COMMENTARY

An Operational Definition for Spatial Disorientation

POOSHAN D. NAVATHE, M.D., and BHUPINDER SINGH, M.D.

EDITOR'S NOTE

The article by Drs. P. D. Navathe and B. Singh, "An operational definition for spatial disorientation," has aroused considerable discussion among its reviewers. The subject is a common one in aerospace medicine, but approaches to it vary according to the purposes and philosophies of those involved: physiology, accident investigation, flight operations, for example. We are publishing this article in the hopes that those concerned will be interested enough in supporting, modifying or refuting the authors' opinions to communicate their views in the "Letters to the Editor." Such a discussion will benefit us all.

David R. Jones, M.D., M.P.H.
Editor-in-Chief

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Spatial disorientation (SD) is a term which continues to have different meanings for different classes of people involved with aviation. The advent of new terms like "situational awareness" (SA), has only added to the plethora of existing definitions, leading to a difference of opinion among researchers worldwide. Lack of agreement regarding the semantics of SD among various aircraft accident investigators leads to different yardsticks in determining whether or not an accident is SD-related. These definitional differences do not allow for inter-Air Force comparisons of SD accident data, and a valuable opportunity to learn from the experience of others is lost. The authors examine the existing definitions, and propose a new practical operational definition of SD, for use in investigation and classification of aircraft accidents.

SPATIAL DISORIENTATION (SD) has been, and remains, a matter of great concern to all involved with both civil and military aviation, and is one of the important causes in the group of human-factors' related accidents worldwide.

Given the need for conserving precious resources, there is an operational need to correctly identify the accidents caused by, or contributed to, SD, and to try and isolate the modifiable factors. While the philosophy of this approach cannot be faulted, its execution has pitfalls.

First, in most aircraft accidents, we have the problem of insufficient evidence. More often than not, SD poses an intractable problem for the accident investigator, particularly in fatal accidents or in cases where the pilot is unable to recall the events immediately preceding the accident. With insufficient evidence to identify the accident as being due to SD, classification of such accidents depends to a large measure on the capability and initiative of the investigator.

Second, at present there is a clear dichotomy of thought among the medical and the pilot populations regarding the definition of SD and related terms. Most pilots, if asked, "What is SD?" are likely to give an answer which may be only partially correct by the textbook definition, in addition to being incomplete. Neither is there any real conformity of thought among different aeromedical workers regarding the definition of SD. This is evidenced by the many different terms used by various workers, and the use of different terms for the same or similar situations.

Although SD has been precisely defined by many workers, significant differences exist between the concepts defined, with attendant ambiguities. For instance, Benson (1) has defined SD as "a term used to describe a variety of incidents occurring in flight, where the pilot 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. In addition, errors in perception

From the Aeromedical Training Centre, Indian Air Force, Air Force Station Hindan, Ghaziabad, India.

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Address reprint requests to: P. D. Navathe, M.D., Institute of Aerospace Medicine Vimanapura Bangalore, 560 017 India.

by the pilot of his position, motion or attitude with respect to his aircraft, or of his aircraft relative to other aircraft may also be embraced within a broader definition of SD in flight." Gillingham (3) defined SD as the experiencing of an orientational illusion in flight. In an attempt to formulate a more practical working definition of SD, he has proposed an operational definition of SD as "an erroneous sense of the flight parameters displayed by aircraft control and performance instruments" (Gillingham KK, Personal Communication, 1992). The ambiguity of these definitions is evidenced by the remarks of Guedry (7), a member of the Advisory Group for Aerospace Research and Development (AGARD) during the Aerospace Medical Panel (AMP) meeting in Norway in 1980, where he disagreed with the separate classification of "error of judgment of speed and distance" and suggested that this should be considered a part of SD. He mentioned that there is particular need to reach an accepted classification of SD, and agreement concerning the terms employed. What was true over a decade ago is even more so today, as noted in recent reviews. The authors (8) had made a case for the review of the operational definition of SD, after revealing the problems of accident cataloging using the existing definition. Lyons et al. (5) have also faced similar problems, and have emphasized the need for agreement in terms of definitions and semantics.

Before discussing the issue of inadequacy of the definitions of SD, let us become familiar with a term used to describe some common disorientation situations: loss of Situational Awareness (SA), sometimes also called Tactical Situational Awareness (TSA). There are several definitions of SA. Fracker (2) refers to two components of SA: namely, Friend Foe Neutral (FFN), and Spatial Awareness. The USAF Air Combat Command definition identifies five sources of relevant knowledge:

- knowing where the friendlies are and what they are doing;
- knowing where the threats are and what they are doing;
- knowing what my flight knows and our options for attack/defense;
- knowing what other flights are and their intentions;
- knowing what part of above is not known or is missing.

Different connotations of SD and SA have emerged with different workers. Kuipers (4) et al. have included loss of SA (LSA) in the list of illusions, whereas Menu (6), perceives spatial orientation as merely a part of SA. Lyons (5) is one of the workers who have sought to overcome the problem by grouping accidents in a different class called SD/LSA, which includes accidents of both these categories. This is convenient for the accident investigator, but has questionable utility in accident analysis.

Benson's definition of SD, while sound conceptually, is perhaps all too encompassing. One can, without too much discomfort, find some justification in labelling each one of pilot error accidents as being due to SD. Gillingham's operational definition, while written in a language familiar to aircrew, refers to flight parameters displayed by control and performance instruments. This includes attitude, pitch, bank, power, airspeed, altitude, vertical velocity, heading, turn rate, angle of attack, and several other parameters. Since pilot error is an error in maintenance of one or more of these parameters, it provides an opportunity for one to label any of these errors as SD. In an accident investigation context, it is difficult to see any advantage of Gillingham's definition over Benson's.

The authors propose a hierarchical structure of Spatial Orientation (SO) as a qualitative subset of SA, accompanied by Geographic Orientation (GO) as another subset (Fig 1). In this graphic presentation, the triangle represents SA, the rectangle represents SO and the square represents GO; their absence will result in LSA, SD, and GSD, respectively. It may be recalled that, as per the Benson and Gillingham definitions, the triangle in toto represents SD, whereas the authors are seeking to separate these factors into SD (receptor input error), GSD (navigational error), and LSA (central error).

SD can then be defined as "the failure of a pilot to correctly sense the attitude or motion of the aircraft or of him or herself, resulting from inadequate or erroneous sensory information (from the receptors)." The causal relationship of "inadequate or erroneous sensory information" is an integral part of this definition, since it implies that this will only include illusions resulting from "input error." This limits SD as defined by the authors to visual, vestibular and somatosensory illusions. This includes all vestibular illusions and those visual illusions which occur as a result of receptor error such as oculogravic, oculogyral, somatogravic, or somatogyral illusions, flicker vertigo, and autokinesis. Conversely, all central modulation resulting in illusions like leaning on the sun, false perceptions, and errors of judgment of height, speed or distance, are considered loss of SA, as is coning of attention, and "breakoff" or other mechanisms which result from higher order factors like arousal or attention. SA also includes the ele-

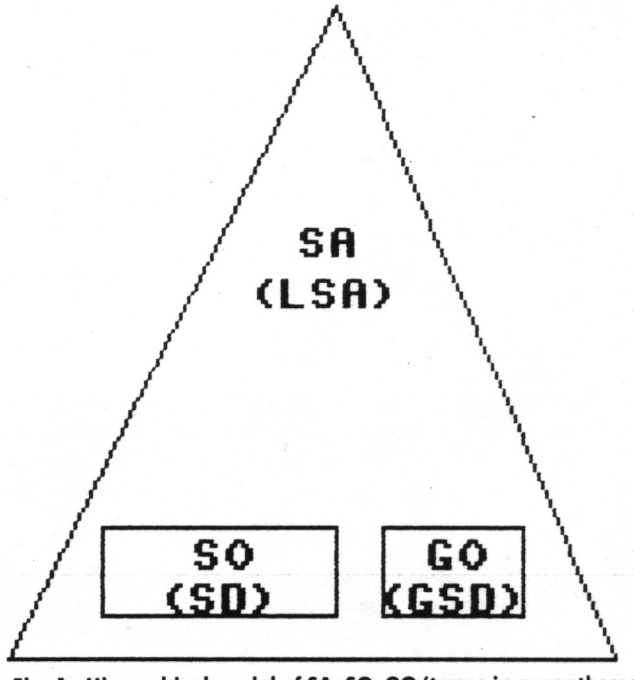

Fig. 1. Hierarchical model of SA, SO, GO (terms in parentheses indicate events occurring when each of these is lost).

ment of GO. LSA would then be defined as "a condition wherein the aircraft enters a dangerous, or potentially dangerous flight path, *as a result of central error*" (either an illusion, or due to error of judgment, preoccupation, etc).

In a simulated or actual combat environment, there may be additional factors like those concerning friend-foe identification, weapon system operation and mission completion, etc., which might result in loss of SA or of one of its subsets. Here, an error in interpretation of one of these factors would be labelled TSA, with no change in our usage of SD and LSA.

The immediate objection to this definition of SD is that it creates an artificial division between peripherally and centrally modulated illusions where perhaps none exists, and ignores the role of the latter in the causation of SD. Also, some illusions will remain in which the error is more "central" than "input"; how would those be classified? To these objections, we would answer that a definition is valid only so long as it is used for the purpose for which it is designed. We make no pretense of propounding a new concept in terms of aetiology or mechanism. The definition has been prepared specifically for use in accident investigation. If we try to evaluate the implications of this definition, particularly as applied to accident investigation, the advantages become apparent. Investigation of SD accidents can now be centered primarily around the issues of illusions and their potential causes. Was there any reason to believe that the pilot had some element of vestibular sensitization?; had the pilot performed on SD simulators?; if so, how well?; etc. If the pilot had GSD, we could focus on navigation skills and history. In the event of a loss of SA, the problem is much more broad-based, and we will have to include a spectrum of all possible factors ranging from personality at one end to task saturation at the other end of that spectrum. In other words, SD is a physiological limitation/overload, whereas LSA is a psychological limitation/overload. To prevent recurrence of an SD, one must look to physiological mechanisms, and to prevent LSA one must look to the human factors specialists. Can there be any disagreement as to the utility of such a distinction in accident causation?

One valid objection raised here could be that what was earlier an all-encompassing definition for SD has been limited, but SA remains a very vaguely defined concept. This only indicates the near synonimity of the terms "loss of SA" and "error of judgment" in certain situations. There may also be a reservation that central factors will not be given due weight in investigation of SD accidents. However, the objection may be countered by understanding the implications of the new definition, in that:

1) the visual-vestibular illusions have been clearly identified;
2) GSD is clearly differentiated;
3) loss of SA is proposed to be applied to all cases of error of judgment relating to aircraft position where threat presence is not a factor, which will lead to emphasis on the central error;
4) TSA is to be applied only in a potential or real combat situation;
5) the clear-cut separation of SD from loss of SA will enable more emphasis on central factors in cases of loss of SA, and emphasis on perceptual input error in cases of SD.

A word about the acceptability of the proposed definition: SD demonstrations and training protocols, by the use of disorientation simulators, are almost exclusively restricted to experiencing visual and vestibular illusions. Further, this definition is already implicit in the last few sentences used in any SD briefing to aircrew; viz., "SD is a normal physiological response to an abnormal situation." Most aircrew, and for that matter most flight surgeons, apply this only to the visual and vestibular illusions and not to central factors such as overarousal or fascination. Our definition is fairly close to Gillingham's earlier definition; it only separates the central errors from other illusions. One could, therefore, say that the entire aerospace community, pilots and physicians, have been moving towards this definition over the years. The flying community should find this definition much closer to its colloquial definition of SD, which is "a condition where the gyro topples," or variants thereof. This should facilitate its acceptance, a factor of some importance because of the need for the aircrew and us, as their medical advisors, to speak the same language.

Our definition, then, provides for use of a single, simple, unequivocal, and well delimited definition of SD when dealing with aircraft accidents. Input errors leading to loss of orientation will be labelled as SD, while the central factors leading, or contributing, to an aircraft accident will continue to be considered under a distinct group; i.e., loss of SA. Some workers already treat "getting lost" as GSD, and we merely reinforce such a usage. Such clear-cut coding will facilitate a cause-wise breakdown of accidents, and present manageable numbers for more detailed study. As regards the model of TSA and SA, it is hoped that acceptance of this hierarchy may help reduce the multiplicity of terms presently in use, and make the literature on the subject more comprehensible.

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