

Supporting Deep Encoding with Non-Invasive Brain Stimulation: A tDCS-fMRI Study in Younger and Older Adults

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Introduction

The decline of episodic memory functioning is a well-documented characteristic of healthy cognitive ageing, frequently linked to structural and functional alterations within prefrontal brain networks. There is evidence to suggest that the left dorsolateral prefrontal cortex (dlPFC) plays a critical role in the formation of new memories, particularly if they are deemed relevant for a person. In a current study, we combine high-definition transcranial direct current stimulation (HD-tDCS) and fMRI to trace the neurofunctional mechanisms underlying relevance detection, and subsequent memory formation, in younger and older healthy adults. The primary objective is to determine how targeted prefrontal activity modulation alters memory networks, relevance detection, and subsequent memory retrieval in an incidental learning paradigm.

Methods

In a randomized, double-blind, and sham-controlled design, healthy younger adults (aged 20-40) and healthy older adults (aged 60-80) are included. The planned target sample size is $N = 196$, with data currently collected from 105 participants. Participants receive active or sham HD-tDCS targeting the left dlPFC (1 mA for 22 min, 4x1 ring electrode configuration) while performing an incidental learning task in an 3T MR scanner. During the task, participants need to decide whether stimuli (i.e., 60 nouns) are edible or animate. A surprising free recall follows a few minutes after engaging in the task as well as 24 hours later. Neuroimaging data will be pre-processed using an automated pipeline in MATLAB and SPM12, incorporating automated quality control.

Results

Since data collection is still ongoing and examiners are still blinded, analyses of stimulation effects have not yet been performed. Instead, preliminary results will be collapsed across stimulation conditions. First analyses from a preliminary sample (see Table 1) reflect expected age-related memory performance differences: younger adults ($n = 66$) significantly outperformed older adults ($n = 39$) in both immediate free recall (16.6 ± 4.5 vs. 13.6 ± 4.9 words; $p = .002$) and 24-hour delayed recall (14.1 ± 5.8 vs. 10.6 ± 6.0 words; $p = .004$). 24-hour proportional retention rates did not significantly differ between groups ($p = 0.305$), but older adults had significantly more memory intrusions ($p = .010$). Age-related memory deficits were mitigated during the 24-hour recognition task. Although younger adults demonstrated numerically higher discrimination sensitivity ($d' = 1.87 \pm 0.60$) than older adults ($d' = 1.65 \pm 0.68$), this difference did not reach statistical significance ($p = .106$). In addition, false alarm rates were similar in both groups ($\sim 18\%$), suggesting that older adults successfully reject novel distractors similar to younger adults when retrieval cues are provided.

Conclusions

This study establishes a multimodal framework to investigate the role of the left dlPFC in episodic memory performance. By combining non-invasive brain stimulation, functional neuroimaging, and behaviour, we aim to characterize prefrontal engagement and memory-related network variations in healthy ageing.

Figures

Table 1. Sample characteristics (N = 105) by age group. Data are presented as mean $\pm$ standard deviation, unless stated otherwise. Between-group comparisons were conducted using independent-samples t-tests; Fisher's exact tests were used for education and sex.

	Younger Adults (n = 66)	Older Adults (n = 39)	p-value
Age in years	26 $\pm$ 5	69 $\pm$ 5	<.001
Sex			.544
Number of female (%)	36 (55%)	24 (62%)	
Number of male (%)	30 (45%)	15 (38%)	
Education			<.001
Compulsory Education	0 (0%)	5 (13%)	
Vocational Education	7 (11%)	10 (26%)	
General Education	59 (89%)	24 (62%)	
Handedness (EHI)	90 $\pm$ 13	85 $\pm$ 20	.213
Vocabulary Test (WST)	34 $\pm$ 3	37 $\pm$ 2	<.001
Mood (PANAS)			
Positive Affect before participation (PANAS Score, Mean $\pm$ SD)	20 $\pm$ 3	22 $\pm$ 3	.004
Negative Affect before participation	22 $\pm$ 4	24 $\pm$ 3	.010
Positive Affect after participation	18 $\pm$ 3	20 $\pm$ 2	<.001
Negative Affect after participation	20 $\pm$ 4	22 $\pm$ 4	.006
Sleep the night before participation in hours	7.18 $\pm$ 0.93	6.80 $\pm$ 1.03	.063

Abbreviations: SD = standard deviation, EHI = Edinburgh Handedness Inventory, WST = Wortschatztest (German Vocabulary Test), PANAS = Positive and Negative Affect Schedule