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TITLE

SPATIAL DISORIENTATION-IMPLICATED ACCIDENTS IN CANADIAN FORCES, 1982-92

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Spatial Disorientation-Implicated Accidents in Canadian Forces, 1982–92

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In a recent survey of CF18 aircrew human factors, 44% of pilots reported experience with spatial disorientation (SD), of whom 10% had experienced more than 3 episodes. In order to investigate further, we have completed a retrospective study of SD-implicated category A accidents (where an aircraft is destroyed, declared missing, or damaged beyond economic repair) in the Canadian Forces (CF) during 1982–92. An overview of all SD occurrences (including accidents and incidents) across aircraft types is also presented. Information was gathered concerning the genesis and severity of disorientation so that research effort and pilot training could be appropriately implemented. Mishap investigation summaries involving category A accidents where SD was implicated were obtained from the CF Directorate of Flight Safety and reviewed. We also examined in detail the Board of Inquiry Reports of these accidents. The role of disorientation in these accidents was assessed. There were 62 category A accidents between 1982–92 and, in 14, SD had been assigned as a possible cause factor in the accident records. When divided into the categories of Recognized SD (RSD), Unrecognized SD (USD), and Incapacitating SD (ISD), all but two fell into the category of USD (the pilots were unaware of the disorientation). Of the SD accidents, 11 involved a total loss of 24 lives. The majority of the accidents happened during the day, and pilots' cumulative flying experience did not appear to be a significant factor. According to our assessment, there were two episodes of vestibular origin, involving the somatogravic illusion. Three episodes of disorientation occurred over frozen lakes, one over glassy water, and one over ocean. Two accidents occurred during tactical training involving more than one aircraft. The causes of two accidents remain undetermined, with SD listed along with other possible causal factors. The suggestion follows that more research effort and pilot education and training should be placed on somatogravic illusions and visual limitations under adverse flying conditions, and pilots should be made more aware of these 14 accident scenarios.

SPATIAL DISORIENTATION (SD) is the failure to perceive, correctly and unequivocally, the position, attitude, or motion of the aircraft. It is an interruption of a continuously successful process of orientation (1,11). Recently, it has been suggested that the operational definition of SD should also include any error in perception of the magnitude or direction of any of the aircraft controls or flight performance parameters (6).

It seems clear that the usual etiology of spatial disorientation includes one or both of two causal factors: a) input errors from erroneous, conflicting or inadequate visual, vestibular, or somatosensory cues; and b) central errors usually stemming from channelized attention, inappropriate expectancy, or perceptual set. Although much is known about some specific forms of SD and their causes, the attention mechanism that allows pilots to select or ignore certain cues on some occasions is not well understood.

In a recent overall survey of human factors in the CF-18 pilot environment, 44% of pilots reported experience with disorientation, of whom 10% had experienced more than three episodes. The authors of that survey rated SD as the most detrimental of all the listed aircraft factor issues in terms of its effects on flight safety and operational effectiveness (3). The present paper is a retrospective study of all SD-implicated category A accidents in the Canadian Forces during the period of 1982–92 to ascertain the pattern, if any, of disorientation accidents. A brief statistical overview of all SD occurrences including other categories of accidents and incidents across aircraft types is also presented. As formal inquiries were held only for category A accidents and not for other accidents and incidents, we limited our review to SD-implicated category A accidents. The objective of the study was to determine appropriate research priorities and training strategies to prevent further SD accidents.

Traditionally, SD in flight is classified as Type I (Unrecognized, when the pilots were unaware of any of the manifestation of disorientation), Type II (Recognized, when pilots consciously perceive some manifestation of disorientation or sensory conflicts), or Type III (Incapacitating, when the pilots may experience an overwhelming, incapacitating physiologic response to physical or emotional stimulus associated with SD). In this study, we avoided the traditional classification of SD. We believe that such classification of SD is helpful, but that the terms "Type I," "Type II," and "Type III" are less informative. Instead of using these esoteric terms, it would be better to say that the three kinds of disorientation are "unrecognized" (USD), "recognized" (RSD), and "incapacitating" (ISD). The terms "Type I," "Type II," and "Type III" are meaningless to the uninitiated and add no information

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to the understandable terms "unrecognized," "recognized," and "incapacitating."

METHODS

The CF Handbook of Flight Safety defines an accident as an event in which an aircraft is missing or in which there is A, B, or C category damage, or a person receives fatal or serious injury. Category A accident is when an aircraft is destroyed, declared missing, or damaged beyond economic repair. Category B accident is when the aircraft must be shipped to a contractor or depot-level facility for repair. Category C is when the aircraft must be flown to a contractor or depot-level facilities for repairs; repairs are carried out by a mobile repair party; or a major component has to be replaced. An incident is defined as an event in which there is D category damage or a person receives minor injury, or E category where there is risk or injury or accident potential, but no actual damage (5). These definitions were adopted for this study.

All SD-implicated category A accidents, based on the assigned cause factors in the summary of ACAIRS (aircraft accident incident reporting system) from the CF Directorate of Flight Safety between 1982 and 1992 were reviewed for this study. The cause factors assigned in the ACAIRS were based on the manual of Flight Safety for the Canadian Forces (A-GA-135-001/AA-001). SD is defined (narrowly) as an incorrect perception of one's attitude with respect to an appropriate reference (usually the surface of the Earth or another aircraft in formation) (5). Three other cause factors: "visual illusions/limitation," "channelized attention," "error of expectancy" described in this manual are in fact the varied mechanisms underlying the disordered perception according to most definitions of disorientation. We included in the study all the accidents in which the ACAIRS summary described causation as "spatial disorientation," or "visual illusions/limitation," or "channelized attention," or "error of expectancy."

Descriptions of these factors from the manual of Flight Safety are as follows: a) Visual illusion/limitations are input errors from external visual cues or from flight instruments; an erroneous perception of stimuli to the visual system such as white-out, prism effect (the illusion created by refraction of light due to a change in the density of the medium), sloping runways; and impairment of visual capabilities by glare, darkness or vestibular-induced nystagmus, b) channelized attention is part of the limitation of the central nervous mechanism when faced with a demanding and unfamiliar task, full attention focused on one stimulus to the exclusion of all others. c) Error of expectancy is when an individual's perception of a particular sensory event is based on a specific temporal-spatial pattern of sensory information associated with that event which may cause an erroneous perception. As a result, there is an anticipation of certain environmental cues and a tendency to search selectively for those cues. The extremes would be an expectancy so strong that the pilot perceives cues that are in fact not there, or such an inappropriate expectancy or complete lack of expectancy that the pilot fails to detect cues that are present.

There were 16 accidents in the ACAIRS summary that listed the cause factors disorientation, visual illusion/limitation, channelized attention, or expectancy/perceptual set. The narrative reports from the Board of Inquiry for each accident were systematically reviewed to see whether SD had been indicated as one of the causal factors. In addition to the assigned causal factors, specific information was collected for each accident: aircraft type, flying experience of the pilot (cumulative flying hours, and total flying hours on the aircraft type involved in the accident), mission profile, time of day, weather conditions, and terrain of the flight path. This information was tabulated and summarized for analysis.

RESULTS

Overview of all SD occurrences: An overview of SD occurrences (accidents and incidents) per 10,000 flying hours in fixed wing aircraft and rotary wing aircraft between 1982–92 was plotted in **Fig. 1** and **2,** respectively. The number of SD occurrences per 10,000 flying hours appeared to be higher in the fixed wing aircraft than helicopters, and there appeared to be no correlation between the number of SD occurrences and a particular year or the total flying hours per year. Further analysis of reported SD-implicated accidents (based on the above definition) versus aircraft types yielded **Table I.** As expected, the occurrence of SD in fighter aircraft is more prominent than other fixed wing aircraft and helicopters.

SD-implicated category A accidents: As mentioned before, formal inquiries were held only for category A accidents and not for other accidents and incidents, so we limited our discussion to SD-implicated category A accidents. Of the 16 accidents obtained from the ACAIRS summary, we determined that in 14 accidents, SD was implicated. In the other two, disorientation was rejected because of the lack of real evidence. Of the 14 SD-implicated accidents, we concluded that 12 were considered to be USD, and one each represented RSD and ISD. From 1982–92, there were a total of 62 category A aircraft accidents in the Canadian Forces. The 14 SD-implicated accidents, therefore, represent 22.5% of all category A accidents for the period. **Table II** summarizes these 14 accidents and their SD classifications.

Aircraft type: SD was involved in the following category A accidents: a CF104 (Starfighter, removed from service in 1986), three CF116 (Freedom Fighter), five CF18 (Hornet, fighter), and one each of CT114 (Tutor, trainer), CC130 (Hercules, transport), CC138 (Twin Otter, search and rescue), CH135 (Twin Huey, helicopter), and CH136 (Kiowa, helicopter). Of these 14, 11 accidents involved the loss of life for a total of 16 military aircrew and 8 civilians. Table II illustrates the aircraft type, phase of flight, time of day, pilot flight experiences in Total (T) cumulative flying hours, and flying hours in the Specific (S) aircraft that was involved in the mishap. It may be significant that only one each mishap involved a transport aircraft, a search and rescue aircraft, and a training jet, while two mishaps involved helicopters, and the balance (nine) involved fighters.

Mission profile: Of the 14 accidents, 2 occurred following aggressive afterburner takeoffs and the rest occurred during flight; none occurred during landing. There were

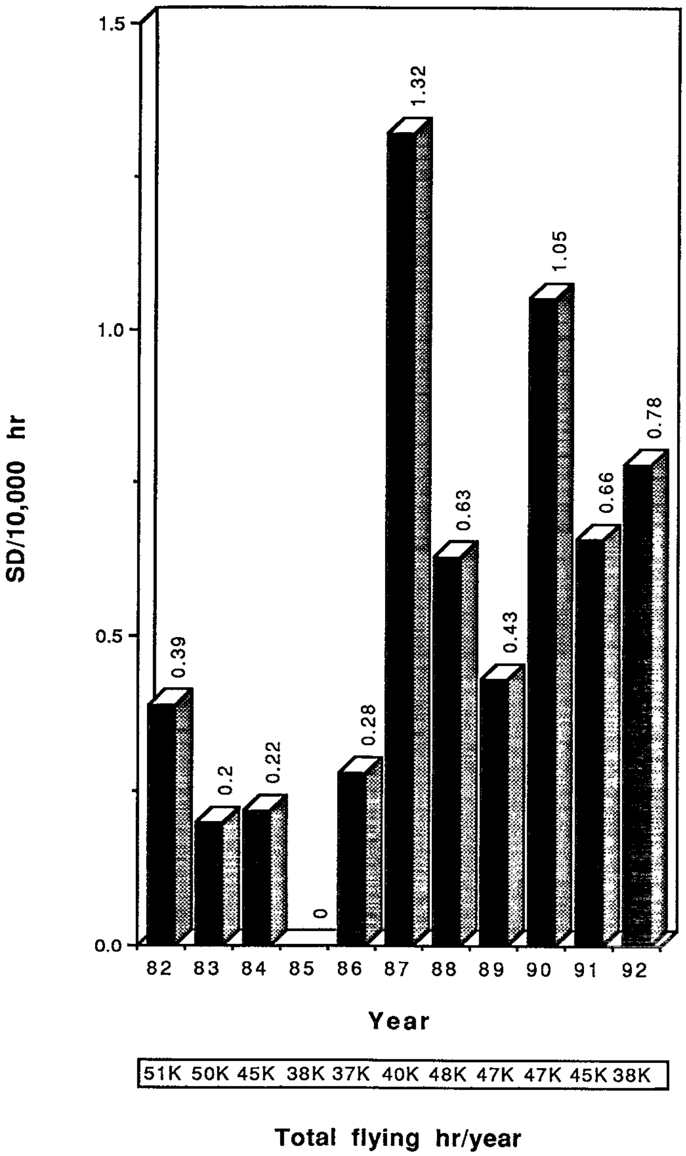

Fig. 1. SD occurrences (accidents and incidents) in fixed wing aircraft per 10,000 flying hours in the Canadian Forces between 1982–92, and the respective total flying hours per year; K = 1000.

five accidents that involved air combat and tactical training, and four that involved routine flying at low altitude and cross country training. One accident involved a functional air test on the CF18 spin recovery mode following an aileron change. The transport aircraft was involved in bulk fuel delivery and the search and rescue aircraft was searching for the wreckage of a crashed aircraft. Formation flying was involved in three fixed-wing aircraft and one helicopter accident.

Time of day: The majority of the SD-related category A accidents, a total of nine, occurred during the day; four occurred at night, and one in twilight. Both single cases of RSD and of ISD occurred during the day. Of the 12 USD accidents, 9 occurred during the day, 2 at night, and 1 during twilight.

Flight topography: Nine accidents occurred over land, three occurred over frozen lakes, one occurred over glassy water (lake), and one over ocean. Both of the single RSD and ISD accidents occurred over land.

Pilot experience: The experience of the pilots appears not to have been a significant factor in the accidents. The cumulative flying hours (in all aircraft) range from 230.7 to 7660 h, with an average of 1954.6 h. The total flying hours on the type of aircraft involved in the accidents ranged from 82.6 to 2122 h with an average of 774.8 h.

Cause factors reported by accident investigators: For any accident investigation, it is difficult to attribute one single cause factor for the mishap, especially in modern fighter aircraft with advanced technology and difficult mission requirements, and most especially when there is a loss of life. The causal factors assigned in this study should by no means be treated as the only causes, but as contributing factors under the circumstances. In fact, of the 16 accidents that were given by ACAIRS, there were two accidents whose cause was still undetermined; they both

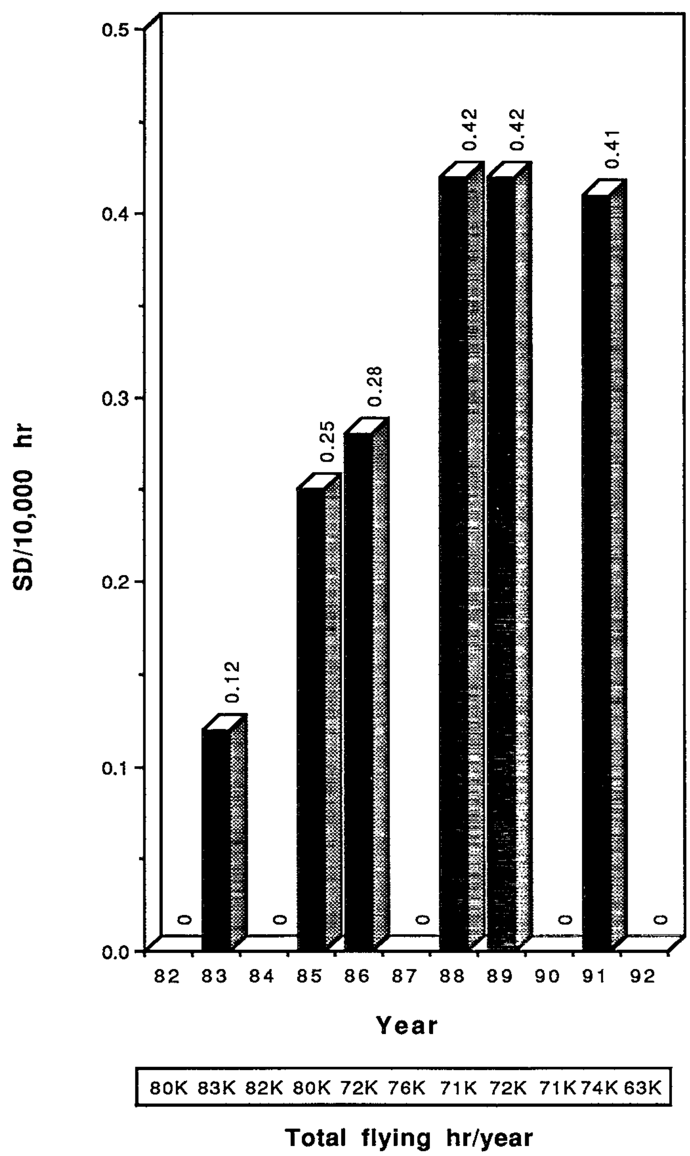

Fig. 2. SD occurrences (accidents and incidents) in rotary wing aircraft per 10,000 flying hours in the Canadian Forces between 1982–92, and the respective total flying hours per year; K = 1000.

TABLE I. REPORTED SD OCCURRENCES IN CF AIRCRAFT BETWEEN 1982–92.

Aircraft Type	A	A/F	B + C	D + E
CF104 Starfighter	1	1	0	1
CF5 Freedom fighter	1	2	0	2
CF18 Hornet	1	4	0	20
CH118 Iroquois	0	0	0	1
CH135 Twin Huey	0	1	0	3
CH136 Kiowa	0	1	4	5
CT134A Musketeer	0	0	0	1
CT114 Tutor	0	1	0	1
CT133 Silver Star	0	1	0	0
CC138 Twin Otter	0	1	0	0
CC115 Buffalo	0	0	0	1
CC130 Hercules	0	1	0	0

A = Category A accident, when an aircraft is destroyed, declared missing or damaged beyond economic repair; A/F = Category A accident when there is a fatality; B = Category B accident, when the aircraft must be shipped to a contractor or depot-level facility for repair; C = Category C accident, when the aircraft must be flown to a contractor or depot-level facilities for repairs, repairs are carried out by a mobile repair party, or a major component has to be replaced; D = Category D incident, defined as an event in which there is minor damage to the aircraft or a person receives minor injury; E = Category E incident, where there is risk of injury or accident potential, but no actual damage.

involved fatalities, and one of the wrecks was not located until a year later. SD was listed along with other human factors such as distraction and misjudgment. There were nine accidents where visual illusion/limitations contributed significantly to the USD mishap, of which eight were due to the lack of visual orientation cues over smooth surfaces where pilots misjudged their height. A search and rescue aircraft struck a rock outcrop because of the absence of shadows and low contrast under ambient light condition and terrain. The somatogravic illusion (where acceleration is perceived as a higher-than-desired climb) played a prominent role in the 2 CF18 accidents that occurred during aggressive departures. Three mishaps were related to channelized attention.

DISCUSSION

In the Canadian Forces, several surveys have revealed significant frequency of SD. A survey from 1 Air Division (a former CF element in Europe) reported that approximately 50% of pilots experienced disorientation, the majority of which were "the leans" (13). In a Fighter Group survey, 48% of pilots reported similar experiences with disorientation, and the survey ranked disorientation as the fifth most serious aircraft accident threat (4).

During the study period (1982–92), the total numbers of aircraft accidents (Cat A, B, and C) involving fixed wing aircraft and helicopters were 108 and 46, respectively. The numbers of category A accidents were 50 in the fixed wing aircraft and 12 in helicopters. The percentage of SD-implicated category A accidents was 22.5% (14 of 62). Recent statistics (8) suggest that the majority of SD-related mishaps in high performance aircraft are caused by USD. Substantiation comes from the USAF FY90-91 statistics that all 13 of their SD mishaps, 9 of which were fatal, were reported to be USD (9). Thus our investigation confirmed the high incidence of USD, since 12 of 14 SD accidents were assessed as USD.

Causes of SD

The role of disorientation in a fatal accident is an extremely controversial issue. The comments and findings of the accident investigation boards we reviewed suggest a range of opinion as to the relative contributions of primary and secondary causation, and a range of understanding of the potential influence of some of the disorienting illusions. In most accidents, a combination of many factors appears to cause the accident, rather than one particular human factor. SD results from an extremely complex set of sensory stimuli. It is rarely due to a single sensory stimulus, but results from inter-related, multi-sensory inputs and the perceptual interpretation of these inputs.

Undetermined Causes

Two accidents occurred in which the cause was still undetermined, but in which SD was felt to contribute. One involved two F18 aircraft on an air defense training mission (case 4): one of the aircraft began to lose altitude rapidly while in a turn and crashed in open ocean. It is speculated that the pilot of the second aircraft became disoriented and flew into the water. A second accident where causes remain undetermined involved a T33 flying a simulated air-to-surface missile profile where the aircraft simulated an attack on a ship; the aircraft crashed, and the wreckage was found a year later. The accident report raised no real evidence to suggest disorientation and it was not included in Table I. The rest of the reported SD-implicated accidents can be discussed under the headings of RSD; ISD; and USD.

Recognized SD

The one RSD accident (case 10) occurred after a night training exercise where the instructor and the student expected to find visual cues during the closed pattern pull-up and after turning off the landing lights. However, the environmental conditions (night without moon or stars, lack of ground lights in the surroundings), provided no visual reference at all. The aircrew were unable to ascertain the aircraft's attitude as it started to descend. When they recognized their disorientation, they ejected.

Incapacitating SD

The one instance of ISD in our review (case 5) involved a maintenance test flight in spin recovery mode (SRM). Here, the pilot allowed the angle of attack to exceed 20°, contrary to the AOI caution, resulting in unpredictable yaw and pitch movements with rapid loss of altitude. The ensuing vestibular, proprioceptive, and visual cues overwhelmed the pilot's cognitive capacity, rendering him unable to take appropriate action (select the SRM switch to NORM). The aircrew appropriately ejected at 12,000 ft as the aircraft was entering cloud.

Unrecognized SD

In our review, the majority of the orientation error accidents were due to USD, in which the pilot does not perceive any of the manifestations of disorientation. In one case (case 8) during a high-G rolling defensive ma-

TABLE II. A SUMMARY OF THE 14 SD IMPLICATED CLASS A ACCIDENTS BETWEEN 1982–92 IN THE CANADIAN FORCES.

Case	A/C	Flight Hours	Weather	Time of Day	Mission Profile	Site	F	Factors Reported by Accident Investigators	SD Type
1	CF18	T2667 S416	poor/overcast/ low ceiling	day	IFR return flight to base	land	1	somatogravic illusion/ distraction	USD
2	CF18	T1957 S546	bright	day	support for tactical airlift	frozen lake	1	depth perception channelized attention/visual limitation/illusion	USD
3	CF18	T1137 S764	darkness	night	take-off	land	1	somatogravic illusion	USD
4	CF18	T2855 S803	broken cloud	day	intercept training	ocean	1	channelized attention/ restricted visibility	USD
5	CF18	T1021 S453	bright and clear	day	maintenance test flight, spin recovery mode	land	0	unpredictable yaw and pitch movement/ unable to recover	ISD
6	CF116	T1999 S299	good weather visibility but dull day	day	3 plane ground to air tactics formation	frozen lake	1	failed to discern height loss	USD
7	CF116	T1682.2 S433.2 T1402.3 S82.6	Unrestricted ceiling and visibility	day	4 plane formation low level air to ground attack	land	2	misperception of height/inattention/ channelized attention	USD
8	CF116	T861 S644	clear good visibility	day	2v1 dissimilar air combat training	land	0	disorientation	USD
9	CF104	T7660 S1800 T1599 S1186	low ceiling poor visibility	twilight	2 plane formation low altitude	frozen lake	2	reduced depth perception/ perceptual conflict	USD
10	CT114	T431.5 S399.5 T230.7 S196.8	scattered mid-level cloud/ high overcast	night	closed pattern circuit	land	0	loss of perception of altitude	RSD
11	CC130	T3465 S2122	scattered cloud	night	bulk fuel delivery	land	4	loss of perception of altitude/ channelized attention	USD
12	CC138	T1562 S954	sunny/clear/ light turbulence	day	search and rescue	land	8	visual limitation	USD
13	CH135	T943.8 S645.5	rain/reduced visibility	night	enroute to deployment exercise	land	1	loss of perception of altitude/lean	USD
14	CH136	T1754 S1427	VFR/excellent visibility	day	lead of formation of 2	smooth lake/ glassy water	2	visual limitation/ loss of perception of altitude	USD

A/C = aircraft type; T = Total cumulative flying hours; S = total flying hours in the specific aircraft; IFR = Instrument Flight Rules; 2v1 = two versus one; F = number of fatality; VFR = Visual Flight Rules; USD = Unrecognized spatial disorientation; ISD = Incapacitating spatial disorientation; RSD = Recognized spatial disorientation.

neuver, the pilot was not fully aware of the actual aircraft orientation, an inappropriate maneuver was attempted which resulted in the aircraft departing from controlled flight, and the pilot ejecting at 1500 m. The rest of the USD cases will be discussed under sub-headings of somatogravic illusion, visual limitation/depth perception, selective attention/inattention, and predisposition to SD.

Somatogravic illusion: Two of the fatal crashes (cases 1 and 3) involved afterburner climbs into an environment devoid of external visual cues. Such an aggressive afterburner climb invites disorientation, since pilots often experience a sensation of nose-high pitch during forward acceleration of the aircraft into environments devoid of external visual cues, (the so-called somatogravic illusion). The inversion illusion that sometimes results when the aircraft is leveled off abruptly after a climb in bad weather is also known to cause the pilots to respond inappropriately by easing forward on the stick and placing the aircraft into an unperceived dive. However, the possibility cannot be ignored that distraction after the transition to flight instruments may have precipitated failure to perceive correct flight information. In addition, from both the human engineering and operational points of view, it is difficult to cross-check in the CF18 due to the location and size of the standby attitude indicator, since pilots must move their heads down to see the instruments. It is known that normal cockpit head movements increase the magnitude and the direction of the somatogravic illusion out of proportion to the simple sum of the somatogravic illusion and the angle and direction of head movement. This "G-excess effect" compounds the somatogravic illusion (7).

The dangers of performing rapid climbs into the cloud are well known (8) and should be stressed to pilots. The somatogravic illusion can have an onset of less than 1 s and can persist up to 30 s. Pilots should develop vigilance for the somatogravic illusion and inversion, and all unnecessary high thrust takeoffs into clouds or conditions devoid of external visual cues should be avoided or undertaken in automated mode.

Visual limitation/depth perception: In an environment of constantly changing airspeed, attitude, and altitude, the most commanding sensory stimulus is vision. Environments with inadequate visual cues, such as frozen lakes or smooth and glassy water, lead to erroneous height perception. Four aircraft in our review (cases 2, 6, 9, and 14) crashed as a result of pilots' maneuvering over smooth water, a frozen lake, or snow-covered lake, and misjudging their height above the surface.

In one case (case 2), the pilot turned steeply at low altitude over the frozen surface of a large lake. This denied him the peripheral visual cues that might have alerted him to the gradually descending turn. The pilot might also have channelized his attention to the task at hand (radar lock-on to demonstrate missile/gun attack) and failed to monitor his descent rate or altitude. In a second case (case 6), the pilot failed, through a combination of human factors (poor visual cues, distraction), to discern altitude loss during a tactical turn and crashed into a frozen lake. Snow on a surface without direct sunlight can look the same at 500 ft as it does at 50 ft, so altitude assessment using visual reference can be difficult. The third case (case 9) involved a two-plane formation proficiency mission under low ceiling and poor visibility over a large flat snow-covered lake surface; the horizon was easily lost in an SD of the "white-out" variety. It is thought that the wing man struck the lead during a turn and both aircraft struck the frozen lake at very high speed. The last case (case 14) involved a helicopter whose pilot disregarded established procedure by flying over the center of the lake at very low level rather than flying along the shore. The calm mirror-like conditions resulted in an inability to accurately assess the height of the aircraft above the water, and as a result it crashed into the lake.

Maneuvering over smooth and flat surfaces is not the only way that pilots lose height perception. Snow-covered approaches to landing can also cause improper height perception because of the absence of visual orientation cues, even over hilly terrain (case 11). This is particularly true in darkness when there are no other visual stimuli outside the cockpit; pilots tend to fixate on the only available outside visual cue (the light at the destination). Under these situations, depth perception is inaccurate, light from the destination seems closer than it actually is, and during the landing approach the pilot can descend sooner than he should and strike the snow-covered ground. Another SD accident related to visual perception (case 12) occurred during overhead search and rescue. The low light conditions, absence of shadows, and low contrast surrounding the rock face masked a rock outcrop and led the pilot into believing that the basin was large enough for flying. The left wing tip struck the rock outcrop during a very steep near-stall left bank from which the pilot was unable to recover.

Selective attention/inattention: Although pilots are taught to do structured instrument cross-checks regardless of attitude sensation, disorientation due to the pilot's failure to make optimum use of reliable information can arise due to the limitation of the central mechanisms which mediate the perceptual process. In case 7, an aircraft struck the ground after jettisonning the empty and partially-expended rocket pods. It appears that the pilot was inattentive to the aircraft flight path while in a low level turn due to distraction or channelized attention. Attention problems are not restricted to the failure of mental activity. Under high workload or when unduly aroused, pilots may restrict their field of attention, which could impair their performance.

Predisposition to SD: In one instance (case 13), review of medical history indicated that a co-pilot who was flying the aircraft suffered a tilting sensation following a head injury almost 2 years prior to the accident. The sensation was diagnosed as benign paroxysmal vertigo. It was reported that "the co-pilot's flying category was only restored after appropriate measures had been taken," but no mention is made of what these measures were. Whether this pilot may have had an increased susceptibility to SD due to this occurrence is not known. Recent reports (2) suggest that pilots who are unable to fly under conditions conducive to SD may be found to show abnormalities in attitude perception or demonstrate an abnormal vestibulo-ocular reflex. An episode of disequilibrium, even if resolved, should be thoroughly investigated by appropriate vestibular testing.

CONCLUSION

Our understanding of SD has changed dramatically over the decades since Maj. William Ocker first proved the existence of SD in 1926 (12). SD should not be synonymous with vestibular or visual illusions alone; it also involves the behavioral responses and the cognitive integration of all sensory inputs. The responses to the physical and mental load imposed by the increasingly demanding flying task must also be considered. The etiology of some typical visual and vestibular illusions has been known for decades. However, the role of cognitive phenomena such as selective attention, expectancy, and the supra arousal effect in pilots' failure to make optimum use of available information about the aircraft's orientation is poorly understood. Since many mishaps are related to visual limitation/illusions (10 of 14), further research on the mechanisms of visual orientation is needed.

To help prevent these accidents, aircrew should be made more aware about SD threats in flight, with special attention to the conditions that favor SD. The crew should also be made more aware of the factors that can aggravate SD, especially those which are unique to the particular aircraft being flown. The present review suggests that SD probably played at least a contributing role in 14 of 62 fatal accidents, so SD clearly constitutes a serious threat to aviation, warranting serious research effort. Despite the fact that SD has long posed such a threat, there is a lack of a consensual definition of SD among medical officers, research scientists, accident investigators, and line communities which led to misclassification problems of SD accidents (10). Remarkably little rigorous research exists concerning the optimal ways in which to prepare aircrew against SD. Although measures such as unusual attitudes, demonstrators (e.g., Báràny Chair), other static trainers, and (more recently) dynamic SD trainers, along with periodic refresher training, are all intuitively appealing, more research must be devoted to defining the role of each in a holistic SD training strategy.

In conclusion, understanding of SD has evolved beyond only vestibular or visual illusions and is now known to be a multidisciplinary problem that should be addressed by a coordinated effort across the operational, flight safety, and research communities. Fourteen category A SD accidents in 10 years are too many for the Canadian Forces. Appropriate attention and resources must be dedicated towards reducing this number.

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