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Measuring the Range of Attention to Preview and Its Momentary Persistence in Simulated Driving

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MEASURING THE RANGE OF ATTENTION TO PREVIEW AND ITS MOMENTARY PERSISTENCE IN SIMULATED DRIVING

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Participants used a position control system to track the center of a simulated winding roadway with preview that ranged from 0.3 to 1.0 s. Participants' spatial distributions of attention were measured by perturbing the roadway with different frequency sinusoids at different roadway positions and then measuring the degree to which those frequencies were present in their tracking movements. Participants exhibited a continuous range of attention, and it lengthened with the amount of displayed preview. When preview disappeared for 5 s, longer time to regress to feedback control was strongly correlated with the amount of preview that was withdrawn. During preview withdrawal, visual sensory memory of the previewed roadway may be used for a fraction of a second to prolong the period of feedforward control. Attention may be shifted to relevant positions of the sensory memory image to anticipate the roadway curvature. The present methodologies may be useful in aviation contexts.

ATTENTIONAL TRAINING IN MULTITASKING FOR UAS SENSOR OPERATORS

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We developed a simulation training battery for the multi-tasking skills required by the sensor operator of a Navy Unmanned Air System when managing subtasks. Specific attentional skills of scanning, dynamic task prioritization, and interruption management were adaptively trained. Six hours of training was administered followed by a transfer trial, and performance was compared with a control group who performed on the same task without specialized adaptive training of the three attentional skills. Although no benefit was observed by the final transfer test, the ATTICUS training did produce significant benefits during training on the important continuous monitoring and situation awareness tasks, and a cost on one of the discrete tasks.

Introduction

Unmanned Aerial Systems (UAS) in the Navy are commonly controlled and supervised by two aviators on the ground, the pilot and the sensor operator (SO). The focus of the current research is on the demands of the SO which frequently exceed the redline of workload from the array of tasks they must concurrently perform. SOs monitor large number of ships using multiple sensors. These sensors are vulnerable to temporary failures when the UAS enters unfavorable operating conditions, due to temperature, humidity, visibility, or other changes. Under these conditions, their operation must be restored, even as the surveillance is continued.

The current research developed a multi-task battery to train multitasking skills necessary to preserve workload below the redline, and avoid any attentional narrowing or cognitive tunneling, that might compromise the primary task of surveillance monitoring. The research progressed in five phases. First, interviews of subject matter expert (SME) sensor operators at Naval Air Station Patuxent River were used to validate concerns on workload overload (one reported that "sensors fail about 10% of the time), understand their tasks, and design a prototype of our battery for them to approve. Our design addressed two competing goals: (a) Achieve sufficient fidelity to capture the information processing (particularly attentional) demands of the SO and some component of the "look and feel" (i.e., greater realism than alternative platforms such as MATB); (2) Attain sufficiently generic and simplified elements so that participants in our initial validation, with none of the specialized training of the SO, could adequately master the task after a few hours of training. With these factors in mind, our second phase completed the design.

The third phase developed adaptive training strategies to foster necessary time sharing skills through explicit training, and adapt the nature of the task as skill developed. To carry out this phase, an extensive literature review identified well understood attentional components of multi-tasking and documented both their "trainability" and their transfer to environments beyond the training tool. Three such attentional skills were identified: visual scanning (S), task prioritization (P) and Interruption management (I).

Visual scanning (S) encouraged the operator keep his or her eyes moving across the various sources of information. Such skills are taught to aircraft pilots and vehicle drivers, where they learn to monitor the out-the-window view as well as other sources of information (e.g., displays, mirrors). Visual scanning is a skill whose performance can be improved by training (Fisher & Pollatsek, 2007). Different domains require specific visual scanning patterns, driven by the importance of information and the frequency with which it changes (Wickens & McCarley, 2008). Training aimed to allocate visual attention to different areas in proportion to the importance and bandwidth (frequency of change) of information at those areas (Fisher & Pollatsek, 2007).

Prioritization (P) is invoked when multi-tasking, resource allocation must respond to dynamic changes in difficulty or priority of those tasks (Gopher, 2007). Research indicates that these skills can be taught and transferred to a more complex environment (e.g., Gopher, Weil, & Barakeit, 1994; Gopher, 2007).

Interruption management (I) is invoked when periodic interruptions require the operator to divert attention from an ongoing task to deal with an interrupting event, and then return fluently to the ongoing task (Wickens & McCarley, 2008). Fluency represents latency to resume the ongoing task, and accuracy at the point of resumption. Exposure to, and practice with, interruption management can improve performance in multitasking situations. Specific interventions can train operators to make a mental note of their "place" and next step needed in an ongoing task, prior to shifting attention (Trafton & Monk, 2007). This intervention supports prospective memory, and is an effective technique for improving interruption management (Dismukes & Nowinski, 2007; Loukopoulos, Dismukes & Barshi, 2009).

Having identified SPI as a trilogy to be instructed, our fourth phase developed adaptive means of training these via **scaffolding removal.** Each attentional skill was given initial instruction, and then scaffolding techniques (visual highlighting to guide attention) were developed to guide the learner through deployment of the strategy early in training, much like training wheels (Hutchins Wickens & Carolan, 2013). Support is adaptively removed as the S, P or I skill improves. Adaptive training, in other skills, has been found to be a reasonably successful technique (Landsberg et al., 2012), although often challenging to implement.

The fifth phase was to collect experimental data to determine how well and rapidly the skills could be trained, and how they might transfer and be retained. Our adaptive ATTICUS training regime was administered over the course of 14 x 20 minute scenarios. Two different comparison conditions were also run. The **maximum difficulty** condition presented the six tasks together from the very beginning (like the ATTICUS group), but contained neither the specialized SPI instructions and scaffolding nor, (obviously) their adaptive removal (since there was nothing to remove). The **fixed increase** condition again contained no SPI instructions, but incrementally increased the difficulty of all subtasks, at the same rate—schedule—for all participants, until reaching the same final level of difficulty as for the other two groups.

Methods

The study was approved by the Colorado State University Institutional Review Board.

45 paid participants were recruited from posters and on-line advertisements to participate in the 6 ½ hour experiment, carried out over 3 sessions within a one-week span, plus a final half hour retention test approximately 2 weeks later.

The ATTICUS task battery, shown in Figure 1, was displayed on a 23" computer screen, subtending a visual angle of 38 x 22 degrees when the participant was seated approximately 75 cm from the screen. The display hosted information for five tasks, described below.

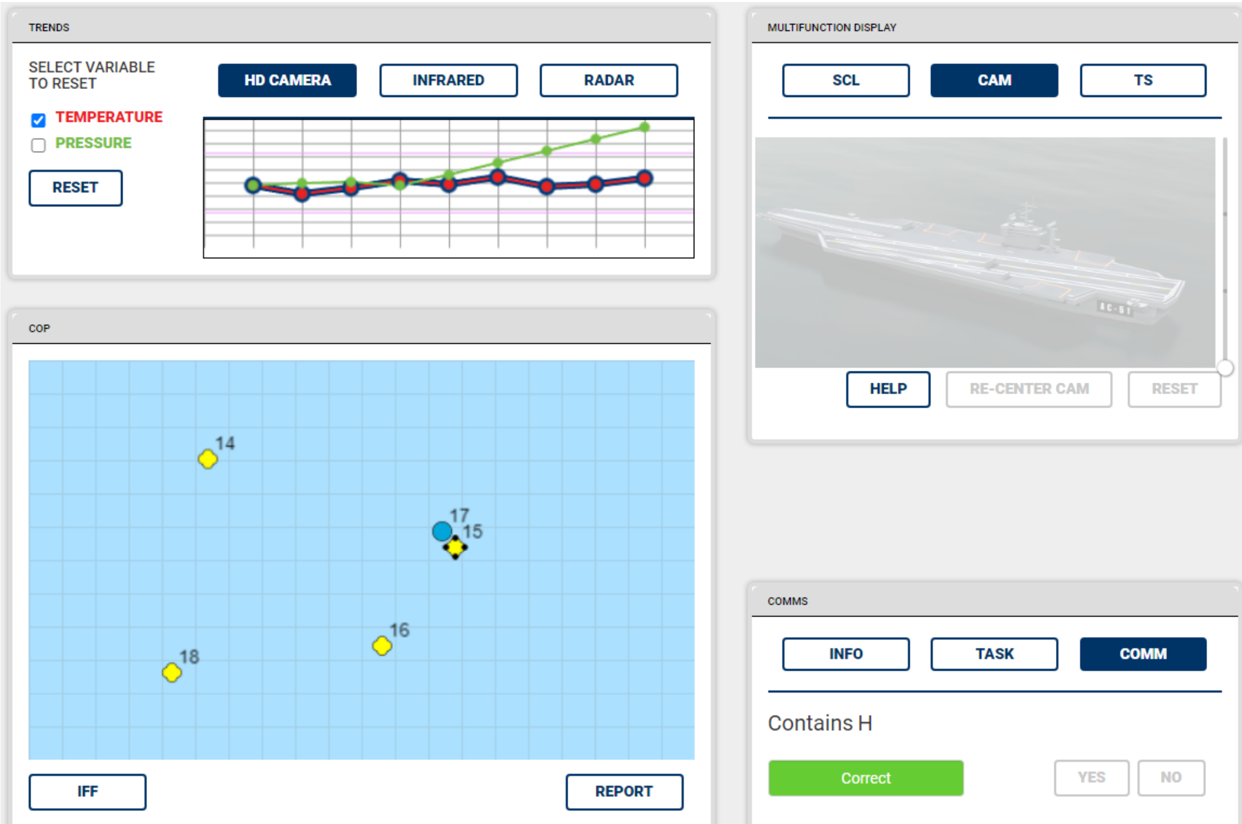

Figure 1: The ATTICUS test bed display (see text for further explanation of the subtasks).

1. ***Common Operating Picture (COP)***. The primary task of the SO is building and maintaining situation awareness of the maritime traffic. Icons representing ships were present in the display on the lower left, updating positions every second. Participants had to identify and flag those engaged in suspicious behaviors: altering course, accelerating (to 50% increased speed), rendezvous with another ship and then separating, pairs of ships moving in parallel (formation), and entering the screen from a pre-designated suspicious direction. These events occurred at random intervals of approximately every minute. There was an average of five ships on the screen.
2. ***Camera task.*** Ships that engaged in suspicious behavior required the operator to seek detailed information on that ship, using three analog controls to control a camera view (upper right window) to locate the hull number, and enter that into the Ship Classification interface.
3. ***Sensor trend monitoring***. Sensor parameters (e.g., temperature, pressure) and trends were displayed on tabs of the window in the upper left. Participants needed to cycle through three

different sensors, each with temperature and pressure indicators, updated every second. If sensor data indicate parameters moving out of range, the operator would intervene to correct the problem by clicking a reset icon. Trend failures were not indicated by any discrete alert.

4. ***Sensor troubleshooting***. A repair sequence required the operator to look up the code associated with an unreliable sensor, diagnose the failure, and then choose the appropriate repair code. This was accomplished through an interactive display that could be called up within the same window as the camera task. In contrast to the trend monitoring task, these major failures were signaled by a red alert. These major troubleshooting events occurred with a mean frequency of one event per min.
5. ***Communicate***. Operators listened to periodic auditory communications, and responded to only designated call signs through entering a corresponding alphanumeric sequence. These also occurred randomly with a frequency of one per minute.

Task scheduling. The COP and the Trend monitoring task characterize what Wickens, Gutzwiller, and Santamaria (2015) characterized as "ongoing tasks," in that they require **continuous** situation awareness (to be performed perfectly) and hence are heavily demanding of visual attention. Of these, as noted, the COP task is of the highest priority. Of the other three tasks, all **discrete** tasks, camera and ship classification are necessary and predictable follow-on's to events within the COP. In contrast, troubleshooting and auditory communications are true **interrupting tasks,** occurring unpredictably.

Experimental Design and Procedures. In an initial two-hour session, participants were introduced to the study and provided approximately five minutes of practice on each of the single task components. Participants performed a pre-test on the COP task, to assess monitoring skill and assure that approximately equal initial skill levels populated each group. Based on their pre-test performance, participants were assigned to one of three training conditions.

1. ***ATTICUS Adaptive Training***. This group was provided with approximately 15 minutes of specific instructions on the three critical attention strategies, as well as the procedures of scaffolding and its removal.

2. ***Maximum Difficulty.*** This group was identical to the Atticus group, except they were given none of the attentional strategies instructions nor received any scaffolding on subsequent trials (and hence adaptive scaffolding removal).

3. ***Difficulty Increase***. In contrast to the other two conditions, this group started dual task training with all five tasks adjusted to very easy levels (e.g., initially only 2 ships on the COP), and as the training progressed these were incrementally increased in difficulty, on a fixed schedule (the same for all participants) to eventually reach a target level identical to the first two groups, one scenario prior to the final one.

Participants then proceeded through 14 twenty-minute training scenarios, scheduled over three days, each within 2-hour sessions. Each scenario was generated with different sequencing of events, so that this was unpredictable by the participant, and for the Atticus and Maximum Difficulty conditions, all scenarios were the same, and of approximately equivalent difficulty. On two thirds of the scenarios, the ship-load of the COP task would ramp up from 5 to 10 for 1 minute, and then decrease back to 5, so that we could provide an explicit period to assess task prioritization in response to those increased demands. On a final transfer trial (Scenario 15), participants in all three groups received the identical scenario. Approximately two weeks later, participants received a final delayed assessment, consisting of a different scenario.

Results.

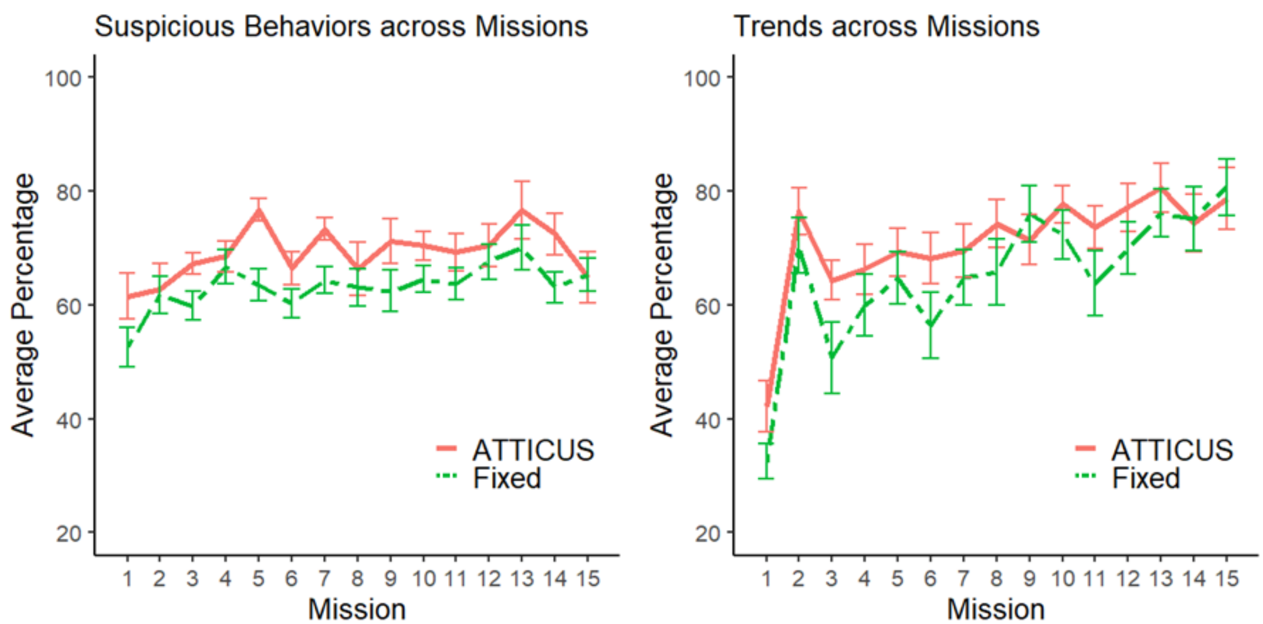

Figure 2: Training data for COP task and Trends task for the Atticus versus Fixed Difficulty groups across 14 training trials plus the final test trial.

Training trial data are only presented for the two groups training at the maximum difficulty, because performance on the increasing difficulty condition throughout most of the experiment is much better (since the tasks were much easier). A multilinear regression model fit through the four curves shown in figure 2 revealed, for the COP, a marginally significant advantage for the ATTICUS group ($F(1,28) = 3.96$, $p = .06$, $\eta^2_p=.12$), and, for the trend monitoring task, a significant ATTICUS advantage ($F(1,28)=7.58$, $p=.01$, $\eta^2_p=.21$). The Trend monitoring task also showed a significant improvement over trials (training effect $F(1, 28) = 10.90$, $p<.01$, $\eta^2_p=.59$), while the COP task did not. Neither the comms task nor the troubleshooting task revealed a difference in accuracy during learning, while the Camera task showed a marginally significant cost for the ATTICUS group ($F(1,28)= 3.89$; $p=.06$, $\eta^2_p=.12$). There were no significant differences between the three training conditions on the transfer trial, on either of the speed and accuracy measures of any of the six subtasks (all p values > 0.10).

Discussion

The results revealed no overall benefit of ATTICUS transfer after 14 sessions of dual task training. At the same time, selective benefits and some costs were interpretable and meaningful. In particular, the two continuous tasks, that can both described as “maintaining situation awareness” revealed an ATTICUS benefit throughout training. This benefit was modest for the most difficult (and important) task of maintaining the common operating picture, and quite large for the other, somewhat easier supervisory task – trend monitoring. The idea that more efficient training can be attained through the use of ATTICUS has important practical implications. ATTICUS training did not produce unmitigated improvement in multi-task efficiency but rather some tendency toward re-allocation of resources in that one of the discrete tasks – camera management followed by ship classification was slightly inhibited. Whether this was from neglect of the task, in the accuracy of reading and remembering the hull numbers, or the accuracy of their entry on the interface is yet to be determined.

The finding that the overall ATTICUS advantage to the continuous tasks, and minor cost to the camera task, is eliminated by the final transfer trial, suggests that the benefits of such training are realized early, and may wash out with extensive training signaling, among other things that such training need not be extensive.

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