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Major causes of spatial disorientation and the role of visual training systems: A survey of experts

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Abstract
Spatial Disorientation (SD) has been a problem since the beginning of aviation, and is still a problem today. There have been numerous attempts to find the best training to combat SD and several researchers have examined the possibility of using visual-only simulators. The goal of the current study was to obtain the opinions of subject matter experts (SMEs), in the area of spatial disorientation, regarding the feasibility and usefulness of visual-only flight simulators for SD training. It is believed that a high fidelity, visual-based simulator could play an important role in SD training. Twenty-three spatial disorientation SMEs completed surveys which asked the following questions: 1. List what you feel are the top three SD-induced flight events that contribute most to aviation mishaps; 2. List what you feel should be the top three goals of SD training; 3. List three things that you feel a high fidelity visual-only flight simulator could be used for in SD training; and 4. On a scale of 1-10, how useful would a visual-only flight simulator be for SD training? Responses received to the above questions suggested that there is a place for a high fidelity, visual only simulator in SD training. Though many SMEs felt that motion was necessary for SD training, they seemed to concur that there were several needs that could be met by a visual-only simulator. Visual-only simulators could play a pivotal role as part task trainers to supplement SD training.

Spatial Disorientation (SD) has been a problem since the beginning of aviation, and is still a problem today. In general aviation, between 1994 and 2003, SD is suspected to have caused over 203 accidents with 184 resulting in fatalities (Wynbrandt, 2004). SD can be defined as the pilots failure "…to sense correctly the position, motion or attitude of his aircraft or of him/herself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical" (Benson, 1999, p. 419). There have been numerous attempts to find the best training to combat SD. Some military and commercial aviation programs have used state of the art motion based flight simulators and some military aviation programs have tried in-flight demonstrations of SD events (Braithwaite, 1997). Unfortunately, some SD events can be impossible to recreate during in-flight training without

endangering the pilots and the aircraft. It is also costly and time consuming to put all pilots through extensive training in a large motion based flight simulator. Fortunately, there is research that suggests that part task training on a PC based simulator can be just as effective as training in a full motion based simulator (Philips, Hulin, & Lamermayer, 1993).

Several researchers have examined the possibility of using visual only simulators for SD training. Estrada et. al. (1998) conducted a study, for the army, examining the usefulness of a visual based simulator for SD training and found that the visual based simulator could effectively increase pilots' awareness of conditions that can contribute to SD as well as provide training on how to recover from SD events. It was their assessment that a visual based simulator could be useful in some aspects of SD training. Visual only PC based simulators have the advantages of easy access, low cost, and even the ability to include self-led programs that can be conducted without the need for an instructor (Koonce & Bramble, 1998).

The goal of the current study was to obtain the opinions of subject matter experts (SMEs), in the area of spatial disorientation, regarding the feasibility and usefulness of visual-only flight simulators for SD training. It is believed that a high fidelity, visual-based simulator could play an important role in spatial disorientation training.

Method

Participants

Eighty SMEs were contacted via email to participate in this study. Twenty-three participants replied, with twenty-one of those contributing useful data, the remaining two claimed they were not qualified to answer. The survey respondents ranged from scientists who study SD to experienced aviators. The SMEs were identified and defined in one of three ways: 1) from a list of attendees at a Defense Advanced Research Projects Agency (DARPA) sponsored Spatial Disorientation Workshop on Dec 16-19, 2001 held at the System Planning Corporation in Rosslyn, VA and arranged by Dr. Kurt Henry; 2) persons who gave SD related presentations at the 2003 Aerospace Medical Association (ASMA) annual meeting held in San Antonio, Texas; and 3) personal contacts of Dr. Eric Muth who are known to work in the fields of SD research, mishap investigation, and or pilots with firsthand knowledge of SD.

Survey

A survey was emailed to the SMEs. The survey asked the following four questions: 1. List what you feel are the top three SD-induced flight events that contribute most to aviation mishaps; 2. List what you feel should be the top three goals of SD training; 3. List three things that you feel a high fidelity visual-only flight simulator could be used for in SD training; and 4. On a scale of 1-10 (where 1 = "not at all" and 10 = "very"), how useful would a visual-only flight simulator be for SD training? Briefly explain the rationale behind your rating.

Data Reduction

Responses to the questionnaire were collected and like responses were grouped together into categories independently by two raters. In cases where the two raters disagreed, a third rater was brought in to resolve the disagreement. Once in categories, the responses were ranked in order of the frequency of occurrence. In this manner, the most important categories (the ones with the most responses falling into that category) and the most important items within a category (those that were reported most frequently) were identified.

Results

Question 1: List what you feel are the top three SD-induced flight events that contribute most to aviation mishaps

There was a wide range of responses to Question 1. We categorized the responses into three categories based on their content in order to facilitate interpretation. *Operator Factors* include factors that are relevant to individual pilots (e.g. inadvertent or inappropriate entry into instrument meteorological conditions (IMC), distraction, improper instrument scanning, etc.). *External Factors* are issues that have to do with the condition of the surrounding environment or task (e.g. lack of good visual cues, night flights, unfamiliar terrain, etc.). The third category is *Design or Human Factors*, which deal with the design and usability of the aircraft instrumentation (e.g. night vision devices, multiple control inputs, etc.).

Table 1 shows the number of responses that fell into each of the 3 categories and what rank the responses were assigned. The overall top three factors that can contribute to SD were: *Inadvertent and/or inappropriate entry into IMC* (*Operator Factor*), *unanticipated meteorological transition into IMC* (*External Factor*), and *high mental and/or visual workload* (*Operator Factor*), respectively.

Question 2: List what you feel should be the top three goals of SD training

The responses were separated into four categories, *Cognitive Based Learning (CBL)*, *Action Based Learning (ABL)*, *Experiential Learning*, and *Broad-Based*. *CBL* techniques are those that suggest lessons that can be taught without the use of simulators or hands on experience, such as physiological underpinnings of SD. *ABL* responses involve students physically practicing techniques and countermeasures. These responses are separated into two subcategories, *Preventative*, which deals with the techniques to avoid experiencing SD, and *Corrective*, which includes ways to correct for SD. *Experiential Learning* responses involve students actually experiencing some form of SD scenario in a simulator or real aircraft. *Broad-Based* recommendations are big-picture topics, which deal with the issue of spatial disorientation at a societal or governmental level.

Table 2 shows the number of responses that fell into each category and what rank the responses were assigned. The overall top three goals of SD training were: *recognizing SD risk factors and avoiding hazardous conditions that may lead to SD* (*CBL*), l*earn techniques that help prevent or overcome SD* (*ABL-Preventative*), and r*ecognize that SD is a normal physiological response to unusual gravo-inertial and visual environments* (*CBL*), respectively.

Question 3: List three things that you feel a high fidelity visual-only flight simulator could be used for in SD training

The responses were separated into three categories, *ABL*, *Experiential Learning*, and *Research*. As above, *ABL* responses deal primarily with training pilots to perform certain tasks better, such as instrument scanning or crew resource management (CRM), while E*xperiential* techniques allow pilots to actually experience various situations involving SD and precursors to SD. Each category is a separate, valuable aspect of training. The *Research* category contains responses that address whether visual-only flight simulators could be used to further basic or applied research in SD.

Table 3 shows the number of responses that fell into each category and what rank the responses were assigned. The overall top three potential uses of a high fidelity, visual only flight simulator were: *demonstrating visual only SD illusions and how to correct for them* (*Experiential Learning*), *improve basic instrument skills/training* (*ABL*), and *recognition of visual scenes that can lead to SD* (*Experiential Learning*), respectively.

Questions 4: On a scale of 1-10 (where 1 = "not at all" and 10 = "very"), how useful would a visual-only flight simulator be for SD training?

Table 4 shows the numbers of responses for each level of the rank order. Respondents generally agreed that it is important to have motion in a good simulator, as motion cues contribute highly to SD. However, some respondents felt that a visual-only simulator could still provide benefits, including, as discussed above, proper instrument scanning, experience of illusions, etc. Some respondents went so far as to claim that SD could not be effectively taught in any existing simulator, as none provides a realistic enough experience.

Discussion

The results suggest that though many of the respondents felt that motion was necessary for SD training, the respondents seemed to concur that there were several needs that could be met by a visual-only simulator. The top two factors that were identified as contributing to SD both concerned flight in IMC. In order to recreate the conditions involved during flight into IMC there is little need for simulator motion, some researchers even suggest that the visual fidelity of current technology provides visual cues that are so realistic that they override the imperfect vestibular cues that are provided by motion platforms (Burki-Cohen, Soja, & Langridge, 1998).

It is understood that a visual only flight simulator is not going to replace full-motion simulators or actual SD flights as the primary tool for SD training. What this brief survey does demonstrate is that a visual only flight simulator may play a role in supplementing SD training, especially in the cases where the visual system is the predominant cuing system (e.g., transition from visual flight to instrument flight, or teaching various countermeasures such as instrument scanning techniques). Evidence suggests that visual only flight simulators could be used for effective part-task training (Koonce & Bramble, 1998). PC based trainers can be set up in every squadron headquarters with 24 hour access to allow pilots to receive yearly, monthly or even weekly training on some of the more provocative visual effects of SD such as the visual to instrument flight transition. Because visual only simulators can be deployed anywhere they could be tailored to train SD events that are more common or problematic in a particular area. If the airstrip that the pilots fly into is sloping or on the edge of a large body of water then the pilots may need extra training on the black hole illusion (Gibb, 2007). Also, if the geography of the base is such that the area is often blanketed in cloud cover the pilots could practice using their instruments when flying into a cloud bank.

The important point that is to be made by these examples is that a visual only PC based simulator can be quickly developed and easily adapted to fit the ever-changing needs of the aviator. However, caution must be heeded based on the modest usefulness ratings that SMEs gave to visual-based SD trainers. Visual-based SD trainers represent part-task trainers. A complete SD training and refresher curriculum needs to incorporate these trainers with other types of training (e.g., classroom training, motion simulators and actual in-flight exercises). Over-reliance on visual only trainers would ignore the important contribution of other important sensory systems (e.g., vestibular and proprioceptive) to the occurrence of SD and hence relevance in training.

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Table 1

Number of responses to Question 1: List what you feel are the top three SD-induced flight events that contribute most to aviation mishaps

	Rank		
	#1	#2	#3
Operator Factors	9	8	9
External Factors	10	11	9
Design Factors	1	2	2

Table 2

Number of responses to Question 2: List what you feel should be the top three goals of SD training

	Rank		
	#1	#2	#3
CBL	14	5	4
ABL-Preventative	2	9	6
ABL-Corrective	0	0	6
Experiential	2	4	2
Broad-Based	3	2	1

Table 3

Number of responses to Question 3: List three things that you feel a high fidelity visual-only flight simulator could be used for in SD training

	Rank		
	#1	#2	#3
ABL	9	9	5
Experiential	8	6	6
Research	2	0	2

Table 4
Number of responses for Questions 4: On a scale of 1-10 (where 1 = "not at all" and 10 = "very"), how useful would a visual-only flight simulator be for SD training?

Rank	# of Responses
1	2
2	1
3	6
4	3
5	1
6	7
7	0
8	0
9	1
10	1