Psychophysiological Monitoring as part of the training of Hellenic Airforce Pilots

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Abstract: - Psychophysiological monitoring as part of the training of pilots of the Greek Airforce and the implementation of an auditory identification task for error monitoring are discussed in this paper. The proposed tones-matching task (TMT) allows investigating, via simultaneous assessment of brain potentials of the two pilots working together, the time course of relevant perceptual, decisional and audio-related information processes in flying task performance. With Event Related Potentials (ERP) research error-related negativities (ERNs) relative to action and perceptual consequences of action in both pilot and co-pilot will be assessed. The TMT will be in this sense a tool of evaluating the co-pilots or trainer’s skills and capabilities. In addition to the above, auditory EEG neurofeedback could be also used for error correction and concentration improvement in pilots.

Key-Words: - psychophysiological recording, pitch identification, error monitoring, pilot training

1 Introduction

In natural environments, military personnel use their senses and especially sight and hearing to trace threats and simultaneously avoid detection by the enemy. Due to the constant advancement of technology, military personnel are often asked to rely on instruments and displays to differentiate friendly from hostile actions. This is also often the case during training emerged in simulated and not natural environments.

It is well known that the senses of vision and hearing are central aspects of our existence constituting the senses that largely determine our sense of space. The collaborative use of these senses is not only the basis of human communication but also assists humans to distinguish and understand speech in noisy backgrounds and detect approaching emergency vehicles.

In parallel, the emerging network-centric warfare policy leads in the distribution of all C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance) means to all operational levels, launched at the level of the individual soldier. It is becoming obvious that with the increase in equipment complexity and dependence upon technology, the cognitive performance, judgment, and decision making of armed forces must be sustained and effectively managed [1].

In this context, in airforce pilot training, emerging technologies such as 3-D audio technology for example are used in order to improve situational responsiveness, dynamic tactical actions and to assess workload management of fighter pilots. In addition, mental workload and performance are also being studied mainly in simulator training environments including also behavioral testing and psychophysiological recordings not only to assess pilot training procedures but also to validate the simulator environments and other assistive technological equipment.

Based on the above mentioned in the case of pilot training, it is evident that psychophysiological recordings and especially during auditory stimuli not only will be useful in the validation of emerging technologies and equipment but will also add significant qualitative and quantitative knowledge regarding the performance and workload of pilots. In this context, the Hellenic Air Force pilot selection and training procedures have changed substantially in the last several years. Pilot selection procedures were augmented with the introduction of computer-based testing to assess pilot aptitude. Training procedures have changed in an effort to modernize
the training fleet and provide better, more specialized training earlier in the training process.

Taking all of the aforementioned into account, the present paper describes a newly developed tone identification experimental procedure which allows the participation of two subjects and simultaneous electroencephalography-event-related potentials (EEG/ERP) recordings. The test has already provided interesting results regarding the performance of a single subject but also of two collaborating persons [2], [3]. In the present paper the role of tone discrimination tasks in pilot training is discussed. Moreover, the newly-developed tone identification task enabling also the simultaneous participation and EEG/ERP recording of two subjects is presented and the feasibility of implementing such a methodology in pilot training is herein discussed.

2 Pitch discrimination and pilot training

Military electronic communication equipment presents single-channel information to both ears through headphones and peripheral hearing protectors degrade the natural ability to trace sounds [4]. The benefits of directional sounds have been studied by several researchers during performance of several visual search tasks while integrating three dimensional (3D) audio and visual displays [5]-[10].

Spatial separation of radio communication in conjunction with integration of radar warning transceivers with 3D audio to improve performance of identification tasks and off-boresight targeting, have been implemented. Helmet mounted sight (HMS) may be performed by the pilot who can target another aircraft via vision and then fire, through the so called “off-boresight” launch procedure. The US airforce research lab (AFRL) engineers for example, demonstrated off-bore sight targeting using an HMD (helmet mounted display) in the Joint Air Strike Technology (JAST) aircraft [11]. Following, they spatially presented through headphones potential target locations. The audio sounds served as guides of pilots’ visual line of sight while flying at an angle towards the potential target. As a result of these successful JAST flights, the F-35 Joint Strike Fighter System Program Office currently lists 3D audio as a planned technology upgrade [11]. In this context, the proposed task (TMT) being an auditory discrimination and identification task will add to the knowledge of the flying skills of pilots and co-pilots.

Moreover, similar tone discrimination tasks as the one proposed have been widely used in the past in pilot training research. For example in [12] cockpit workload in terms of neurophysiological monitoring has been assessed in pilot and non-pilot participants during flight missions in highly realistic flight simulators environments.

In the first experiment, non-pilot males were trained on a simulated landing task and a tone discrimination task. Recordings of heart rate, skin conductance and brain event-related potentials were continuously carried out throughout the experiments.

The results of the recordings’ analysis interestingly showed that heart rate proved a good measure of workload as well as learning and performance. More specifically, heart rate increased during each final approach to landing, and mean heart rate decreased as the subjects performance improved at the task as a function of practice [12]. Four ERP components (N100, P200, N200, P300) were statistically evaluated. Differences in amplitude and latency were observed as a function of workload and performance. Finally, the intercorrelation of the four ERP components was investigated resulting in a good measure of performance prediction during the landing tasks [12].

It is evident from the aforementioned that auditory task identification and discrimination tasks combined with psychophysiological monitoring may provide good measures of workload and performance during pilot training. The auditory identification task described in the next section comprises all these measures mainly through error monitoring and feedback information processing but also affords analysis from another point of view, very significant in collaborative action setups such as between the pilot and a co-pilot; with concurrent EEG/ERP monitoring of two subjects workload, performance as well as joint-action measures maybe acquired and analyzed simultaneously for two persons working together.

3 A Future Possibility-Measuring collaboration factors

The ability to monitor ongoing performance is critical to behavioral adaptation in changing environmental settings. Comparison of performed actions with their expected result guides the adaptation of ongoing behavior in a changing world. Especially, the monitoring and detection of performance errors serves to the optimization of
future response behavior, the improvement of the overall performance and learning through trial and error [13].

Recent research has shown that errors are reflected on certain patterns of brain activity. Additionally, current findings support the idea that similar brain mechanisms are activated during acting and observing [14]. Up to date, the exact mechanisms underlying the error system continue to be a subject of ongoing investigation and still remain poorly understood. In this sense, it is interesting to study potential differences in the pattern of activity elicited by observed errors versus self-made errors in two-participant conditions where the roles of acting and observing are alternating [2], [3].

Figure 1. Experimental Setup of Tones Matching Task

With this view, a simple task, the Tones Matching Task (TMT) has been designed to compare the electrophysiological effects related to observed and self-made errors during performance monitoring in two-participant conditions of varying complexity [2]. The equipment used for the electrophysiological recordings during the TMT affords simultaneous data acquisition of two subjects performing the task as they alternatively exchange roles between acting and observing. With synchronous two-subject recordings, comparisons of the elicited ERP conventional parameters (amplitudes, latencies), could be made both between actors and observers as well as between error and non-error conditions [2].

The experimental setup is depicted in Figure 1. During the experiment, the subjects are seated opposite each other with a wooden wall raised in between them preventing any visual contact. Each person sits in front of a computer screen. During the experiment, the subjects were headphones and hold gamepads (Fig. 2). The main scope for subjects participating in this task is to correctly map an active tone-frequency range onto a horizontal bar, by selecting a slider position that matches a stimulus tone that is presented to him/her in the beginning of each trial. In other words, each participant is presented a stimulus tone of a preset - clearly audible – frequency that has to be reproduced by means of a joystick manipulation. The joystick manipulation displaces a slider that is presented on the computer screens in front of which the participants are seated (Fig. 2). The participants execute the task and play the role of the actor and of the observer, alternately. The actor’s task is to position the slider presented on the computer screen with the joystick so that the slider position would match the frequency of the tone presented in the beginning of the trial, namely, the stimulus tone. At the start of trial blocks, participants do not know how the slider position was mapped onto the frequency height of the tones. After having selected a slider position, the actor and the observer both make a prediction concerning whether or not that position would result in the tone that was earlier presented as a stimulus. Following that prediction, the actor and observer are presented the tone that belongs to the selected slider position by the actor. Next, both participants make a second judgment as to whether the height of the tone associated with the slider position is identical to the stimulus frequency presented at the start of the trial.

Figure 2. Actor’s and observer’s screens during the Tone Matching Task

The stimulus tone is randomly selected for each trial within a fixed frequency range (200-600 Hz) which does not change throughout the whole experiment. The experiment consists of 40 trials for each participant.

Up to date, this test has been performed in non-pilot participants [2], [3]. Interesting results regarding the ERP characteristics of both actors and observers regarding performance, error commitment and workload have been elicited. Most importantly, it has been found that observers can better judge performance of actors than actors themselves [2].

Taking the above into account, the next step is to perform EEG/ERP recordings with pilot volunteers performing this task with their co-pilots. The TMT allows investigating via simultaneous assessment of...
brain potentials of the two pilots working together, the time course of relevant perceptual, decisional and audio-related information processes in flying task performance. With ERP research error-related negativities (ERNs) relative to action, perceptual consequences of action in both pilot and co-pilot will be assessed. The TMT will be in this sense a tool of evaluating the co-pilots or trainer’s skills and capabilities. In addition to the above, auditory EEG neurofeedback could be also for error correction and concentration improvement in pilots.

4 Conclusion
The result of a number of experimental studies of human auditory and visual information processing behavior and their possible relationship to the pilot's flying skill will be explored in terms of the proposed auditory identification task, using both behavioral and EEG/ERP data acquisition. Moreover, the skills of the trainer and/or co-pilot will be also assessed through error processing and monitoring in the joint collaboration conditions of the TMT task. This kind of monitoring during pilot training could contribute to the broader scope of involving emerging technologies to enhance cognitive performance in the operational environment.

References: