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A COMPUTATIONAL MODEL-BASED FRAMEWORK FOR HOLISTIC MITIGATION OF SPATIAL DISORIENTATION IN SENSORY-DEPRIVED ENVIRONMENTS

Abstract

Purpose: Spatial disorientation (SD), an incorrect perception of one's orientation, position or motion, jeopardizes the safety and performance of aviators, astronauts, and professionals in other domains such as SCUBA and firefighting. Active countermeasures (CMs) can assist navigators in real-time with maintaining orientation – and may mitigate the deleterious impacts of SD. A necessary component of such a system, however, is a method by which to estimate possible SD being experienced, and detect when intervention is warranted. Computational tools utilizing models of human spatial orientation perception provide an unobtrusive means to estimate the spatial awareness of the navigator. Previously proposed computational detection methods, however, have been designed to capture specific SD experiences that are commonly experienced by fixed-wing aircraft pilots. We propose a generalizable computational framework that can be adapted to different environments, vehicles (e.g. spacecraft) and operating theatres.

Methods: We leverage the state-of-the-art Observer model to compute spatial orientation perception in sequence with an integrative algorithm to capture the severity of orientation misperception over time. A Bayesian likelihood model is used for system and parameter identification of the proposed algorithm candidates we have developed. A novel two-part experimental methodology was created to first gather necessary data for informing the Bayesian likelihood model, and then assess the potential system benefits (e.g. safety, control performance) while using a well-tuned computational detection tool in real-time.

Results: Simulated motion stimuli and subjective ratings of SD were used in the development of algorithm candidates and optimization techniques. As a proof-of-concept effort, we have developed an experimental paradigm representing a helicopter piloting scenario in the presence of mission-related distractions. Our simulation results and application of the generalized framework to a specific, relevant context demonstrate the utility of capturing all state parameters related to orientation perception (e.g. acceleration, angular velocity, zenith etc.) which enables the system to capture the continuum of SD involving a variety of different stimuli.

Conclusion: The proposed computational tool, when appropriately fitted for the environment of relevance, can be used to trigger real-time countermeasure interventions for the goal of mitigating adverse impacts of SD events in operational environments. SD can manifest in drastically different ways given the sensory environment, such as an absence of a tonic loading of gravity during spaceflight. The holistic and generalizable nature of this framework may facilitate translatable progress in SD mitigation research across the many domains which it plagues.