

Effects of tDCS and tACS on Associative Memory Performance in Healthy Elderly

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1. Introduction

- Possible beneficial effects of transcranial electric stimulation (tES) methods on associative memory performance in healthy older adults have been shown for:
 - **Transcranial direct current stimulation (tDCS)**¹
 - **Transcranial alternating current stimulation (tACS)**²
- Aging-related memory deficits include difficulties in linking together unrelated units into one cohesive episode³ (associative memory)
 - **Hippocampus** function progressively impaired with age⁴, critical brain structure for rapid encoding of flexible associations underlying associative memory performance^{5,6}
 - Older adults' associative encoding performance benefits from increased activity in the **prefrontal cortex** regions⁷

2. Methods

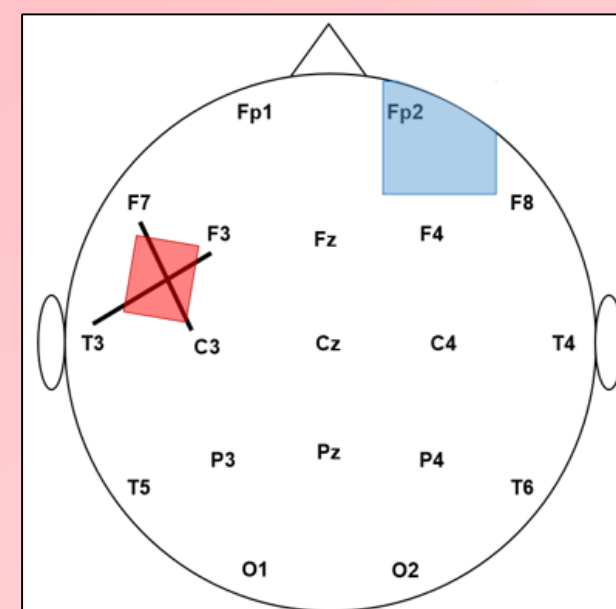
- Double-blind, sham-controlled, cross-over study
- Each participant attended three sessions (Figure 1)
- Associative memory performance was measured with a face-occupation association task (Figure 2) and data analyzed with linear mixed models
- Sequencing order of stimulation methods was randomized over participants and the following stimulation parameters were applied:

Stimulation intensity

- **tDCS – 2 mA**
- **tACS – 1 mA, sinusoidal, 5 Hz (theta)**
- Sham (control condition)

Stimulation sites

- **Left ventrolateral prefrontal cortex** (electrode 5 x 7 cm, anode/red) ->
- **Right supraorbital area** (electrode 10 x 10 cm, cathode/blue) ->



Stimulation duration

- **20 minutes**

3. Participants

28 healthy older adults (f=16; m=12) participated. All participants were German speakers, non-smokers and met no exclusion criteria.

Table 1. Demographic variables

Descriptives	Mean	SD	Median	Range
Age (years)	71.18	6.42	71	59 – 83
School edu. (years)	10.5	1.77	11	7 – 14
MoCA (points)	27.25	2.17	27	23 – 30
PAL (words)	13.11	2.74	13	8 – 18

Note. MoCA, Montreal Cognitive Assessment; PAL, Paired Associates Delayed Recall Task (Baseline).

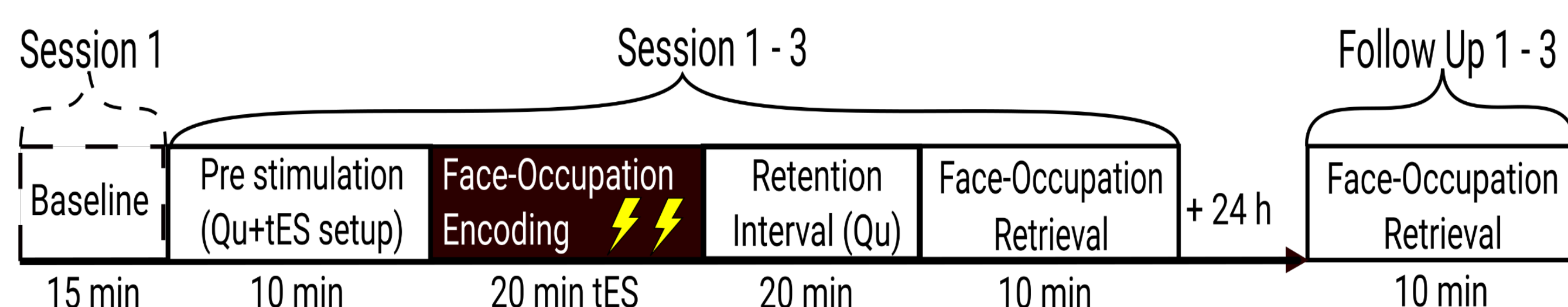
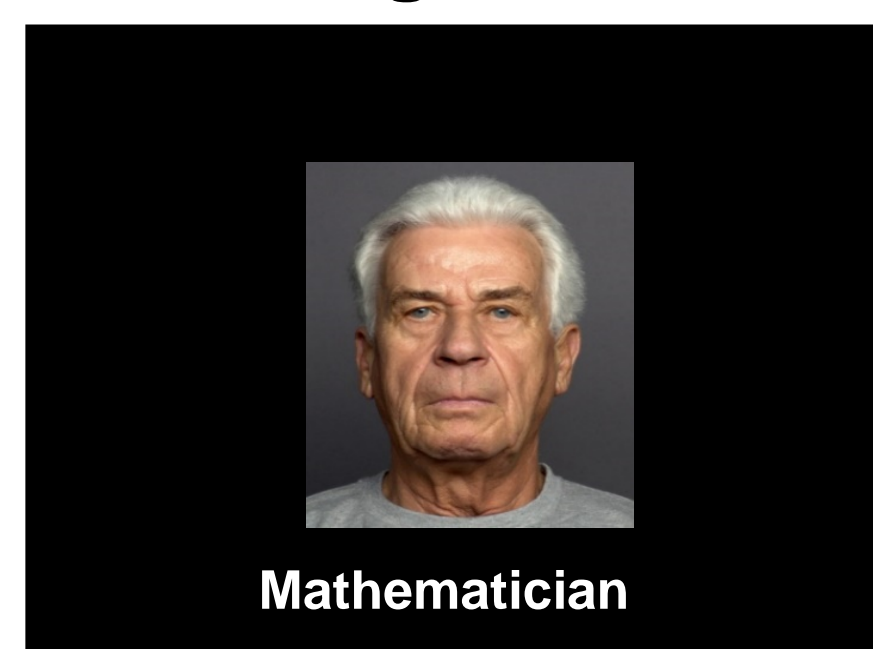
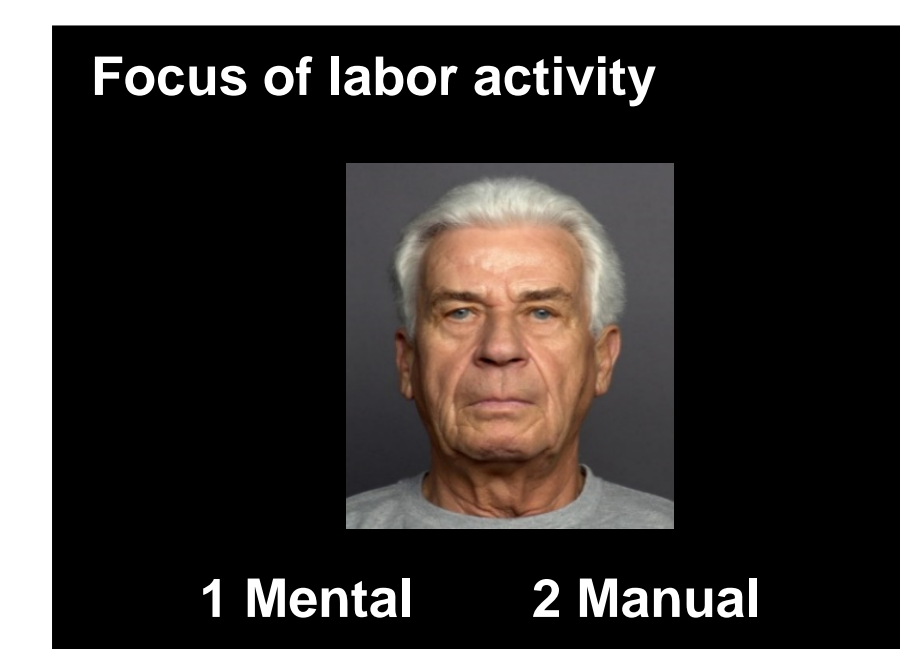


Fig 1. Study Schedule – Minimum of 72 h between each session; Qu, Questionnaire; tES, transcranial electric stimulation

Encoding



Cued Recall



Recognition

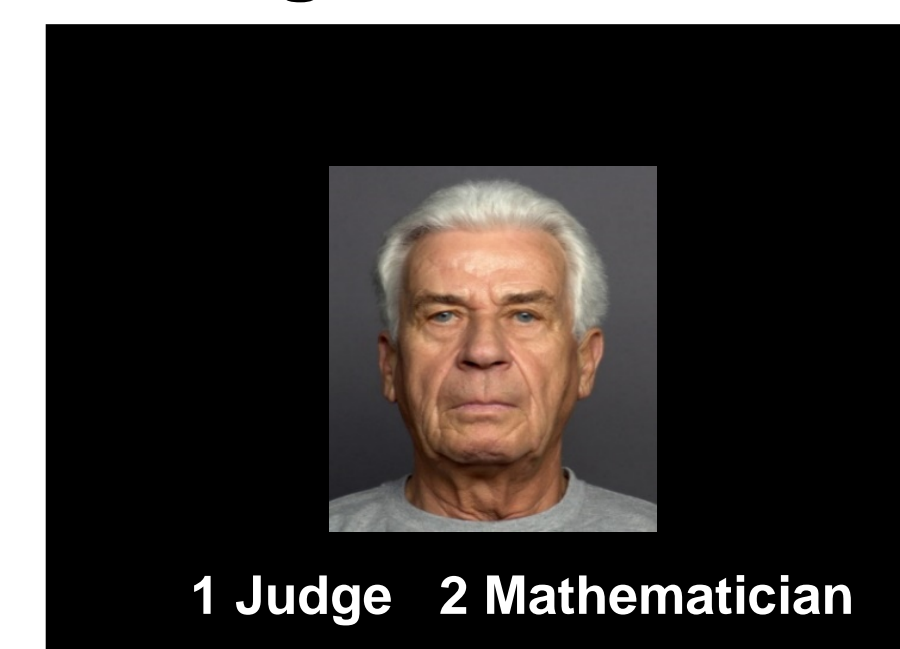


Fig 2. Face-Occupation task with three semantic categories (Education, Maximum Income, Focus of Labor Activity).

4. Results

- Overall, neither tDCS nor tACS showed effects on associative memory performance ($F_{(2,48)}=1.52, p=0.23$)
- The interaction of age and stimulation method showed a trend towards a significant difference ($F_{(2,48)}=2.84, p=0.07$)
- Post-hoc tests for outcome on the cued recall task revealed that **with increasing age** participants performed:
 - **Significantly worse under sham** ($\beta=-1.58, 95\%-CI: [-2.64, -0.52]$)
 - **Showed no difference under tACS** ($\beta=-0.4, 95\%-CI: [-1.47, 0.67]$) **or tDCS** ($\beta=-0.52, 95\%-CI: [-1.62, 0.58]$)
- Further comparison of fixed age effects between stimulation methods revealed:
 - **A significant difference between tACS and sham** ($\beta=1.18, 95\%-CI: [0.16, 2.2]$)
 - Trend towards a significant difference between tDCS and sham ($\beta=1.05, 95\%-CI: [-0.02, 2.12]$)

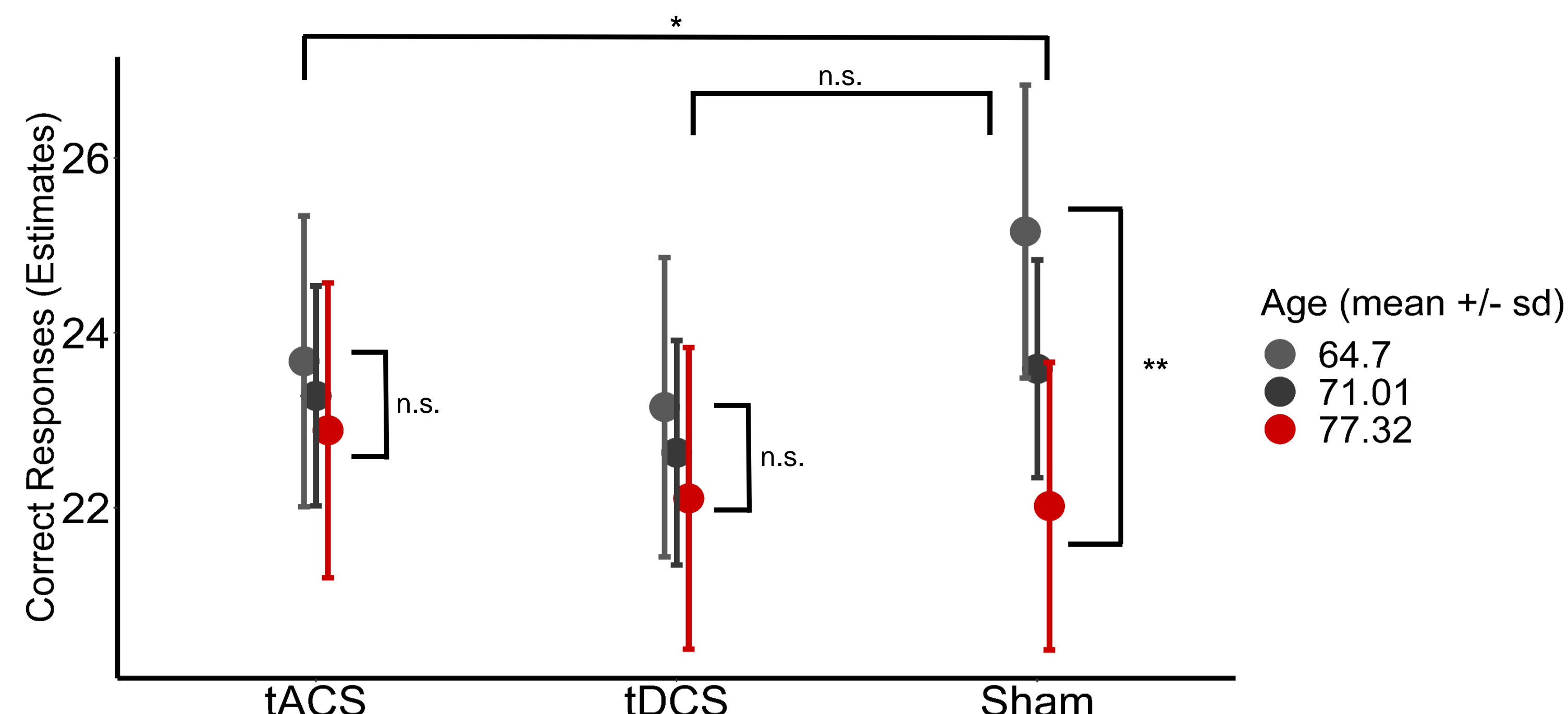


Fig 3. Predicted marginal effects for the interaction term Stimulation * Age are plotted with confidence intervals as error bars. The y-axis depicts estimates for number of correct responses on the cued recall task during sessions.

Conclusions

- Our **mixed results** show that reliable and reproducible stimulation effects on memory performance in healthy older adults are not yet easily achieved.
- Ideally, future studies probing the enhancement of associative memory performance in aging should identify **measurable neurophysiological correlates** that define **optimal time windows of individual responsiveness to tES**.
- Our findings indicate the **potential of theta tACS** to positively influence the widespread network communication needed to maintain successful associative memory formation with increasing age.



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