QUALIFYING EXAMINATION

INVESTIGATING THE DORSAL AND VENTRAL PATHWAYS OF READING THROUGH BEHAVIOURAL AND NEURAL MARKERS: A MULTIMODAL APPROACH USING TDCS AND EEG

SAGARIKA BHATTACHARJEE, PSYCHOLOGY

Abstract

Reading is a skill that requires processing of orthography, phonology, and semantics associated with a word. Contemporary brain network models help us understand how reading occurs through a combination of a dual route and a connectionist model. The dual route model of reading, proposes reading to involve by two independent parallel neuronal pathways in the left hemisphere: (1) dorsal route involved in sub-lexical grapheme-to-phoneme conversion comprising of inferior parietal lobule, superior temporal gyrus, and inferior frontal gyrus (2) ventral route comprising the semantic access from orthography encompassing left middle temporal gyrus, basal temporal area, and inferior frontal gyrus. This model provides explanation for frequent and regular words to be processed faster. Building on this, the connectionist dual process model (CDP) proposes the existence of semantic connections between the two pathways (dorsal and ventral) in parietal and temporal lobes to further explain the effect of subtle lexical variations on word recognition process. The CDP model is supported by neuroimaging studies, however the resultant conclusions are correlational in nature. Thus definitive inferences about the involvement of a particular brain region underlying a behaviour is difficult. In this aspect, non-invasive brain stimulation technique such as transcranial Direct Current Stimulation (tDCS) which directly modulate the targeted brain region could provide more causal evidence. tDCS passes a very low amount of current through the cortex via two or more electrodes positioned over the skull (referred to as tDCS montage). Previous studies have found that reading performance in both typical and atypical readers is enhanced following tDCS. However, meta-analyses across these studies reported inconsistency in the findings. This could be attributed to three reasons - (1) variability in the tDCS montages - , 2) variability in reading task - , 3) lack of functional segregation of dorsal and ventral pathways - , across the studies. Furthermore, attempts to establish a neural marker underlying tDCS induced changes in reading behaviour has not been made in previous studies. Given these research gaps, the present thesis aims to achieve three research objectives (1) determining the target specific montage for dorsal and ventral pathways through computational modelling, (2) apply these montages on reading tasks that involves either lexical or sub-lexical processing, and (3) specifying the neural correlates (marker) of reading from electroencephalogram (EEG) recordings with and without tDCS.

Tuesday
12 May 2020

10am

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continued……

In order to conduct tDCS on the respective dorsal and ventral routes involved in reading, we need to ensure that the two tDCS montages employed could stimulate the routes separately with least overlap. Deciding the tDCS montages for two pathways is challenging because there is diffused spread of current due to stimulation. Thus, Study 1 was motivated by the need to determine such a montage. A Systematic Approach for tDCS Analysis (SATA) that uses a computational framework to select appropriate montages for stimulating the dorsal and ventral pathways of reading is designed. SATA estimates the current density (CD) received by each cortical lobe and gyri of the brain taking into consideration of the size of electrodes and the placement of anode and cathode. Our simulations through SATA revealed two optimal montages with electrode size of 5 × 5 cm2 and optimal tDCS electrodes (anode and cathode) placements. Specifically, placing the anode at CP5 and the cathode at CZ stimulated the inferior parietal lobule for dorsal pathway whereas anode at TP7 and cathode at the nape-of-the-neck, stimulated middle/inferior temporal gyrus for ventral pathway.

Study 2 utilizes these selected montages to investigate the behavioural effects of tDCS on Chinese-English (C-E) bilingual reading. It was expected that recruitment of dorsal and ventral pathways in the bilingual neuro-network will depends on the orthographic depth of the script and reading proficiency. Sixteen balanced bilinguals were recruited in a double-blind, sham-controlled, within-subject experiment where anodal tDCS was applied across the dorsal, ventral, and sham sessions. They were asked to read word lists for each language before and after stimulation. We found dorsal stimulation facilitated reading for both the languages, whereas ventral pathway stimulation only enhanced Chinese reading. Proficiency in either language was negatively correlated with the stimulation effect of the dorsal pathway. However, stimulation of the ventral pathway did not enhance English reading, and reading performance was not associated with the ventral pathway stimulation effect. These findings led us to hypothesize that higher proficiency in English may have resulted in to the maximum recruitment of the ventral pathway, thereby leaving no room for further improvement following tDCS consistent with previous literature. In addition, the ceiling effect of reading performance suggested the wordlists were not challenging enough to distinguish high from low performers in lexical processing capability.

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Given findings from above, we propose Study 3 to investigate the effect of tDCS on relatively difficult reading tasks like perceptual and conceptual word priming. Perceptual priming is expected to recruit sub-lexical processing, whereas conceptual priming is expected to involve lexical processing. A pilot behavioural study showed that lexical priming elicited maximal performance in contract with conceptual priming where there is still room for improvement. Based on our findings from study 2, we expect the lexical pathway recruitment during conceptual priming to be sub-maximally utilized. Therefore, we hypothesize that only the ventral pathway stimulation would enhance the conceptual priming effect. To confirm this, we will apply concurrent EEG recording to show the neural correlate (N400) of conceptual priming task during ventral stimulation to be significantly different from sham. Whereas we would expect the neural correlate of perceptual priming task (N170) to not change when compared to sham. As the priming tasks has the ability to distinguish high performers from low performers, it provides an opportunity to investigate the association of lexical efficacy with ventral pathway stimulation effect. We propose to conduct a double-blind, sham-controlled, within-subject experiment with 25 participants. tDCS with simultaneous EEG will be applied during the priming tasks across dorsal, ventral, and sham sessions. Behavioural performance (accuracy and reaction time) and EEG measures (latency and amplitude of ERP) obtained during different conditions (stimulation or sham, priming and task type) will be submitted to a linear mixed model analysis to examine effects.

In summary, the present thesis first identified appropriate montages that targets the regions in dorsal and ventral pathways of reading with minimal overlap in the spread of current. Subsequently, these montages were used to investigate the effect of dorsal and ventral pathways on reading in two languages and priming tasks with an expectation of segregating the functions of lexical and sub-lexical processing. We found that possibly both lexical and sub-lexical processing are crucial for processing either language. In particular, language proficiency plays an important role in determining the tDCS induced stimulation effects.

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We also expect to find an association of both lexical and sub-lexical processing efficacy to be deterministic in exhibiting tDCS stimulation effect following dorsal and ventral pathway stimulation, respectively. In addition, with the help of EEG neural markers we expect to find that tDCS effectively modulates only the sub-maximally utilized pathway (irrespective of being lexical/sub-lexical) involved in a task. These results show that the functional segregation of dorsal and ventral pathways should be considered, while modulating reading performance with tDCS. Finally, the proposed research in this thesis hopes to show how both reading and priming are modulated by brain stimulation of the associated reading pathways. This will provide further understanding of the underlying mechanisms supporting the CDP model of reading.

Proceedings

Duration	Session
5 mins	Chair Welcome & Introduction of Panel
30-45mins	Presentation by Student
15 mins	Q&A (by audience – faculty / students)
Break	Audience to leave the TEAMS meeting
30 mins	Q&A by Panel
15 mins	Chairperson to ask candidate to leave the TEAMS meeting Private Panel Discussion and Decision on the Student's examination
15 mins	Candidate invited back by Chairperson to the TEAMS meeting Feedback and Outcome of Qualifying Examination

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