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A Comparison of Three Determinants of an Engagement Index for use in a Simulated Flight Environment

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Abstract

The following report details a project design that is to be completed by the end of the year. Determining how engaged a person is at a task is rather difficult. There are many different ways to assess engagement. One such method is to use psychophysical measures. The current study focuses on three determinants of an engagement index proposed by researchers at NASA-Langley (Pope, A.T., Bogart, E.H., and Bartolome, D.S., 1995). The index (20 Beta/(Alpha+Theta)) uses EEG power bands to determine a person's level of engagement while performs a compensatory tracking task. The tracking task switches between manual and automatic modes. Participants each experience both positive and negative feedback within each trial of the three trials. The tracking task is altered in terms of difficulty depending on the participants current engagement index. The rationale of this study is to determine the optimal level of engagement to gain peak performance. The three determinants are based on an absolute index which differs from the past research which uses a slope index.

Introduction

There has been a recent surge of interest in the area of adaptive automation. Automation is the result of advancement of technology and the need for complex systems to be operated in a more simplistic manner. The theory behind adaptive automation is that the system is flexible. The theories of adaptive automation have found their way into the field of aviation. A majority of airline accidents are the result of human error. The logical answer to the problem would be to remove the human (and the human error) from the scenario. Chambers and Nagel (1985) suggest this should increase safety and decrease the number of accidents due to human error.

While automation in the cockpit has increased the level of performance, it has also changed the role of the pilot from that of active participant to one of controlling and monitoring. The major question that needs to be addressed is the best level of automation in the system. Several approaches can be taken to determine allocation of function within an automated system. The first approach has the user in control of the decision to use automation. The second approach gives control of automation back to the system. Adaptive automation combines both of these approaches and allows the operator as well as the system to control in the level of automation (Scerbo, 1994). Although many believe that automation is the solution to human error, several authors have expressed the potential problems associated with the implementation of adaptive automated systems (Weiner, 1988; Rouse and Morris, 1985; Parasuraman, Bahri, Deaton, Morrison, and Barnes, 1990). They have foreseen problems related to alienation of aviation personnel, perceived loss of control, and erosion of skills.

One method to demonstrate the usefulness of adaptive automation is using bio-cybernetic measures to determine when changes in automation should occur (task allocation). This has been proposed by Morrison and Gluckman (1994) and researchers at NASA-Langley (Pope, Bogart, and Bartolome, 1995) are currently collecting empirical evidence to support the use of bio-cybernetic measures (EEG).

Pope et al. (1995) have formed a closed-loop, bio-cybernetic system which adjusts the mode of operation (manual/automatic) based on EEG power band ratios (Beta/(Alpha+Theta)) under different feedback contingencies. In the current system, the slope of an engagement index determines the task allocation.

The task functions in one of two modes, manual or automatic. The level of automation in the bio-cybernetic system is based on the level of the engagement index (EEG power band ratios). Under the negative feedback condition, the tracking task was switched to (or maintained in) manual mode when the engagement index was decreasing (negative slope) over a moving forty second window. This moving window is updated every epoch (2 sec). Under positive feedback, the level of automation was switched to (or maintained in) automatic mode when the index was decreasing (negative slope).

Therefore, under negative feedback, the changes in the level of automation are designed to induce a steady, stable environment (illustrated by many small oscillations). The index can neither be too high or too low without the task changing mode. In comparison, during a positive feedback condition, the level of engagement will be retained and amplified. Smith and Smith (1987) showed that positive feedback, if left uninterrupted, will lead to an environment that is unstable (illustrated by large oscillations).

A study based on the original Pope et al. (1995) findings was conducted by Prinzel, Scerbo, Freeman, & Mikulka (1995). They attempted to examine how increases in task load affected the closed-loop system. Using the Multi-Attribute Task (MAT) Battery (Arnegard and Comstock, 1991), these researchers varied the task load by having the participants perform a number of tasks simultaneously. Prinzel et al. (1995) found that more task allocations were made in the multi-task conditions in comparison to the single task condition. These results are in parallel with the findings of Arnegard (1991). She found that performing multiple tasks did, in fact, increase task load. Prinzel et al. (1995) also found that tracking performance was increased in the negative feedback condition.

The current study will examine another determinant for task allocation. The previously mentioned studies (Prinzel et al., 1995, Prinzel et al., 1995)) have all used the slope of the engagement index as the measure to determine task allocation. The limitation of this method lies in that a floor and/or ceiling effect may be encountered. This study will test three different parameters (.2, .5, and .8 standard deviation) using an absolute index. A median level of engagement will be determined from a five minute baseline of performance from the tracking task. Six levels of engagement exist and the absolute distance between each level (measured in standard deviations from the median) will be manipulated to determine the most sensitive parameters. The six levels of the tracking task differ in difficulty. The first level being the most difficult and the sixth level being the easiest (automatic mode).

The present study will gather performance, physiological, and subjective measures of workload. Based on the Prinzel et al. (1995) study, it is predicted that better performance, increased number of task allocations, and increased levels of subjective workload will be seen in the negative feedback condition.
Also based on the data from the Prinzel et al. (1995) study it is hypothesized that the parameter estimate of .5 will result in increased tracking performance, increased number of task allocations, and increased subjective workload.

Method

Participants

Participants were xx graduate and undergraduate students (both males and females) taking psychology courses at Old Dominion University. They either received $10 for their participation or class credit.

Tasks

The Multi-Attribute Task (MAT) Battery was used for the experiment (Arnegard & Comstock, 1991). Of the five tasks in the battery, only the compensatory tracking task was utilized.

Equipment and Apparatus

Electrocortical activity was recorded with an Electro-cap sensor EEG cap. The cap consists of 22 recessed Ag/AgCl electrodes arranged according to the International 10-20 system (Jasper, 1958). All EEG signals were amplified by BioPac differential amplifiers with high and low pass settings of 1.6 Hz and 55 Hz, respectively. The analog signal was routed to an EEG interface with a LabVIEW Virtual Instrument (VI) on a Macintosh computer. The VI calculates the total EEG power in three bands: Alpha (8-13 Hz), Beta (13-22 Hz), and Theta (4-8 Hz) for each electrode site. The VI performs the engagement index calculations and commands the MAT task mode changes. A WIN 386 SX computer with a NEC MultiSync 2A color monitor was used to run the MAT. An Analog Edge joystick was used for the compensatory tracking task with a gain setting of 60% of its maximum.

EEG Engagement Index

EEG was recorded from four sites (Cz, Pz, P3, P4) as defined by the 10-20 system. A site between Fpz and Fz was used as the ground site and a reference electrode was placed on the left mastoid.

Before beginning the task, EEG was recorded for five minutes at difficulty level 3 of the tracking task. This was done to establish a baseline (median and standard deviation). Once the trial begins, the participants EEG index is derived every two seconds (one epoch) based on a window of the last 40 seconds. Every two seconds the window is moved forward and a new absolute index is derived. An EEG index above the baseline measure indicates that a participants' arousal is above normal and an index below baseline indicates that a participants' is below normal.

Feedback Conditions

Under the negative feedback condition, if a participants' EEG index is above baseline the task difficulty is lowered. If the index is below baseline then the task difficulty is increased. This condition never allows the participant to deviate too far in either direction. This condition should induce a steady and stable state with no large oscillations being observed.

Under the positive feedback condition, if the EEG index is above baseline then the task difficulty is increased. If the EEG index is below baseline, then the task difficulty is decreased. This condition demands continuous increases in arousal for the manual mode and the automatic mode requires further decreases in arousal.

Experimental Design and Dependent Measures

A 2 task mode (automatic or manual) X 2 feedback condition (positive or negative) X 3 parameter estimate (.2, .5, or .8 SD) within subjects design was used.

The dependent measures included number of task allocation between positive and negative feedback and the EEG engagement index. To measure the performance of the tracking task, the RMSE was analyzed. A subjective workload measure was taken using the NASA-TLX (Hart & Staveland, 1988).

Procedure

The electrode cap was fitted to the participant's head and the reference electrode was attached behind the left ear. Impedance levels for all electrodes were brought below 5 kohms. The participants were then seated in front of the MAT computer and the head cap was plugged into the BioPac amplifiers. They were allowed to practice the task for 5 minutes. After the practice session, EEG was recorded for a 5 minute period to establish a baseline measure including the median and standard deviation. Half of the participants started in the negative feedback condition while the other half began in the negative feedback condition.

Each subject was exposed to 3 sixteen minute trials. Each trial consisted of 2 blocks (8 minutes in length) of alternating positive and negative feedback conditions. The order of the three trials (parameter estimates) was counterbalanced. Following each block, the participant was asked to rate subjective workload on the NASA-TLX.

Results

The data will be analyzed using several techniques. These will include multivariate analysis of variance, regression analysis, and factor analysis. The results and conclusions from this project will be discussed in an upcoming contractor's report.

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