

Feb 98

DCIEM No. 98-R-32

**RECOMMENDATIONS TO ENHANCE
SPATIAL DISORIENTATION TRAINING
FOR THE CANADIAN FORCES.**

B. Cheung

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
Toronto, Ontario
Canada M3M 3B9

- © HER MAJESTY THE QUEEN IN RIGHT OF CANADA (1998)
as represented by the Minister of National Defence
- © SA MAJESTE LA REINE EN DROIT DU CANADA (1998)
Defense Nationale Canada

DEPARTMENT OF NATIONAL DEFENCE - CANADA

DISTRIBUTION STATEMENT 4

Approved for public release;
Distribution Unlimited

DTIC QUALITY INSPECTED 3

19980608 067

Executive Summary

Spatial disorientation (SD) in flight wastes millions of dollars worth of defence capability and continues to kill aircrew. A number of CF (Canadian Forces) surveys have identified SD as the most detrimental of all listed aircraft and human factor issues in terms of its effects on flight safety and operational effectiveness. Two retrospective studies by Hartzell and Cheung et al. confirmed that SD was a significant contributing factor in 12 (between 1968-78) and 14 (between 1982-92) accidents respectively. Following a series of SD implicated mishaps in the CF-18 between 1986-90; the Commander of AIRCOM directed the initiation of ground-based disorientation training and the acquisition of an effective ground-based SD trainer. However, without a recent mishap, on-going fiscal restraint and other factors, the support and resources for acquiring an effective ground-based trainer are not available. In order to solve the SD problem, we believe that research on underlying mechanisms is productive and that hardware improvements will eventually provide substantial additional protection. Research and technological improvements that deal with SD will require a great deal of effort and money to implement and is a distant goal. For the near term, the only practical approach is to enhance SD awareness training for pilots and should be addressed without delay. This report reviews current SD training practices in the CF, and makes recommendations to enhance spatial disorientation training on the ground and in-flight. It is hoped that this report will generate continued discussions among pilots, aeromedical instructors, flight surgeons and research scientists in maintaining progress towards mounting an attack on SD.

Key words: spatial disorientation, demonstration, training enhancement.

Abstract

In the Canadian Forces (CF), several surveys have revealed a significant frequency of SD occurrences. Two retrospective studies on aircraft accidents indicated that there were 12 (between 1968-78) and 14 (between 1982-92) accidents in which disorientation was listed as a major contributing factor. To solve the SD problem, we believe that: (1) research on underlying mechanism is productive; (2) hardware improvements will eventually provide substantial additional protection and (3) improved ground-based SD demonstration and training will be useful in the short run. Research and technological initiatives that deal with SD countermeasures will require a great deal of effort and resources to implement. However, SD training enhancements where appropriate, can be readily achieved and should be addressed immediately. This report provides a brief review of SD problems in the CF, current training procedures, and provides recommendations to enhance interim and long-term SD training strategies.

Table of Contents

	Page
Executive Summary	i
Abstract.....	ii
Introduction.....	1
Current SD Training in the CF.....	4
Summary of Findings.....	8
Recommendations to Enhance SD Training for the CF.....	9
Conclusion.....	16
References.....	17
Acknowledgments.....	19
Appendix.....	20

Introduction

During peace time, two of the most life threatening aeromedical problems that the air force might encounter is spatial disorientation (SD) and G induced loss of consciousness (G-LOC). For the past 3 decades, Canadian Forces (CF) flight statistics have revealed the significance of spatial disorientation as a contributing factor in aircraft accidents. From 1968-78, there were 12 accidents in which disorientation was listed as a cause factor, which resulted in the total loss of 10 aircraft and the lives of 8 aircrew (1). More recently, two separate CF surveys (2, 3) and a CF study (4) have identified SD as the most detrimental of all listed aircraft and human factor issues in terms of its effects on flight safety and operational effectiveness.

- 50% of pilots in 1 Air Division Survey (3) reported disorientation
- 48% reported disorientation in the Fighter Group Survey (2)
- 44% reported problems with disorientation, of which 10% have experienced more than three incidents

However, for comparison:

- In 1 Air Division Survey (3), no pilots reported G-LOC, several reported instances of "grey-out"
- In the Fighter Group Survey (2), 11% reported G-LOC incidents, 12% reported grey-out
- In the CF-18 Human Factors study (4), 4% reported G-LOC incidents, 62% reported incidents of G-induced visual decrement.

It seems that most Pilots see no need for improvement in G protection, but a better system would be welcome if available (3).

A retrospective study by Cheung et al. (5) confirmed that SD is a significant contributing factor in about 23% (14/62) of all category A accidents between 1982-1992. Category A accidents is defined as an event when the aircraft is destroyed, declared missing, or damaged beyond economical repair. Eleven of these accidents involved the loss of lives of 16 military and 8 civilian personnel. Disorientation is a factor not limited to flying trainees. It affects experienced pilots as well. SD is a flight safety hazard in all aircraft but is particularly hazardous in single seated aircraft and when combat pilots engage in activities that are known to cause and aggravate disorientation.

Following a series of SD implicated mishaps in the CF18 during the period of 1986-90; the Commander of AIRCOM directed the initiation of ground-based disorientation training for the CF-18 pilots. As an interim solution, pilots were trained on an existing USN disorientation device, the Multi-station

Disorientation Demonstrator (MSDD). The MSDD is a circular platform with a vertical axis of rotation that could accommodate from 1-10 trainees. Each trainee was seated in a circular capsule capable of rotating 90 degrees, relative to the main platform. A projector assembly with identical rotation parameters to those of the main platform provides seven display patterns to the trainee. The purpose of this trainer is to demonstrate some forms of disorientation, which can occur in flight.

The program was not considered to be effective (Memo 3725A-P51CB ALS, 23 September 1996). Specifically, 3 Wing in Bagotville participated in a disorientation course involving the MSDD during 1991-92. The course was considered to be cost ineffective by the pilots due to the mild nature of the disorientation which had no effect on experienced pilots (Memo 3773 3FE12, 23 January, 1998).

Efforts have been made to identify an existing disorientation device that meets the Commander's direction. Partly as a result of aggressive marketing, a perception surfaced that disorientation trainers/demonstrators exist commercially and are effective in training pilots against SD in flight without preliminary research. Director General of Aerospace Development (DGAD) was to acquire an Advanced Spatial Disorientation Demonstrator (ASDD), but action was deferred for financial reasons.

However, without a recent mishap (possibly due to fewer squadrons and reduced flying hours), on-going fiscal restraints and other factors, the impetus of support and resources for SD countermeasures are not available. Before the purchase of the CF-18, it was predicted by (then) Maj. W. G. Hartzell that one or more of these aircraft (at the cost of 10 million dollars each in 1979) were likely to be lost in a disorientation incident in the next twenty years (1). As of 1995, Directorate of Flight Safety (DFS) records showed that five CF-18s were lost (at a cost of 38 million dollars each in 1995) in SD-implicated fatal accidents (4).

With the expanding role of helicopters in military aviation, spatial disorientation has become an important factor in rotary-wing flight safety. Helicopters are conducive to the occurrence of disorientation due to their ability to move in any direction, a true three-dimensional flight. SD imposes a particular hazard to rotary-wing operations, which differ in many respects to that experienced by fixed-wing operators. Modern helicopters now are equipped with comparatively sophisticated automated stabilization equipment and improved instrumentation. However, improvements in aircraft design are counterbalanced by the ability to operate in more difficult areas and weather conditions, and by the requirement for aircrews to make use of visual devices such as NVG (Night Vision Goggles) and FLIR (Forward Looking Infra-Red). Also to be considered are the physical limitations likely to be imposed by the use

of aircrew chemical defence ensembles in the future. A survey completed by the US Army revealed that between 1987-1995, 30% of all helicopter accidents were considered to have had SD as a major or contributory factor (6).

The CF has found itself on the eve of acquiring a new fleet of modern helicopters; the AW520 Cormorant search and rescue (SAR) helicopters at the cost of \$39.5 million each. One or more of these aircraft are likely to be lost in disorientation accidents in the next 10 years. Although one cannot predict that a comprehensive SD training program will prevent this, it seems to be prudent to promote efforts aimed at prevention and training before the next SD mishap. These efforts could reduce the risk of loss of life and military assets.

Research and technological initiatives that deal with SD will require a great deal of effort and money to implement. However training enhancements where appropriate, can be more readily achieved and so should be addressed without delay. This paper attempts to provide some perspective on SD training in the Canadian Forces and to provide recommendations for interim and long term training strategies.

Current SD Training in the CF

Ab Initio aircrew first encountered disorientation training during their Basic Pilot Aeromedical Training program or during HAI (High Altitude Indoctrination) at Canadian Forces School of Aeromedical Training (CFSAT) in Winnipeg. In addition to the didactic lecture, most students are exposed to the Barany chair and Vertigon (please see page 5 for description). Videos and slides on visual illusion and spatial disorientation are also available for presentation to the trainees. These trainees may have very limited flying experience and very likely no experience with disorientation in flight. They are being instructed by Biosciences Officers and Aeromedical Technicians with limited training aid. This seriously limits the value of this aspect of the initial aeromedical training. The next exposure to disorientation training is at CFB Moose Jaw. At the Initial Instrument Test phase of their training, the ground school program provides one hour during which the Flight Surgeon is to provide the last disorientation training that these trainees will receive, and for some, a long way into their careers. After completing the pilot training and receiving their wings, qualified pilots would receive re-certification training scheduled 5 years from initial training. This involves lectures and case histories only. It is recognized that it is more difficult to make this training practical and credible for experienced aircrew if no standardized and realistic SD training is available.

While this problem exists at all flying bases where the Flight Surgeon has a responsibility for aeromedical training which is not well defined. It is more acute at training bases, which have responsibility for giving the aircrew their foundation in the subject of disorientation. In general, the absence of central coordinated control and support for this vital part of aeromedical training is apparent. For example, it must be emphasized that there is no provision in the Tutor Flying Training Program for airborne disorientation training exercises. Classroom training is only a supplement. The Tutor-Manual of Flying Training CFP167 makes reference to disorientation in four locations (sections 6.29, 6.34, 6.37, and 13.15). However it does not discuss corrective or preventive measures or airborne disorientation training. Similarly, CFP 167 (2A) Flying Instructors Guide for Undergraduate Pilot Training refers to disorientation very briefly only twice: in the Instrument Mass (Ground) Briefing Outline and in General Night Flying Section. In neither instance is any reference made to airborne practice or prevention. Finally, in the CF-18 How to Fly manual (AL 12/86), SD was mentioned twice (sections 1-33, 2-16), again, without reference to prevention or correction.

At the Squadron level, a recent telephone surveys from 16 Flight Safety Officers revealed that SD training is limited to films and videos that are available for viewing during poor weather conditions when flying is not feasible (Memo 3773 3FE12 ALS, 23 January 1998). This type of training environment is not

conducive to SD being perceived as a credible factor to be considered in active flying. All SD flying training is done in an informal atmosphere where experiences were passed on to junior pilots.

Current SD Lectures

Current classroom didactic lectures from CFSAT are very comprehensive. The syllabus is separated into 4 different categories depending on whether the students are pilot trainees, airborne electronic sensor operators or experienced pilots. The objectives are well defined for the instructors. More time could be assigned to certain topics. However, the assessments of the student on the lecture material are not clearly defined. Without some practical demonstration, there is no opportunity to make the theoretical understanding of the problem of SD meaningful. The practical understanding of SD can only come through exposure to visual and vestibular illusions and actual disorientation in the flight environment in a well-planned and controlled manner.

Current classroom discussions are performed by Aeromedical Technicians, Biosciences Officers, and Flight Surgeons. These instructors do not all have a pilot background which makes the discussion of SD difficult. In order to have an in-depth appreciation of SD, the subject of disorientation requires a very high level of practical understanding of flight, flight dynamics, etc. It seems the program would have a greater impact if it were delivered by qualified Pilots or Flight Surgeons with a pilot background.

Current Available Ground-Based Devices for SD Training

1) Barany Chair

The Barany chair is useful for demonstrating to the pilot trainees some very basic vestibular sensations and illusions illustrating the inadequacy of our organs of balance and the dominance of other sensory systems. However, the Barany chair lacks the capability and realism to be useful in SD training with the sophisticated training systems of today, and is of questionable value with experienced aircrew. The inadequacy of the Barany Chair as a spatial disorientation training device has been reported since 1930 (7).

2) Vertigon (Flightmatic Inc., Teterboro, N. J.)

The Vertigon is a demonstrator with a limited range of visual illusions. A Coriolis illusion is induced by having the subject move his head after a sustained rotation about the yaw axis. This illusion is expected to degrade the ability of the pilot to "make the instruments read right" and it was suggested that this exercise induces a useful training effect. If the proper simulated visual scenes are present

and are reacting appropriately to the control stick inputs, the pilot might be convinced that he is actually controlling the motion of the vehicle. However, if the visual scene is removed and the pilot realizes that there are no associated vestibular sensations corresponding to control movements and instrument readings, the pilot will simply become mis-oriented (suffering an orientational illusion). Moreover, it is extremely dangerous for a pilot to be told that he is combating disorientation, when in fact the control inputs are not related to the vehicle motion as sensed by the vestibular cues. Under these circumstances, a false sense of security may be generated. Often the only memory the aircrew had of the Vertigon is the unpleasant motion sickness symptoms as a result of the Coriolis cross-coupling effect.

3) GYRO IPT (Environmental Tectronics Corporation, Southampton, N.J.)

At the time of writing this report, the CF is in the process of acquiring the GYRO IPT (Integrated Physiological Trainer) which is the latest version of the GYRO-1 series of flight simulators with upgrades on the pitch and roll motion capability. The major advantage is purported to be its closed-loop feature that forces the trainee to relate any demonstration to actual flight situations. However due to the limited pitch (± 15 degrees) and roll (± 30 degrees) capability and the lack of planetary rotation, illusions that can be demonstrated are limited to Coriolis cross-coupling and some visual illusion such as autokinesis that can be demonstrated by other means. Autokinesis is the apparent motion of a small stationary light in the dark. The capability of visual illusion demonstration is limited by the small visual field provided by a 21 inch display monitor. Due to the lack of G forces, which normally accompany such illusions in the aircraft, the demonstration of graveyard spiral and graveyard spin will not be convincing. The listing of nystagmus as an illusion is erroneous. Nystagmus (involuntary eye movements) is a physiological response to sustained angular acceleration and deceleration acting on the semicircular canals. The potential of the GYRO IPT as a SD training tool will be limited to the demonstration of some illusions at the undergraduate pilot training level only. It remains to be investigated that the GYRO IPT is more effective than previous demonstrators.

Current In-Flight Training: Unusual Attitude Recovery

There is no standardized in-flight training on SD demonstration nor recovery from SD. Current in-flight training includes the demonstration of unusual attitudes to student Pilots, requiring them to recover the aircraft. The emphasis of the demonstration is on recovery, not the causes or solutions of disorientation. Although some believe that the in-flight training of recovery from unusual attitudes is SD training, this is not entirely correct. If one is to understand it correctly, in an unusual attitude recovery procedure, the Pilot is taught the most efficient method of righting an aircraft, which has been placed in

a dangerously extreme attitude. Although SD could conceivably occur during the recovery, it probably does not occur very often because the student expects an unusual attitude and has a clearly conceived set of options in his mind when he is given the task to right the aircraft. This could be why the procedure of unusual attitude recovery tends to be devoid of complication from SD. The important element of having allowed oneself into the disorientation situation is notably absent during unusual attitude recovery exercises. The same argument also applies to the "under the bag" instrument unusual attitude recoveries. The instrument flying hood forces the pilot to concentrate on the instruments, eliminates the distractions in his peripheral vision, and eliminates transitions from VFR to IFR conditions and other factors which would normally aggravate a disorientation situation.

Summary of Findings

It is noteworthy that the findings listed below are very similar to previous findings listed by Maj. Hartzell.

1. SD is a significant flight safety hazard in the CF.
2. Ground based SD training in the CF concentrates on comprehensive didactic lectures with some basic demonstration of SD.
3. CF Pilots can be better prepared in training to prevent, recognize and combat SD.
4. Personnel in the CF charged with providing ground-based SD training could be better trained or supported.
5. Although lecture objectives are clearly defined for the instructor, there is no course training standard that has to be met by either the instructor or the student and subsequent assessments of student knowledge on the material of SD.
6. Current lecture materials devote insufficient time to discuss how to deal with SD in flight. This is in direct contradiction to the opinion that aircrew should never hear about disorientation without also receiving instruction on how to deal with SD in flight (8).
7. The CF should attempt to obtain a closed-loop SD demonstrator/training device that will allow realistic demonstration of the visual and vestibular illusions, and to develop strategies that will allow the trainee to fly through such illusions.
8. Specific airborne SD training is not carried out during in-flight training in the CF.
9. Airborne SD training in the CF is not defined by standardized course training syllabi. The students are not given sufficient practical training in SD to become confident of their ability to handle the problem in the air.
10. Re-certification training is scheduled 5 years from initial training, but attendance may is not enforced.

Recommendations for Enhancement of SD Training in the CF

A) Different pedagogical techniques in SD lectures

i) The principle objective of instruction given on the ground is to provide factual knowledge about spatial orientation and disorientation in flight. A formal approach is suitable for the teaching of Student Pilots. This approach usually takes the form of lectures supported by visual aids, such as slides, overhead transparencies, cine film or videotape. Classroom training should be presented by personnel who have the appropriate theoretical background in physiology, and psychophysics, and who also are familiar with mission, aircraft, and aircrew with operator input.

ii) This approach is suitable for the teaching of Student Pilots. However, informal group discussion about personal experiences and current hazards by type of aircraft led by an experienced instructor or former Pilot is most effective for the refresher training of established aviators who have "heard it before." The reasons are as follows.

- For established Pilots, they are more likely to be attentive to accounts by their flying colleagues who learned about flying from disorientation incidents, or even accidents of which they had personal experience.
- A former Pilot will have an appreciation of what goes on in the cockpit, an in-depth understanding of the mission, and know the type of disorientation likely to be experienced in the aircraft type. Such an instructor will have credibility with the students.

iii) Within the operational flying squadron, SD awareness could be raised by having experienced Pilots list and discuss recurring SD situations that are specific to that aircraft type (see example in Appendix). This awareness training should be made mandatory.

iv) Scientists play a role in providing up-to-date information for the development of academic programs, interpreting the various types of disorientation to basic physiological and psychological mechanisms and serving as consultants to accident investigation. However, unless these Scientists are Pilots, it is difficult to gain appropriate rapport with Pilots being trained. Clinical discussion of SD using medical or research jargon is definitely not attractive to aircrew.

B) Timing of SD training

If SD training is too far in advance of flight training, it may cause flight students to forget important material concerning SD before they get the chance to experience SD in flight. It is suggested that training of any nature is more effective if distributed over several sessions. Therefore, reviewing SD is more effective after primary flight training and before instrument flight training. It is recommended that the initial block of SD training be retained at its present stage, but a second short refresher block should be inserted after students have completed some elementary flight training and before they commence instrument flight training and before OTU (Operation Training Unit). An assessment of the retention of aeromedical knowledge in SD would also be valuable. Much of what students learned about SD is not formally tested and therefore may not receive the attention it deserves. SD should be explicitly included not only as part of crew coordination training and situation awareness training, but also during the mission risk analysis when planning specific missions. Poor crew coordination has been cited as a factor leading to an increased risk of SD in many aircraft accidents (9).

C) Ground-based training tools

In order to enhance ground-based demonstration and training, it is imperative that the sensations induced by the simulator are isomorphic (of the same form or equivalent to the sensations felt during the real flight profile being simulated.) They should also be isomorphic to the coordinated subconscious reactions elicited from various sensory-motor systems during an actual flight. The training application of these devices requires careful consideration, not only in terms of who is exposed, but also in the nature of the demonstrations. Research laboratories are in an excellent position to guide the choice of training tools and suggest ways for implementation to achieve the final goals.

i) Current device

The Barany chair is probably an adequate introductory tool and should be used to demonstrate the perceptual threshold and limitation of rotation sensations, the somatogyral illusion, the Coriolis effect and the demonstration of the vestibulo-ocular reflex which cause a loss of dynamic visual acuity due to nystagmus. As many students as possible should experience these phenomena. The experience of using GYRO-IPT (if the acquisition is successful) should be monitored.

ii) Dedicated SD demonstration and training device

Experiencing disorientation is a training condition that should be an aspect of IFR proficiency training. Disorientation training should occur in a flight

simulation environment, within the context of a realistic flying task that contributes to IFR proficiency. An effective ground based closed-loop trainer must be realistic and provide aircrew with an opportunity to "fly through" the disorientation or control and recover the trainer. Such a device should have a realistic cockpit with a 3 degree-of-freedom motion base in addition to the planetary rotation and a wide field of view visual display (visual angles of 130° horizontal x 60° vertical.) The CF should continue to pursue this option. The cost of acquiring such a demonstrator/trainer and the accompanying training program over the next twenty years is negligible compared to the losses that have been sustained and, which, likely will continue (in terms of personnel and equipment).

Even though the past 6 years' effort to purchase a CF disorientation demonstration/training device appears to have collapsed, two areas of training have been investigated and require further development.

iii) SD training in existing flight simulators

The CF should examine the benefits of incorporation of SD training into present and future flight training simulators. Both motion- and fixed-base simulators should be considered to demonstrate SD situations, and to safely train students in SD avoidance and recovery procedures. Specific scenarios derived from accident sequences would be valuable for the student to obtain direct experience in preventing and overcoming SD in a realistic setting.

In view of the fact that DCIEM was not successful in acquiring a state-of-the-art SD demonstrator/trainer, the idea of using existing flight simulators for SD familiarization training was explored through a collaborative contract (10). One of the major findings indicated that illusory self-motion and self-tilt in a flight simulator should not require a motion base when the visual scene contains features that will provide an up-down orientation. This is likely to be the case during take-off and landing. In other words, we could use existing non-motion based simulators to demonstrate and teach pilots to cope with some of the visual illusions that one might encounter during take-off and landing. In order to continue with the above effort, access to flight simulators is required to conduct further studies into training effectiveness.

iv) Eye Tracking/Visual Scan Training

Pilot flight proficiency is an erodable skill. The critical flight proficiency requirement is to maintain control of the aircraft despite disorientation. In addition, channelized attention has long been recognized as a central etiological error for SD. In this case, when under stress or when disoriented, a pilot attempts to perform a demanding or unfamiliar task, and allows his attention to be

confined to one aspect of the task, he/she therefore fails to make optimum use of information about the aircraft orientation. This limitation is a normal behavioural response to the physical and mental load imposed by the mission profile. For example SD and target fixation is a hazard during weapons delivery. Current development of visual scan monitoring technology has demonstrated that the technology could be applied in combating channelized attention (11). As mentioned above, disorientation training should contribute to IFR proficiency. Visual scanning technology should be employed in active training squadrons to demonstrate correct and effective cross-check procedures and outcomes, to provide immediate feedback to student pilots with a real time performance record, and to establish and reinforce habit pattern and enable immediate intervention to correct faulty patterns. Task demonstration and immediate feedback have been shown to improve the speed and quality of training (12).

D) SD in-flight training

While ground based training is helpful, it has been shown that demonstrations of SD within the actual flight environment are extremely valuable and are complementary to the ground-based didactic lectures. In addition, there is a distinct difference between in-flight demonstration of SD, and training to overcome the problem once it has occurred. SD demonstration in flight consists of reinforcement of the limitations of the orientation senses in flight, and the enhancement of aircrew awareness to potential SD situations. On the other hand, SD training consists of a series of flight procedures to cope with disorientating circumstances and illusions. Since the British Army instituted its in-flight demonstration program (British Army SD Demonstration Sortie), their SD mishaps have decreased by 50% (13). It appears that the most meaningful way to train aircrew to recognize and overcome SD in flight is to conduct SD training in flight. A formal program of in-flight spatial orientation training, particularly with more emphasis on Unrecognized SD (Type II) needs to be implemented. The availability of flight time may preclude any serious use of in-flight spatial orientation training. However, pilots and instructors could utilize the time made available on their way to mission sites.

The current exercise of recovering from unusual attitudes and related eye-closed manoeuvres is valuable. A suggestion is to routinely allow the student to enter an unusual attitude and then recover from it. This is in addition to the more traditional method wherein the instructor pilot places the student into an unusual attitude.

However, rigorous conditioning-type of training should be avoided due to the possibility of transferring negative learning to flying the aircraft. For example, the large gaze shifts and large head movements performed while transferring attention between cockpit and target aircraft, could introduce a

combination of cross-coupled accelerations and G-excess effects, either of which could induce nausea in some subjects. When head movements are disconcerting to a pilot due to a combination of G-excess and cross-coupled stimulation, the pilot will tend to avoid or minimize the motion-generated stimulus by making smaller head movements with larger deviation of gaze. Such movements are not necessary in the aircraft environment where the cross-coupled effects are reduced due to the large turning radius and, thus, reduced angular velocity.

E) General recommendations to enhance SD awareness in the CF

1. Implement standardized SD training as part of the flying course. SD should be an integral part of both flying training and continuation training in Pilots.
2. As stated in the NATO Advisory Group for Aerospace Research and Development (AGARD) panel in 1974 (8), the need for ground-based as well as in-flight training, for both student pilots and experienced aircrew is highly recommended and emphasized.
3. Ground based training for student pilots should include lectures with improved quality of demonstrations and exposure to effective ground-based rotating devices, but avoiding amusement park types of demonstrations. Motion stimulus should not evoke symptoms of motion sickness.
4. Focus verbal training patterns on maintaining orientation awareness and disorientation prevention. This training should precede in-flight disorientation demonstrations, aerobatics and formation flight training with routine refresher training every 2-3 years.
5. SD training should be implemented before graduate Pilots enter an Operation Training Unit. That is, SD training should be emphasized at Moose Jaw (jet training) and at Portage La Prairie (helicopter and multi-engine training).
6. Operational squadrons should implement a formal and standardized SD awareness training as part of the training syllabus for the type aircraft. The instruction designed for individual aircrews by aircraft type should address the effects that aircraft flight characteristics, cockpit environment that could affect aircrew performance moment by moment in the cockpit. Specifically:
 - i) List and discuss previous accidents and incidents, and the most probable situations to lead to SD occurrences in the specific aircraft type. An example for the CF-18 is attached in the Appendix.
 - ii) Also discuss preventive measures, for example use ADI (Attitude Display Indicator), avoid A/B (After Burner) take-off, and R/T (Radio Transmission), etc.
 - iii) Being forced into SD situations during in-flight training, for example, formation flying, ACM (Air Combat Manoeuvres), wx (weather), etc.

iv) Cockpit management training, employing radar altimeter descent profiles.

7. Improved training for associated aviation personnel: Flight Surgeons, Biosciences Officers, and Aeromedical Technicians:

It is observed that the quality of SD training varies depending upon the trainer. Flight Surgeons, Defence Scientists, Biosciences Officer and Aeromedical Technicians could be given more flight experience and provided with up-to-date teaching material. If the expert and best teachers in the CF were video-recorded giving their lectures, and these films distributed, then all training would be of enhanced quality.

8. There is a need for a "feedback relationship" between the research and training communities, particularly if new and technologically advanced simulators or training materials are being considered. Some examples of such co-operation include avoiding the designations of a particular device solely for training or research, and including trainers and researchers in device planning meetings.

F) Some practical recommendations to improve SD awareness in the CF

1. Look for potential human performance problem areas prior to and during missions. Prioritize tasks to avoid and manage the anticipated problems.

The reasons are as follows:

- The mental functions involved in maintaining appropriate flight control involve more than processing of orientation sensory inputs, task saturation, and channelized attention. Distraction and other factors have been identified as affecting mental processes contributing to mishaps.
- Understanding how mental processing takes place helps the aviator to understand how even the most competent pilot may lose true awareness of flight conditions.
- Knowing the flight conditions, which can introduce erroneous perception of aircraft attitude, might alert the Pilot to avoid those conditions.
- Identifying traps, and conveying appropriate knowledge to deal with insidious, unavoidable threats to safety.

2. Pilots are often told to "Believe your instruments." However, it is important to be sure that the Pilot does not simply indulge in an attempt at belief of perception when disoriented. Pilots should be told that, in case of disorientation, "Control the aircraft to make the instruments read right." (14)

3. Realize that a Pilot's instructions about what to do in case of disorientation can be useful only in case of recognized disorientation. Unrecognized disorientation can be dealt with by avoiding situations that are prone to induce disorientation.

Aircrew should be taught to recognize conditions, which can be traps to a loss of orientation.

4. Avoid unrecognized disorientation:

- Avoid approaches over non-illuminated terrain or over smooth snow, or calm sea.
- Avoid head movements under conditions greater than 1G (although this is impractical during operational flying, the awareness of the potential of G-excess effect on orientation is note-worthy).
- Avoid removing the gaze from flight instruments when in cloud and maintain crosscheck.
- Abstain from drinking alcohol for 24 hours before flying. Alcohol produces a light (low density) spot that changes location in the semicircular canal during the post-ingestion decrease of the blood alcohol concentration. This light spot predisposes pilots to pilot to disorientation and it persists for up to 34 hours after drinking (15).

5. Pilots should be aware that sometimes disorientation is misperceived as a failure in the flight instruments, such as in the artificial horizon, or a failure in an aircraft control system. Therefore, when a failure in a flight instrument or in the control system is "suspected" the Pilot must verify the correct diagnosis of the problem before reacting.

6. Lastly, many problems of disorientation can be solved by using the autopilot or by passing control to another Pilot (when available) who is not disoriented.

Conclusion

As the late Dr. Gillingham pointed out, the eventual solution to the SD problem, other than remotely-piloted aircraft, is the use of computer-generated, wide-field-of view, helmet mounted visual display of the real world, which the Pilot can use to maintain SD in the natural manner (16). But realization and implementation of such a display are a distant goal, and interim measures to prevent SD mishaps must be sought. For the near term, the only practical approach is to improve SD awareness training for Pilots and to improve ground-based and in-flight training methods for demonstrating to Pilots the potential for SD and the means of coping with it.

References

1. Hartzell WG A study of the aeromedical aspects of spatial disorientation training, 1979 DCIEM report.
2. Fighter Group Safety Survey, CFB North Bay, Ontario: Fighter Memorandum, Canadian Forces, May 1990.
3. One Air Division Introspective Safety Survey - Final Report. CFB Baden, Germany, NDHQ 18 May 1990 Memorandum 1011-6.
4. Davidson RA et al. (1991) Human Factors in the CF-18 pilot environment DCIEM report no. 91-11.
5. Cheung B, Money K, Wright H, Bateman W (1995) Spatial disorientation implicated accidents in Canadian Forces 1982-1992 Aviat Space Environ Med 66(6) 579-585.
6. Braithwaite M, Groh, S, Alvarez E (1997) Spatial Disorientation in the US Army helicopter accidents: an update of the 1987-92 survey to include 1993-95 USAARL Report No. 97-13
7. Ocker WC (1930) Symposium on blind flying The journal of Aviation Medicine 1(3) 132-150.
8. Benson AJ (1974) Orientation/disorientation training of flying personnel: a working group report. AGARD report No 625, Technical Editing and Reproduction Ltd., London.
9. Lawson B, Braithwaite M, Yauch D Training in spatial disorientation. The proceedings of the second meeting of a subgroup of the Triservice technical working group for spatial orientation and situation awareness. Armstrong Laboratory, Brooks Air Force Base, San Antonio, Texas. September 16-17, 1997
10. Howard I, Cheung B, Groen E (1997) Disorientation training in non-motion based simulator. DCIEM Contractor Report PWGSC Contract No. W7711-5-7256
11. Cheung B, M. Brush, M. Eizenman, K. Hofer, M. Cole (1998) Application of visual scanning/point of gaze technology to spatial disorientation training. Research Panel on Countermeasures to Spatial Disorientation -International Initiatives, Aerospace Medical Association Aviat Space Environ Med 69(3) 251 Abstract #311.

12. Goldstein IL (1974) Training in organizations: needs assessment, development, and evaluation. Pacific Grove, CA Brooks/Cole Publishing.
13. Braithwaite M, Alvarez E, Cashwell K, Collins C, Estrada A, Groh, S (1997) Evaluation of the spatial disorientation sortie in training aviators. USAARL report No. 97-22.
14. Money KE (1997) Disorientation, Nouvelle Revue D'Aeronautique Et D'Astronautique No. 4, 40-43.
- 15 Money KE (1991) Alcohol as a flight hazard (part II). Aeromedical and Training Digest volume 5, issue 4.
16. Gillingham KK (1992) The spatial disorientation problem in the United States Air Force. Journal of Vestibular Research, Vol 2, 297-306.

Acknowledgments

The author thanks Capt Mike Brush, Capt Wayne Wong and Dr. Ira Jacobs for helpful discussions, Maj RG Jones's contribution to situations most probable to lead to SD in the CF-18, Mr. Kevin Hofer for editorial comments and formatting of this manuscript.

Appendix

Situations most likely to lead to SD occurrences (Major RG Jones)

1. Take off with after-burner at night and/or weather conditions:

Corrective action taken as a result of SD suspected in two take-off accidents:

- (i) ADI (Attitude Display Indicator) must be up on the DDI (Digital Display Indicator) for take-off into weather/night meteorological conditions.
- (ii) A/B is only used when absolutely necessary.

2. Flying in formation:

Leans are easily experienced when flying on the wing at night or in weather/white out conditions. Breaking in and out of cloud can also be very disorienting especially on the wing:

- i) Flying with the ADI up on the DDI that is on the lead's side can be included in the crosscheck to overcome SD tendencies.
- ii) Lights improperly adjusted on the lead aircraft will also cause problems at night

3. Air Combat Manoeuvring:

Three-dimensional manoeuvring in tactics such as rolling scissors can cause SD particularly in the "soup bowl" weather conditions. In order to keep orientation, the pilot must have a distinct horizon to refer to at least in his peripheral vision.

4. Instrument Fixation/Channelised Attention:

Channelized attention on the radar or the velocity vector frozen in the HUD (Head Up Displays) will lead to situations of SD or potential unusual attitude recoveries. A continuous and rapid cross check of interdependent instruments will avoid these situations

5. Target fixation/Loss of Depth Perception:

Fixation on rejoins with excessive overtake have caused mid-air collisions. Fixating with aiming systems for weapons solutions on ground or air targets could cause pilots to lose depth perception. These risk factors can be reduced by spatial orientation awareness training and perform frequent crosschecks.

6. Meteorological Conditions:

Stars can look the same as the ground over the prairies and in the north. Flying over water, especially glassy surface can cause depth perception problems. Flying during whiteout can cause the disappearance of horizon.

Unclassified
SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Establishment sponsoring a contractor's report, or tasking agency, are entered in section 12.) Defence and Civil Institute of Environmental Medicine 1133 Sheppard Ave W PO Box 2000 Toronto, Ontario Canada M3M 3B9		2. DOCUMENT SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable) Unclassified													
3. DOCUMENT TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.) Recommendations to enhance spatial disorientation training for the Canadian Forces															
4. DESCRIPTIVE NOTES (the category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.) DCIEM Report															
5. AUTHOR(S) (Last name, first name, middle initial. If military, show rank, e.g. Burns, Maj. Frank E.) Cheung, Bob Ph.D.															
6. DOCUMENT DATE (month and year of publication of document)		7.a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 21													
		7.b. NO. OF REFS. (total cited in document) 14													
8.a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)		8.b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)													
9.a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) 98-R-32		9.b. OTHER DOCUMENT NO.(S) (any other numbers which may be assigned this document either by the originator or by the sponsor.)													
10. DOCUMENT AVAILABILITY (any limitation on further dissemination of the document, other than those imposed by security classification) <table border="1" style="width: 100%; border-collapse: collapse;"><tr><td style="width: 30px; text-align: center;">☒</td><td>Unlimited distribution</td></tr><tr><td style="text-align: center;">☐</td><td>Distribution limited to defence departments and defence contractors; further distribution only as approved</td></tr><tr><td style="text-align: center;">☐</td><td>Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved</td></tr><tr><td style="text-align: center;">☐</td><td>Distribution limited to government departments and agencies; further distribution only as approved</td></tr><tr><td style="text-align: center;">☐</td><td>Distribution limited to defence departments; further distribution only as approved</td></tr><tr><td style="text-align: center;">☐</td><td>Other</td></tr></table>				☒	Unlimited distribution	☐	Distribution limited to defence departments and defence contractors; further distribution only as approved	☐	Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved	☐	Distribution limited to government departments and agencies; further distribution only as approved	☐	Distribution limited to defence departments; further distribution only as approved	☐	Other
☒	Unlimited distribution														
☐	Distribution limited to defence departments and defence contractors; further distribution only as approved														
☐	Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved														
☐	Distribution limited to government departments and agencies; further distribution only as approved														
☐	Distribution limited to defence departments; further distribution only as approved														
☐	Other														
11. ANNOUNCEMENT AVAILABILITY (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (10.) However, where further distribution (beyond the audience specified in 10) is possible, a wider announcement audience may be selected.)															
12. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.) Defence and Civil Institute of Environmental Medicine 1133 Sheppard Ave W, PO Box 2000 Toronto, Ontario Canada M3M 3B9															

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

Spatial disorientation (SD) in flight wastes millions of dollars worth of defence capability and continues to kill aircrew. A number of CF (Canadian Forces) surveys have identified SD as the most detrimental of all listed aircraft and human factor issues in terms of its effects on flight safety and operational effectiveness. Two retrospective studies by Hartzell and Cheung et al. confirmed that SD was a significant contributing factor in 12 (between 1968-78) and 14 (between 1982-92) accidents respectively. Following a series of SD implicated mishaps in the CF-18 between 1986-90, the Commander of AIRCOM directed the initiation of ground-based disorientation training and the acquisition of an effective ground-based SD trainer. In order to solve the SD problem, we believe that research on underlying mechanisms is productive and that hardware improvements will eventually provide substantial additional protection. Research and technological improvements that deal with SD will require a great deal of effort and money to implement and is a distant goal. For the near term, the only practical approach is to enhance SD awareness training for pilots and should be addressed without delay. This report reviews current SD training practices in the CF, and makes recommendations to enhance spatial disorientation training on the ground and in-flight. It is hoped that this report will generate continue discussions among pilots, aeromedical instructors, flight surgeons and research scientists in maintaining progress towards mounting an attack on SD.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible, keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Spatial disorientation, demonstration, training enhancement.

DSIS DCD03
HFD 07/94

SECURITY CLASSIFICATION OF FORM
(Highest classification of Title, Abstract, Keywords)