Acute Stress Causes Overconfidence in Situation Awareness

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Abstract — High levels of acute stress increase risk-taking and limit objective Situation Awareness (SA), actual knowledge of what is around you. Little research, however, has been directed toward understanding how stress influences subjective SA, an individual's assumption of their objective SA accuracy. The present experiment uses newly developed methods for highly controlled manipulations of stress, and newly designed measurements of risk-taking in a complex combat simulation. Results of this research indicated that high levels of acute stress may lead individuals to be overconfident in their SA and take more risks. Results are discussed in terms of their importance for individuals who require adequate SA in order to perform occupational tasks effectively, such as air-traffic controllers, pilots, and military personnel.

Keywords — *STRESS RISK-TAKING SITUATION AWARENESS OVERCONFIDENCE*

I. INTRODUCTION

Situation awareness (SA) is defined as knowing what is around you. SA contains three levels. The first level of SA relates to perception of elements in an individuals' environment within a volume of time and space [1]. This knowledge is imperative for air-traffic controllers, pilots, military personnel, and indeed anyone who requires adequate SA to perform occupational tasks effectively [2]. Attending to the context and parameters of a problem (adequate SA) may indeed lead to effective problem solving strategies [3]. In addition, SA may relate to an individual's performance. When SA is complete and accurate relative to inaccurate, performance may improve [4]. SA may also be in important in the long-run for complex mission performance [5].

SA is not, however, decision making [6], but rather the understanding decision making may be based on. SA is not the knowledge stored in long term memory or a mental model; long-term memory loss is slow, whereas SA loss in a dynamic environment with a continuous stream of data can be rapid [7]. SA is influenced by many constructs, such as task workload [8] and an individual's goals [9]. SA is also influenced by stress, wherein a certain amount of stress may be beneficial to SA. High levels of acute stress, however, can be detrimental to SA [2, 10]. Little recent empirical research, however, has

examined the effect of acute stress on SA, and behavioral outcomes associated with this causal connection.

A. Situation Awareness and Stress

Stress is defined as the physiological or sympathetic nervous system activity governed by the hypothalamus–pituitary–adrenal axis response to a challenging or demanding stimulus [11]. Stress, importantly, is adaptive in bringing about the homeostasis of an organism [12]. High levels of acute stress, however, can become deleterious to the early stages of the decision-making process and affect cortical activity within the brain [13]. High levels of acute stress, furthermore, may lead to SA loss. High levels of stress can narrow an individual's attentional field to include only a limited number of central elements, with scattered or poorly organized scanning of the environment [14, 15]. Relatedly, instances of acute stress, such as time pressure, can increase the Need for Closure (NFC), that is, a decrease in the amount of information gathered to arrive at a decision [16, 17]. A stressed individual, therefore, may arrive at a decision prematurely [18, 19]. These results are also in line with research demonstrating that participants exposed to stressors, time pressure and noise blasts, relative to participants not exposed to stressors have difficulty using complex, but not simple, decision-making strategies [20]. Finally, complex tasks wherein multiple sources of information must be considered simultaneously have been found to be most affected by stressors [21].

B. Overconfidence in Situation Awareness

Thus far, objective SA has been considered. That is, actual knowledge of an individual's surroundings during a task [4]. There are, however, subjective measures of SA. That is, an individual's confidence in their objective SA [22]. Research with fighter pilots has indicated that participants may be overconfident in their SA. This may be problematic. If an individual is overconfident, they may prematurely stop searching for relevant information. They may feel as though they "know the truth". They may, therefore, make decisions that are prone to errors, take greater risks, and take aggressive approaches when a situation should be handled cautiously [7]. High levels of stress may also cause individuals to arrive at decisions prematurely, with less information seemingly to be considered [10]. Is it possible, therefore, that there is a

continuum; that stress may cause individuals to be overconfident in their SA?

C. Stress and Risky Decision Making

In the decision making literature, stress has also been shown to increase the probability of making risky-decisions. Neurally, stress is thought to shift prefrontal to subcortical processing of information, resulting in a loss of top-down control and more stimulus driven reactions [23]. Stress, therefore, may override cortical cognitive mechanisms, leading to higher probabilities of choosing risky options [24]. Relatedly, risk-taking has been associated with higher activations in subcortical brain structures, the insula in particular [25]. In subjects with lesions to the prefrontal cortex, furthermore, impaired decision-making under stress is often observed [26].

This literature suggests that stressed individuals may act on “gut” feelings – what they believe to be correct in a situation, rather than examining the context of the situation. What is less understood is if a highly stressed individual is under the impression that they grasp a situation. If overconfidence in one’s knowledge of their surroundings occurs, increased risk-taking may be a behavioral consequence.

D. Present Experiment

In this research, participants completed a newly designed combat simulation measuring risk-taking. We manipulated stress with a newly designed technique. Participants completed 2- and 0-back tasks with salient feedback for incorrect responses, to induce stress. Given that high levels of stress [2] and overconfidence [7] influence SA in similar fashions, we predicted that high relative to low stress would create overconfidence in SA. In particular, we predicted that high relative to low levels of stress would not influence subjective SA confidence, despite having a clear effect on objective SA. A predicted increase in risk-taking due to acute stress, furthermore, may suggest a behavioral consequence of SA overconfidence.

As a secondary research question, analyses were performed to determine the point at which stress elicited by the *n*-back manipulation (see Methods) was associated with increased risk-taking behavior.

II. METHODS

A. Participants

Twenty-one civilians (5 women), mean age 31, mean video game ability 3 (proficient on a 1 = very poor to 5 = exceptional video game ability, scale), volunteered to participate. Participants were randomly assigned to condition, and the experimenter was blind to condition. Participants were informed the purpose of the experiment was to better understand how cognitive tasks influence performance in a combat simulation. One participant asked to be excused during the high stress 2-back variant. This participant lacked *n*-back, risk-taking, and SA data and was not included in the final analyses.

Test participants who volunteered were given an orientation on its purpose and the details of their participation. They were briefed on the procedures, and any questions that participants voiced regarding the experiment were answered accordingly. Participants were asked to complete an Informed Consent Form. Its contents were explained verbally, and they were asked to read and sign the form if they decided to participate. Test participants were informed that they could withdraw from participation at any time without consequences. This experiment was approved by the IRB board within the Human Research and Engineering Directorate (HRED) at Aberdeen Proving Ground (APG).

B. Stimuli

Participants completed *n*-back tasks. In the high stress *n*-back task, participants responded to items (capital letters, e.g., H) that had occurred two steps earlier (two-back task). In the control *n*-back task, participants were asked to respond to a single item (i.e., the letter H consistently, 0-back task) each time it appeared. Correct responses in each task were followed by the text, “Correct” on the white screen. Incorrect responses were followed by the screen briefly going red and the text, “WRONG” being displayed in large font. Pilot study results indicated that the 2-back task is more challenging, producing more errors and more incorrect feedback, thus making the task appear more stressful.

Figure 1: Example of an incorrect 2-back (high stress condition) response

The combat simulation/scenario that participants completed was programmed using Armed Assault 2 (ARMA 2) software (Bohemian Interactive, 2007). The scenario presented a town wherein participants needed to eliminate enemy threats in houses in a set order (i.e., a sweep and clear scenario). There were no friendly non-targets. Upon dying, participants were punished with a frustrating count-down timer of 30 seconds. After reaching zero, participants respawned and the game continued. Respawns were designated at set locations, in each case further back than where participants died. As a result, participants needed to navigate back to the visual waypoint where they had previously died and attempt to engage the enemy again. Thus,

deaths in the simulation were associated with risks, namely, resulting frustration.

In total, the scenario included 10 houses that needed to be cleared of enemies. Enemies were rooted in place, and could only turn in 360 degrees to engage the participant upon discovering them in line of sight. Participants could visually keep track of time, the amount of ammunition currently possessed, and the next/current house needing to be cleared, which were all displayed on the participants' heads up display. Enemies were quasi-randomly (at the start of each trial) positioned inside buildings in all but one unique location. After the first three houses and moving toward the fourth, two enemies ambushed the participant from behind cover. Several

Figure 2: Images of the ambush and the consequent SA probe screen. Ambushers are circled in red.

seconds after these enemies were visible to the participant, the screen was blacked out and the first SA probe was

administered. The presence or lack of enemies at this location was counterbalanced along with conditions.

SA was recorded with a modified Quantitative Analysis of Situational Awareness [QUASA; 27] technique, with some modifications to the associated statistical analyses due to the constraints of our combat simulation. At set points during the simulation, participants answered a SA probe. There were four probes for each simulation trial, each aiming to test the first level of SA, perception of elements in the environment [2]. Upon arriving at set locations in the simulation, participants' screens were paused and blacked-out. Thereafter, they were presented with a true/false question assessing the first level of awareness of their environment. These questions were presented via a computer tablet on the participants' desks. Each simulation trial included one of each of the following questions: (1) An enemy is out in the open, (2) less than (X) amount of time has transpired in the simulation, (3) you have less than 25 rounds in your current magazine, and (4) at most you have died (X) times. Question values (i.e., the amount of time or deaths displayed in the SA probes) were derived from a pilot study. Aside from the first question, which always occurred first in conjunction with the ambush or lack of the ambush, question order was randomized. Following each true/false statement, participants answered a confidence scale asking them how confident they were of their response. The scale ranged from 1 (very low confidence) to 5 (very high confidence).

Self-reported stress was measured with the single item at the end of the experiment, "How stressed are you currently?" This scale ranged from 1 (Not stressed at all) to 5 (Very stressed).

C. Procedure

Participants completed tasks in a sound attenuated room. Viewing distance from a 140 cm monitor was standardized at 152 cm. Participants used a keyboard and mouse to complete

Figure 3: Sound attenuated whisper rooms wherein participants completed tasks.

tasks. Participants first completed demographic information. Then, participants completed a practice trial of the simulation. The experimenter stood behind the participant, giving instructions on controls, the information available to participants on the screen (e.g., time elapsed), and other

elements of the simulation (such as SA probes). The experimenter was only present during the practice trial. Next, participants completed a high or low stress n -back task. Then, they completed a simulation trial wherein both SA and risk-taking were measured. Finally, they filled out the end-of-experiment questionnaire item assessing self-reported stress. On the following day, participants completed the second condition, which included the same order of tasks and either the high or low stress n -back task, depending on within-subjects counterbalancing. The simulation was the same basic layout in each condition, the only element changing being the quasi-random placement of enemies at the start of the simulation.

III. RESULTS

A MANOVA was performed for the high- and low-stress conditions on the measure of risk-taking (total number of deaths), objective SA (proportion of correct responses), subjective SA confidence, n -back error rates, and self-reported stress measured at the end of the simulation. The omnibus test was significant, $F(5, 15) = 8.74$, $p < .001$, $\eta^2 = .74$. Table 1 presents follow-up results of this test.

TABLE I. Paired t -tests

	High Stress	Low Stress	t	95% CI
	Mean (SD)	Mean (SD)		
Risk-Taking	26.4 (14.43)	18.5 (14.93) ^a	2.76	1.92 / 13.87
Objective SA	0.48 (0.23)	.63 (.23) ^a	2.44	-0.27 / -0.02
SA Confidence	4.12 (0.81)	4.4 (.7)	1.81	-0.59 / 0.04
n -back Error	0.06 (0.03)	.02 (.019) ^b	4.21	-0.05 / -0.017
Stress	3.45 (0.68)	2.75 (.85) ^a	2.77	-1.22 / -0.17

^aMeans significantly different at $p < .05$.

^bMeans significantly different at $p < .01$.

A repeated-measures regression (subject-level random effects model) was used to assess the n -back error rates on risk-taking behavior (total number of deaths). The model was iteratively fit with both a linear and quadratic term for n -back errors, both of which significantly impacted the model, $t(18) = 2.90$, $p = .009$, and $t(18) = 2.14$, $p = .046$, respectively. An unstructured variance-covariance structure was used for random subject-level effects. Model validity was confirmed by visually assessing constant variance and normality of errors. The predicted effect of n -back error rate on risk taking behavior can be seen in Figure 3. The calculated 95% confidence intervals account for the uncertainty in the fixed effects and are conditional on the estimates of the random-effect variances. These analyses were performed in R 3.1.2, using the nlme [28] package. Figure 3 was created using the ggplot2 package [29].

Figure 4: Predicted estimate of risk taking (# deaths) for a given n -back error rate estimated from the repeated-measures regression model. The gray band is the 95% confidence interval for the line estimate computed via the z-score methodology. Circles indicate individual data points used in the regression model.

IV. DISCUSSION

The present experiment examined risk-taking, objective SA, and subjective SA within a complex virtual scenario simulating a real-world environment. With the inclusion of an SA measure, our simulation affords new opportunities to measure the complex connections between cognitive processes and behavioral responses influenced by stress. Previous techniques have examined risk-taking [24], and SA [5, 8, 10] measured individually within an experiment.

As predicted, our manipulation influenced self-reported stress, such that higher reported stress occurred in the high relative to low stress n -back conditions. These findings add to previous validations that our manipulation can indeed elicit varying levels of stress. By simply increasing the difficulty of the n -back task (e.g., to a three-back), our manipulation offers the ability to create gradations in acute stress conditions. Previous acute stress manipulations have offered the ability to only measure control, versus high levels of stress [30], with no middle ground conditions.

Furthermore, we found novel evidence that stress influences objective, but not subjective SA. Importantly, participants in both conditions were confident in their subjective SA. This is especially troubling in the high stress condition. In this condition, objective SA was slightly lower in accuracy than pure chance, indicating that participants were guessing on our SA probes. Thus, participants in the high stress condition were overconfident in their SA. These results extend prior theorizing that overconfidence [7] and high levels of stress influence SA in the same manner [2]. Our results suggest a continuum; acute stress may lead an individual to become overconfident in their SA understanding.

Our results also replicated previous findings that higher relative to lower levels of acute stress may result in more risk-taking behavior [24]. Greater risk-taking may be a behavioral consequence of overconfidence in one's abilities. The causal connections between acute stress, SA overconfidence, and risk-taking may suggest a core problem – the inciting stimulus

(stress) the cognitive mechanism (SA overconfidence) and the behavioral outcome (increased risk-taking).

In order for these findings to be concretely utilized, more research is necessary. Examining if physiological signals associated with stress (e.g., increased heart rate) map to SA overconfidence would help us bridge our findings into the development of a biometric alerting system. New, non-invasive technologies recording heart rate, blood pressure, and other physiological indicators with infrared cameras on wearable devices are available. Once properly calibrated, such a device could alert users to increased physiological indicators of stress levels. Whereas past research has suggested that these signs may indicate a drop in objective SA, we would suggest that users be informed that such signs may produce overconfidence in SA, and to be wary of unnecessary risk-taking behavior. Such a system, for example, may help save the lives of military personnel, and improve the performance of air-traffic controllers.

Our results also suggest a common neural substrate for these processes. It has long been understood that cortical activity within regions of the prefrontal cortex, in particular the dorsolateral prefrontal cortex [31], are involved with the cognitive resources. When these resources are relatively depleted, through either acute stress [24] or some other mechanism [26], risk-taking is often observed. We suggest that overconfidence in SA may also increase, and that SA loss may also be linked with prefrontal cortical activity, in particular, a shift toward more subcortical processing.

Errors in the n -back also predicted risk-taking behavior in the combat simulation. The non-linear relationship between n -back error rates and risk taking behavior suggests a threshold effect whereby risk taking only increases in relation to n -back errors after a certain point. This data may inform researchers how much stress is required to elicit the risk-taking behavioral response. These results, therefore, suggest a novel method for eliciting stress, one that is highly controlled. More common stress manipulations, such as the Tier Social Stress Test [32] lack such control; these manipulations present multiple tasks (i.e., delivering a speech followed by completing difficult math problems) in conjunction with one another to induce stress. Thus, it is difficult to determine which parts of which task are indeed causing the stress response.

In conclusion, our paradigm presents newly developed manipulations of acute stress, and newly developed measures of risk-taking in a complex scenario that also measures objective and subjective SA. High levels of acute stress may cause overconfidence in SA and increase risk-taking. Thus, a highly stressed individual may think they are in control of a situation, when in fact they are not. These findings provide important information for air-traffic controllers, pilots, military personnel, and indeed anyone wherein adequate SA during occupational tasks is imperative.

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