Time Index of Neural Network Variability (TINNV): a novel electrophysiological measure of mental workload

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Abstract

The present study contributes to the current debate about electrophysiological measurements of mental workload. Specifically, the allocation of attentional resources during different complexity levels of tasks is a fundamental question of interest. To address this issue, we investigated mental workload using tasks with an incrementally-varying difficulty while participants performed an auditory oddball target task. For data analysis, we applied a novel method to analyze event-related potentials (ERPs) by intra-block sweep averaging of P2 and P3a-P3b amplitude components for the infrequent target stimuli. We obtained eight consecutive blocks of 5 sweeps each. The comparison between blocks of the amplitude of these ERP components allowed elaborating a Time Index of Neural Network Variability (TINNV). In both the easy and the more constraining memory task, the amplitude of P2 decreased beginning with the second block of the sequence. In contrast, the amplitudes of P3a-P3b linearly decreased following the repetition of the target in the more constraining memory task but not in the easy task. Statistical analysis revealed intra-block differences on specific TINNV-ERP patterns between the easy and the more constraining memory task, supporting our method to assess mental workload. Since a subject is his own control, the TINNV represents a new electrophysiological index for individual measurement of mental workload and may therefore be applicable in clinical routine.

Effect of chronotypical variations in alertness on inhibitory dynamics of the dorsal attentional networks

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According to an influential model, attention is mediated by two distinct networks in the brain: a ventral network controlling non-spatial attention (e.g., alertness) and a dorsal network governing spatial attention, which is closely linked to eye movement control. The dorsal networks of the two hemispheres compete to direct attention towards the contralateral hemifield, thereby exerting reciprocal inhibition. The balance of this reciprocal inhibition is thought to depend on input coming from the ventral network. Yet, little is known regarding the interactions between ventral and dorsal attentional networks. We aim to further elucidate the latter by investigating the effects of an alertness manipulation on the reciprocal inhibition of the dorsal networks.

Alertness level will be manipulated through synchronicity between chronotype and time of the day. Morning types are expected to show high alertness in the morning and low alertness in the evening, the opposite pattern is expected for evening types. Healthy participants' alertness level will be evaluated subjectively and objectively. The deployment of visual attention in space will be assessed by means of a free visual exploration task during which eye movements will be measured. In order to contrast the influence of the spatial location of salient features, both visual stimuli with lateralized salient elements (landscapes) and with spatially homogeneous saliency (patterns) will be used. Furthermore, the cortical excitability of the dorsal network of each hemisphere will be directly assessed using a transcranial magnetic stimulation (TMS) twin-coil approach over parieto-motor cortical circuits and measuring motor evoked potentials (MEP).

We expect to find a relationship between non-spatial attention (alertness level) and spatial attention allocation during visual exploration. The cortical excitability of the left dorsal network is expected to be increased during low compared to high alertness, whilst the opposite should be found for the right dorsal network. Behavioural and physiological measures are expected to correlate. These results will further clarify the impact of the ventral attentional network on the reciprocal inhibition of the dorsal networks, and the influence of these interactions on attentional performance.

Does Melanin Concentrating Hormone play a role in Neuroprotection? A study on the effect of sleep deprivation on stroke in rats

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Background: The literature states that sleep deprivation (SD) before stroke induces ischemic tolerance and may represent a new form of preconditioning. The microarray analysis performed in our study suggested that the increase of Melanin concentrating hormone (MCH), which was observed in pre-ischemic SD rats, may play a role in mediating this effect. MCH is involved in the regulation of the sleep/wake cycle and other functions such as feeding behaviour and energy balance. The main goal of this new study is to clarify the role of MCH in the neuroprotective effect of pre-ischemic SD.

Methods: The time course of MCH gene expression was performed at: 4h; 12h: 24h and 3 days after treatments in adult Sprague-Dawley rats. Animals were assigned to three experimental groups of four animals each: 1) TSD.IS: total SD performed before stroke; 2) IS: stroke without previous SD; 3) Sham: sham surgery without SD. Quantitative Real-time PCR was performed in order to evaluate the gene expression of MCH in ipsilateral hemisphere. The infarct size was assessed by cresyl violet staining. The electroencephalogram was recorded for all animals to evaluate changes in sleep.

Results: The real-time transcriptional profiling of MCH gene showed a significant increase of MCH during the acute phase of stroke (4h;12h;24h) in IS group compared to TSD.IS and Sham groups. Conversely, an increase in MCH gene expression was observed at 3 days in TSD.IS group compared to IS group. Rats treated with SD before stroke showed a reduction of infarct size at 12h ($p \leq 0.02$) and not at 24h and 3 days. Moreover, changes in the amount of total sleep and wakefulness were observed during the dark phase, but not at the light phase that occurred 12h later.

Conclusion: Sleep deprivation before stroke induced a substantial modification of MCH gene expression. A significant reduction of infarct volume was observed at 12h, suggesting that changes in sleep during the dark phase may play a role in neuro-protection.

High-Precision All-Optical Method for Cell-Based Drug Screening on Voltage-Gated Ion Channels

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Voltage-gated ion channels (VGC) regulate many physiological and vital functions and are central targets for pharmaceutical intervention. However, current techniques for channel screening rely on costly, low-throughput techniques such as automated patch-clamping.

We introduce a novel, entirely optical screening technique for fast VGCs, combining optogenetic channel activation and optical channel activity readout. Optogenetics is based on expression of fast light-activated microbial rhodopsins which allow precise de- and hyperpolarization of cells under physiological conditions. For imaging channel activity and to minimize excitation spectrum overlap, we used the fast far-red voltage-sensitive Di-4-ANBDQPQ.

We transiently co-expressed an optogenetic fusion protein containing the 473nm light-activated depolarizing cation channel ChR2 and the inhibitory 550nm light activated hyperpolarizing proton pump ArchT in combination with the inactivating human voltage gated cardiac sodium channel hNav1.5 in undifferentiated neuroblastoma cells. We chose hNav1.5 since it is a prime target for antiarrhythmic drugs. We showed in whole-cell patch clamp recordings of transfected cells that delivery of sub-millisecond blue laser pulses induces consistent actuation of sodium spikes under red-light mediated hyperpolarization up to frequencies of 5 Hz. hNav1.5 activity was reliably blocked by Lidocaine. In combined patch-clamp and optical readout experiments, we confirmed that the optical traces exactly follow time-course and amplitude of the electrical traces. In conclusion we show that optical hNav1.5 screening renders analogue results to patch-clamp recordings. We therefore suggest this technique as a novel and promising concept for future high-throughput screening assays of VGCs.