USAARL Report No. 97-13

Spatial Disorientation in U.S. Army Helicopter Accidents: An Update of the 1987-92 Survey to Include 1993-95

By

Malcolm Braithwaite
Shannon Groh
Eduardo Alvarez

19970422 046

Aircrew Health and Performance Division

March 1997

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U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

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Released for publication:

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Colonel, MC, MFS
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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release, distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
USAARL Report No. 97-13

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
U.S. Army Aeromedical Research Laboratory

6b. OFFICE SYMBOL (If applicable)
MCMR-UAS

7a. NAME OF MONITORING ORGANIZATION
U.S. Army Medical Research and Materiel Command

6c. ADDRESS (City, State, and ZIP Code)
P.O. Box 620577
Fort Rucker, AL 36362-0577

7b. ADDRESS (City, State, and ZIP Code)
Fort Detrick
Frederick, MD 21702-5012

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL (If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code)

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
0602787A	3M162787A879	OA	177

11. TITLE (Include Security Classification)
(U) Spatial disorientation in U.S. Army helicopter accidents: An update of the 1987-92 survey to include 1993-95

12. PERSONAL AUTHOR(S)
M.G. Braithwaite, S.L. Groh, E.A. Alvarez

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM TO

14. DATE OF REPORT (Year, Month, Day)
1997 March

15. PAGE COUNT
25

16. SUPPLEMENTAL NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
01	02	
01	04	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Spatial disorientation, accidents, night vision devices, rotary-wing, situational awareness

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
This report updates the survey of U.S. Army helicopter accidents (1987-92) by Durnford et al., (1995) to include fiscal years 1993 through 1995. Those accidents in which spatial disorientation (SD) was considered to have played a major role were identified and compared to those in which SD played no part. In addition, an attempt was made to identify the factors behind each SD accident together with potential solutions. Of the 970 accidents now on the database, 30 percent were considered to have had SD as a major or contributory factor. Of particular note is the increased incidence of SD during helicopter operations during night aided flight. SD remains an important source of attrition of Army helicopter operations, costing an average of $58 million and 14 lives each year. The contribution of SD accidents to the overall accident rate is not getting smaller. The increase in risk associated with the use of night vision devices when compared to day flying is of particular concern. Recommendations are made in the following four areas: education, training, research, and equipment. In addition, control factors are discussed both on an individual, U.S. Army, and triservice basis.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Chief, Science Support Center

22b. TELEPHONE (Include Area Code)
(334) 255-6907

22c. OFFICE SYMBOL
MCMR-UAX-SI

DD Form 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

Acknowledgments

The authors would like to acknowledge the kind and generous help of Ms. Reta Dyson of the U.S. Army Safety Center, Fort Rucker, Alabama. Much of the data used in this study could not have been extracted without her patient help.

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Introduction

In a survey of U.S. Army helicopter accidents (1987-92), Durnford et al., (1995) reviewed all Class A through C accidents. Those accidents in which spatial disorientation (SD) was considered to have played a major role were identified and compared to those in which SD played no part. In addition, an attempt was made to identify the factors behind each SD accident together with potential solutions. Of the 583 accidents entered into the study, 32 percent were considered to have had SD as the major factor (by which it was meant that there would have been no accident if there had been no SD). This is a higher figure than had been reported before, possibly because of differences in definitions. SD cost the U.S. Army $308,887,000 and 78 lives during that period. A distinct trend between various types of night flying and SD was evident, the maximum risk being associated with the use of night vision goggles (NVGs) and forward looking infrared (FLIR). The risk was 10 to 15 times higher than for ordinary daytime flight. The rate of SD accidents was also particularly high during Operations Desert Shield and Desert Storm.

There were few identifiable episodes of visual or vestibular illusions in that accident series. Classical causes of SD, such as "whiteout," "brownout," and "inadvertent entry to instrument meteorological conditions (IMC)" were relatively rare and accounted for only 25 percent of the SD accidents. By contrast, distraction of the aircrew from maintaining a safe flight path appears to have played a predominant role. The major potential solutions that were identified reflect this "situational awareness" problem. Recommendations were made which included training changes, equipment changes, and further research into specific areas.

As part of the monitoring effort of the U.S. Army Aeromedical Research Laboratory (USAARL) SD research team at Fort Rucker, Alabama, a similar review of the Class A through C accidents from the end of Durnford's study (April 1992) through September 1995 was conducted. The overall database was thus enlarged to include 970 accidents in this 8-year 4-month period.

This short report updates the findings of the previous comprehensive review. Graphical, rather than tabular, presentations of the findings are provided, and comprehensive recommendations are discussed.

Methods

The methodology, classification, and definitions used for this analysis were identical to that of the 1987 to 1992 report and so will only be briefly described.

Summaries of all Class A-C Army rotary-wing accidents were obtained from the U.S. Army Safety Center (USASC). Three flight surgeons, acting independently, reviewed each accident summary and extracted information as described by Durnford et al., (1995). Accidents were classified by each researcher into one of the following groups:

Class 1. SD was the "major" component of the accident sequence (by which it was meant that all other contributory factors would normally have been overcome without mishap).

Class 2. SD was a "contributory" component of the accident sequence (by which it was meant that other contributory factors would have led to a mishap in any case - but SD made the accident sequence more difficult to deal with or the outcome more severe).

Class 3. SD was an "incidental" component (by which it was meant that SD occurred but did not affect the outcome).

Class 4. SD did not occur.

Class 5. The role of SD was unknown.

The minimum standard for all assessments was not one of absolute certainty but was one of "more probable than not" in the view of the researcher. This was because proof of SD was often absent following an accident and what was sought was the most accurate picture rather than the picture that was most "provable."

For the purpose of this study, the definition of SD was that given by Benson (1978) as follows: "the situation occurring when the aviator fails to sense correctly the position, motion, or attitude of his aircraft or of himself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical." Also used was Vyrnwy-Jones' (1988) additional clause: "the erroneous perception of the aviator's own position, motion, or attitude to his aircraft, or of his aircraft relative to another aircraft." Geographic disorientation (or getting lost) was specifically excluded. Contact with an obstacle known to be present, but erroneously judged to be sufficiently separated from the aircraft was included as SD. Contact with an obstacle whose presence was simply unknown was not considered to be SD unless it was associated with other manifestations.

Results and discussion

Of 993 Class A through C accidents during the period, 970 were entered into the study. The remainder were either simple listings of other aircraft involved in multiple-aircraft accidents, or had been reclassified lower than Class C by the time computer analysis began. For clarity, the findings are briefly described in each section.

The role of SD in accidents

SD was regarded as having a "significant" impact on the accident sequence if it was classified either as major or contributory (see figure 1). Therefore, 30 percent of all accidents involved SD. Ninety percent of the SD accidents were considered to be type 1 SD (unaware of the error), and 8 percent were type 2 (a conflict between a correct and incorrect perception of orientation).

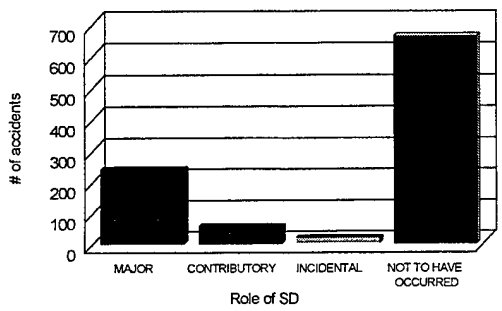


Figure 1. The role of SD.

Differences between SD and non-SD accidents

Severity

SD accidents had a particularly severe outcome. Thirty-six percent of SD accidents were Class A compared to 18 percent of non-SD accidents.

Cost

The total cost of the 30 percent of all accidents in which SD was implicated was almost as much as the 70 percent in which SD was not a factor (see figure 2). The average cost of the SD accidents ($1.62 million) was significantly greater than the average cost of non-SD accidents ($0.74 million), ($p<0.0001$ on t-testing).

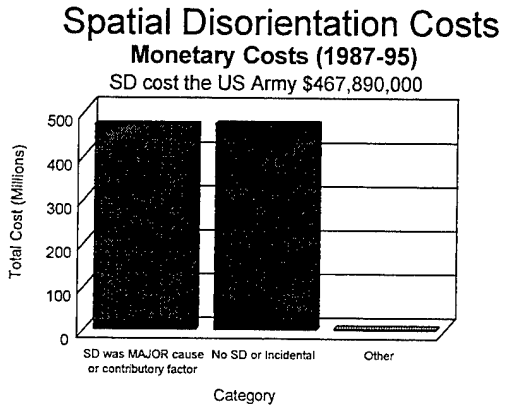


Figure 2. SD costs (monetary).

Lives lost

One hundred and ten lives were lost in 291 SD related mishaps compared to 93 in 679 other accidents (see figure 3). The average number of lives lost per SD accident (0.38) was significantly higher than the average per non-SD accident (0.14), ($p<0.0001$ on t-testing). Eighty-four of the SD deaths (75 percent) occurred in night accidents.

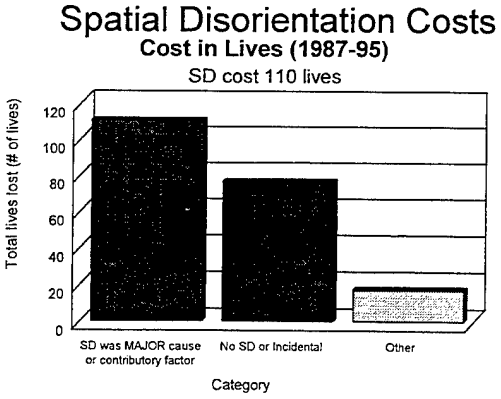


Figure 3. SD costs (lives lost).

Height and speed

Accidents involving SD were associated with a significantly lower height above the ground at the onset of the emergency than accidents in which SD did not occur (SD accidents mean = 65 feet, non-SD accidents mean =455 feet; p=0.00001 on t-testing). SD accidents occurred at a significantly lower airspeed (SD accidents mean=28 knots, non-SD accidents mean = 44 knots; p<0.0001 on t-testing). Figures 4 and 5, respectively, show the mean height and speed at the center of each box with the variation represented by the box (1 standard deviation) and whiskers (2 standard deviations). These results are not surprising as the end point of incorrect or inappropriate control from SD is hitting the ground, and if the aircraft is near it to start with, the chances are greater. The high number of hover SD accidents is reflected in these findings.

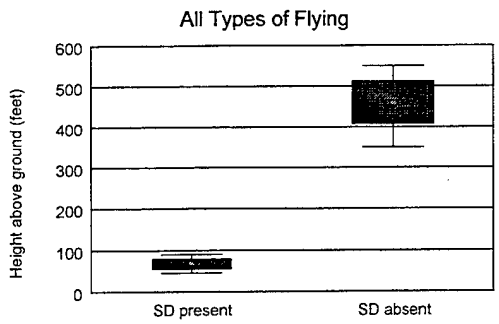


Figure 4. Height above the ground at the time of emergency.

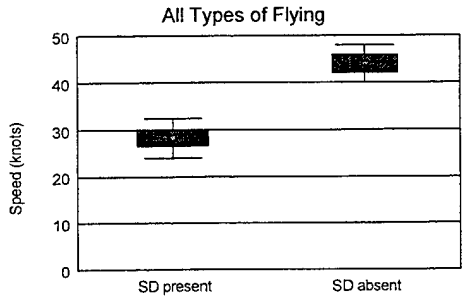


Figure 5. Airspeed at the time of emergency.

SD accidents by type of aircraft and flight

Proportions

In figures 6 through 8, the SD accidents are broken down by aircraft according to the type of flying: day and night; and night, both unaided and aided. The percentages relate to accidents caused by SD for that type of helicopter. The average percentage for that type of flying overall is shown by the horizontal line. Chi-square testing indicates that only the UH-60 and AH-64 SD proportions are significantly higher than the average. Durnford et al., (1995) found similar results, and their conclusion remains extant. Both of these helicopters have features that might be considered as potential factors in SD: the UH-60 has large windshield pillars blocking a part of the view from the cockpit, and the AH-64 has the FLIR night imaging system. There are, however, other potential factors at play, such as combat roles, and it would be rash to draw conclusions at this stage, other than aircrew flying today's missions in modern aircraft appear to be at just as great a risk of SD as before.

For NVG flight, the OH-58A/C models, and the UH-1 feature above average SD accident proportions, and of particular note is that 64 percent of AH-64 FLIR accidents were attributed to SD.

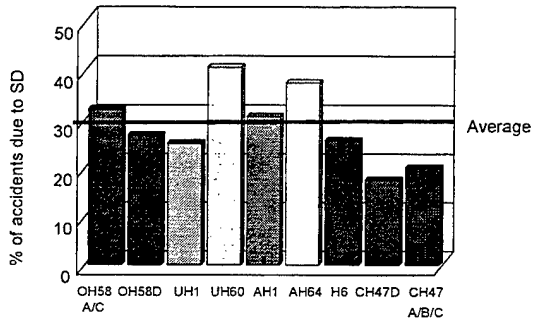


Figure 6. Percent SD accidents - day and night.

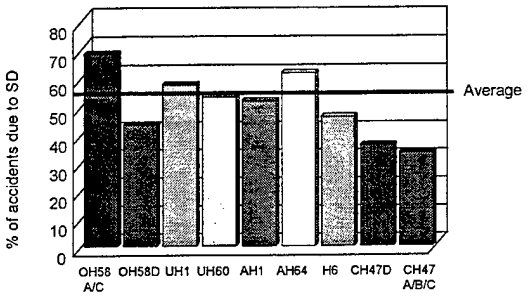


Figure 7. Percent SD accidents - night.

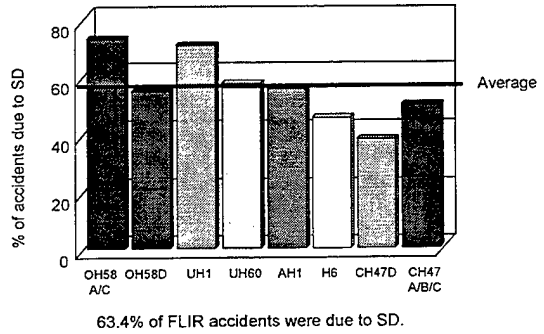


Figure 8. Percent SD accidents - NVG.

Flight hours data

Flight hours data for all flying were available for the whole period studied, and since 1990, specific daytime flying and the various forms of night flying data for each type of aircraft was obtainable. Where there were enough accidents to analyze, rates were calculated. In figure 9, it can be seen that SD accidents (broken line) represent an almost constant proportion of the overall (solid line) Class A through C accident rate. Although there is a downward trend after the peak during Operation Desert Storm, matters are not getting better. Figure 10 shows the overall rate and the rate broken down into the various types of flight for all helicopters. The night aided SD rate closely follows the overall accident rate for this category.

The solid line in figures 9 through 11 represent the overall accident rate, and the broken line, the SD accident rate.

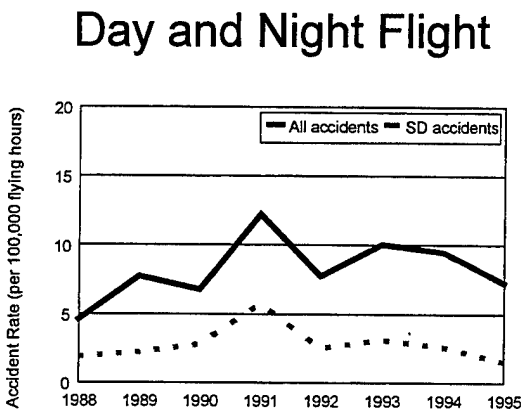


Figure 9. Total accident rates.

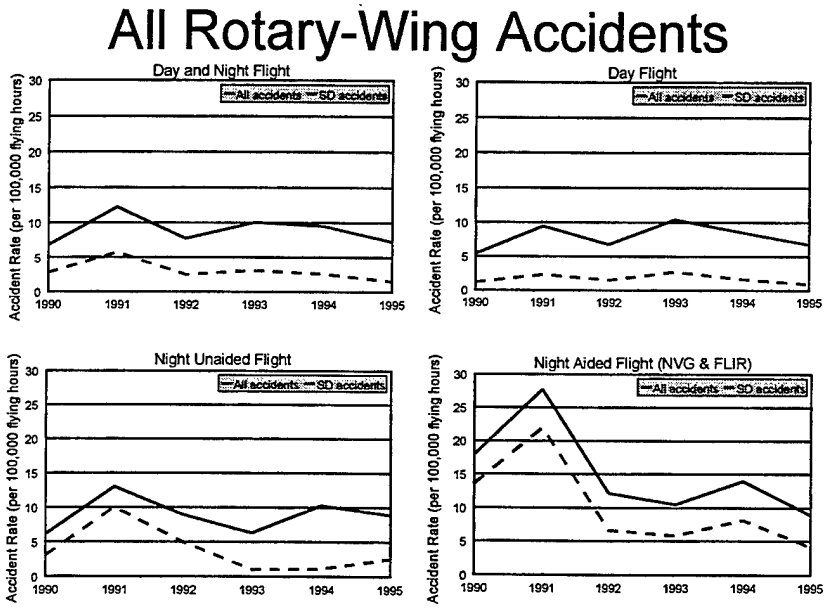


Figure 10. All rotary-wing accident rates.

If the rates are broken down by individual types of aircraft, some differences become very striking (figure 11). As a comparator, the overall rate is in the top left. The other graphs show total day and night rates for the OH-58A/C models, the OH-58D, and the AH-64. It is evident that the OH-58D and the AH-64 have both a higher overall accident rate and an equally high SD rate.

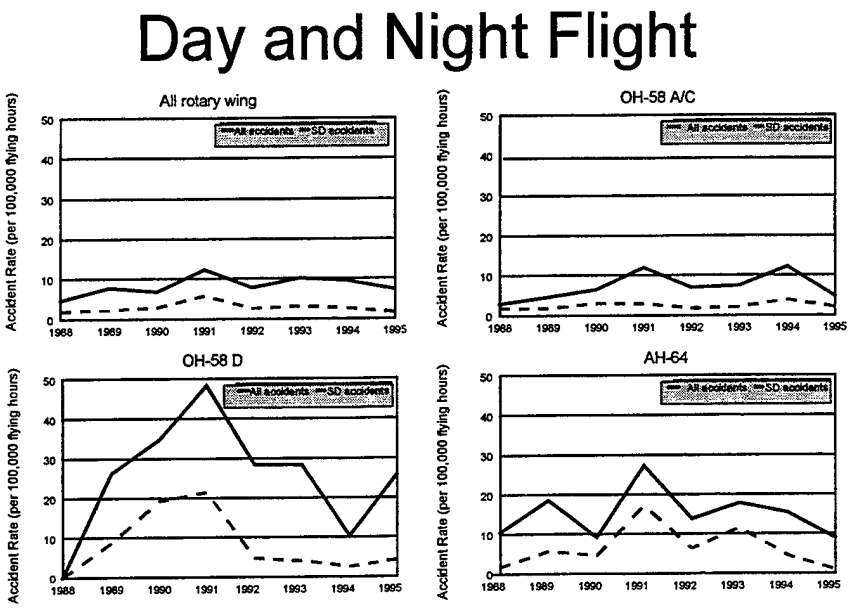


Figure 11. Day and night flight accident rates.

Flight with night vision devices (NVDs)

Only 13 percent of non-SD accidents occurred during night vision device (NVD) use, whereas 46 percent of SD accidents involved aircrew using NVDs. The increased risk of SD with NVDs can be summarized in the accident rates for the various types of flight (figure 12). As flying is a highly visual occupation, it follows that when vision is degraded, SD becomes more likely. SD has long been a recognized shortcoming to the otherwise enormous advantage of NVDs. Although the clarity of the night vision device image is improving with technology, limitations remain, particularly from the loss of depth perception cues and the restricted field-of-view.

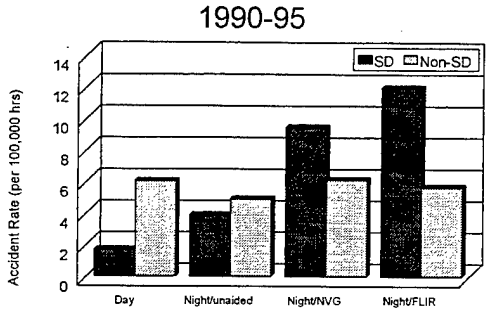


Figure 12. The influence of day/night conditions in the SD and non-SD rates.

This much higher rate of SD accidents when flying with NVDs is clearly a considerable concern for operational effectiveness. A study is in progress to further examine the factors associated with these accidents.

Features of SD accidents

Number of crew disoriented

In 59 percent (178) of all SD accidents, both front seat crewmembers were considered to have been affected by SD. This can be broken down into day and night figures as shown in figure 13. In an aircrew survey (Durnford et al., 1996) which asked about aviators' personal experience, it was much less frequent for both crew to have lost orientation. The fact that there was an accident, of course, implies that the other crewmember was not "oriented" enough to prevent the disorientation of the handling pilot, leading to loss of control. Alternatively, the non handling pilot did not have sufficient time to react to the situation.

Both crew were disoriented in:

- 59% of all SD accidents
- 70% of Night SD accidents
- 49% of Day SD accidents

[Aircrew survey: 2 crew disoriented in 29% of SD episodes]

Figure 13. Both crew disoriented.

Distraction

The assessors considered that at the onset of the accident sequence, there was a distraction inside the cockpit in 26 percent of SD accidents and outside the cockpit in 29 percent. In some accidents, there were distractions both inside and outside. Distractions inside were predominant in OH-58A/C and D models and the AH-64, particularly during night aided flight, and distractions from outside were predominant in UH-1 and UH-60 accidents again during night aided flight. These findings are probably mission related. This is obviously a most important feature in the sequence leading to the SD accident, and one which can probably be alleviated by vigorous crew coordination training. The type of distraction from the flying task that tends to precipitate SD is to be examined in future research.

Events

Although the USASC provides data on some of the effects of the disorienting episode, the research team found it more useful to use a modified event classification when specifically considering SD. Although all aircraft ended up on the ground or in the water, the first category in figure 14 represents both controlled flight into terrain (CFIT) and inadvertent ground (or water) contact in translational flight.

The second largest group, drift and/or descent in the hover, is peculiar to vertical landing and take-off aircraft. These studies have emphasized the importance of SD in this phase of flight. It was considered that most hover accidents were due to movement of the helicopter at a rate certainly below the threshold of the vestibular apparatus, and in many cases, below that of the visual system. Recirculation events (brownout and whiteout) accounted for some 18 percent of all accidents.

If one asks aircrew "In what conditions are you most likely to get SD ?," the majority will answer, "IMC." There is no doubt that there are probably more SD episodes in IMC, but this analysis shows that there are very few accidents as a result. This is probably because aircrew expect SD in IMC and so are ready to counteract it, and also that events generally occur well away from the ground, so there is more time to recover.

The small percentage of SD accidents associated with flight over water probably reflects the service role. The hazard is certainly there. Disorientation is possible in good sight of the ground, or even on the ground. In taxi and hover-taxi accidents, perception of the gravitational vertical and horizon are generally good, but judgment of clearance from obstacles has been poor or not attended to in some cases.

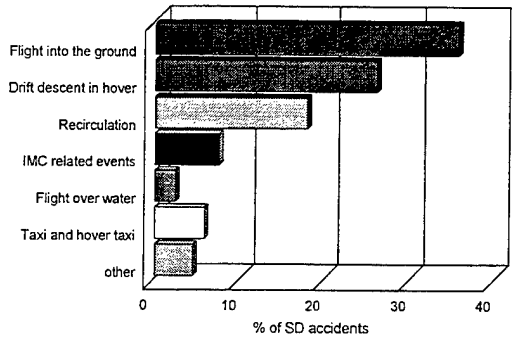


Figure 14. The types of SD event - all accidents.

The graph for day accidents alone is similar in its relative proportions to that for all accidents and is not reproduced in this report, but there are some subtle differences in night flight. In unaided night flight (figure 15), the top two categories again predominate. The proportion of IMC-related events, however, has not surprisingly gone up. Unaided night flight is generally conducted closer to the weather.

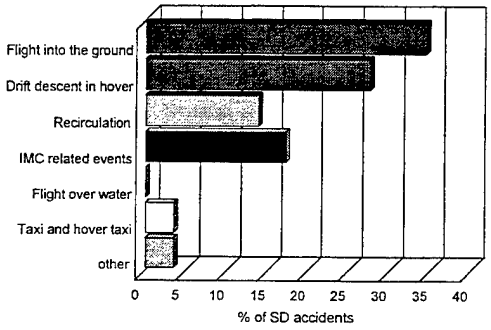


Figure 15. The types of SD event - night unaided.

In night aided flight (figure 16), the hover drift category is almost as great as flight into ground. The high proportion of AH-64 and OH-58 strikes on ground obstacles is reflected in this category. There was a higher proportion of brownout in this type of flight. NVDs may make perception of some visual cues better when they can be seen, but not when they are obscured by environmental factors.

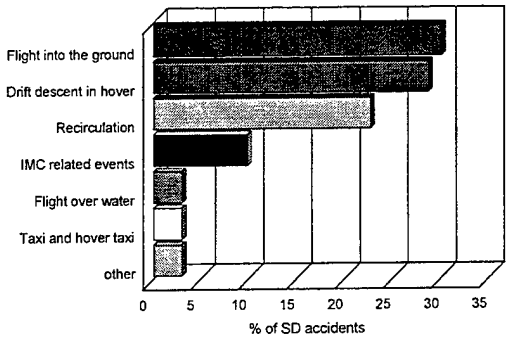
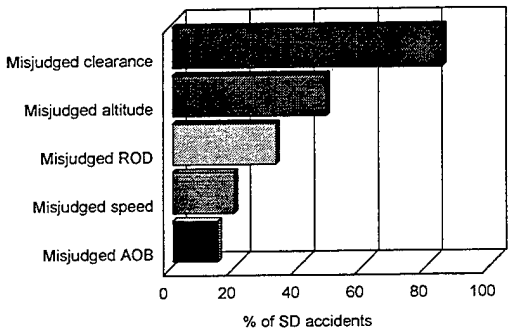


Figure 16. The types of SD event - night aided.

Factors leading to the mishap

The factors that caused the accident were examined in several ways. Figure 17 shows that misjudgment of clearance from an obstacle was overwhelming in its prevalence, most of the instances occurring in the hover. Similarly, misjudgment of altitude was more frequent. This was due to the large proportion of hover accidents where there was less room for error.



[ROD= rate of descent, AOB = angle of bank]

Figure 17. Misjudged flight parameters.

Some other important features are shown in figure 18. Brownout alone accounted for almost 15 percent of the SD accidents. Illusions from remote sensors are peculiar to the AH-64 in the current fleet of Army helicopters. There were only four cases, but this will continue to be a potential problem when viewing an image that is generated a distance from the eye.

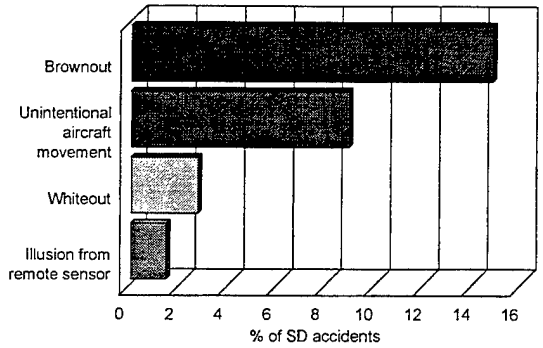


Figure 18. Potentially important features.

Perceptual difficulties

It can be seen in figure 19 that very few illusions caused SD accidents, whereas a deficiency of visual cues (i.e., absence of the primary aid to orientation) featured in almost 25 percent of them. An interesting comparison can be made between SD accidents and incidents. Figure 20 shows these features in the percentage of accidents compared to the percentage of SD episodes gathered from the 1993 survey of aircrew (Durnford, et al., 1996). It can be seen that while there were still many cases of insufficient visual cues in both series, misleading visual and vestibular cues (the illusions) were much more frequent in SD episodes that did not lead to accidents. In other words, these instances of type 2 SD are recognized by aircrew and are generally overcome.

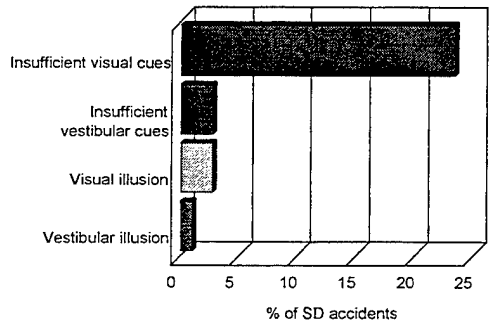


Figure 19. Perceptual difficulties.

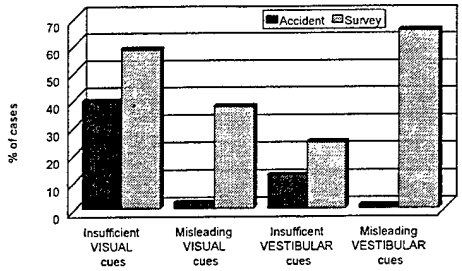


Figure 20. Frequency of visual and vestibular factors in the accident analysis and aircrew survey.

Because of the high proportion of SD accidents using NVDs, an initial attempt at determining the factors was made. Figure 21 illustrates that the visual limitations associated with these devices, particularly the restricted field-of-view, were considered to contribute to almost 30 percent of the SD accidents. The middle two categories in figure 21 both relate to AH-64 FLIR accidents. Although the information to assist orientation is presented in the integrated helmet and display sighting systems (IHADSS), it is not necessarily interpreted correctly or may even be ignored.

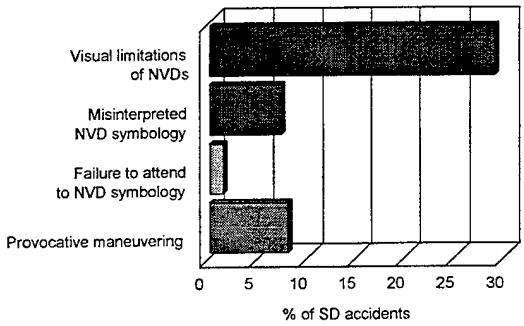


Figure 21. Sensory difficulties.

Predisposing factors

As in previous surveys, aircrew experience, as measured by their total flying hours or years spent flying, does not confer immunity to SD. There was no significant difference between SD and non-SD accidents for any of the personal flight hours data (total, instrument, last 30 days, etc.). The absence of a link with "currency" (as defined by flying hours in the previous 30 days)

suggests that either the accident numbers involved are too small to be sensitive to slight variations in currency, or maybe aircrew with less "currency" give themselves greater margins for safety. It is reassuring that neither hours of work nor hours of sleep prior to the accident appear to be related to SD accident rates, but there should be no complacency in monitoring these areas. In common with the 1987-92 survey (Durnford et al., 1995), there was no association between SD accidents and the sex of the aviator involved.

Combat training losses

Durnford et al. (1995) fully described the increased risk of SD during training for Operation Desert Shield/Storm. For completeness, their conclusion is repeated here. Fifty percent of the total helicopter losses in Saudi Arabia were considered to have involved SD as the major factor. When these data were compared to those from other desert locations, there was a significantly greater proportion of SD accidents from the Gulf, so terrain is unlikely to be the factor. As in previous studies, there seems to be a "wartime effect" on SD, the increased pressures of war or perhaps reduced safety margins. "Owning the night" does not come without risks; 81 percent of nighttime losses in Saudi Arabia were due to SD. It must be remembered that the operational costs of SD are not limited to aircraft losses since few episodes of SD actually lead to accidents. A high SD accident rate therefore implies an extra loss of operational efficiency due to SD incidents of varying severity.

Mishap coding issues

Only 32 accidents had been coded as SD by the USASC. These were mostly brownout, whiteout, and some IMC-related mishaps. It was agreed that these codings were appropriate, but at least an additional 44 accidents should have had the disorientation USASC code. A further 214 accidents were considered to have had SD as the major or contributory factor. In these accidents, one of the other two USASC "SD related" categories, scan and estimate, was applied as shown in figure 22. Many of the SD accidents, therefore, may well be hidden in other USASC categories. This disparity in classification is due in part to semantics. SD means different things to different groups of people and the gray area that surrounds all human factor accidents adds to the problem. Similarly, if boards of inquiry have not been primed to watch for SD, they may not consider it, or may classify accidents to related factors such as lack of crew coordination.

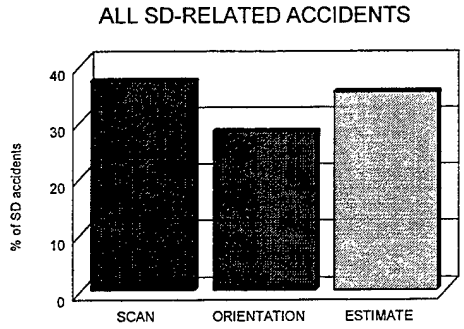


Figure 22. Safety Center categories.

The nature of rotary-wing SD

This update further confirms the wide ranging nature of SD in U.S. Army helicopter operations. While the well known causes do exist, they do not appear to predominate. For example, "brownout," "whiteout," or "inadvertent entry to IMC" account for only 25 percent of the SD accidents. Other "textbook" conditions, such as flicker vertigo or illusions due to downwash, proved almost nonexistent in our accident database, although they were reported in the aircrew survey. Similarly, there were no obvious cases of vestibular illusions causing accidents, although low grade vestibular disturbances cannot be ruled out. Aircrew distraction was thought to play a part in 44 percent of SD accidents. The role of poor visual cues was highlighted by the relationship between SD and night flight, and by the high percentage of accidents in which the inadequacies of NVDs were considered to have played a part. There is possibly a poor awareness among aircrew of how to prevent and overcome SD, but this is conjecture until the hypothesis is properly tested.

Durnford et al. (1995) concluded that the "typical" picture of rotary-wing SD is less one of a classical vestibular or visual illusion giving a pilot vertigo, but more one of hard-pressed aircrew, flying a systems intensive aircraft using NVDs, failing to detect a dangerous flight path. This matches with the finding that the high proportion of SD type 1 accidents that are present, as classical SD episodes such as inadvertent entry to IMC or recirculation problems are more likely to be type 2. This update confirms that conclusion.

Potential solutions

The flight surgeons who reviewed the accidents were asked to check a list of potential solutions for their applicability to the accident in question, as well as offering alternative recommendations. Figure 23 illustrates the findings. In a similar fashion to the previous survey (Durnford et al., 1995), the potential solution most often cited had nothing to do with technical hardware, but was simply "improved crew coordination." Indeed many of the recommendations from the accident reports suggested that the training in this area, that has now been started, should be enhanced. In many accidents, better allocation of crew duties, for example, one pilot with his head "inside" and one with his head "outside" the cockpit, might have meant that at least one crewmember would have escaped disorientation. Allied to better crew coordination was another frequently identified potential solution, "improved scanning." As far as hardware solutions are concerned, the most immediate benefit would be the introduction of an audio warning on the radar altimeter. This is lacking in many aircraft, even though technology is "on the shelf" and cheap. Given the situational awareness demands on modern aircrew, this simple and highly beneficial device should be introduced without delay. Hover-locks would enable aircrew to hold a hover with a lower workload, and drift indicators could provide important information about station-keeping. Peripheral vision devices and other improvements in general instrumentation do not appear likely to be of great benefit.

Another potential solution of particular importance to night flyers was injected symbology for NVGs, the NVG head-up display (HUD). However, as mentioned earlier, providing symbology does not necessarily mean that aircrew will pay attention to it.

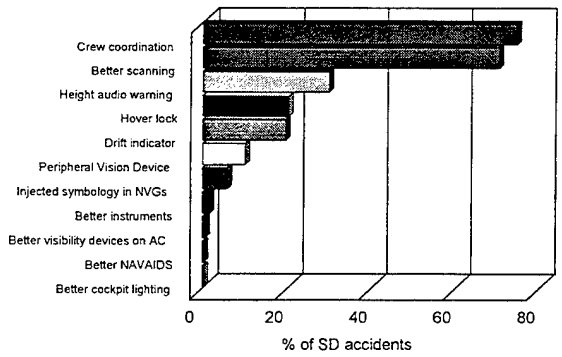


Figure 23. Potential solutions.

Conclusion

The following points are made in conclusion:

⇒ SD is an important source of attrition of Army helicopter operations, costing an average of $58 million and 14 lives each year.

⇒ SD accidents increased significantly during the Gulf War. Similar findings from other war zones (for example, the Falklands) suggest that combat may lead to lowered safety margins. The fact that 81 percent of nighttime accident losses in Saudi Arabia could be attributed to SD highlights the grave military implications of this problem.

⇒ The contribution of SD accidents to the overall accident rate is not getting smaller. The increase in risk associated with NVDs when compared to day flying is of particular concern.

⇒ The conditions which predispose to type 2 SD, such as brownout or inadvertent entry to IMC, are likely to be well known to aircrew and thus more readily overcome. The helicopter SD accident is not one of classical vestibular or visual illusions giving a pilot "vertigo," but is one of loss of orientational cues leading to contact with the ground or an obstacle.

⇒ The fact that better crew coordination or scanning might have prevented many accidents suggests that aircrew are less likely to be aware of the risk of distraction, and the limitations of their orientational senses which lead to type 1 SD. This aspect is open to training.

Recommendations

Work is required in the following four areas, which are comprehensively covered by Braithwaite (1997a): education, training, research, and equipment. They are summarized below.

Education

Aviation commanders and aircrew need to be made aware of the potential threat that SD poses during peace and war. There are two requirements to improve the understanding of this hazard:

⇒ Data collection to accurately define and monitor the size of the problem.

⇒ Dissemination of the lessons learned from accident analysis, research, and training on a regular basis.

Training

Although the syllabus for training aircrew in SD is covered generically in a Standard NATO Agreement (STANAG) and a proposed Air Standardization Coordination Committee Air Standard, this issue needs to be fine tuned. A review of the ground-based SD training has already been done by USAARL (Braithwaite, 1997), and the U.S. Army School of Aviation Medicine is rewriting its lesson plans based on the recommendations of that review. An evaluation of the SD demonstration sortie as flown by the British Army has recently been conducted at USAARL to determine whether it will be an effective adjunct in training aircrew in SD. A technical memorandum has been distributed (Braithwaite 1997c), and a full technical report is under review (Braithwaite et al., 1997) which will be published shortly.

Research

Research into SD needs to be of definable benefit to the operational community. Research is applicable to rotary-wing operations of all services, and coordination of the research occurs through the technical working group on situational awareness and SD.

Equipment

This analysis of accidents includes a list of potential equipment and development solutions to help both prevent and overcome SD. These are applicable to triservice helicopter operations and include the following items:

⇒ Audio warnings on all radar altimeters.

⇒ Flight data recorders.

⇒ The introduction of the NVG HUD.

⇒ The development of "hover locks" to aid station keeping and reduce pilot workload.

⇒ The development of a helicopter-specific instrument panel to include the provision of hover and drift information.

⇒ The identification of devices such as simulators that are best capable of simulating SD that could be used both as demonstrators and trainers.

References

Benson, A.J. 1978. Spatial disorientation: general aspects. In Aviation medicine. Dhenin, G. (ed). Tri-Med Books, London.

Braithwaite M.G. 1997a.
Spatial Disorientation - Initiatives to overcome a significant impact on rotary-wing operations. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Technical Memorandum No. 97-11.

Braithwaite M.G. 1997b.
A Review of Training in Spatial Disorientation. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Technical Memorandum No. 97-20.

Braithwaite M.G. 1997c.
Evaluation of the spatial disorientation demonstration sortie in training aviators. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Technical Memorandum No. 97-26.

Braithwaite M.G., Alvarez E.A., Groh S. 1997.
Evaluation of the spatial disorientation demonstration sortie in training aviators. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 97-26 (In review).

Durnford, S.J., Crowley, J.S., Rosado, N.R., Harper, J., DeRoche, S. 1995.
Spatial Disorientation: A Survey of U.S. Army Helicopter Accidents 1987-92. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 95-25.

Durnford S.J., DeRoche S., Harper J., Trudeau L.A. 1996.
Spatial Disorientation: A Survey of U.S. Army Rotary-wing Aircrew. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 96-16.

Vyrnwy-Jones P. 1988.
Disorientation Accidents and Incidents in US Army Helicopters, 1 Jan 1980 - 30 Apr 1987. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 88-3.