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Research report

Functional brain microstate predicts the outcome in a visuospatial working memory task

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HIGHLIGHTS

- Brain activity preceding the memory trial could determine its outcome.
- Pre-trial EEG microstate could predict the subsequent response.
- Right middle occipital gyrus activity might influence response accuracy.

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ABSTRACT

Humans have limited capacity of processing just up to 4 integrated items of information in the working memory. Thus, it is inevitable to commit more errors when challenged with high memory loads. However, the neural mechanisms that determine the accuracy of response at high memory loads still remain unclear. High temporal resolution of Electroencephalography (EEG) technique makes it the best tool to resolve the temporal dynamics of brain networks. EEG-defined microstate is the quasi-stable scalp electrical potential topography that represents the momentary functional state of brain. Thus, it has been possible to assess the information processing currently performed by the brain using EEG microstate analysis. We hypothesize that the EEG microstate preceding the trial could determine its outcome in a visuospatial working memory (VSWM) task. Twenty-four healthy participants performed a high memory load VSWM task, while their brain activity was recorded using EEG. Four microstate maps were found to represent the functional brain state prior to the trials in the VSWM task. One pre-trial microstate map was found to determine the accuracy of subsequent behavioural response. The intracranial generators of the pre-trial microstate map that determined the response accuracy were localized to the visuospatial processing areas at bilateral occipital, right temporal and limbic cortices. Our results imply that the behavioural outcome in a VSWM task could be determined by the intensity of activation of memory representations in the visuospatial processing brain regions prior to the trial.

1. Introduction

Visuospatial Working Memory (VSWM) refers to the essential cognitive ability that enables us to encode, maintain, manipulate and retrieve information in the visual space to execute the ongoing behaviour [1]. VSWM is a dynamic temporary memory space of a few minutes' duration that enables us to encode/update spatial position of objects, retain & manipulate it till the execution of current behaviour goal and to discard such information instantly after use to make the brain resources available for the upcoming tasks. It enables humans to depart and take turn at appropriate points to reach a destination safely by either road, water or air, especially when in a new environment. Inspite of serving an important role for our day-to-day activities, VSWM capacity is limited to only 3–5 integrated items of information [2,3]. Limited human working memory capacity gets manifested by the increase in the number of errors when challenged with more difficult tasks like the task with higher memory load i.e. more number of items required to be encoded, rehearsed and later retrieved from memory [2–5].

Previous functional neuroimaging and electrophysiological studies have investigated the effect of memory load on the neural

Abbreviations: EEG, electroencephalography; VSWM, visuospatial working memory; GFP, global field power; GEV, global explained variance; sLORETA, standardized low resolution brain electromagnetic tomography.

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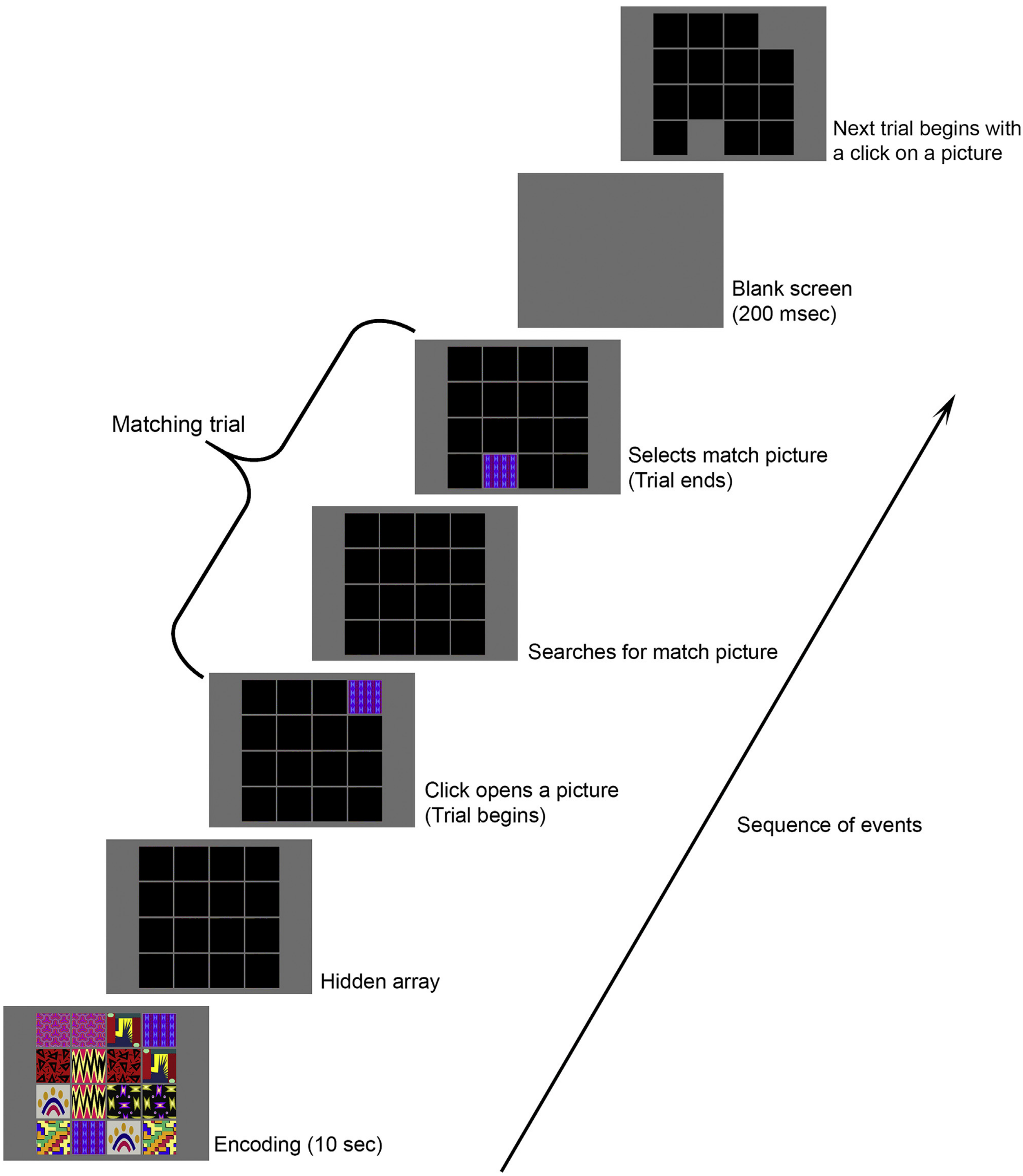

Fig. 1. Design of VSWM task used in this study. An array with 8 pairs of identical abstract pictures has to be encoded in 10 s, following which all pairs of pictures hidden in the array have to be correctly matched for the completion of the task.

substrates of working memory and interpreted the brain sources that showed memory load changes to be responsible for increase in the error responses at higher memory loads [4–12]. Even though the error responses are significantly more at higher memory loads, there are correct responses as well. To the best of our knowledge, none of the studies have compared the difference in the brain sources of correct and error responses at higher working memory load. Understanding the neural mechanisms that determine response in a VSWM task could potentially improve our current knowledge of physiology of VSWM during health as well as pathophysiology during disease states such as Alzheimer's disease [13,14], schizophrenia [15,16], autism [17,18] and ADHD [19,20], where VSWM is affected.

Temporal changes in the topography of global scalp electric potentials have been considered to reflect differences in the underlying neuronal generators irrespective of their frequency [21]. These momentary scalp electric potentials topography does not change randomly over time, but it remains stable for ~80–150 ms