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ORIGINAL ARTICLE/ARTICLE ORIGINAL

Right frontal event related EEG coherence (ERCoh) differentiates good from bad performers of the Wisconsin Card Sorting Test (WCST)

La cohérence EEG liée à l'événement mesurée en frontal droit permet de distinguer les bons des mauvais performeurs au test de Wisconsin

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KEYWORDS
WCST performance;
EEG coherence;
Frontal lobe;
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Abstract
Aim. — To investigate changes in Event-Related Coherence (ERCoh) associated to good and bad resolution of the Wisconsin Card Sorting Test (WCST).
Methods. — Event-Related Potentials (ERPs) were recorded from a sample of 30 university students while they performed a computerized version of the WCST. ERCoh was calculated for frontal and parietal electrodes for two specific moments: immediately before the response and after the feedback cues.
Results. — Bad performers presented significantly reduced ERCoh at the right frontal region (in alpha, beta-1 and beta-2 bands), while no consistent group differences emerged for parietal ERCoh. Furthermore, the strength of functional coupling (ERCoh) between midfrontal and right-frontal electrodes was a good predictor of WCST behavioural parameters, such as the percentage of perseverative errors or the number of categories achieved.
Conclusions. — The results suggest that the right prefrontal cortex is specifically involved in executive functions, such as planning and foresight, tapped by the WCST. Although the specificity of the WCST to explore frontal lesions has been recently questioned, the present findings support that prefrontal areas are specifically involved in the successful resolution of the test by healthy subjects.

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MOTS CLÉS
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Mémoire de travail

***Résumé*. —**
***Objectif*. —** Étudier les modifications de cohérence spectrale liées à l'événement (event-related coherence, ERCoh) associé à la résolution correcte ou incorrecte du test Wisconsin de classement de cartes (WCST).
***Méthodes*. —** Nous avons étudié, chez 30 étudiants universitaires, la cohérence spectrale sur les régions frontales et pariétales à deux moments spécifiques du test, à savoir (a) juste avant de donner la réponse à chaque carte-test, et (b) après avoir reçu le signal indiquant si la réponse avait été bonne ou mauvaise. Les sujets furent classés comme « bons » s'ils réussissaient à compléter les six catégories du test lors de sa première passation. Ils étaient considérés comme « mauvais » dans le cas contraire.
***Résultats*. —** Le groupe de sujets ($n = 8$) ayant réalisé le test de façon incorrecte montrait une diminution significative des niveaux de cohérence spectrale alpha, beta-1 et beta-2 sur la région frontale droite exclusivement. Aucune différence significative n'était visible sur les électrodes pariétales ni frontales gauches. De plus, l'intensité du couplage fonctionnel entre les électrodes Fz et F4 —estimé par leur niveau de cohérence mutuelle— était prédictive des performances comportementales au test WCST (pourcentage d'erreurs persévératives et nombre de catégories complétées).
***Conclusions*. —** Ces résultats suggèrent que le cortex frontal droit est spécifiquement impliqué dans les fonctions exécutives frontales interrogées par le test Wisconsin de classement de cartes, et en particulier, la planification et la flexibilité cognitive à court terme.

Introduction

The Wisconsin Card Sorting Test (WCST) explores complex cognitive functions such as working memory, abstract reasoning and conceptual shifting, and has been widely used as a neuropsychological test to detect frontal dysfunction [12,16,31]. It was often shown that subjects with prefrontal damage perform poorly the WCST, in particular, they find it difficult to shift the sort criterion, achieve few categories and make more perseverative errors than both age-matched controls and patients with non-frontal brain injury [2,31,40,47]. However, some other studies questioned both sensitivity and specificity of the test for prefrontal lobe function, as they proved unable to demonstrate sorting deficits in patients with documented frontal damage [43] or did not differentiate between patients with frontal vs. non-frontal brain lesions on the basis of WCST alone [1,52].

Functional imaging studies using Positron-emission Tomography (PET-scan), functional Magnetic Resonance (fRMI) or Near-infrared Spectroscopy (NIRS) supported a WCST-related significant activation of prefrontal regions, by showing increased frontal regional blood flow (rCBF) during the performance of the test [8,17,28,30,32,35]. In parallel, failure to activate prefrontal regions during the WCST has been described as characteristic of disorders in which major dysfunction of frontal lobes is postulated, such as schizophrenia [10,36,56,58]. Although these data strongly support the implication of the frontal lobes during WCST resolution, the test has also been shown to provoke rCBF increases in other non-frontal cortical regions, mainly the secondary visual cortex and the junction of parietal, temporal and occipital lobes [8,32,35]. These later findings may be explained by the fact that, besides 'executive functions' such as rule learning, planning and set-shifting, the WCST also involves cognitive operations not directly subserved by the frontal lobes, notably spatial attention and visual analysis of the stimulus attributes. The relative contributions of frontal and non-frontal activities may vary across the different stages of the test, as well as within each trial between the presentation of the card and the subject's classificatory decision. Since neuroimaging techniques provide an average of the brain activity across these different stages, they may not be able to dissociate brain activities associated to the initial identification of the card from those provoked by the subsequent process of searching the rule and/or classifying the stimulus.

As an alternative, electrophysiological techniques with millisecond time resolution appear as an adequate tool for discriminating the neurophysiology of different steps involved in WCST resolution. However, the electrophysiological approach has provided so far very scarce direct evidence of specific frontal activation during the performance of the WCST. In a pioneer study, Mattes et al. [29] used event-related potentials (ERPs) to explore possible differences in frontal responses between schizophrenic patients and controls at various points within each WCST trial (before card presentation and after feedback stimuli). Although schizophrenics showed electrophysiological signs of attentional decrease (attenuation of positive potentials after feedback) and failure of anticipation processes (reduced contingent negative variation before card presentation), no specific impairment of frontal ERPs was detected in that study.

Following this line of research, Barceló et al. produced a series of studies [3—6] exploring the characteristics and topographical distribution of brain electrical changes during the performance of the WCST. In these investigations, ERPs were recorded in response to the presentation of card stimuli, with the aim of differentiating responses to early (2nd and 3rd) versus late (6th and 7th) cards within the same category. The main ERP differences between early and