closed, may be allowed to fly himself into unusual attitudes when attempting to fly straight and level or to perform a standard rate turn through, say, 90° and then fly straight and level.

Flight manoeuvres developed in the USN and USAF for the induction and demonstration of spatial disorientation in flight are presented in Annex F.1&2. While acknowledging the utility of these manoeuvres in the hands of an experienced instructor, the Working Group had reservations about their efficacy when executed by the competent but less involved instructor. More information is needed on the consistency with which specific illusions can be elicited in the flight environment. Preliminary experiments (reported in Annex F.2) have been carried out by a member of the Working Group, but much more work is needed before positive recommendations can be made on the manoeuvres to be employed for the in-flight demonstration of spatial disorientation.

(b) Instrument Flying Training

Studies of critical incidents have shown that spatial disorientation occurs much more frequently when flying by instruments than when the pilot has good external visual cues. It is not difficult to explain why this should be so, for instrument displays in general lack the 'strength' of the cues provided by the sight of aerial and terrestrial objects viewed from the cockpit. Instrument cues are symbolic, the information is fragmented by the use of separate dials and gauges so that the perceptual task of interpreting such displays is experientially one which is less familiar than the interpretation of external visual cues.

Simply, flying by instruments is a more difficult psycho-motor task than flying by external visual reference. Hence the task of instrument flying is more susceptible to impairment by task load, anxiety or other stresses that may raise the level of 'behavioural arousal' above the optimum. In common with other psycho-motor skills, the particular skill of instrument flying is less likely to suffer impairment under stress if the task is 'overlearned': the desirable state is for flight by instruments to be as 'natural' and as 'automatic' as flight using external visual cues. Unfortunately, this condition is rarely, if ever, reached even in highly proficient pilots who are in current instrument flying practice. Nevertheless, it is an ideal to which training should aspire.

One of the problems in instrument flying training, or in the maintenance of efficiency in this type of flying, stems from the need to simulate appropriate flight conditions, for the simulation attenuates those stresses which are a normal concomitant of flight in Instrument Meteorological Conditions (IMC). Thus when flying 'dual, under the hood' external visual cues are largely excluded and the student can devote his undivided attention to the instruments. Similarly, when a visor is used, visual attention is confined and, as when flying 'under the hood', the student is reassured by the presence of the safety pilor or instructor.

Whereas these features are in many ways desirable during the early phases of instrument flying training they tend to isolate the pilot from the situations which characteristically cause spatial disorientation in normal operational conditions. There is no demand in this training mode, to look outside the cockpit and maintain surveillance for other aircraft. Accordingly, there are no external visual cues to compete with instrument cues in the perception of aircraft orientation, as occurs when flying IMC in cloud or atmospheric haze. Yet, when flying 'under the hood' or with a 'visor', cues of aircraft orientation can be obtained from the light distribution within the cockpit; when a visor is used, a brief view of the external scene on making a small head movement can provide cues sufficient to permit correct aircraft orientation.

Once the rudiments of instrument flying have been gained by the student the subsequent training is mainly in 'procedural' flying. Recovery of unusual attitudes does feature in the more advanced phases of the training programme, but once mastered, the ability to interpret instruments and establish control in the presence of conflicting orientational cues is rarely stressed. This is unfortunate, for it deprives the student of the opportunity to develop his ability to fly by instruments in the presence of disorientation and other stresses, and so to build up his confidence in his ability to cope with disorientation if and when it occurs during the course of normal flying duties.

The foregoing comments should not be restricted to the student pilot, for no less a need exists for the experienced pilot to develop and maintain his ability to resolve conflicting cues and preserve control when flying on instruments.

(c) Proposals for More Realistic Instrument Flying Training

The following proposals merely outline what seem to be the optimal principles which should be considered in defining the best approach to instrument flying training:-

i The simulation equipment of the aircraft should attempt to reproduce instrument flight in haze. The trainee should not be so isolated from the outside world that he is not obliged to look out. It is only by looking out of the cockpit that he will experience the problems which can arise due to visual/vestibular conflict and gain experience of rapid transfer from external to internal (instrument) references.

ii The instrument flying flight procedures should be aimed at a positive approach to the control of the aircraft by the trainee pilot when exposed to disorientating cues. The instrument flight profile should be continuous over a period of at least 20 min and include a series of flight manoeuvres which induce disorientating sensations. The trainee would be required to recover the aircraft smoothly from these unusual positions despite the presence of disorienting conditions.

The emphasis should be placed upon positive aircraft recovery, where the pilot retains complete control over the aircraft by correct interpretation and belief in his instruments and disregard of disorientating cues. This is considered to be a powerful tool for increasing the individual's confidence in his ability to fly his aircraft in extreme situations which are very real, as well as teaching him not to attend to vestibular and 'seat of the pants' sensations. It is important to note that the whole in-flight disorientation training programme should lead up to this goal and be so graduated in duration and severity that an individual's confidence is not undermined in the early stages

iii Consideration should be given to allowing the more senior students to carry out solo instrument flying in haze or cloud and ultimately this should include the ability to recover from unusual positions whilst flying solo. Clearly, a balance between the dictates of operational efficiency and flight safety must be worked out. It is felt, however, that the present inhibited approach to solo instrument practice during flying training leads to a disproportionate increase in difficulty as soon as the individual starts his operational training. At that time he will be expected to carry out operational manoeuvres in such conditions without having an adequate training lead-in. In the long run it would seem more effective, and indeed safer, if he had been introduced to solo operational type manoeuvres in instrument conditions during his flying training.

iv There is a continuing need throughout the aviator's flying career to maintain proficiency at IMC flight, which should include all the situations described in these proposals.

RECOMMENDATION (9:1). All student pilots, both military and civilian, should be given an in-flight demonstration of spatial disorientation before being allowed to fly 'solo'. (p.30)

RECOMMENDATION (9:2). Further demonstrations should be given during the early phases of instrument flying training. (p.30)

RECOMMENDATION (9:3). Civilian private pilots should be encouraged to obtain an instrument flying rating. (p.30)

RECOMMENDATION (9:4). Research and development should be undertaken to make the airborne simulation of instrument flight more realistic by the introduction of an element of external visual search, as is required in certain phases of flying in real Instrument Meteorological Conditions and in Variable Meteorological Conditions. (p.31)

RECOMMENDATION (9:5). As skill is acquired during instrument flying training the student should be required to fly the aircraft and recover satisfactorily from unusual attitudes in the presence of disorientation and other stresses. (p.31)

RECOMMENDATION (9:6). Senior students should be allowed to do instrument flying in real, rather than simulated Instrument Meteorological Conditions, and should be introduced to operational manoeuvres during flying training, whenever possible. (p.31)

RECOMMENDATION (9:7). Examination of the pilot's ability to recover on instruments from disorienting unusual positions should be a regular feature of flying proficiency tests. (p.32)

Sect. 10. THE DURATION AND PHASING OF ORIENTATION/DISORIENTATION TRAINING

In view of the wide differences in the time devoted to orientation/disorientation training by both military and civil authorities in the NATO countries, the Working Group felt obliged to make formal recommendations on such training programmes. These recommendations, which represent the consensus of the Working Group, are intended to be guidelines for those in each organisation responsible for aircrew training, rather than a rigid formulation of training policy which does not acknowledge differences in aircrew role or local conditions. The validation of educational policy is difficult, even when the subject taught is amenable to objective testing. When the subject is disorientation, and the efficacy of the programme is to be revealed only in the unclean statistics of aircraft accidents, validation is a long term exercise of uncertain outcome. Nevertheless, the inability to prove, in an objective manner, the benefits which should accrue from an implementation of the recommendations made in this report is not a justification for a laissez-faire policy.

Table 5 summarises the Working Group's recommendation for orientation/disorientation training of both military and civil flying personnel. The schedule proposed for all aircrew during basic training is similar. Major differences arise only during advanced or conversion training and subsequent refresher training.

TABLE 5

ORIENTATION/DISORIENTATION TRAINING RECOMMENDATIONS

Aircrew Category	Stage of Training	Ground		In-Flight	
		Nature of Training	Duration	Nature of Training	Duration
	BASIC				
Military Commercial	Initial Flying Training < 20 hr	Lecture + Film + Demonstration or familiarisation	$\nless$ 2 hr	(1) Demonstration + indication of significance and required action	15-30 min
	Before night flying	Review (optional)	10-15 min	Recovery from unusual attitudes (RUA)	Until proficient
	Before instrument flying	Review (optional)	10-15 min		
	Instrument flying training			Further demonstration	15 min
	When proficient in IMC			(2) Recovery from unusual attitudes with disorientation stress in IMC	Until proficient
Private	Initial flying training	Lecture or film + demonstration or familiarisation Encouraged to obtain Instrument Rating	$\nless$ 30 min	Demonstration (as 1)	15-30 min
	Before night flying	Review	10-15 min	RUA	Until proficient
	Instrument flying training			Further demonstration and RUA as (2)	15 min
	ADVANCED				
Military	Advanced on operational type	Review (optional) + lecture of special problems on type	15-30 min	IMC training (as 2) Maintain IMC proficiency and practice	Until proficient
Civil Transport	ditto	ditto	ditto	Demonstration of specific problems	
	REFRESHER AT LEAST EVERY 3 YR				
Military High Performance Aircraft		Summary lecture or film, and demonstration or familiarisation	$\nless$ 1 hr	(3) Assessment of proficiency at RUA with disorientation stress	
Military & Civil Transport		ditto	ditto	As (3) or simulator assessment	
Private Instrument Rated		ditto	ditto	Proficiency assessed (as 3)	
Not instrument Rated		ditto Encouraged to obtain Instrument Rating	$\nless$ 30 min	Demonstration (as 1) (During biennial review)	15-30 min

It is considered desirable that all pilots should be proficient in recovery on instruments from unusual attitudes when exposed to disorientation stress, though it is acknowledged that pilots of heavy transport aircraft are unlikely to be exposed to this type of perceptual conflict during normal operations other than during severe turbulence. Likewise, it would seem unreasonable to deploy such an aircraft for training in which it was required to execute atypical flight manoeuvre. Assessment of such pilots in a smaller aircraft was considered, as a desirable and economically attractive alternative, though it does raise problems related to 'familiarity on type'. Accordingly, it was concluded that this aspect of training and assessment has, in general, to be carried out on a ground based simulator of the aircraft with which the aviator is in current flying practice, despite the lack of adequate disorienting motion stimuli.

In view of the high incidence of orientation error accidents amongst private flyers, the Working Group was particularly concerned about the training received by these aviators, both in the basic phase of the programme and in subsequent refresher training. Table 5 lists the recommended minimum duration of instruction which private pilots should receive, but the difficulty lies in the implementation of these recommendations rather than in their formulation. In general, the private flyer has no formal instruction on medical problems in aviation, either during basic training or later in his flying career, though in some clubs lectures are given by medical examiners or other qualified personnel. Likewise, the use of simple familiarisation devices, such as a manually operated spin-chair, is purely a local matter. Regular refresher training, which in the opinion of the Working Group should be given at least every three years, is rarely received by the private aviator. By chance he may attend a lecture or participate in a Flight Safety Seminar where disorientation may be discussed, but at present he is under no obligation to undertake such training.

The vagaries and uncertainties of the ground-school training of the private pilot extend to the flight environment. He may receive an in-flight demonstration of disorientation and limitations of sensory mechanisms, but this is by no means universal. In the opinion of the Working Group, it behoves all instructors to impress upon their pupils, preferably by means of a personal demonstration in the air, that adequate control of the aircraft cannot be maintained in the absence of reliable visual cues. A corollary of such a demonstration is to encourage all private flyers to become proficient in instrument flying and, once having acquired such skill, to maintain proficiency by frequent and regular practice. Another corollary is to impress upon all non-instrument rated pilots the extreme danger of continuing flight into marginal weather conditions.

RECOMMENDATION (10:1). The time devoted to orientation/disorientation training of aircrew during the basic and advanced phases of flying training should be in accord with the recommendations made in Table 5. Refresher training should be given at intervals of not more than 3 yr. (p.3?)

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ANNEX A

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* Edit v.t. to prepare for publication: to superintend the publication of: to compile, garble or cook up into literary shape (Chamber's Twentieth Century Dictionary).

ANNEX B

QUESTIONNAIRE ON ORIENTATION/DISORIENTATION TRAINING

	Question	Response
Q.1	Do aircrew in the Service Organisation you represent receive any formal instruction about the problems of orientation and disorientation in flight?	If Yes please indicate and go to Q.2. If No please indicate and to to Q.7.
Q.2a	Are lectures given to students and/or aircrew about orientation and disorientation in flight?	If Yes please indicate and go to Q.2B. If No please indicate and go to Q.3.
Q.2b	What topics are covered in these lectures?	Please give syllabus in space below or attached sheet.
Q.2c	What is the time allotted to such lectures?	Please give time in hours.
Q.2d	At what stage in aircrew training are such lectures given?	Please give details in space below.
Q.2e	Are lectures given to trained aircrew?	If Yes please indicate and go to Q.2f. If No please indicate and to go Q.3.
Q.2f	When do trained aircrew receive lectures on disorientation?	Please give details in space below.
Q.3a	Are students or qualified aircrew given any demonstration on the ground of the illusions which may disorientate them in flight?	If Yes please indicate and go to Q.3b. If No please indicate and go to Q.4.
Q.3b	What is the form of this demonstration/ familiarisation?	Please give details.
Q.3c	Do all students have an opportunity to use the demonstration/familiarisation device?	Please indicate Yes or No.
Q.3d	Is the demonstration/familiarisation repeated during the aviators flying career?	If Yes please indicate and go to Q.3e. If No please indicate and go to Q.4.
Q.3e	When do trained aircrew have such a demonstration of disorientation?	Please give details.
Q.4a	Are films on orientation and disorientation in flight used in the training programme?	If Yes please indicate and go to Q.4b. If No please indicate and go to Q.5.

Q.4b	What is (are) the title(s) of the film(s) which are used?	Please give title(s) origin and reference number(s) of films.
Q.4c	Are the films used alone or in conjunction with lectures and/or demonstrations?	Please give details.
Q.5a	Are the problems associated with orientation and disorientation specifically demonstrated in the air during flying training?	If Yes please indicate and go to Q.5b. If No please indicate and go to Q.7.
Q.5b	What form do these in-flight demonstrations take?	Please give details, including the way in which external visual cues are excluded.
Q.5c	Are in-flight demonstrations given to trained aircrew?	If Yes please indicate and go to Q.5d. If No please indicate and go to Q.7.
Q.5d	What is the form of such in-flight demonstrations, and when are they given?	Please give details.
Q.6a	How many hours instrument flying practice (airborne - actual or 'under the hood') do students receive during stages of flying training?	Please give details.
Q.6b	How many hours instrument flying (per month/year) must trained aircrew complete in order to maintain their rating?	Please give details.
Q.7a	Is it the general opinion of the Service you represent that the current programme of orientation/disorientation training is adequate?	If Yes please indicate and go to Q.8. If No please indicate and go to Q.7b.
Q.7b	In what way is the training programme inadequate?	Please give details.
Q.8a	Does your personal opinion differ from that expressed in the answers to Q.7a and b?	If Yes please indicate and go to Q.8b. If No please indicate and go to Q.9.
Q.8b	In what respect do <u>you</u> consider the present training programme to be inadequate?	Please give details.
Q.9a	Is there any aspect in the training and teaching of aircrew about orientation and disorientation in flight, not already covered in your answers to Q.1-7, upon which you wish to comment.	If Yes please indicate and go to Q.9b. If No please indicate and go to Q.10.
Q.9b	What additional comments do you have?	Please give details.
Q.10	Have you completed this questionnaire?	If Yes - Thank you very much. If No - Please do so and then return to Q.10.

ANNEX C

I. EXTRACT FROM SYLLABUS FOR THE INITIAL AEROMEDICAL TRAINING OF FLIGHT PERSONNEL

NATO Standardisation Agreement STANAG 3114 Edition 5 of 1970 (no subsequent amendments)

Sect. 11. Sensory Phenomena Associated with Flight

a. Scope

(1) Orientation in Flight
- (a) Role of visual system.
- (b) Role of vestibular system.
- (c) Role of touch and kinaesthetic sensory systems.
- (d) Discussion of physiological limitations of non-visual sensory systems in flight.

(2) Disorientation in Flight
- (a) Definition.
- (b) Etiological factors.
  1. Cockpit environment.
  2. Conditions of flight.
  3. Individual differences.
- (c) Description of specific types of disorientation and precipitating environmental factors.
- (d) Effect of sensory conflict and heightened arousal on performance.
- (e) Prevention.
  1. Habituation.
  2. Proficiency in instrument flying.

b. Method

(1) Lectures.
(2) Films.
(3) Demonstrations of vestibular illusions.

Sect. 10. (Vision) includes

(5) Visual Perceptions:
- (a) Autokinetic illusions - includes visual perception of movement.
- (c) Optical illusions - includes oculogyral and oculogravic illusions.

II. PROPOSED LECTURE SYLLABUS

1. Introduction

Definition of Spatial Orientation in flight, hence Spatial Disorientation.
Importance of correct percpetion of orientation in aircraft control.
Spatial disorientation jeopardizes flight safety because:

a. Control based on false perception leads to loss of control and the 'orientation-error' accident.

b. Conflicting orientation cues or abnormal sensations can heighten arousal (some may be quate alarming) and performance may be impaired.

Aircrew need to know.

a. Types of illusory perceptions occurring in flight.
b. Flight conditions and manoeuvres likely to induce spatial disorientation.
c. How to cope with disorientation if and when it occurs.

2. Mechanism of Orientation in Flight

Dependent upon correct integration and interpretation (perception) of sensory information from:

a. Eyes.
b. Inner ear, especially vestibular part.
c. Other receptors in skin, capsules or joints and supporting tissues responding to the force environment.

(b. and c. are the 'seat of the pants' sensations)

Vision is the only reliable channel of information using either:

a. External visual cues, when flying in Visual Meteorological Conditions (VMC) (Syn. VFR).
b. Internal visual cues from instruments, when flying in Instrument Meteorological Conditions (IMC) (Syn. IFR).

Aviator has to learn how to interpret cues.
Interpretation of instrument cues is a more recently learned and more difficult task than interpreting external cues; proficiency has to be maintained by practice.
Non-visual cues are frequently either inadequate or erroneous and do not allow the aviator to maintain a correct perception of aircraft orientation. They do, however, assist the pilot in sensing transient changes in aircraft attitude and motion and hence with visual cues can contribute to correct orientation in flight.

3. Mechanism of Disorientation in Flight

Caused either by:

a. Erroneous or inadequate sensory information transmitted to brain.
b. Erroneous or inadequate perception of sensory signals by the brain.

Input error

a. External visual:
Cues inadequate as when flying at high altitude, at night, in cloud or other poor visibility conditions.
Cues erroneous (i.e. departing from expectancy) e.g. sloping edge of cloud bank or auroral display.
b. Instruments:
Inadequate sensitivity to displayed variable.
Erroneous signal caused by malfunction or dynamic limitations.
Vision impaired by nystagmus, glare, flash etc.
c. Vestibular and other receptors:
Fail to indicate change in angular velocity or direction of gravity when stimulus below 'threshold'.
Semicircular canals do not signal sustained rotation.
'Erroneous' signals are generated by linear and angular acceleration stimuli which differ in time course and/or intensity from those to which the body is normally exposed on the ground, e.g. post-rotary phenomena, somatogravic illusion, stimulation of semicircular canals by pressure change etc.

Central error

a. Limitation of span of attention-coning of attention or fascination.

b. False perception of cues because of:

Error in expectancy (e.g. cloud leans, somatic autokinesis)

Disturbed cerebral function consequent to:

i. High arousal (anxiety)

ii. Low arousal

iii. Alcohol and other drugs

iv. Hypoxia and hypocapnia

v. Illness

vi. Fatigue

c. Dissociative sensations e.g. Break-off Phenomenon

4. Commonly Described Illusions

a. False perception of attitude

i. 'The Leans' (sub-threshold acceleration)

ii. Somatogravic illusions - pitch-up on acceleration, pitch-down on deceleration, inversion during bunt ('Jet upset' incidents).

iii. Misinterpretation of visual cues - false horizontal reference, ground/sky confusion, 'lean on the sun' illusion.

iv. Cross-coupled and 'g excess' illusions.

b. False perception of motion

i. Somatogyral illusion - on recovery from prolonged angular motion.

ii. Sub-threshold accelerations.

iii. Cross-coupled (Coriolis) stimulation.

iv. Pressure (Alternobaric) vertigo.

b. Flicker vertigo and other illusory sensations induced by moving visual stimuli (waterfall effect in helicopters).

c. Dissociative sensations

'Break-off' phenomenon.

5. Causal Factors

a. Flight environment

i. I.M.C. - in particular on transfer from external visual to instrument cues.

ii. Night - isolated light sources enhance probability of oculogravic, oculogyral and autokinetic illusions; ground/sky confusion.

iii. High altitude - Dissociative sensations. False horizontal reference. Also 'break-off' in helicopters at lower altitudes or on crossing escarpment.

iv. Flight over featureless terrain - false perception of height.

b. Flight manoeuvres

i. Prolonged acceleration and deceleration in line of flight and catapult launches-somatogravic and oculogravic illusions.

ii. Prolonged angular motion - sustained motion not sensed, somatogyral illusions on recovery, no sensation of bank during co-ordinated turn, cross-coupled and 'g excess' illusions if head movement made while turning.

iii. Sub-threshold changes in attitude - 'The Leans' induced on recovery.

iv. Workload of flight manoeuvre - High arousal enhances disorientation and reduces the ability to resolve perceptual conflict.

v. Ascent or descent - Pressure vertigo.

vi. Cloud penetration - VMC/IMC transfer and attendant problems; especially when flying in formation or on breaking formation. 'Lean on the sun' illusion.

vii. Low altitude hover - dust or water may obscure external cues (VMC/IMC transfer); 'waterfall' illusion.

c. Aircraft factors

i. Inadequate instruments.

ii. Inoperative instruments.

iii. Visibility of instruments.

iv. Badly positioned displays and controls - head movement required to see and operate.

v. High rates of angular and linear acceleration, high manoeuvrability.

vi. View from cockpit - lack of visible aircraft structure enhances 'Break-off', poor visual frame of reference.

d. Aircrew factors

i. Flight experience.

ii. Training, experience, and proficiency in instrument flight.

iii. Currency of flying practice.

iv. Mental health - high arousal and anxiety increases susceptibility to disorientation.

v. Physical health - upper respiratory tract infection and 'Pressure Vertigo'.

vi. Alcohol and drugs - impair mental function, also alcohol and barbiturates, even at low levels, impair ability to suppress nystagmus.

6. Practical Advice to Aircrew

Prevention

a. Remain convinced that you cannot fly by the 'seat of the pants'.

b. Do not allow control of the aircraft to be based at any time on 'seat of the pants' sensations even when temporarily deprived of visual cues.

c. Do not mix flying by instruments with flying by external visual cues, unnecessarily.

d. Aim to make an early transition to instruments when flying in poor visibility etc; once established keep on instruments until external cues are unambiguous.

e. Maintain a high proficiency and be in practice at flight in IMC.

f. Avoid unnecessary manoeuvres of aircraft or head movements which are known to induce disorientation.

g. Be particularly vigilant in high risk situations, such as at night and weather, in order to maintain intelluctual command of the orientation and position of the aircraft.

h. Do not fly with an upper respiratory tract infection (URTI), when under the influence of drugs or alcohol or when mentally or physically debilitated.

i. Remember, experience does not make you immune.

How to cope with disorientation

a. Persistent minor disorientation conflict (e.g. the Leans) may be dispelled by making a positive effort to redirect attention to other aspects of the flying task; a quick shake of the head, provided aircraft is straight and level, is effective with some pilots.

b. When suddenly confronted by strong illusory sensations or difficulties are experienced in establishing orientation and control of the aircraft.

i. Get on to instruments; check and cross check. Ensure good instrument illumination.

ii. Maintain instrument reference. Control the aircraft in order to make the instruments display the desired flight configuration. Do not attempt to mix flight by external visual references with instrument flight until external visual cues are unambiguous.

iii. Maintain correct instrument scan; do not omit altimeter.

iv. Seek help if severe disorientation persists. Hand over to co-pilot (if present), call ground controller and other aircraft, check altimeter.

v. If control cannot be regained, abandon aircraft.

c. Remember: nearly all disorientation is a normal response to the unnatural environment of flight. If you have been alarmed by a flight incident discuss it with colleagues, including your medical officer or Flight Surgeon. Your experience will probably not be as unusual as you thought.

ANNEX D

ASSESSMENT OF FILMS AND SLIDES FOR ORIENTATION TRAINING OF MILITARY PILOTS

by

K.E. Money and R.E. Malcolm

SUMMARY AND CONCLUSIONS

Fourteen movie films and three slide sets were studied and assessed for their effectiveness in teaching military pilots to cope with disorientation problems. It was concluded that two films, 'Perception of Orientation' (RCAF) and 'Upset' (FAA), and one slide set 'Vertigo' (FAA) collectively contain most of the relevant information that is available in visual-aid form. Exposure to these three aids is recommended as a worthwhile part of orientation training for military pilots.

I. MOVIE FILMS

The movies were rated on a 4 point scale as very good, good, fair, or unsuitable. The ratings refer only to effectiveness in orientation training in military pilots who are instrument rated or receiving instrument flying training. Some films were considered excellent for teaching non-instrument rated private pilots but totally unsuitable for military pilots; other films were obviously effective as general introductions to aviation medicine but not adequate for orientation training specifically. The movies are all 16 mm with English sound track.

1. 'Pilot Vertigo' — United Stages Air Force training film 5689, FLC - 22 - 0033 (24 mins).
   RATING: GOOD — The film is not scientifically sound, but its practical advice is nevertheless correct.

2. 'Freedom in Flight' — Moody Institute of Science Film (29 mins).
   RATING: GOOD — The film implied that pilots should have faith in attitude instruments as they have faith in God; this may not be good advice for some pilots.

3. 'Stable and Safe' — FAA, FA - 704 (20 mins)
   RATING: FAIR — The film is intended for pilots who are not instrument rated.

4. 'Rx for Flight' — FAA, FA - 606 (20 mins)
   RATING: FAIR — The film is a general introduction to aviation medicine for civilian student pilots.

5. 'One Eye on the Instruments' — FAA, FA - 209 (16 mins)
   RATING: FAIR — The film is an introduction to instrument flying and disorientation for civilian student pilots.

6. 'Disorientation Crashes' — USN, MN 4353C (5 mins)
   RATING: FAIR — The film is very brief and very elementary.

7. Spatial Disorientation in Flight' — USAF MV 9604 (16 mins)
   RATING: GOOD — The film is directly on topic and describes disorientation well, but it gives insufficient emphasis on how the pilot should cope.

8. 'Perception of Orientation' — RCAF 22025 (37 mins).
RATING: VERY GOOD — This film is probably the best one available for an overall examination of the topic.

9. 'Upset' — FAA, FA 611 (45 mins).
RATING: VERY GOOD — This film describes the 'jet upset' phenomenon and how to avoid it and it is the only film to do so.

10. 'Medical Facts for Pilots' — FAA, FA-01-70 (25 mins).
The film was booked up for months in advance so that we were unable to see it.

11. 'Vision in Military Aviation-Illusions' — USN, MN 9480 B
RATING: UNSUITABLE — The film has several important scientific errors.

12. 'Vision in Military Aviation - Sense of Sight' — USN, MN 9480 A
RATING: UNSUITABLE — The film is not relevant.

13. 'Vision in Military Aviation - In flight Recognition and Closure. — USN, MN 9480 C
RATING: UNSUITABLE — The film is not on topic.

14. 'Vision in Military Aviation - Errors in Vision' — USN, MN 9480 D
RATING: UNSUITABLE — The film is not relevant and does not even do a good job of teaching vision.

15. 'Disorientation' — FAA, FA-09-73 (19 mins).
RATING: FAIR — The film is intended for private pilots.

None of the films gave sufficient emphasis to what the pilot should do when he recognises or suspects disorientation. Some of the films gave the (correct) instruction 'believe your instruments', but they gave it quietly, and only once or twice. It should be given loudly and repeatedly. This instruction is probably adequate except when panic reigns; it should probably be augmented by the instruction: 'control the aircraft to make the flight instruments read correctly, regardless of your sensation of aircraft attitude.' The point here is that a panic-stricken pilot who can only remember 'believe the instruments' might concentrate on believing them while he stops flying or continues to fly only according to his sensations, whereas a pilot who can remember only 'make the instruments read correctly' will be controlling the aircraft to make the instruments read correctly. It is probably important that student pilots never hear about disorientation without hearing the instructions for dealing with it.

It is recommended that the films 'Perception of Orientation' (RCAF) and 'Upset' (FAA) both be shown to military aircrew as part of their disorientation training. It appears that most of what one might hope to accomplish in this area can be accomplished by showing these two. It might be possible to make a better film by adding in parts of other films and by adding some illustrative material not available in films, but the increase in effectiveness, over showing only the two recommended films, would be slight. The lecturer should repeat the instructions for dealing with disorientation.

II. SETS OF SLIDES

Three sets of slides were examined. The 'USAF SAM Spatial Disorientation Lecture Kit' (sometimes called 'the Gillingham USAF' kit) is excellent but it is intended for medical officers and could not easily be used for teaching aircrew. The slides in the second kit, the 'USAF SAM Spatial Disorientation Hazards Training Kit' cover most of the vital points but it was felt that a strong lecturer would be needed to be effective with this set, since many essential details are not presented. For a brief presentation this set would seem to be best, and the kit includes a script. The third set, the FAA 'Vertigo' set, is apparently based on the Gillingham set but the 'Vertigo' set is simpler and would be better than the Gillingham set for instructing pilots. For a comprehensive presentation to pilots, the FAA 'Vertigo' slides are the best of the three sets assessed.

III. PROCUREMENT

Most of the movies and slide sets can be borrowed or purchased. Enquiry can be made at one of the following addresses:

FAA Film Library AC-44.5 — (For movies 3, 4, 5, 9, 10, and 15 and the FAA slide set).
Federal Aviation Administration
P.O. Box 25082
Oklahoma City, Oklahoma 73125
U.S.A.

USAF School of Aerospace Medicine — (For movies 1 and 7, and for USAF slide sets).
Aerospace Medical Division, AFSC,
Brooks Air Force Base, Texas 78235
U.S.A.

USAF Central Audio Visual Library — (For movies 1 and 7)
AF Audio Visual Center
Norton AFB
California 92409
U.S.A.

National Defence Headquarters — (For movie 8)
Ottawa, Ontario,
Canada
K1A 0K2
Attention: National Defence Film Bureau

Moody Institute of Science Films — (For movie 2)
Moody Institute of Science
12,000 E. Washington Blvd
Whittier, California 90606
U.S.A.

ANNEX E

RECOMMENDATION FOR A FAMILIARISATION DEVICE TO DEMONSTRATE DISORIENTATION

by Dr F E Guedry and Lt T O'Leary USN

The purpose of this trainer is to demonstrate several kinds of disorientation which can occur in flight, to illustrate the fact that any normal pilot is subject to these disorienting effects and to illustrate some of the ways disorientation can be controlled. The objective is to augment training which is otherwise given in lectures and in flight. It is intended as a demonstration and not as a means of producing habituation to disorienting conditions. It is not recommended to design a trainer which will double as a research tool because the price of the device would increase considerably.

GENERAL DESCRIPTION

The device is a circular platform with a vertical axis of rotation and an overall radius of 7.5 feet. The device, as shown diagrammatically in Fig. 1, will accommodate 12 trainees, though it need not necessarily have this capacity. Each trainee will be seated in a circular capsule capable of rotating 90 deg, relative to the main platform, about a vertical axis displaced 6.0 feet from the center of the main platform. In the initial orientation, trainees would face tangentially looking in the direction of rotation, and the head would be at a radius of 6 feet. The 90-deg rotation would place the trainees in a second orientation facing directly outboard with the head at a radius of about 5.5 feet.

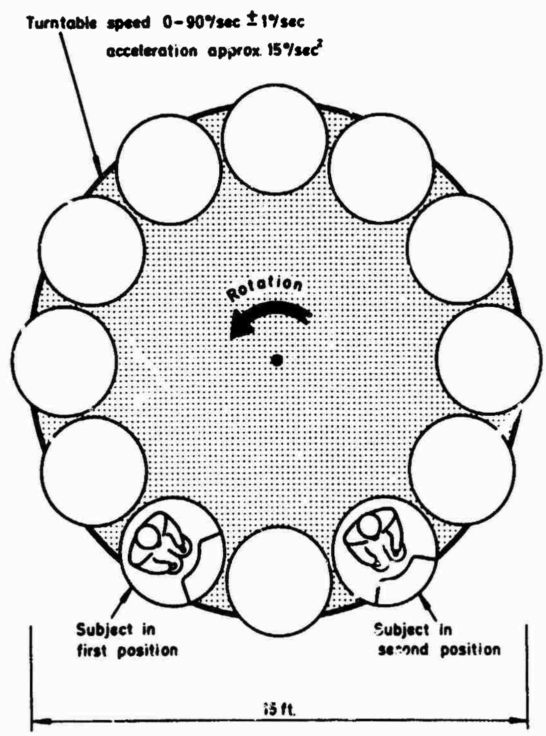

FIG. E.1. PROPOSED 12 SEAT FAMILIARIZATION DEVICE

A. Rotation Characteristics of Main Platform

1. Maximum rotation velocity to be 15 rpm (90 deg/sec) in either CW or CCW direction. Velocity should be constant, ± 1 deg/sec. Speed changes due to changes in the moment of inertia should not be

corrected by oscillatory hunting for the present speed, but rather by highly damped recovery. Such changes should be minimized by reducing inertia changes, rather than by expensive close-loop drive systems.

2. The angular acceleration need not be absolutely constant either in attaining speed or in stopping, but speed changes should be accomplished in a repeatable manner without jerks. A 90 deg/sec speed change should be accomplished in 6 sec or less (ie 15 deg/sec^2); however, mean angular acceleration should not exceed 30 deg/sec^2.

B. Characteristics of Capsule

1. The capsule should be capable of a 90 deg heading change. This change should be smooth and accomplished in about 10 sec.

2. A simulated instrument panel with

a) A vertical luminous line which the trainee can adjust to apparent vertical: either when the line is simply offset in the YZ plane or optionally when it is driven by a slow sinusoidal driving function.

b. A vertical series of lights with a control stick determining which light is lit.

3. The overhead capsule lighting should be externally controllable and monitored.

4. Two-way voice communication between trainee and instructor should be provided.

5. Head movements of the trainee should be monitored, either by a position-indicating device or TV monitor.

6. An arrangement for removing a cover on the capsule windshield to provide external view.

7. A circular external surround with an artificial horizon slightly below the trainee's eye level.

OUTLINE PROTOCOL OF TRAINING SCHEDULE

1. Place all trainees in capsule and indicate that rotation is about to start. Darken the capsule interior except for one small light. Move main platform a little and have each trainee poised to signal onset of rotation. Allow about 90 sec for autokinetic and autogyral effects to occur. Note signals from trainees and mention that most resulted from autokinetic and autogyral effects. Point out that some trainees saw the light move; others felt the entire capsule move; i.e. indicate that both subjective and objective autokinesis occur.

2. Accelerate to 15 rpm, instructing trainee to note turning sensation and to signal when it stops. Allow 60 sec. Explain end of sensation.

3. Illuminate vertical line and have trainee adjust to apparent vertical, describe the forces involved in the somatogravic and oculogravic illusions. Illuminate capsule to show setting relative to gravitational vertical. Provide an accurate true gravity reference. Allow 60 sec.

4. Darken capsule except for panel lights. Make tilt and return head movement to demonstrate Coriolis coupling effects. (Trainee could be required to lean to side in order to see digits, rather than have a head monitoring system). Explain effect. (Possible demonstration of inadvertent stick movement during head movement.) Check for motion sickness and instruct trainee appropriately.

5. Rotate capsule 90 deg from tangential to outboard heading. Could be accomplished by hand crank. Continue explanation of Coriolis phenomenon. After 30 sec, have trainee use vertical series of lights to locate apparent horizon. Leave setting as it is. Then make two head movements to again demonstrate Coriolis coupling.

6. Provide external view. Illustrate error in horizon setting. Check for motion sickness and instruct appropriately. Further explain oculogravic illusion. Repeat previous head movements to demonstrate the reduction of Coriolis coupling effect with external view.

7. Close capsule. Decelerate to 7.5 rpm with capsule illuminated. Provide external view to illustrate error in turning sensation. Close capsule, turn off all lights. Decelerate to stop. Open capsule 2 sec after stop. Explain oculogyral illusion. Explain effect of external reference.

8. Give explanation in darkness with suggestions appropriate for the inducation of autokinetic phenomenon.

The demonstration will provoke a number of questions and will motivate a considerable interest in the subject matter. For this reason, the demonstration should be introduced by a brief lecture on disorientation and followed by a more complete lecture on disorientation including a question and answer period. The demonstration can be completed in 10 min.

POINTS DEMONSTRATED

1. Visual and somatic autokinesis.

2. Oculogyral and somatogyral illusions on angular acceleration and deceleration.

3. Coriolis coupling effects.

4. Oculogravic and somatogravic illusions.

5. Effects of external view on vestibular 'illusions'.

6. Effect of head movement on inadvertent control stick movement (possibility).

7. The demonstration can be used to explain how many of the illusions experienced in flight are normal responses to unnatural stimuli, though the autokinetic effects show how errors can occur even in the absence of unusual angular or linear accelerations. Practical advice, on how to deal with spatial disorientation in the flight environment, can be coupled with explanations of the specific illusions reported by the students.

IN-FLIGHT DEMONSTRATION OF SPATIAL DISORIENTATION

Schedule based on techniques developed by Lts W R Crawford and H F Davis, MC USN. VF-126 Ser 136 of 24 March 1967

Flight Manoeuvres in TF-90 Aircraft to Demonstrate Disorientation

1. Straight and level for at least 15 seconds; smooth level turn to left for 90° standard rate turn; then increase bank enough to pull 1½-2 G (Sensation: climbing).

2. Straight and level for at least 15 seconds; put in skid, hold for 15 seconds, ease out of skid (Sensation: skid or bank in opposite direction).

3. Straight and level for at least 15 seconds; smooth level turn to right for 90° standard rate turn; then increase bank enough to pull 2½ G; have him look down at right console (into the turn); hold for 10 seconds; then face instrument panel. Head movements must be rapid (Sensation: change of attitude (variable) due to "G" excess and cross coupled stimulation).

4. Straight and level for at least 15 seconds; maintain level flight; decelerate as rapidly as possible with power and speed brakes (Sensation: diving).

5. Ease nose over to about 20° below the horizon; accelerate rapidly; 2 G pitch-up to about 45° above the horizon; ½ G' over-the-top recovery (Sensation: inverted as continuing a loop or tumbling or rolling as coming out of ½ Cuban eight).

Procedure

The student (back-seat) pilot is briefed on the following points:

a. This portion of the flight is to demonstrate the unreliability of the balance mechanism (vestibular) and body position (proprioceptive) sensations and to convince the pilot he must constantly monitor and believe his instruments.

b. It is a smooth, insidious, typical 'vertigo', not the accustomed, violent manoeuvring, which is expected during unusual attitude manoeuvres and causes unorientation rather than disorientation.

c. Give a running commentary over the aircraft communication system of positional sensations/attitudes encountered (pitch, roll, yaw).

d. Sit straight and keep eyes closed until the instructor pilot (IP) says to open them.

e. Hood will be utilised to eliminate sun cues. If sun is not a factor, hood will be down for faster orientation when told to open eyes.

The IP flies through the manoeuvres and continues each of them until the desired responses are attained at which time he immediately tells the back seat pilot to open his eyes. In all cases disorientation has proven to be rather rapid, and though not all responses are identical, the manoeuvres produced the desired illusions.

The demonstration is made on three flights. On the first, the flight manoeuvres outlined above are performed. On the second, the student pilot, under the hood, is required to fly simple manoeuvres with eyes closed, namely:-

a. Straight and level for 15 - 20 seconds.

b. Standard rate turn through 90° and then straight and level.

The student opens his eyes on command from the instructor and recovers to straight and level flight on instruments - with the aid of the instructor if necessary.

On the third flight, full treatment is given. This includes demonstrations such as having the hooded pilot simulate changing channels on the radio. noise, pressurisation and temperature fluctuations, etc. The instructor has the option of flying into the manoeuvre of allowing the hooded pilot to do so, or both.

Partial panel is utilised for some of the disorientation practice. The time required for this training varies depending upon the responses attained and proficiency displayed.

ANNEX F.2

IN-FLIGHT DEMONSTRATION OF SPATIAL DISORIENTATION

Schedule based on USAF practice

Start all manoeuvres with student's eyes closed

1. Sensation: climbing while turning.

Instructions: Make 90-degree turn of about 1½ G. (The roll into the turn must be imperceptible. The application of G-forces in this circumstance suggests to the trainee that a nose-up change of attitude is being accomplished.)

2. Sensation: diving during turn recovery.

Instructions: Make 90-degree turn of about 1½ G; student opens eyes about half-way through recovery. (During the 1½ G turn, the student adapts to the above-normal G-loading, so that as the excess G-force is removed, he falsely senses nose-down change in pitch.)

3. Sensation: tilting to right or left.

Instructions: execute slight skid to left from straight and level flight. (The skid changes the direction of the net gravitoinertial vector, with the result that the student falsely perceives himself to be tilted relative to the earth's gravity-force vector.)

4. Sensation: reversal of motion.

Instructions: Hold nose level and on a point, while rolling to 45-degree banked attitude. (The illusion generated here is the leans. The motion usually generated by this manoeuvre is one of a sub-threshold roll followed by a sudden stop: the trainee is left with a sensation that he has rolled in the direction of the angular acceleration generated by the stop, which is opposite in direction to the roll that was actually accomplished by the initial, sub-threshold acceleration.)

5. Sensation: diving or rolling beyond vertical.

Instructions: During a coordinated 30-degree to 45-degree banked turn, lower head, look to right or left, and immediately assume normal seated position. (This is an attempt to generate the coriolis or G-excess phenomenon.)

6. Sensation: climbing

Instructions: Maintain straight and level flight and increase airspeed. (The illusion created is the somatogravic illusion; it can be generated very effectively in the T-38 during application of afterburner.)

IN-FLIGHT TEST OF MANOEUVRES FOR DEMONSTRATION OF SPATIAL DISORIENTATION

A preliminary report

by

Major Chr. Henning, OSA? GAF

The following manoeuvres have been test-flown in order to assess their suitability for the in-flight demonstration of spatial disorientation. In general the manoeuvres have been performed out of typical instrument flying phases. The flight characteristics of these phases have been set up, and were kept for a certain time, corresponding with or being higher than the adaptation time of the vestibular apparatus to steady motions. Out of the thus established conditions the "action part" of each manoeuvre took place. The intended simulation of each action part will be explained in the following descriptions of the manoeuvres.

METHOD

The test aircraft was a two seat jet trainer, the Fiat G91 fighter-bomber. All manoeuvres were flown in Visual Meteorological Conditions under an overcast cloud layer in order to avoid moving shadows inside the hooded rear cockpit. In all, three sorties were flown and in each several manoeuvres were executed two or three times. Some were not repeated in the third sortie, due to negative results in the two preceding trials. During the first and second sorties the author, who himself possesses a standard-rated pilot qualification, acted as the test subject in the rear cockpit. On the third sortie a senior pilot with a check-pilot qualification, was the subject.

Manoeuvre No 1: This was a climbing turn of a normal SID of at least 180° of turn or more.

Flight characteristics: IAS 350 knots - steady
Bank 30° - steady
Power 100% RPM

Action:
1. Power idle
2. Wings level (roughly for both)
3. Smooth power adjustment (just to maintain a climb, airspeed slowly decreasing).

The action was to simulate the situation of a wing man in a two ship formation who, on losing sight of his leader, has to apply "Power back" and "Level the wings" in order to avoid a collision. If this should happen, the flight situation for the pilot would be unexpected and perhaps not recoverable by routine actions. He might be distracted from his instruments and become disorientated by the emergency manoeuvre.

Manoeuvre No 2: This simulated normal instrument take-off, being already airborne, but still within the take-off danger envelope for jet aircraft, i.e. below 250 IAS and lower than 1000 ft.

Flight characteristics: IAS 200-250 knots increasing - straight and level flight.
Power 100%

Action: Power back (on one of trials back to idle, on two back to 65% RPM).
Keep level flight without power adjustment.

The manoeuvre differed from the real take-off situation as no climb was established and level flight was maintained, thus a higher acceleration was achieved which on interruption should induce the expected spatial disorientation. The action was to simulate a sudden power loss, or even flame-out, of the engine. Possible attempts by the pilot to fly the aircraft might induce the expected somatogravic illusion of a nose-down change in attitude, with a consequent pulling of the stick and stalling the aircraft.

Manoeuvre No 3: This simulated a sudden and perhaps unprepared entry into clouds from visual flight conditions.

Flight characteristics: Level turn with 30° of bank, lasting 180° (twice) and 90° (once).

Action: i. Quick closure of the hood (rear cockpit)
10 sec later: roughly wings level.

ii. Quick closure of the hood (rear cockpit
10 sec later: smoothly wings level.

The action was to simulate the transfer from external visual cues to instrument cues. During this phase the pilot may become disorientated because he accepts subjective orientation information before he has fully interpreted the flight instruments.

Manoeuvre No 4: This was an "arc-to-radial-interception".

Flight characteristics: Normal arc flying procedure: 10° straight and level, 10° level turn changing at least three times along the arc.

Action: Out of the last turn and increase to 45° of bank of turn (maintaining always level flight).

The manoeuvre was like that which occurs when a pilot finds that he is overshooting the determined radial. The increased-g-load was supposed to produce a false nose up sensation in the turn or nose down sensation after the turn. None of these feelings occurred. This can be explained by the relatively small g-load increase, when bank is increased from 30° to 45°, and the negligible change in the direction of the resultant acceleration vector relative to the pilot.

Manoeuvre No 5: This was similar to flying in a holding pattern for a high level jet penetration.

Flight characteristics: IAS 250 knots, bank 30° for a 180° level turn (3°/sec). The test person moved his head, and kept it turned and bent down, to the left side panel throughout the turn.

Action: i. The test person quickly brought his head back to the normal upright position.

ii. As above, but, when the head movement was made the pilot quickly recovered from the turn and levelled the wings of the aircraft.

Both actions (i and ii) were intended to simulate cockpit work involving movement of the head, as on changing frequency, reading the let down plate, etc. Action ii was considered to generate a more complex cross-coupled (Coriolis) stimulus.

RESULTS

Manoeuvre No 1 was executed 5 times. Every time it consistently produced erroneous sensations which were: (a) being banked in the roll-out direction, (b) after 5-10 sec a nose-down change in attitude which was sustained as long as the climb after a smooth power adjustment was maintained (approx 30 sec).

Manoeuvre No 2 was flown three times during the first and second mission only once did a positive but weak disorientating sensation develop when the power was rapidly pulled back to idle, and this disappeared as soon as the necessary power adjustment was made to keep level flight.

The two variants of manoeuvre No 3 were each flown 3 times. The sensation produced by the action ii was a feeling of bank in the roll-out direction for about 20-30 sec. With action ii no change in apparent attitude was induced. When the hood was closed after the aircraft had turned through 90°, the sensation of continued turn persisted. However, when hood closure was made after 180° of the turn the subject felt that the aircraft was in a wings-level attitude.