Preliminary Survey of Spatial Disorientation in UK Military Pilots and Navigators

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SUMMARY

Background: The direction of future spatial disorientation (SD) research and training is shaped primarily by the outcome of formal investigation of aircraft accidents and incidents. However, another source of vital information is aircrews' experience of SD that does not result in reported incidents. In order to access these experiences, Project Group 117 of Working Partly (WP) 61, Aircrew Standardisation Co-ordinating Committee (ASCC) developed a SD survey postal questionnaire (INFO PUB 61/117/5), with the aim of providing a standard format for data collection and analysis. This paper reports the findings of a preliminary survey of UK aircrew. ***Method:*** For the UK survey, a total of 1320 questionnaires were distributed to 5 Naval Air Squadrons, 22 Joint Helicopter Command Units and 7 Royal Air Force stations. Seven hundred and fifty-two questionnaires, comprising responses from 606 pilots and 146 navigators were returned. ***Results:*** Analysis was conducted primarily on the pilot data. The most frequently experienced SD episodes were the leans (by 92% of respondents), loss of horizon due to atmospheric conditions (82%), misleading altitude cues (79%), sloping horizon (75%) and SD arising from distraction (65%). When asked to rate the severity of their most recent SD episode, 3.5% (21) categorised their incident as severe ('flight safety was at risk'). In general, the frequency of SD episodes and ratings of severity of the worst ever SD episode were postively related to flying experience (hours-on-type, total hours $p < 0.05$). Overall, pilots who had received in-flight SD training reported more episodes of SD than those who had not participated in this training ($p < 0.05$). Differences in types of SD experienced were found between aircraft categories, which mainly reflected the use of aids to flying: more episodes of SD during NVG use were reported by rotary-wing pilots compared to fast jet aviators ($p < 0.05$). Fast-jet pilots reported more incidences of SD during HUD use than all other aviators ($p < 0.05$). ***Conclusion:*** This preliminary survey has shown that SD is still a significant hazard of military flying. The relatively high incidence of SD resulting from poor crew co-ordination and distraction highlights the need for situation awareness SD instruction in addition to the more traditional 'illusion' training. The differences in SD experienced between aircraft type suggests that specific airframe SD training may be required. This survey has also shown the role of experience (flying hours) in the recognition of SD, and has highlighted the potentially beneficial effects of in-flight SD demonstration and training. Overall, this study shows that the WP61 postal SD Questionnaire is a useful tool for assessing how SD training and experience may benefit the recognition of situations that may cause SD. However it is difficult to access those situations where aircrew were truly disorientated. Phrasing questions in such a way

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that differentiates between experiencing an illusion and being disorientated because of the illusion may be beneficial.

INTRODUCTION

Pilot spatial disorientation (SD) has long been identified as a major cause of UK military aircraft accidents. The percentage of UK accidents attributable to SD over the past 30 years has varied from 6% (Navy, 1972-1984; [1]), to 12% (RAF 1973-1991, [2]) and as high as 21% (Army 1971-1982, [3]). The most recent data show that pilot SD still contributes to UK military aircraft accidents. During a two-year period over 1999-2001, there were 7 accidents in the UK in which SD was believed to be a causal factor [4,5]. Four of these 7 mishaps resulted in fatalities of aircrew and loss of the aircraft.

Although most military aircrew receive some form of SD training (lectures and/or ground-based demonstrations, and/or in-flight demonstrations) the rate of aircraft accidents attributable to SD does not appear to be diminishing. For example, SD has been cited as a main causal factor in 4-5% of US military aircraft accidents (Army, Navy and Air Force) over the last 5 -10 years [6,7,8]. One reason for the lack of decline in this percentage, despite aircrew SD training, may be the introduction of new, agile aircraft (with unusual dynamic and visual environments), and an increase in frequency of night vision aided flights. Although they are undoubtedly a mission-enhancer, night vision devices (NVDs) provide the pilot with poor quality visual cues and are associated with a higher incidence of SD accidents relative to unaided daytime flying [9].

At present, the direction of future SD research and training is shaped primarily by the outcome of formal investigation of aircraft accidents and incidents. However, another source of information is aircrews' general experience of SD (that does not result in reported incidents). Infrequent SD surveys of aircrew over the past 50 years have reported some commonalty in aviator SD experience. The leans, and misinterpretation of aircraft orientation due to sloping cloudbanks or atmospheric conditions, were the most frequently reported SD phenomena in the majority of these surveys [10 as cited in 11;12,13]. Only the most recent surveys [12,13] have investigated SD experiences during visually aided flights (e.g. Night Vision Goggles) or SD resulting from the use of Helmet Mounted Displays (HMDs) or Head-up Displays (HUDs). Between 2 and 14% of aviators surveyed by Sipes and Lessard [13] reported SD arising from NVDs, HMDs or HUDs compared to 94% for the leans, and 79% for the black hole illusion. The relatively low usage of these types of NVDs and displays amongst those surveyed may explain this apparently low percentage.

Durnford [14] completed the most recent questionnaire survey of UK SD experiences amongst Army aviators in 1992. Unlike the previously cited surveys, which were concerned with the frequency and type of SD experienced, Durnford focused on descriptions and categorisation of the severity of SD episodes. The 440 respondents were asked to report the number of 'minor'('flight safety had not been jeopardised'), 'significant' ('flight safety had not been jeopardised, but could have been put at risk if circumstances had been different'), and 'severe' ('flight safety had been jeopardised') episodes both over their entire careers and the 4 months prior to the survey. Durnford found that episodes of the leans were generally minor. The most severe episodes of SD appeared to occur after inadvertent entry into instrument meteorological conditions (IMC). Ten percent reported that they had never been disorientated; 83% reported at least one minor episode; 56% had experienced at least one significant episode and 24% one severe episode over their entire careers. In the four months prior to the survey, the figures were 43%, 44%, 11% and 5% respectively.

Durnford found that younger pilots were more likely to have rated their worst ever episode as severe than older pilots. In addition, he reported that inexperienced pilots (in terms of total flying hours) were more likely to rate their worst ever SD episode over their entire career as 'significant'. Durnford also found that both Lynx helicopter crew members were disorientated in 44% of NVG related SD episodes.

Although all of the above surveys have provided information on SD incidence across different air platforms, services, and countries, inconsistencies between survey design and analysis has made it difficult to draw direct comparisons between airframe types and/or nations. In addition, the lack of a standard SD survey has made it difficult to track changes in SD incidence across time, or assess the impact of new aircraft or display technologies on pilot SD. To this end, Project Group 117 of Working Partly (WP) 61, Air Standardization

Co-ordinating Committee (ASCC) developed a SD postal survey questionnaire (INFO PUB 61/117/5) [14], with the aim of providing a standard format for data collection and analysis. This paper reports the findings of a preliminary survey of UK Navy, Army and RAF aircrew (undertaken during 2000), which used the WP 61 SD postal questionnaire.

SURVEY CONTENT AND DISTRIBUTION

The SD survey postal questionnaire comprises 2 sides of A4 and has been designed to ascertain the type and frequency of SD illusions experienced by aviators (in their current aircraft type) and a description of their most recent SD experience. The latter requires the participant to give details of his or her SD experience, indicate the conditions of flight at the time and rate the severity of the episode. Respondents are also asked to rate the worst ever SD episode in their current aircraft type. A copy of the questionnaire can be found in Annex A.

For the UK survey, a total of 1320 questionnaires were distributed to 5 Naval Air Squadrons (fixed-wing and rotary), 22 Joint Helicopter Command Units and 7 RAF stations (mainly fixed-wing) during September 2000. Seven hundred and fifty-two questionnaires, comprising responses from 606 pilots and 146 navigators, were returned by January 2001. The return rate of 58% is lower than the real return rate, as the number of questionnaires dispatched to each unit was overestimated. The questionnaire was well received by aircrew, which was mainly attributed to its concise nature. Data from navigators were collected in order to compare the frequency and type of SD experienced compared to pilots. Although SD in navigators should not normally adversely affect flight safety, there are some, abet rare, situations where pilots may call on their navigators to help re-orientate them when they are severely disorientated. Hence it was of interest to ascertain the frequency and severity of navigators' SD experience relative to their pilot colleagues.

UK DATA COLLATION AND ANALYSIS

The returned survey data were entered into a Microsoft Access® Database. The aircraft types were categorised as rotary, fast-jet, multi-engine or trainer. The descriptions of the most recent SD experience were categorised by Subject-Matter Experts (Pilot-Physicians) into the five main types of illusions (see Annex A): Body Sense, Visual, Miscellaneous, Displays, Other,. They also summarised the SD description into a few key words (e.g. 'the leans', 'hidden ridge during low level over snow-covered terrain', 'Pitch up sensation on acceleration after takeoff').

The analysis was performed to investigate the effects of the main independent variables: age, crew position, total hours flown, aircraft type, hours-on-type. Controlling for these factors, the effects of training type, rating of training and training personnel (medic, pilot-medic etc) on the dependent variables were also considered. The factors, factor type and levels used in the analysis are listed in Table 1 and Table 2. Due to the skewed distribution of the responses mainly towards 'never' and 'rarely', the responses were weighted as follows: 0 for 'never' and 1 for 'rarely or above'.

The dependent variables comprised the frequency of illusions, combined and in separate categories, and the rated severity of the most recent and worst ever SD experience (see Table 3). The display illusions were analysed as a group, with SD during NVG, HMD, HUD also analysed separately. It was decided to separate miscellaneous illusions (see Annex A) into three separate items: central psychological SD (giant hand, feeling of detachment), SD due to task saturation, and SD due to poor crew co-ordination, as these disparate items would provide meaningless data if analysed as a single group.

Table 1 Main independent variables used in the analysis

Variables	Type	Levels
Age	covariate	
Crew Position	factor	Student Pilot, Pilot, Instructor Pilot
Total Hours Flown	covariate	
Aircraft Type	factor	Trainer, Multiengine, Fast-jet, Rotary, Not Specified (NS)
Hours-on-type	covariate	

Table 2 Training independent variables used in the analysis

Variables		Type	Levels
Time since last SD training		factor	0-6, 6-12, 12-24, 24-48, 48+ months
Type of training:	In-flight	factor	Not Given, Given, NS
	Ground Demo	factor	Not Given, Given, NS
	Lecture	factor	Not Given, Given, NS
Rating of training		covariate	
Trained by		factor	Doctor, Physiologist, Pilot, Lecturer, Doctor &Physiologist, Doctor & Pilot, Other

Table 3 Dependent variables used in the analysis

Variables	Levels
All illusions	Principal Component
Visual illusions	Principal Component
Body Sense illusions	Principal Component
Displays illusions	Principal Component
Central psychological (giant hand & detachment)	No (never), Yes (rarely or above)
Distraction due to task saturation	No, Yes
Poor crew co-ordination	No, Yes
HUD illusions	No, Yes
HMD illusions	No, Yes
NVGs illusions	No, Yes
Severity of most recent SD experience	Never/minor=0, Significant=1, Severe=5
Severity of worst ever SD experience	Never/minor=0, Significant=1, Severe=5

The dependent variables 1-5 are the results of applying a principal component procedure to obtain a single measure to describe the effect.

The natural logarithm of total flying hours and hours-on-type terms was used in the analysis. The variables were selected from the possible combinations (age, crew position, total hours flown, aircraft type, hours-on-type, frequency of training, type of training and rating of training) by a 'stepwise' method. Responses with missing data were excluded from the each analysis on a case-by-case basis. Hence the total number of responses used varied for each analysis undertaken. Mutliple Analysis of Variance was used, with a significance criteria of $p < 0.05$. Newman-Keuls, Scheffe and Bonferroni post-hoc tests were performed to identify the source of any significant effects.

RESULTS FOR UK PILOT DATA

General descriptives – pilot data (excluding navigators)

Respondents included pilots from fast-jet (Tornado, Jaguar, Hawk, Harrier), rotary (Sea King, Puma, Lynx, Gazelle, Apache) multi-engine (mainly Canberra, Nimrod) and trainer aircraft (mainly the Squirrel helicopter). For 78 records, the respondents did not specify aircraft type, make and model, and it was not possible to confidently assume the aircraft type from the questionnaire origin or content. The mean age of respondents was 33.7 years (sd 6.7 years), with a range of 21 to 64 years of age. The mean number of total flying hours (over entire career) was 2,217 (sd 1,728 hrs), with a range of 40 to 12,300 hrs. The majority of the descriptive statistics are illustrated by Figures 1 to 5.

The most common SD experience was the leans (92% of respondents), followed by SD resulting from the loss of the horizon due to atmospheric conditions (82%). The rank order of the most commonly experienced SD is provided by Table 4.

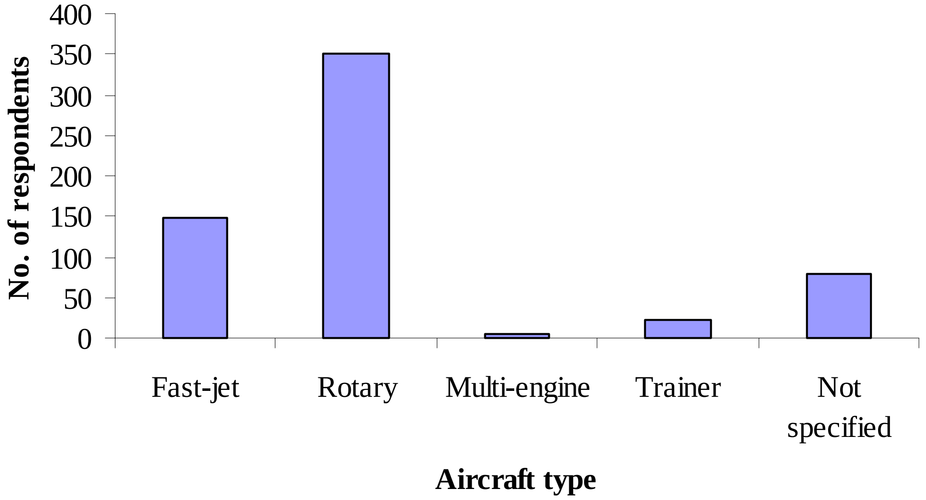

Figure 1 Distribution of responses by aircraft type

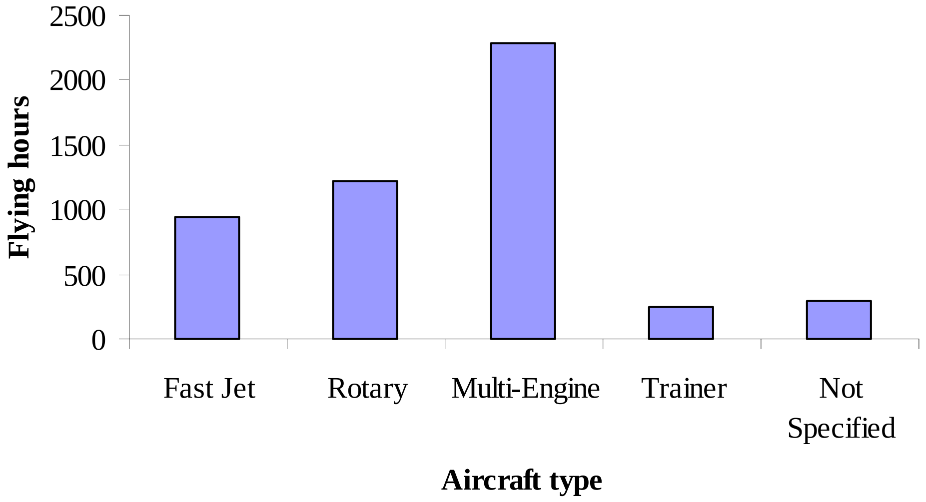

Figure 2 Mean flying hours by aircraft type

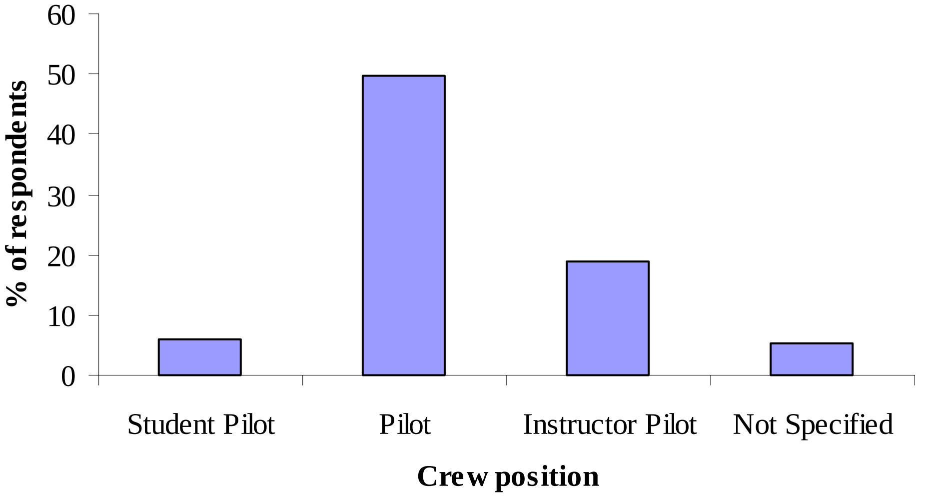

Figure 3 Distribution of crew position

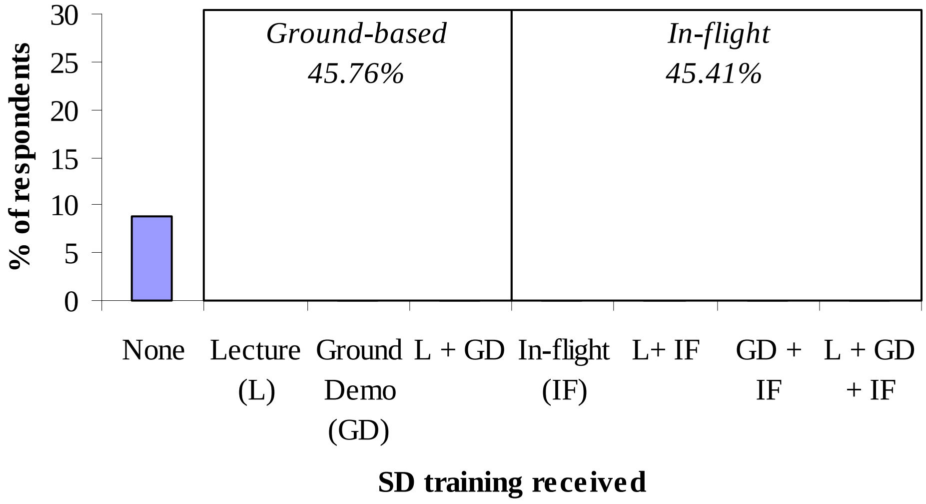

Figure 4 Distribution of SD training received amongst respondents. The mean time since last SD training was 3.5 months (sd 4.9 months) with a range of 0 to 45 months.

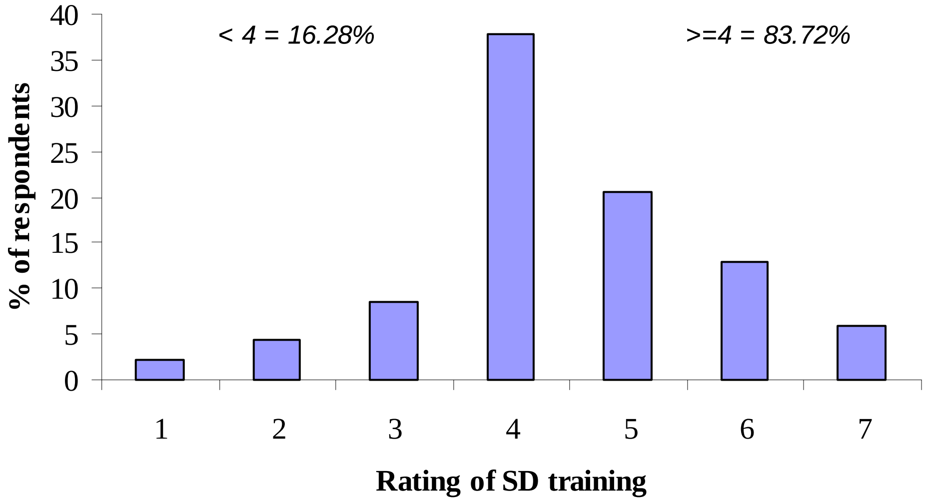

Figure 5 Respondents' rating of SD training (1 = no value, 4 = satisfactory, 7 = excellent)

The majority of respondents (78%) had either not experienced/recognised a recent episode of SD on their current aircraft type or had classified an episode as minor SD (flight safety was not at risk). However, 110 respondents (18%) reported a SD experience which they classified as 'significant: flight safety was not at risk, but could have been under different conditions'. Twenty-one respondents (4%) rated their most recent SD experience as 'Severe: flight safety was a risk'. Forty five percent of these severe incidents had occurred more than 1 year before the survey, with 30% at less than 1 year, 15% at less than 6 months and 10% at < 1 month. There were a higher number of responses (15%) in the 'severe' category of SD experience when the respondents were asked to rate their worst *ever* SD episode. These results are illustrated in Figure 6 and Figure 7. A selection of recent severe SD episode descriptions is provided below:

'Night fatigued (at work 18 hours, 8 hours flying). Alouette II helicopter, initiated climb to clear mountains next to sea. Intended to do a spiral climb but lost airspeed and started descending at 1500 ft.p.m. Recovered at 300 AGL (having lost 1000ft) by reference to instruments. Went home and cancelled the next sortie. No NVG.'

'NVG approach at high elevation thought it was normal approach but we were going backwards and down. I was the Instructor Pilot at the time. I cross referenced with the instruments and recovered with forward cyclic. Pilot was very unsure what had occurred, and the sortie was terminated.'

'Whilst flying in night the formation on a transit a turn was initiated. Our jet subsequently dropped back somewhat. Whilst trying to regain formation a millibar change was given and a descent was initiated. Whilst changing the HUD millibarsetting I looked up and saw the other A/C very close. At night I had incorrectly perceived the other A/Cs heading.'

'Pulled up in IMC from the hover due to white out. Extreme difficulty in rolling out from turn. Solved by plugging in altitude hold and rolling wings level and letting aircraft fly itself.'

'During night exercise with very little ambient, light and no horizon, I turned to cross the path of Sea King on reciprocal heading (over sea in company with ships). Estimated Sea King to be distant due to visual cues (navigation lights). As turn proceeded I realised that the Sea King was much closer than expected and executing avoided action. Estimated separation of 500 yds.'

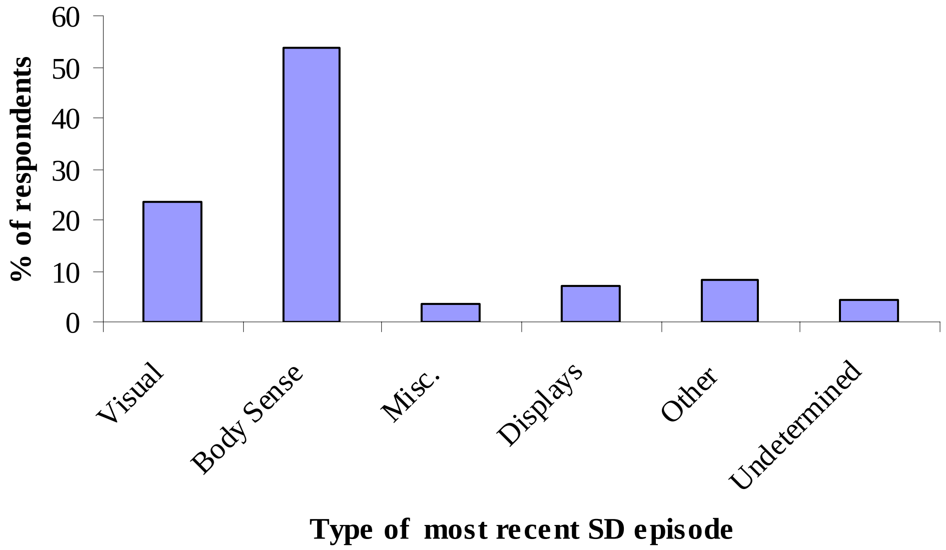

Figure 6 Distribution of type of most recent SD episode, as categorised by Subject-Matter Experts.

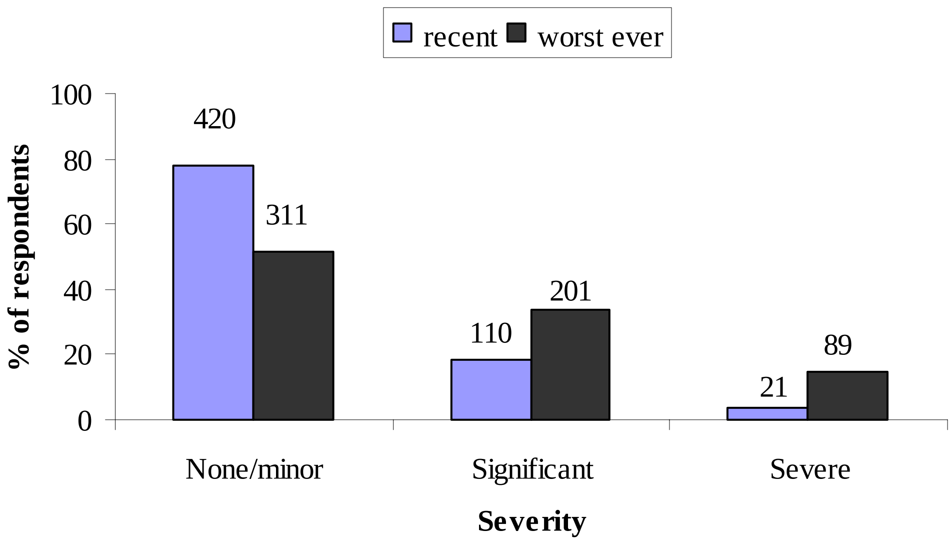

Figure 7 The distribution of respondents' categorisation of their most recent and worst ever SD episode. The value displayed above the bars is the number of respondents in each category.

Table 4 Rank order of most frequently experienced illusions

Rank	SD experience	% of respondents
1	Leans	92
2	Loss of horizon due to atmospheric conditions	82
3	Misleading altitude cues	79
4	Sloping horizon	75
5=	Distraction	66
5=	Tumbling sensation (Coriolis)	66
7	Night approach	60
8	Loss of horizon due to sand/snow	56
9	Undetected drift (Rotary only)	55
10	Poor crew co-ordination	50
11	NVGs	48
12	Autokinesis	43
13	Graveyard spiral	43
14	Misjudgement of position	37
15	Elevator illusion	35
16	False sense of pitching up	34
17	G-excess	33
18	Giant hand	31
18=	Roll-reversal error	31
20	Head down displays	30
21	Inability to read instruments clearly following recovery from maneuver	29
22	False sense of pitching down	28
23	Instrument malfunction	24
24	False sense of yaw	20
25	False sense of inversion	18
26	Inappropriate use of sun, lights as vertical cue	17
27	Feeling of detachment (high altitude)	17
28	HUD	13
29	FLIR	11
30	SD whilst using drifting/descending aerial flare	10
31	Vertigo caused by flickering light	8
32	Graveyard spin	7
33	HMD	2

Statistical analysis

Table 5 provides an overview of the results from the statistical analysis of the UK SD survey data. As illustrated, it shows that factors that influenced the data were mainly aircraft type, crew position, hours-on-type, total hours flow, and whether pilots had received in-flight SD training.

All illusions

Analysis of all the SD illusions experienced by the respondents in their current aircraft type revealed an effect of aircraft type ($p < 0.0001$) and in-flight SD training ($p < 0.0001$). Fast-jet pilots reported more SD experiences overall than rotary and trainer aircraft aviators ($p < 0.05$). The respondents who had received in-flight SD training reported more SD experiences overall than those who had not received any in-flight training ($p < 0.05$). The linear covariate, hours-on-type, had a positive effect on all SD illusions ($p < 0.001$).

Visual

There was an effect of aircraft type ($p < 0.001$) crew position ($p < 0.05$) and in-flight training ($p < 0.001$) on experience of visual SD illusions. Pilots and instructor pilots reported more visual SD experiences than student pilots ($p < 0.001$). There were more visual SD illusions experienced by aviators who had received in-flight training compared to those who had not ($p < 0.001$). The covariate of total hours was found to have a positive effect on experience of visual SD illusions ($p < 0.001$).

Body sense

The experience of body sense illusions was affected by in-flight training ($p < 0.05$) and aircraft type ($p < 0.0001$). Pilots who had received in-flight training reported more body sense illusions than those who had not received in-flight training ($p < 0.05$). Fast-jet pilots reported more body sense illusions than rotary-wing aviators ($p < 0.001$). The linear covariate, hours-on-type, had a positive effect on body sense SD illusions ($p < 0.05$).

Display

Aircraft type had an effect on the experience of display SD illusions ($p < 0.001$). This was attributable to fewer reports of display illusions from rotary-wing pilots than fast-jet aviators ($p < 0.01$).

Central psychological

There was an effect of aircraft type on the experience of ‘central psychological’ SD illusions, giant hand and feeling of detachment ($p < 0.001$). Rotary pilots reported more of these types of SD experiences than trainer aircraft aviators ($p < 0.01$).

Distraction caused by task saturation

Spatial disorientation caused by distraction was affected by in-flight training ($p < 0.05$). Individuals who had received in-flight SD training reported more incidents of SD due to distraction than those pilots who had not received this training ($p < 0.05$).

SD caused by poor crew co-ordination

There was an effect of crew position ($p < 0.01$), in-flight training ($p < 0.01$), ground training ($p < 0.05$), and SD lecture ($p < 0.01$) on SD caused by poor crew co-ordination. Both instructor pilots and pilots reported more SD incidents of this type than student aviators ($p < 0.001$). Pilots who had received either in-flight, ground based training or an SD lecture reported more incidents of SD resulting from poor-crew co-ordination than aviators who had not received any of these training types ($p < 0.05$).

HUD

There was an effect of aircraft type on the experience of HUD illusions ($p < 0.0001$). There were more HUD illusions reported by fast-jet pilots than trainer and rotary aviators ($p < 0.01$, $p < 0.001$ respectively).

HMD

The covariate of total hours had a positive effect on HMD illusions ($p < 0.0001$), whilst hours-on-type had a negative effect on this data ($p < 0.0001$).

NVG

Aircraft type and in-flight SD training had an effect on the experience of NVG illusions ($p < 0.0001$; $p < 0.05$ respectively). Rotary-wing pilots reported more NVG SD experiences than fast-jet aviators ($p < 0.05$). Pilots who had received in-flight training reported more NVG illusions than those who had not received in-flight training ($p < 0.05$). The covariate of hours-on-type had a positive effect on the experience of NVG illusions ($p < 0.01$).

Severity of most recent and worst ever SD experiences

The severity of the most recent SD episode was affected by in-flight SD training ($p < 0.01$). Pilots who had received in-flight training reported more severe recent episodes of SD than those who had not received this training ($p < 0.01$). The covariate of hours-on-type had a positive effect the worst ever SD episode ($p < 0.001$).

Comparison of pilots and navigators

Data obtained from navigators was added to the responses obtained from pilots, and the principal component analysis for all responses in all categories ('All Illusions') was recalculated. Analysis of variance, including 'navigator' as an additional factor level in the category of 'crew position' was undertaken. This analysis found a significant effect of crew position ($p < 0.005$), which was attributable to fewer SD experiences reported by navigators relative to pilots ($p < 0.01$).

Table 5 Overview of results from statistical analysis of UK SD survey data (*p < 0.05, **p < 0.01, ***p < 0.001).

	Aircraft type		Crew position		In-flight training		Total hours	Hours-on-type
All	fast-jet	> trainer* > rotary*			given	> not given***		+ve ***
Visual			student	< instr. Pilot*** < pilot***	given	> not given***	+ve ***	
Body sense	fast-jet	> rotary***			given	> not given*		+ve *
Display	fast-jet	> rotary**					+ve *	
Central Ψ	rotary	> trainer**						
Distraction					given	> not given*		
Crew co-ordination			student	< instr. Pilot*** < pilot***	given	> not given*		
HUD	fast-jet	> rotary*** > trainer**						
HMD							+ve***	−ve***
NVG	rotary	> fast-jet *			given	> not given**		+ve**
Most recent SD					given	> not given**		
Worst ever SD								+ve***

DISCUSSION

This preliminary SD questionnaire study is the first tri-service survey of UK military pilots and navigators, and the most recent in the UK since Durnford's (1992) survey of Army aviators [14]. The leans was the most commonly experienced SD episode, followed by SD caused by atmospheric conditions and misleading attitude cues, such as sloping cloud banks, an order in agreement with the previously cited SD incidence surveys [10, as cited in 11;12,13,14]. It is important to note that in all of these questionnaire surveys (including the current investigation) pilots reported SD episodes that they had *recognised* during flight and could categorise accordingly. It is therefore not surprising that the leans was the most frequently reported SD experience, as it is the most commonly stressed example of SD, and is a powerful illusion. Spatial disorientation experiences such as 'a false sense of pitching down with abrupt deceleration' may not be so recognisable or memorable.

Spatial disorientation due to the loss of situation awareness ('distraction due to task saturation') was reported by 66% of respondents, a figure similar to that reported by Sipes and Lessard [13]. Unlike the previous surveys, poor crew co-ordination was one of the main factors contributing to an SD event, having been encountered by 50% of respondents. The relatively high experience of both these types of SD episodes emphasises the importance of training aircrew to overcome and, most importantly, avoid the loss of situation awareness due to distraction and task loading. In addition, it highlights the need to train for good crew-co-ordination and investigate how poor crew co-ordination arises and its effect on SD. For example, are crews who have worked together for many months more or less likely to be disorientated due to poor co-ordination than those who have recently started to operate together? Research indicates that an increase in crew familiarity can foster complacency and over-confidence [16].

SD episodes during NVG use were experienced by a relatively high percentage (48%) of respondents. This is probably due to the 61% of rotary-wing pilots who participated in the survey. Pilots on this platform type are more likely to use NVGs than fast-jet aviators, which explains why more NVG SD experiences were reported by rotary than fast-jet pilots. Similarly, the greater experience of HUD SD illusions reported by fast-jet pilots relative to all other aviators is probably due to the more frequent use of HUDs in this airframe. Given these differences, it may be beneficial to provide specific SD training on SD resulting from NVGs to rotary pilots, and HUDs to fast-jet pilots.

The greater incidence of body sense SD illusions reported by fast-jet pilots compared to rotary-wing aviators is probably a reflection of the questionnaire design. The vast majority of the SD descriptions in this category could only be experienced in the fast-jet environment, with the exception of the leans and undetected aircraft drift, the latter of which was only completed by rotary-wing pilots (see Annex A). These facts may also explain why fast-jet pilots appeared to report more SD episodes overall (‘all illusions’) than other aircraft types.

The more experience a pilot had on their current aircraft type (hours-on-type), the more episodes of all types, body sense, and NVG illusions reported, and greater the severity of the worst ever SD experience. This data may simply reflect the greater chance of experiencing, and/or recognising, SD with increasing number of hours flown. The positive relationship between total flying hours and episodes of visual, display, and HMD SD episodes indicates that experience of these types of SD episodes ‘carry over’ to different aircraft types. For example, for fixed-wing aviators, visual illusions will be experienced during initial training in propeller aircraft, as well as during fast-jet training, whereas body-sense illusions will mainly be experienced in fast-jet aircraft. This serves not only to increase experience of visual SD over total hours flow, but also reinforces the recognition of types of visual SD. This may be reflected by the greater experience of visual illusions reported by pilots and instructor pilots compared to students. An interesting finding was the dichotomous relationship of total hours (positive) and hours-on-type (negative) with SD experiences related to HMD use. This suggests that as with visual SD, pilots will experience more episodes of HMD SD with increasing hours of flying experience. However, when pilots convert to a new type of HMD on a different aircraft, their experience may not readily transfer. This may be attributable to differences in sensor type (thermal or image intensifying; monocular, binocular or biocular), and symbology sets. Hence it is likely that pilots initially suffer SD episodes related to the new HMD, which reduce in frequency (and possibly severity) as they adapt to the technology.

One of the most interesting findings of the UK survey was the greater incidence of SD episodes reported by individuals who had received in-flight SD training. As previously stated, in completing this survey pilots reported SD episodes that they had recognised during flight and could categorise accordingly. It is possible that pilots who had received in-flight SD training were more able to recognise and categorise SD episodes for two reasons. Firstly, they may have experienced the types of SD that cannot be generated in ground-based simulators (e.g. pitch-up illusion, elevator illusion). In addition, in-flight SD demonstrations provide a realistic, contextual environment for SD training. The greater incidence of SD reported by those who received in-flight training provides evidence for the beneficial effects of this type of instruction. Once a pilot recognises that he/she is disorientated, they can take measures to rectify the situation (e.g. recovery manoeuvres).

Although all UK services provide their aircrew with in-flight training to prevent/overcome SD (e.g. procedures upon inadvertent entry to IMC and recovery from unusual attitudes) the Army Air Corps is the only service with a formal in-flight programme to demonstrate the limitations of the orientation senses [17]. An in-flight SD demonstration sortie has been designed for RAF fast-jet aircraft, although its implementation within the current training programme has yet to be established. It appears that RAF and Navy pilots receive ‘informal’ individual in-flight SD demonstration from some instructor pilots, although the nature, type, and frequency is currently unknown. It would be interesting to compare SD experiences and rating of demonstration and training between those pilots who have attended the formal AAC in-flight programme and those who have received informal in-flight RAF/Navy SD training. Regrettably, it was not possible to ascertain the source of pilots' SD training from the current data set. This could be achieved in a future survey.

Pilots who had received in-flight SD training rated their most recent episode of SD to be more severe than those who had not received this training. It is possible that these pilots may have responded to this question in terms of their rating of the severity of the SD itself as opposed to the effect on flight safety. A revision of this question to differentiate between severity of SD episode and effect of SD episode on flight safety may clarify this issue. The rating of 'severe' ('flight safety was at risk') was given by 89 respondents for their worst ever, and 21 participants for their most recent SD episode (the conditions of which have yet to be analysed). Very tentatively, these were 110 potential accidents. Given the beneficial effect of in-flight SD training on the recognition of SD, SD training should contain an element of in-flight instruction, and teaching specific to aircraft type (e.g. NVG for rotary). In addition, the relatively high incidence of SD related to poor crew co-ordination and distraction (task saturation) suggests that SD training should include these types of scenarios. We are currently undertaking a study evaluating the effectiveness of simulator training for this purpose.

The time since last SD training and rating of SD training appeared to have no effect on the frequency, type and severity of SD experienced. The latter may be explained by the high ratings given for the quality of SD training (over 80% of respondents rated satisfactory or above). The lack of any relationship between time since last SD training tentatively suggests that frequency of training may not be an issue affecting SD incidence. Overall, it appears that the most beneficial effect of training may not be the frequency, but the type of training provided (specifically in-flight).

Navigators reported fewer incidents of SD than their pilot colleagues. This is not a surprising result, as the navigator is not primarily responsible for the flying task. For example, navigators spend much of their time heads-in and may not experience the visual illusions.

Overall, while the results of the questionnaire provide interesting information on the recognition and classification of SD illusions in flight by aircrew, they do not give a clear indication of the frequency of spatial disorientation. It is difficult to discern from the results those instances that led to a significant error in aircraft attitude or position or that resulted in significant confusion in the mind of the pilot about the orientation of his aircraft. Such instances represent true spatial disorientation. By contrast, an illusion in flight can only be recognised if there is a simultaneous awareness of the true situation, through instruments or other visual cues (e.g. the leans), when it *might* therefore be argued that the pilot is no longer disorientated.

This questionnaire provides some evidence for the beneficial effects of SD training in the recognition of circumstances that could lead to spatial disorientation. In fact, the true instances of spatial disorientation may often be found embedded in the miscellaneous categories of distraction, poor crew co-ordination and errors in the interpretation of displays.

There were a relatively large number of missing data on aircraft type, make and model (13%). This may be attributable to the design of the questionnaire. It appears that this question is easy to miss (see Annex A). The layout of the questionnaire is currently in progress to rectify this problem.

CONCLUSIONS

This preliminary survey has shown that SD is still a significant hazard of military flying. The relatively high incidence of SD resulting from poor crew co-ordination and distraction highlights the need for situation awareness SD instruction in addition to the more traditional 'illusion' training. The differences in SD experienced between aircraft type suggests that specific airframe SD training may be required (e.g. NVG SD training to rotary-wing crews). This survey has also shown the role of experience (flying hours) in the recognition of SD, and has highlighted the potentially beneficial effects of in-flight SD demonstration and training in the recognition of SD. Overall, this study shows that the WP61 postal SD Questionnaire is a useful tool for assessing how SD training and experience may benefit the recognition of situations that may cause SD. However it is difficult to access those situations where aircrew were truly disorientated. Phrasing questions in such a way that differentiates between experiencing an illusion and being disorientated because of the illusion may be beneficial.

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ANNEX A - SPATIAL DISORIENTATION SURVEY

The purpose of this **anonymous survey** is to gather information from **aircrew** on the frequency and types of spatial disorientation (SD) being experienced in order to target future research and **help prevent SD accidents**. Please take the time to answer the questions as indicated, whether or not you have knowingly experienced SD in-flight. The definition of SD for the purposes of this survey is as follows:

An incorrect perception of your linear/angular position, or of your motion, relative to the Earth's surface or another aircraft, <u>SUFFICIENT TO AFFECT YOUR PERFORMANCE, SITUATIONAL AWARENESS OR WORKLOAD - HOWEVER SLIGHT THAT EFFECT MAY BE</u>.

Please complete **both sides** of this survey.

PART 1

Age (Yrs)	Crew Position *(Circle)*	Flying Hours (Total)
	Student Pilot / Pilot / Navigator/ Instructor Pilot	

What training have you received on SD? *(Circle all that apply)*	None / Lecture / Ground-Demonstration / In-Flight
How long ago did you last receive dedicated SD training?	______Years _____Months
Who gave you your last SD training (pilot, physiologist, etc)?	
How do you rate your overall SD training to date? *Rating Scale (1-7): 1 (no value) to 4 (satisfactory) to 7 (excellent in all respects)*	

Please record how frequently you have experienced each of the listed SD illusions **IN YOUR CURRENT AIRCRAFT TYPE** with a mark in the appropriate column (if current on more than one type, choose the aircraft in which you have the greatest number of hours). **Please read each description carefully**. Do not include scheduled in-flight SD demonstrations.

Current Aircraft Type	Type / Model:		Hrs Flown on Type:	

N*ever = Never or N/A,* ***R****arely = 1-2 episodes only,* ***S****eldom = <5% of* **ALL** *sorties,* ***O****ccasional. = 5-25% of* **ALL** *sorties,* ***F****req. = >25% of* **ALL** *sorties*

N	R	S	O	F	DESCRIPTION	
					Inappropriate use of the sun, moon or northern lights as a vertical cue	VISUAL
					Sloping horizon – orientation against sloping clouds or terrain	VISUAL
					Loss of horizon - SD caused by atmospheric conditions blending earth and sky	VISUAL
					Loss of horizon - SD caused by blowing sand, dust or snow (brown-out/white-out)	VISUAL
					SD while using a drifting/descending aerial flare as a reference	VISUAL
					Misjudgment of position in night formation trail due to poor visual cues	VISUAL
					Night approach to a runway with misleading visual cues – black-hole approach	VISUAL
					Misleading altitude cues from ground texture (e.g., over flat water, small trees etc)	VISUAL
					Apparent motion of a fixed point light source (autokinesis)	VISUAL
					False sensation of yaw caused by anti-collision light reflecting off cloud/fog	VISUAL
					Vertigo caused by flickering light – strobe light or sunlight through rotor disc/prop.	VISUAL
					Inability to read instruments clearly following recovery from a flight maneuver	VISUAL
					Sensation of rolling/pitching after abrupt head movement in a turn (Coriolis)	BODY SENSE
					False or exaggerated sense of bank in a high-G turn (G-excess)	BODY SENSE
					False sense of upward/downward motion as if in an elevator	BODY SENSE
					False sense of inversion – e.g., after abrupt level off	BODY SENSE
					Recover from a spin, spin perceived in opposite direction, spin re-entered (graveyard spin)	BODY SENSE
					Roll level from coordinated turn, sense roll in opposite direction, re-enter turn (graveyard spiral)	BODY SENSE
					Leaning in response to a false sensation of bank after recovery to wings level (the "leans")	BODY SENSE
					False sense of pitching up on take-off or when accelerating in flight	BODY SENSE
					False sense of pitching down with abrupt deceleration in flight	BODY SENSE
					Undetected drift/descent in the hover **(Rotary/VSTOL ac only)**	BODY SENSE

Never = Never or N/A, Rarely = 1-2 episodes only, Seldom = <5% of **ALL** *sorties, Occasional. = 5-25% of* **ALL** *sorties, Freq. = >25% of* **ALL** *sorties*						
N	**R**	**S**	**O**	**F**	**DESCRIPTION**	
					Perceived inability to make input to correct bank angle (like a giant hand holding the wing down)	MISC
					Feeling of detachment/no longer being in control of own aircraft (high altitude/absent horizon)	
					SD caused by distraction or task saturation	
					Poor crew coordination	
					Problems interpreting spatial orientation information on the head-down displays	DISPLAYS
					Problems interpreting spatial orientation information on a head-up display (HUD)	
					Problems interpreting spatial orientation information on a helmet-mounted display (HMD)	
					Erroneous bank correction using any attitude indicator (roll-reversal error)	
					Disorientation while using night vision goggles (NVG)	
					Disorientation while using forward looking infra-red (FLIR) or other targeting aids	
					Disorientation due to instrument malfunction (proven malfunction only)	
-	-	-	-	-	Other disorienting illusions/factors *(please describe)*:	OTHER
					1.	
					2.	
					3.	

If you have experienced any of the above proceed to part 2

If not, please tick the box and return the survey. Thank you for your participation ☐

PART 2

How long ago did you **last** experience SD in flight? *(Circle one)* <1 Wk / <1 Mo / <6 Mo / < 1Yr / >1Yr

What was your last disorienting illusion/incident **in your current aircraft type**? *(Brief description - describe what you felt, what caused it, how you recovered – attach 2nd sheet if necessary)*

What were you doing at the time? *(Please circle appropriate condition)*

Take-off	Departure	Air-to-Ground	Air-to-Air	Air Refueling
Formation – Lead	Formation – Trail	Formation – Wing	Turning	Instrument Approach
Transition to Land	Low Level Nav.	Med/High Transit	Aerobatics	Hover
Other (Specify):				

Which of the following conditions applied at the time of this incident? *(Please circle as appropriate)*

Wx Conditions:	VMC	Borderline VMC	Intermittent IMC	IMC	Simulated IMC (Hood)		Not known
Illumination Level:	Bright	Overcast	Twilight	Dusk	Moon	Stars	No Moon	Not known
Devices (if applicable):	HUD	HMD	NVG	FLIR	Hood	Other:	Not known

Classification: Please indicate the severity of **this, most recent, (A)** SD incident and your **worst ever (B)** SD incident in your **current aircraft type**. *(one tick in each column)*

A	**B**	
☐	☐	MINOR – Flight safety not at risk
☐	☐	SIGNIFICANT – Flight safety not at risk but could have been jeopardized under different conditions
☐	☐	SEVERE – Flight safety **was** at risk

END OF SURVEY - Thank you for you help and participation

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