SPATIAL DISORIENTATION

Naval Medical Research Unit Dayton

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The mission of Naval Medical Research Unit Dayton (NAMRU-D) is to optimize the readiness, performance, and survivability of operational forces through environmental health effects, toxicology, and aerospace medical research and development. As one of two science directorates within NAMRU-D, the Naval Aerospace Medical Research Laboratory (NAMRL) conducts aerospace-relevant basic and applied research in the biomedical and allied sciences. Within NAMRL, the Acceleration and Sensory Sciences Department specializes in research addressing the principal contributing aeromedical factor in Class A aviation mishaps: spatial disorientation.

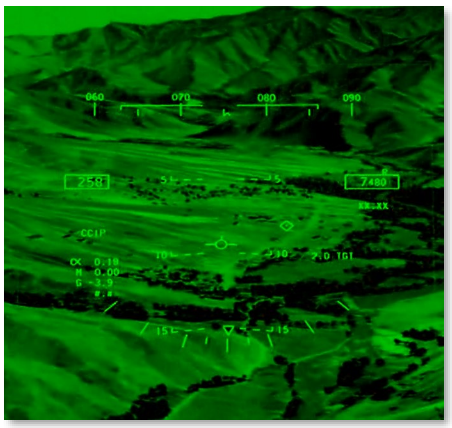
Spatial Disorientation (SD) occurs when pilots incorrectly perceive the attitude of their aircraft with respect to the earth, gravitational vertical, or other aircraft.2 Many aspects of the flight environment can give rise to SD. For example, degraded visual environments may require pilots to transition to instrument-only flying, which they may not trust over their "seat of the pants" gut feeling. Acceleration forces experienced during flight can also cause pilots to experience gravity through the floor of the aircraft, even though this may not truly represent the gravitational vertical. Other forces may be so subtle or prolonged that the pilot does not perceive changes in the aircraft's attitude or heading. For example, control reversal errors occur when pilots make a stick input in the wrong direction, such as the direction that would steepen the aircraft's angle of bank rather than return it to level. The amount of time pilots spend in unusual attitudes (e.g., extreme angles of bank) is also a good indicator they have become disoriented. These behaviors may serve a proxy for SD because it is unlikely that a pilot would maneuver into these positions under normal circumstances. Whatever the causes of SD, the effects can be devastating, leading to controlled flight into terrain, midair collision, or inappropriate control inputs resulting in aircraft stalling or departure from controlled flight.

*"Spatial Disorientation is the **#1 killer of aircrew.** Nearly all pilots experience SD during their careers"*

Surveys indicate nearly all pilots experience some form of SD during their careers. The U.S. Naval Safety Center cites SD as the number one aeromedical causal factor of Class A mishaps (those resulting in a loss of life, permanent disability, and/or more than $2 million in property damage). A review of 20 years of U.S. Air Force Class A mishap data found that 12% included SD as a causal factor, with 101 lives lost. A comparison of non-SD and SD-related Class A mishaps found that while 16.1% of non-SD mishaps involved a fatality, 61.1% of the SD-related mishaps were fatal. In the general aviation community SD has been cited as a causal factor in 11-16% of all fatal accidents. Furthermore, in general aviation accidents that were attributed to SD, the fatality rates are alarmingly high (90-92%). Clearly SD is a danger in military, commercial, and general aviation.

Because there are multiple causes of SD, a range of investigations are necessary to capture and quantify this experience. In addition to its extensive work since the Navy's earliest days of manned flight, NAMRU-D's current $12.3M SD research portfolio spans 10 active protocols, ranging from basic science investigations on the neural correlates of SD-evoking motions, to advanced studies of helmet mounted display symbologies for improving spatial awareness among tactical fighter pilots. Collectively, these studies recreate a variety of simulated events that are likely to cause SD, in order to produce self-report, neuro-physiological, and behavioral outcome data, as needed to inform SD prevention and mitigation strategies for the fleet.

One basic science investigation underway aims to better understand the audiogyral illusion. This well-documented but poorly understood phenomenon is caused by interactions between the auditory and vestibular systems wherein angular and linear accelerations shift the perceived location of sound sources. Three-dimensional audio (3DA) displays are being developed and transitioned to military aircraft to enhance communication effectiveness, improve threat avoidance and targeting, increase situation awareness, and reduce SD. Plans to integrate this technology into current and future airframes has made understanding the audiogyral illusion a fleet necessity. With 3DA, a pilot could receive a critical cue such as a missile or collision avoidance alert during a banked turn, but due to the audiogyral illusion they may perceive it as



Helmet Mounted Display symbologies may help reduce spatial disorientation, but must not obscure vision or create clutter

coming from the wrong location: a system intended to eliminate SD could actually *contribute* to this type of mislocalization, leading to a mishap. This project will establish an empirically-based perceptual model of the audiogyral illusion to facilitate the development of countermeasures, thereby improving the veracity of 3DA intended to prevent aviation mishaps.

Another ongoing study uses eye tracking and flight simulators to investigate instrument scan patterns that may be useful to mitigate two visually-driven SD conditions: the black hole and false horizon illusions. The black hole illusion occurs during night landing approaches to a runway with sparse cultural lighting and depth cues in the foreground. The illusion causes pilots to perceive they are above the ideal glide slope, and so they mistakenly descend to a lower, shallower glide slope. This can cause pilots to land short or collide with unlit obstructions. False horizons can occur when flying above a sloping cloud deck. The pilot may misperceive the cloud deck as being parallel to the obscured true horizon, and errantly level the wings into alignment with the false horizon. Lighted highways, shorelines, or other terrain features at night can also induce this effect. control.

In this study, pilots must aviate and land in multiple weather and terrain conditions under varying amounts of workload to reproduce conditions that induce these illusions. Flight performance, occurrences of SD, subjective reports, and eye tracking will be used to develop training strategies to prevent these illusions from occurring in aircrew. A novel upcoming project will build upon previous NAMRU-D fixed-platform SD and hypoxia research. Reduced oxygen availability can result from cabin depressurization or oxygen system failure, resulting in light-headedness, dizzi-ness, and eventually loss of consciousness.[14] Along with the subjective symptoms, hypoxia leads to several cognitive impairments that may prove threatening to a pilot's ability to safely perform. Functional decrements include impairments in visual processing, attention, reaction time, and motor control. Hypoxia can also have deleterious effects on decision making, memory, and logical reasoning and may exacerbate the effects of SD. Previous efforts have examined the impact of workload and hypoxia on performance in stationary environments. This project will examine the effects of hypoxia under different workload conditions in a moving environment using a device developed at NAMRU-D to deliver air gas mixtures in both normoxic and hypoxic (simulating an altitude of 17,500 ft) while pilots fly the full motion, 6-degree-of-freedom Disorientation Research Device (DRD, or The Kraken) in formation flight through a series of turns, climbs, and descents in and out of clouds to determine how hypoxia contributes to SD in true-motion environments.

An aeromedical issue as operationally-critical and medically complex as SD requires communication and engagement throughout DoD, federal, and scientific communities. Since 2020, NAMRU-D has produced 14 scientific-sound deliverables on SD. Researchers within the Acceleration and Sensory Sciences Department collaborate with a wide range of internal and external partners, including the Biomedical Sciences, Environmental Physiology, and Engineering & Technical Support Services departments within NAMRL; the Environmental Health Effects Laboratory at NAMRU-D; fleet customers Naval Air Systems Command (NAVAIR) and Naval Air Training Command (CNATRA); aeromedical partners at the Naval Aerospace Medical Institute, U.S. Air Force 711th Human Performance Wing, U.S. Army Aeromedical Research Laboratory, and both the U.S. Air Force and U.S. Army Schools of Aerospace Medicine; federal partners at the Office of Naval Research, Defense Health Agency, NASA, and U.S. Coast Guard; and a multitude of other academic and industry partners.

LT Sarah Sherwood, (AEP #160), sits in a rotary chair used to investigate the audiogyral illusion.

Dayton, OH. Members of NAMRU Dayton's Spatial Disorientation Research Team stand in front the Disorientation Research Device (The Kraken). (L-R): LCDR Brennan Cox (AEP# 142), LT Sarah Sherwood (AEP #160), Dain Horning (Statistician), Dr. Hank Williams (AEP #105) & Senior Scientist), Dr. Eric Robinson (Research Psychologist), Dr. Kyle Pettijohn (Research Psychologist), CAPT Rich Folga (Aerospace Operational Physiologist), Ali Ludwig (Research Assistant), LCDR Adam Preston (Aerospace Optometrist)