Stress, Cognition, Drones, and Adaptive Tasks

William D. Fraser

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To determine the impact of fatigue, drugs, hypoxia, acceleration, thermal loading, and other stresses on human performance, a wide range of cognitive tasks have been used in controlled laboratory settings, including target tracking and reaction times;[1] suites of cognitive tasks testing memory, multitasking, mathematical performance, and situational awareness;[3,4,10] and sophisticated simulators of real-world systems.[13,14] Performance degradation in operational settings with actual vehicles and other systems can be monitored, but the level of stress cannot be manipulated for obvious safety and ethical considerations.

A number of issues related to testing the effect of stress on performance include: 1) the relevance of performance degradation on simple cognitive tasks to real-world operational tasks; 2) the availability of real-world operators such as qualified pilots and/or the cost in money and time involved in the training of subjects when using high-fidelity simulators; 3) the increasing number of independent forcing factors and multiple response variables with the inherent complexity of statistical analysis and interpretation; 5) the difficulty in monitoring of performance change over short time periods where the stress is rapidly changing such as during dynamic flight maneuvers; and 6) recruiting and then motivating subjects to maintain maximum effort and performance during the test session. This last issue is problematic when there is a wide variance in capabilities, such that for a given stress a highly skilled individual can maintain optimal performance with minimal effort, and noticeable performance degradation would occur with the less experienced individual exposed to the same level of stress.

The use of a complex "real-world" cognitive task that is relatively simple to learn, inexpensive to implement, demanding for all subjects, fun to perform, and that results in a single performance metric could be a powerful tool in investigating the impact of stress on human performance and address some of the problems with current techniques.

Drones

With advances in communications, battery, and manufacturing technology, the use of unmanned aerial vehicles, i.e., drones, for military, surveillance, search and rescue, scientific, agricultural, and commercial applications has become commonplace.[15] Due to the low cost, individuals can readily procure and fly drones as a hobby. One increasingly popular use of the technology is for first-person view (FPV) drone racing, where participants fly lightweight, remote-controlled, ultra-maneuverable vehicles through a gated course while viewing a live 3D video feed using head mounted displays.[5] Multiple amateur, military, and professional competitions are now held worldwide, with often significant monetary prizes and corporate sponsorship of racing teams.[5,11] An entire culture has developed around the sport, including enthusiastic spectators, similar to that seen in the video game-based e-sports.[7] Unlike actual aircraft acrobatic and racing competitions,[12] these competitions do not require formal training or qualifications, pose no physical risk to the competitors, and can be undertaken in indoor and outdoor settings. Scoring is usually based on the shortest transient time through the course, made up of a series of fixed gates. However, like many cognitive tasks, course difficulty is fixed, though only a single performance metric is recorded: successful completion time with no collisions or missed gates. Both the drones and the gates are designed such that there is minimal damage if collisions do occur.

Adaptive Tasks

The use of adaptive tasks for performance measurement and training was pioneered by Kelly,[8,9] where the level of task

From Silatyuk Research, Toronto, Ontario, Canada.

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difficulty is the primary performance metric. The better the performance, the greater the difficulty of the task. A major advantage of this technique is that each subject is scored based on their maximum ability, thus any stressor would be expected to result in a degradation of performance which might not be observed if the subject or operator could perform a standardized task with a fixed level of difficulty, in spite of some degree of cognitive degradation.

Adaptive tracking tasks do not appear to have been used in investigations of the impact of various stresses on human performance except for the study by Eaton,[6] who implemented a simple one-axis tracking task where the target was a spot of light on an oscilloscope screen that moved left and right in a sinusoidal motion along a single x-axis. The subject controlled a second spot on the screen and was instructed to maintain this spot on top of the generated target. The frequency of the sinusoidal target was automatically adjusted in real time depending on the ability of the subject to maintain his or her input to successfully track the target. If the subject kept the spot within some predefined distance from the target, the frequency of the target movement back and forth across the screen increased. If the subject could not keep up, the frequency of the target sweep decreased. The stressor involved was pain, as the subjects were required to move the joystick driving the chase spot using an unsupported arm fully extended in front of the body. After several minutes on the task, discomfort and then pain in the shoulder and arm developed, increasing in severity until the subject abandoned the task. The frequency of the target spot, not the root-mean-squared deviation from the target, time-on-target, or other measure of error, was correlated with the perceived pain ratings over the course of the experiment.

Adaptive FPV

The concept of an adaptive task, where the difficulty of the task is the performance metric, can be applied to FPV racing. The most straightforward approach would be to adjust the width of the gates for each pass through the course until the subject's drone collided with the gate (see **Fig. 1**). The gate width of the last successful completion of the course would be the performance score. Another approach would be to have the gate diameters decrease over the length of the course, thus requiring only one pass for each test session. Current FPV racing courses use gates with fixed diameters, but it should be relatively straightforward to set up an adjustable gate and sensor system such that a successful pass through a gate would result in a real-time decrease in the subsequent gate on the course. Contact with the gate edges (virtual or actual) would result in an increase in the diameter of the gate, which would be the final performance score.

Although task difficulty, e.g., the frequency of the track display in Eaton's study or the width of the gates in an FPV course, can be the performance metric, other variables can be used as the adaptive variable to control the task difficulty, including the primary stress itself. For example, the oxygen saturation of the subject could be adapted until collision with a gate of fixed dimensions occurs. Thus, the oxygen saturation value would be the performance metric. Sustained acceleration could also be used, where the G_z imposed by the centrifuge could be adjusted according to the ability of the subject to avoid gate collision in a simulated FPV environment, or even while flying a drone in a real-world FPV course with the video feed provided to the centrifuge flight simulation display. The maximum G_z level tolerated by the subject prior to gate collision would be the cognitive metric. Secondary stresses can also be used as the adaptive variable, such as visual degradation of the video feed from the course or the difficulty of secondary tasks.

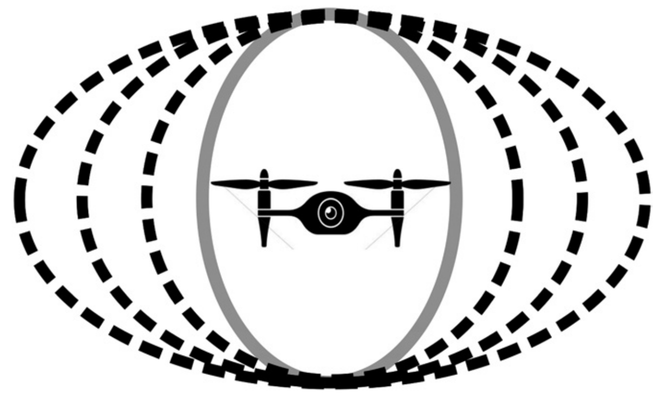

Fig. 1. A schematic of an adaptive FPV gate. The inner gray oval's minor axis corresponds to the width of an FPV drone. The dashed ovals represent variation in the dimension of the minor axis which can be changed in response to the performance of the operator. As performance improves, as measured by course completion time, the gate size would decrease until collision with the gate occurs. The final gate dimension is the performance score.

Discussion

The use of adaptive FPV as a cognitive performance tool has a number of advantages. The actual task is relatively easy to learn, inexpensive, is inherently safe but real-world, not virtual, can be done indoors or outside, and is fun to perform and highly motivating for most subjects. This note focuses on the application of adaptive task scoring techniques to FPV racing, but some drones allow downloading and analysis of flight performance data if additional metrics of are interest. To minimize costs, training can be done in a simulated environment using a commercial FPV simulator software,[2] or with the development of custom simulators using modern, free commercial game engines.[16] Nonracing performance metrics could also be used as the adaptive variable when focusing on specific military or security relevant tasks. The combination of FPV drones and the adaptive task concepts offers a range of research opportunities. For example, it would be interesting to compare the impact of various stresses on performance in the simulated and actual FPV environments.

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