Neurophysiological evidence suggesting an incremental increase in cognitive workload as a function of task demand.

Introduction

- Behavioral and phenomenological evidence suggest that cognitive workload changes as a function of task demand (Beilock & Carr, 2002). Thus, as task demand increases there is an incremental change in cognitive workload. However, there is little physiological evidence in support of this notion.

- Electroencephalography (EEG) provides a record of the electrical activity from the brain and is thought to be generated by the apical dendrites of the pyramidal cells of the cerebral cortex. Importantly, EEG can be used to infer information about cognitive states (e.g. workload). Specifically, alpha power can be extracted from the EEG and is thought to be inversely related to cognitive workload. For instance, alpha power is prominent when an individual is in an awake, restful state and engaged in minimal cognitive processing. Moreover, alpha power increases when an individual closes his or her eyes relative to eyes open, as there is reduction in visual processing. Alpha can be further broken down into low (8-10 Hz) and high alpha (11-13 Hz). Low alpha is inversely related to generalized arousal, while high alpha is inversely related to specific cognitive tasks (Pfurtscheller G. S., 1996).

Brain Waves

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Mental Condition</th>
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<tbody>
<tr>
<td>8 - 13 Hz</td>
<td>Alpha wave</td>
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Purpose

In an effort to characterize changes in cognitive workload as a function of task demand we incrementally increased the difficulty of a visuo-motor task and examined how EEG alpha power changed. Thus, the purpose of this study was to thoroughly examine the relationship between continuous alpha power and visuo-motor task difficulty. We predict that as task difficulty increases, there will be a dose response decrease in alpha power, which is indicative of greater cognitive workload.

Methods

The study was performed on 4 right-handed voluntary college students (3 females and 1 male) between the ages of 18-20. All participants filled out a questionnaire assessing prior experience with Nokia's Snake game and other computer games.

- Task. We used a modified version of the computer game Snake (by Nokia) with 9 levels of increasing speed.

Level 1 was the simplest and least difficult and level 9 was the fastest and most difficult. In both sessions the lights were dimmed, participants were asked to attain a comfortable posture and only use their right hand to manipulate the keyboard.

- Procedure:
  - Session 1 - Practice: The first session was a 20 minute practice session at the middle difficulty level (5). This session was designed to familiarize the participant with the task and minimize learning effects during the second session.
  - Session 2 - Task: Participants played 11, 2-minute trials of the game at various levels of difficulty. The first and last trials were pre- and post-tests at level 5. Trials 2 - 10 were randomly ordered and included all levels, 1-9.

- Electroencephalography: Participants were prepared for EEG recording using a 30-channel ElectroCap international elastic cap with non-polarizable silver/silver chloride electrodes mounted according to the international 10-20 system (Jasper, 1958). EEG was referenced to linked earlobes and a common ground (FPz) and impedances were maintained below 10KΩ. A Neuroscan Synamps 1 linked to Neuroscan 4.3 Acquisition/Editing software was used to amplify the signal 1,000 times. Data were recorded using an online bandpass filter from 0.05 – 100Hz. Thirty seconds of data from each of the two minute trials was extracted and transformed into the spectral domain using Fast Fourier Transform. Alpha frequency bands were extracted and data for each electrode were averaged across all four subjects.

Results

Figure 1: Decrease in high alpha power (11-13 Hz) as task difficulty increases

Discussion

- The topographic plots displayed in Figure 1 represent averages of high alpha (11-13Hz) across all four participants for levels 3, 6 and 9. Blue represents lower power and red indicates higher power. As task difficulty increased from level 3 to level 9, high alpha power decreased suggesting that cognitive load does change as a function of task demand. Thus, this study supports that cognitive load does incrementally increase as a function of task difficulty.

- The changes observed in high alpha power between conditions was seen predominantly in regions of the brain associated with visual processing and sensory-motor integration (occipital and parietal regions, respectively). This regional specificity is not surprising given that this task requires integrating visual input with motor feedback to successfully navigate the task.

- Our changes were specific to high alpha power, which is consistent with the notion that high alpha power is indicative of task-specific cortical arousal. We did not observe any changes in low alpha power, which is associated with general arousal and alertness. This may indicate that the participants maintained relatively consistent arousal and attention throughout the testing session.

Future Directions

- The decrease in high alpha seems to change concurrently with the incremental change in difficulty. Future studies may try to quantify the difference in alpha at additional levels of difficulty to further support a dose-dependent relationship.

- The trend we observed in figure 1 was not ubiquitous across every level of difficulty and in one case a relatively high level of alpha power during a relatively difficult task level was observed (level 8, see Figure 2). This combined with reports from participants that none of the levels were very challenging suggests there was probably not enough difference in difficulty between each level and that we should increase task challenge. Increasing the range of challenge may reveal a more stable relationship between alpha power and task difficulty.

- This pilot study included only four subjects. More subjects are required to see if the results are consistent and to determine if the relationship is statistically significant.

References


