Chapter 6 – OPTIMISATION OF SD TRAINING

6.1 INTRODUCTION

Research and technological initiatives that deal with SD will generally require a great deal of effort and financial resources to implement. This cannot be an argument to skip SD avoidance training, because this training is mandatory for flying training and continuation training for pilots according to STANAG 3114 (see Section 2.1, and [67]). However, training enhancements based on current knowledge and technology, where appropriate, can be more readily achieved and should therefore be addressed without delay. 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. Although spatial disorientation avoidance training is targeted primarily for pilots, improved training for associated aviation personnel: flight surgeons, physiologist, aeromedical instructor/technicians, other aircrews such as loadmasters and search and rescue technicians would be ideal. This chapter attempts to provide some perspectives on the optimisation of training methods to minimize SD in NATO nations and to provide recommendations for interim and long-term training strategies.

6.2 ORGANISATION OF TRAINING

6.2.1 Timing of Training

Ab Initio (undergraduate) aircrew should first be provided with orientation training during the initial basic aeromedical course, which is commonly part of the undergraduate flying training program. If SD training is too far in advance of flight training, it may cause flight students to forget important material concerning SD before they may experience SD in flight. Training of any nature will be more effective if distributed over several sessions **when possible**. Therefore, a review of SD after primary flight training should be encouraged and emphasise the operational relevance of SD for that particular aircraft type. It is recommended that the initial block of spatial orientation training be retained at its present stage **(initial basic aeromedical training)**, but that short refresher blocks should be inserted before instrument flight training and during advanced flying training and before and during assignment to an operations training unit. It is also recommended that operational squadrons implement formal and standardized SD awareness training as part of the training syllabus for their specific type of aircraft. The instruction designed for individual aircrews by aircraft type should address the effects of that aircraft's flight characteristics and cockpit environment that could affect aircrew performance with respect to SD. For example:

a) List and discuss previous accidents and incidents, and the most probable situations to lead to SD occurrences in the specific aircraft type.

b) Discuss preventive measures, for example use ADI (Attitude Display Indicator), avoid After Burner (AB) take-off, and RT (Radio Transmission), etc.

c) Force student pilots into SD situations during in-flight training, for example, formation flying, ACM (Air Combat Manoeuvres), weather, etc.

d) Perform cockpit management training, employing radar altimeter descent profiles.

6.2.2 Instructional Techniques

A variety of pedagogical techniques should be employed in SD lectures and discussion according to the background and experience of the aircrew. The principal objective of instruction given on the ground is to provide factual knowledge about the sensory systems that are involved with spatial orientation and

disorientation in flight. A formal approach is suitable for the teaching of pilot candidates and novice aircrew. This approach usually takes the form of didactic lectures supported by visual aids, such as slides, overhead transparencies, PowerPoint presentations, cine film or videotape. The length of the instruction would depend on the individual countries' capabilities and schedules. Examples of past mishaps where SD is a contributing factor will serve as ideal supplements. Personnel who have the appropriate theoretical background in physiology, psychophysics, familiarity with flight missions, aircraft, and possess an understanding of operations should present the classroom training. Scientists with operational research background play an important 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. In this respect it is recommended that Flight Surgeons, Scientists, Physiologists and Aeromedical Technicians will be given more flight experience and will be provided with up-to-date teaching material. 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 designation of a particular device solely for training or research, and including both trainers and researchers in device planning meetings. If the expert and best teachers in the air force were video-recorded giving their lectures, and these films distributed, then all training would be of enhanced quality. Availability of handouts with useful SD information for pilots is recommended (see Chapter 8).

The approach described above is suitable for the teaching of pilot candidates. However, informal group discussion about personal experiences and current hazards by type of aircraft led by experienced instructors, or flight surgeons who are also flight qualified, is most effective for the refresher training of established aviators who have "heard it before" The reasons are as follows: Established pilots are more likely to be attentive to accounts from their flying colleagues who learned about flying from disorientation incidents, or even accidents in which they had personal experience. A flight-qualified instructor will have an appreciation of what goes on in the cockpit, an in-depth understanding of the mission, and will know the type of disorientation likely to be experienced in the aircraft type. Such an instructor will have credibility with the students. 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 3 – 5 years. It is also emphasized that aviators receiving SD scenario training in Full Flight Simulators increased their situational awareness of the conditions and events that lead to SD. It is vital that the scenarios are not viewed in isolation, but instead embedded in a complete training package that is part of the larger training process (Section 3.5).

Having experienced pilots describe and discuss recurring SD situations that are specific to the aircraft type can improve SD awareness within the operational squadron. This awareness training should be made mandatory. Examples of the situations that most frequently lead to SD occurrences and corrective actions are summarized in Table 6.1.

Table 6.1: Examples of Situations that have Caused SD Incidents or Accidents

Situations	Cause and/or Preventive Measures
1) Take-off with after-burner at night and/or weather conditions (somatogravic illusion)	i) ADI (Attitude Display Indicator) must be up on the DDI (Digital Display Indicator) for take-off into weather/night meteorological conditions. ii) AB is only used when absolutely necessary.
2) Flying in formation	Leans are easily experienced when flying as wingman 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) Make sure lights are properly adjusted on the lead aircraft, because improperly adjusted lights 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. i) 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	Channelised attention, e.g. on the radar or the velocity vector frozen in the HUD will lead to situations of SD or potential unusual attitudes. i) 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. i) These risk factors can be reduced by spatial orientation awareness training and performance of frequent crosschecks.
6) Meteorological Conditions	Stars can look the same as the ground over the prairies and in extreme latitudes. Flying over water, especially glassy surface can cause depth perception problems. Flying during whiteout can cause the disappearance of the horizon.
7) Emergency pull up	Sense of excess of pitch up during the initial phase of an emergency pull up procedure.
8) Entering IMC conditions	Sudden entering in IMC often induces a loss of the correct sense of attitude.
9) Refueling from side baskets of tanker aircraft	Refueling from side baskets of tankers having tilted wings during flight (e.g. ITAF Boeing 707) usually induces a sense of false horizon.

6.2.3 Training Assessment

It is recommended that air forces determine a method of evaluation of the training effectiveness of the ground-based and/or in-flight SD demonstration. 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 [68].

6.3 TYPES OF TRAINING

6.3.1 Ground-Based SD Demonstration and Training

Ground-based **demonstration** is defined as the demonstration of the limitations of the orientation senses in a demonstration device or flight simulator. Essentially, this comprises further reinforcement of classroom instruction and is best conducted with groups of students by an aeromedical professional (flight surgeon, physiologist). Ground-based **training** is defined as learning and then demonstrating competence in handling simulated in-flight disorientating circumstances and illusions, e.g. recovery from unusual attitudes and procedures for inadvertent entry to instrument meteorological conditions (IMC). This is the responsibility of flight instructors (who have themselves been appropriately trained to teach the procedures and to assess competence).

A demonstration of the limitations of the orientation senses is an essential part of initial and refresher aeromedical training. As shown in Chapter 2 most NATO countries perform some form of demonstration using many different types of ground-based devices (e.g. Barany chair and multi-axis electromechanical devices). 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 about the yaw axis, the Coriolis Effect and the demonstration of the vestibulo-ocular reflex, which causes a loss of dynamic visual acuity due to nystagmus (see Table 6.2). As many students as possible should experience these basic vestibular and visual phenomena. In addition, other laboratory devices such as off-vertical axis rotation chair, optokinetic drum and other devices can be used to demonstrate the limitations and inadequacies of our sensory systems in maintaining orientation. The demonstration should be followed by a simple explanation based on the physiology and psychophysics that were taught. More details for a number of those vestibular and visual illusions are described in Section 3.2. This part is essential because it provides the building bricks for understanding the in-flight illusions.

Table 6.2: Barany Chair (Category 1) Ground-Based SD Demonstration

Illusion/limitation of Senses	Type	Initial Training		Refresher Training	
		Essential	Desirable	Essential	Desirable
Somatogyral	Vestibular	√		√	
Decrease of Visual Acuity (Vestibulo Ocular Reflex	Vestibular-Visual	√			√
Oculogyral	Vestibular-Visual	√			√
Rotation Thresholds	Vestibular	√		√	
Coriolis	Vestibular-(Visual)	√			√

There is definitely a role for dedicated SD demonstration and training devices. 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. This follow-up of the basic SD demonstration is described in detail in Chapter 3.3 and 3.4. It is obvious that some flying skills are required for the student pilots to control these flight simulator devices.

Ideally, in order to enhance ground-based demonstration and training, the sensations induced by the simulator must be 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. However, the flight envelope cannot be reproduced on the ground; it is therefore imperative that the objectives and limitations of any ground-based demonstration and training be explained fully to the trainees. 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 (Sections 3.3 and 3.4). Research laboratories are in an excellent position to guide the choice of training tools and to suggest ways for implementation to achieve the final goals (See also Section 6.3.4.3, and [31]).

6.3.1.1 What Illusions Should be Demonstrated

As it is unrealistic to suggest that all pilots should experience all illusions, specific in-flight illusions should be defined as either essential or desirable. Essential illusion demonstrations are those that all pilots should experience or witness. Desirable illusions are those that are not essential but are considered worthwhile for the pilot to experience.

The ASCC Air Standard 61/117/14 is in this respect of interest since this standard suggests which illusions are considered to be essential to incorporate in the demonstration and which illusions are desirable (Table 6.3 for RW and Table 6.4 for FW aircraft): The more so since this standard is incorporated in the draft version of Edition 8 of STANAG 3114 (see Section 2.1).

Table 6.3: Rotary-Wing Aircraft Ground-Based SD Demonstration

Illusion/limitation of Senses	Type	Demonstration Device Category	Initial Training		Refresher Training	
			Essential	Desirable	Essential	Desirable
The Leans	Vestibular	2, 3, 4	√		√	
Somatogyral	Vestibular	2, 3, 4	√		√	
Oculogyral	Visual-Vestibular	1, 2, 3, 4	√			√
Coriolis	Vestibular	1, 2, 3, 4		√		√
Autokinesis	Visual	2, 3, 4	√		√	
Size constancy (Runway width)	Visual	2, 3, 4	√			√
Shape constancy (Runway upslope)	Visual	2, 3, 4	√			√
Vection illusion	Visual	2, 3, 4		√		√
False sensation of rotation	Vestibular	1, 2, 3, 4	√			√

Table 6.4: Fixed-Wing Aircraft Ground-Based SD Demonstration

Illusion/limitation of senses	Type	Demonstration Device Category	Initial Training		Refresher Training	
			Essential	Desirable	Essential	Desirable
The Leans	Vestibular	2, 3, 4	√		√	
Spin Recovery (Somatogyral)	Vestibular	2, 3, 4	√		√	
Graveyard Spiral	Vestibular	4				√
Oculogyral	Visual-Vestibular	1, 2, 3, 4	√			√
Somatogravic	Vestibular	2, 3, 4		√		√
Oculogravic	Visual-Vestibular	3, 4		√		√
Coriolis	Vestibular	1, 2, 3, 4	√			
G- Excess	Vestibular	4		√		√
Autokinesis	Visual	2, 3, 4	√			√
Size constancy (Runway width)	Visual	2, 3, 4	√			√
Shape constancy (Runway upslope)	Visual	2, 3, 4	√			√
Black-hole landing	Visual	2, 3, 4	√			√
False sensation of rotation	Vestibular	1, 2, 3, 4	√			√

It should be noted that in the terms of Chapter 3, some of these illusions could be demonstrated better during the Demonstration of Basic Visual and Vestibular Illusions (Section 3.3) than during the Ground-based Training of In-flight Illusions (Section 3.4). The Task Group favours the demonstration of the basic visual and vestibular illusions before the student pilots are confronted with the in-flight illusions, to make sure that they have some understanding of why these illusions happen, and that these illusions are not emerging out of the blue, which should be frightening.

It is also recognized that there is substantial benefit to be gained from pilots observing their peers experiencing the illusions on the demonstration device. This will allow the students to realize that there are individual differences in susceptibility and level of response. With devices of category 2, 3 and 4 (Table 3.1) special effects are used to induce the SD illusions: this requires some explanation to the subjects watching the demonstration. Air Forces should ensure that each pilot will personally experience at least one visual illusion and one vestibular illusion and witness others undergoing the demonstration. Training objectives for both initial and refresher training should reflect this training.

AIR STD 61/117/14 [31] also suggests a number of factors that should be considered when choosing which limitations of spatial orientation or illusions to demonstrate to aircrew:

1) The effectiveness of the device at producing/reproducing the illusion without inducing negative transfer of training should be investigated. A flight surgeon or SD training instructor

(e.g. physiologist) should confirm the effectiveness of a particular device to demonstrate the illusion (see also Section 3.4.3.6).

2) The illusions demonstrated should be operationally relevant. For example, the graveyard spiral is not commonly encountered in rotary-wing flying. Therefore, there is little to be achieved by the demonstration of this illusion to a helicopter pilot.

3) Consideration should also be given to demonstrating illusions at a time that is of relevant to the stage of flying training, e.g. demonstrating autokinesis before initial night flying training.

4) Some limitations/illusions (e.g. "the Leans") can be demonstrated effectively during an in-flight demonstration. Therefore, if an air force has this capability, it adds to the demonstration on the ground.

5) The role of distraction should be emphasized because the generation of some illusions may be "enhanced" by the incorporation of a simultaneous distracting task. This will also stress the operational importance of distraction in the generation of SD in flight.

6) Flight training and experimental simulators may be used as SD demonstration devices where appropriate. The idea of using existing flight simulators for SD familiarization training was explored through a collaborative contract [69]. 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 or motion based operational flight simulator, as discussed in Section 3.5, to demonstrate and teach pilots to cope with some of the visual illusions that one might encounter during take-off and landing. As discussed in Chapter 3.5 NATO Air Forces 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. See for this argument also Section 3.5.4 (Usefulness of Full Flight Simulators for SD Training).

6.3.1.2 Eye Tracking / Visual Scan Training for Refresher Courses

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 channelised attention [70,71,72,73]. 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 crosscheck 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 during ground-based training. Task demonstration and immediate feedback have been shown to improve the speed and quality of training [74].

6.3.2 SD In-Flight Demonstration and Training

It has been shown that demonstrations of SD within the actual flight environment are extremely valuable [75] and are complementary to the ground-based didactic lectures and demonstrations. In addition, there is a distinct difference between in-flight demonstrations 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% [75]. It appears that the most meaningful way to train aircrew to recognize and overcome SD in flight is to conduct SD in-flight training. A formal program of in-flight spatial orientation training, particularly with more emphasis on unrecognized SD (Type I) needs to be implemented. The availability of flight time may limit the conduct of SD demonstration and training. However, pilots and instructors could utilize the time made available on their way to mission sites (see also Section 4.3 In-flight SD Training Scenarios).

The current practice of recovering from unusual attitudes and related eye-closed manoeuvres is valuable. However, an enhancement to these procedures would be 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 should be avoided, because of 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.

6.4 SOME PRACTICAL RECOMMENDATIONS FOR AIRCREW TO IMPROVE SD AWARENESS

1) Look for potential human performance problem areas prior to and during missions. Prioritize tasks to avoid and manage the anticipated problems [67]. The reasons are as follows:
   - The mental functions involved in maintaining appropriate flight control involve more than processing of orientation sensory inputs. Task saturation, channelised 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 what you want them to.” [76].

3) Realize that a pilot’s instructions about what to do in case of disorientation can be useful only in the case of recognized disorientation. Unrecognised 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 unrecognised disorientation by being aware of the flight conditions with which it is most associated:

- Avoid approaches over non-illuminated terrain, over smooth snow, or calm sea and take into account the possibility of facilitating circumstances, as cloud layers merging with sea fog, false sky effects and others.
- 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 noteworthy).
- 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 disorientation and it persists for up to 34 hours after drinking [77].

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