The Influence of Emotional States on Short-Term Memory Retention by Using Electroencephalography (EEG) Measurements: A Case Study

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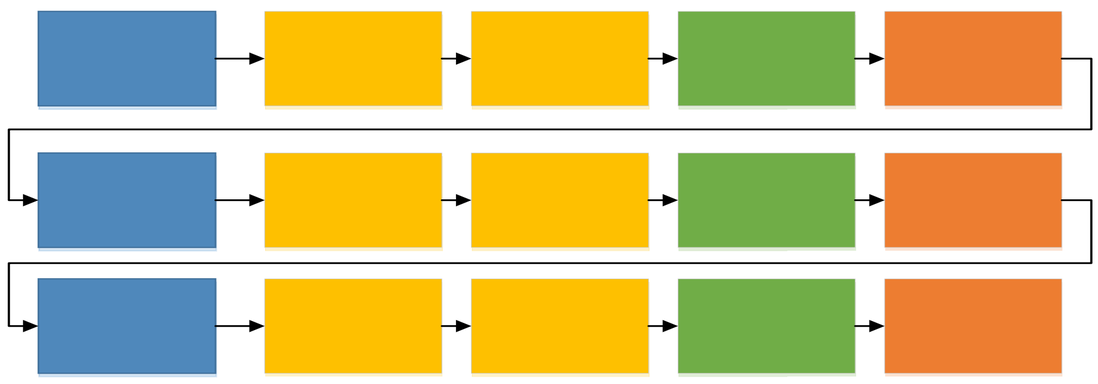
Motivation

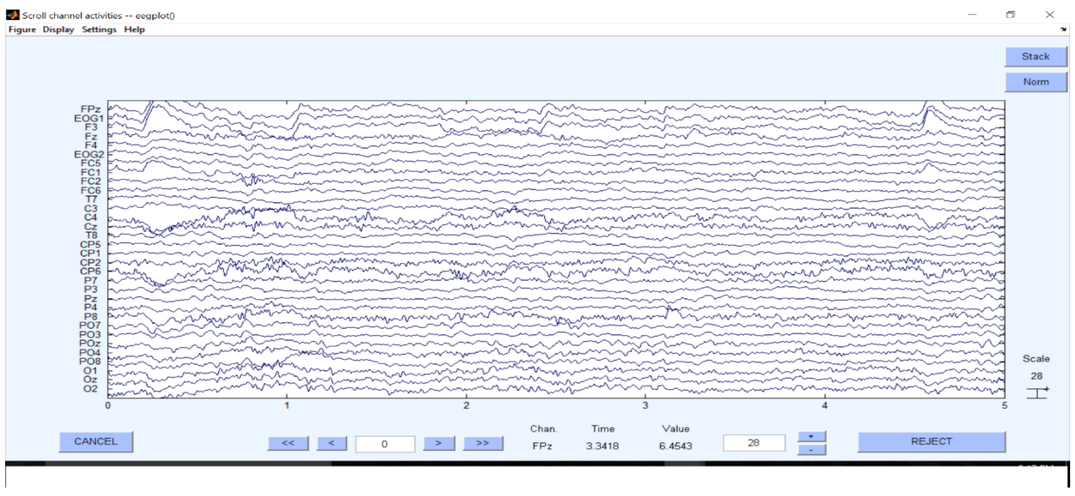
It is well known that positive and negative emotions affect the brain's function (LeDoux, 2000; Damasio, 2005). Neuro-scientific studies have shown that emotions exert influences on various behavioral and cognitive processes. For example, positive emotions have been proven essential for cognitive organization, thought processes, creativity, flexibility in problem solving, and intrinsic motivation (Isen, 2000; Kort, Reilly, and Picard, 2001; Chaffar and Frasson, 2004). On the other hand, it has been reported that anxiety can lead to decision latency, deficit in reasoning, and reduced memory capacity (Bower, Gilligan, and Monteiro, 1981). Consequently, educators can use findings from neuroscience research to create emotional climates in the classroom that can influence learning.

Introduction

The electroencephalogram (EEG) is a non-invasive test that records the electrical activity of the brain as wave patterns generated by various brain structures. The electrical activity is recorded from the scalp surface after being picked up by metal electrodes (small metal discs) and conductive media. This study explored how emotions can impact short-term memory retention, and thus the process of learning, by analyzing five mental tasks: relaxation, memorization of ten words, memorization of ten two-digit numbers, visual exposure to emotional stimuli, and recall of the 10 words and 10 numbers. The word list contained ten words as five event-related (directly related to the type of emotion triggered) and five not event-related words. The visual task was separated into three categories corresponding to the type of images extracted from the public domain International Affective Picture System (IAPS) library, which in turn correspond to three emotional states assumed to be evoked by them: neutral, negative (e.g., sadness), and positive (e.g., happiness). Event-related potentials (ERP) were measured by EEG with the ANT Neuro system. The ASA software and EEGLab were utilized for the analysis of ERPs in five EEG bands: Delta (0-3.9Hz), Theta (4-7.9Hz), Alpha (8-12.9Hz), Beta (13-30 Hz), and Gamma (31-50Hz). Eleven participants (ten males and one female between 20 and 25 years old) were included in this case study. *To date, no other studies have been reported to use EEG measurements in the evaluation of the influence of emotional states on short-term memory retention.*

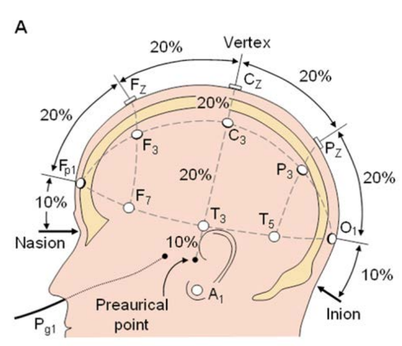
EEG Data Acquisition from Mental Tasks



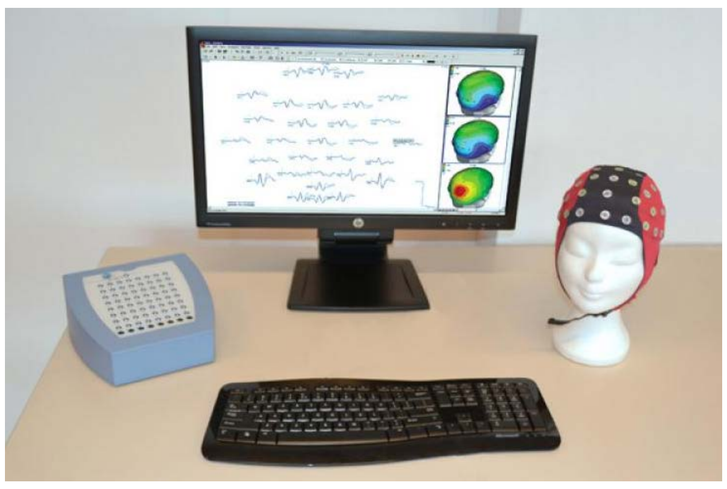


The 10-20 electrode system and EEG acquisition device

The American Electroencephalographic Society standardized a 10-20 electrode system to measure EEG signals. The location of the placing of the electrodes on the scalp are shown below. The location of the electrodes on the cap are determined by the partition of parameters by10% or 20%.



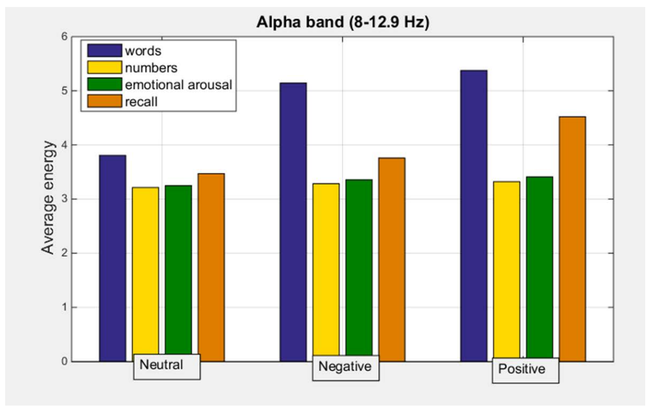
Left side view of electrode positioning

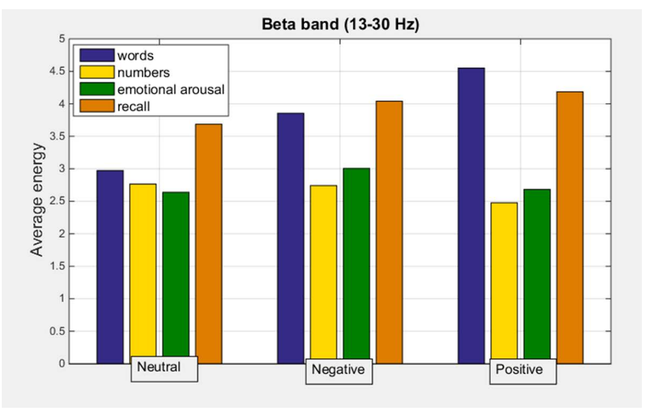


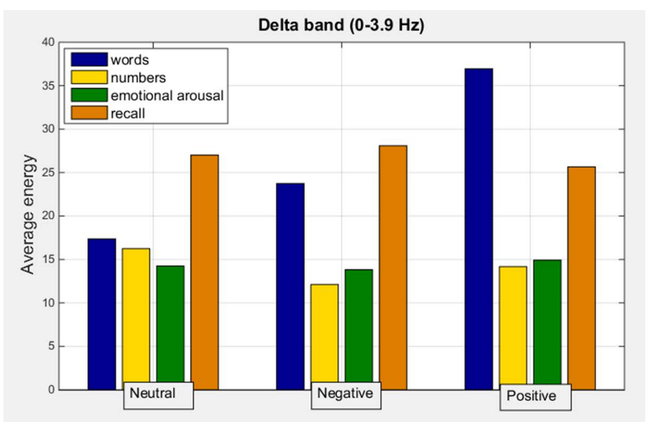
EEG acquisition device designed by ANT Neuro

An EEG cap is used to record the evoked potentials from the human brain, placed on scalp it includes an adjustable circlet with fairly inflexible straps across all the electrode positions used to record the potentials.

Average energy of Alpha, Beta, and Delta bands for different tasks







Findings

When data were analyzed as frequency of recalled words, event-related words, and numbers, dependent upon participants' exposure to various emotional stimuli (neutral, negative, and positive), we have found the following:

A chi-square test of independence ($\chi2(4) = 10.485$, $p < 0.05$) indicated that ***participants exposed to negative emotions tended to recall more event-related words*** (56.25%) than participants exposed to positive emotions (52.94%) or neutral emotions (50%). We concluded that ***negative emotions have a stronger effect on memory retention and in consequence, when exposed to words related to such emotions, individuals recall these words better***. No significant interaction was found between evoked emotions and recalled words (not related to any emotion) at $p = 0.05$. This comes in contradiction to results reported by Valiente *et* al. (2012), who found that the highest memory retention was associated with neutral emotions, such as being in a calm state.

A chi-square test of independence ($\chi2(7) = 22.030$, $p < 0.05$) indicated that ***participants exposed to positive emotions tended to recall more numbers*** (56%) than participants exposed to negative emotions (42%) or neutral emotions (28 %). We concluded that participants' capacity to memorize numbers was related to emotion: ***positive and negative emotions increased memory retention when compared to neutral emotion***. Nonetheless, exposure to positive emotions increased individuals' capacity to memorize numbers.

Alpha (8-12.9 Hz), Beta (13-30 Hz), and Delta (0-4 Hz) bands have been shown to be related to learning, mental calculation, and semantic tasks, respectively (Harmony, 2013; Subha, 2010). Analysis of ERPs in response to all five tasks was performed on the basis that ERPs can serve as indicators of brain changes that take place during mental tasks (Kelly and Garavan, 2005).

The highest energy for all tasks was observed in the Delta band which is known to increase during mental calculation and semantic tasks.

We observed that ***brain activity (energy) in all EEG bands was the highest while participants were memorizing the words and recalling words and numbers***. ERPs in all EEG bands showed similar levels after exposure to neutral and positive emotions.

Memorization of the numbers did not cause a significant increase in brain activity compared to the memorization of words.

We also observed that ***the energy levels of the memorization of words and recalling increased in time but the energy levels of the memorization of numbers and watching images did stay similar in time***.

Future work includes:

- More participants to be included in the study; More diverse participant cohort; Mapping of the ERPs in all bands to be performed for the cerebral lobes (frontal, parietal, temporal and occipital); Correlation between induced emotion and behavioral indicators.