Classification of working memory load using feature fusion based on simultaneous EEG-fMRI

Abstract

Working memory is responsible for the online manipulation of information necessary and short-term storage for higher cognitive functions, such as language, problem-solving and planning ([Cohen et al., 1997](#_ENREF_2)). So the research of working memory load is of great value. However, classification of working memory load is a challenging task. Many studies reported in the literature are based on the brain activity patterns using fMRI, EEG and so on ([Hogervorst et al., 2014](#_ENREF_3), [Ahmad et al., 2017](#_ENREF_1)). EEG and fMRI considered as two complementary neuroimaging modalities in terms of their temporal and spatial resolution to map the brain activity in different working memory load. For getting a high spatial and temporal resolution of the brain at the same time, simultaneous EEG-fMRI is meaningful. In this research, we propose a new method based on simultaneous EEG-fMRI data and feature fusion approach to classify the working memory load. We acquired EEG-fMRI data simultaneously on the thirteen healthy human participants in the n-back task. Feature fusion approach is used to merge EEG and fMRI feature. Results showed that this approach has been achieved superior classification performance with simultaneous EEG-fMRI data as compared to the EEG and fMRI feature standalone.

Introduction

We developed different classification models using EEG features, fMRI activation features or a combination (fusion).

Working memory is a cognitive system with a limited capacity, which is involved in the maintenance and online manipulation of information in the mind. WM load increases with the amount of information that an individual needs to process at one time.

Early studies on workload and performance used direct performance measurements, such as the number of errors made; or physiological parameters such as heart rate variability, blood pressure, respiration rate, pupil size, eye blink frequency, and skin conductivity in order to infer and examine workload levels.

Generally, memory can be classified into two main categories, i.e. , one is long-term memory (LTM) and the second one is short-term memory (STM). Long-term memory is the memory of past events etc. Short term memory is defined as the ability of the human brain to store information for a short span of time like in seconds. STM can be checked using the digits test. The normal test for healthy subjects to test working memory is 6-7 digits. STM is also called working memory(WM); and, STM and WM are still used interchangeably on many occasions. WM is a concept of storing information for a short time to perform the cognitive function, for example learning, reasoning, language comprehension etc.

Different studies investigated the neural basis of the WM in the human brain. Efforts have been made to localize the brain areas responsible for WM processes. The results shown, consistently, implicated regions found within the frontal cortex. Therefore, the frontal cortex has a significant role in the WM process. Different studies on humans as well as on animals have shown that the frontal lobes have a critical role in the neural networks which support the WM process. One third of the human cerebral cortex is comprised of the frontal lobes. The frontal lobes can be divided into three main parts: premotor cortex, paralimbic cortex and the prefrontal cortex (PFC). In studies on humans and primates, the neurobiological findings show that the PFC plays a vital role in the storage and manipulation of information in the WM. Further, the PFC can be portioned into smaller regions which serves as subparts of the different WM components. Baddley et al. [42, 43] has described that WM is not based upon a unitary system. It consists of many distinct functional units, i.e., central executive, episodic buffer, phonological loop, visuo-spatial sketch pad etc. Figure 3 shows the block diagrams of the memory model. Maintenance of the verbal information in the WM is necessary for language comprehension. The WM can be subdivided into the encoding, retention and recall of information.

The features from EEG

Electroencephalography (EEG) in many studies has been widely used for WM assessment and to understand the neural mechanisms during the WM processes [45, 49–54]. Normally, theta (\*4–7 Hz) and alpha (\*8–12 Hz) frequencies are dominant during the cognitive or WM tasks. Event related responses (ERPs) which are derived by averaging the EEG signal in the time domain have been widely used to understand and for the investigation of human cognition. It was reported that the theta frequency exhibits an increase in power associated with a higher level of cognitive or WM tasks. Table 2 shows the brain regions activated during WM experiments and also the behavior of different frequency band powers [55].

The features from fMRI

Functional magnetic resonance imaging (fMRI) has been widely used for WM assessment, and these studies have shown brain activation during the WM process in the areas of the prefrontal cortex (PFC), occipital region, parietal regions and medial temporal areas. The summary of these activations is shown in Table 3.

Separate session EEG and fMRI

本次调研主要是从四个方面，分别是：

* 首先调研的是记忆负荷研究的意义及其研究的价值，（第一段）
* 其次讲述EEG特征，主要是时域特征、频域特征、相位特征，对记忆负荷分类的优点及研究价值，（第二段）
* 然后讲述fMRI特征，主要是激活特征和FC，对记忆负荷分类的优点及研究价值，（第三段）
* 第四段讲述同步EEG-fMRI的优点，多模态数据的特征融合的优点（引用文献EEG+NIRS），及其多模态数据的特征融合能够带来哪些性能的提升，说明本工作的研究价值，引出本文的研究内容。（第四段）

Reference

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