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Number processing in stroke patients: a study of functional reorganization using fNIRS

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Background and Aims

Number processing is essential in our culture as everyday life activities often require using numbers for counting, measuring, and comparing. Lesions involving the parietal and the frontal regions may cause deficits in number processing tasks, such as transcoding, conceptual knowledge, or arithmetical facts and rules [1]. Due to the social and daily life impact of these deficits, understanding neural activity underlying numerical deficits and the relative recovery after brain damage may be of outstanding importance.

Previous studies used functional near-infrared spectroscopy (fNIRS) to explore network reorganization in motor recovery in subacute stroke patients and reported increased contralateral functional connectivity [2, 3]. However, no study has investigated the recovery of cognitive functions in stroke patients using fNIRS and how different types of cognitive trainings could affect recovery processes.

Here, we will study the functional reorganization in stroke patients with numerical deficits. In particular, we hypothesize that changes in the activity of the contralesional hemisphere could reflect compensatory processes for brain damage, and that contralesional activity could increase over time as a function of recovery and of the type of rehabilitation program.

Methods

Participants

- 30 patients with subacute stroke (onset <6 months)
- 30 healthy controls

Inclusion criteria - patients:

- Age of 40-85 years
- Diagnosis of first unilateral ischemic/haemorrhagic stroke
- Preserved comprehension of simple instructions
- Preserved mobility of at least one hand

Inclusion criteria - healthy controls:

- Age of 40-85 years
- No pathologies that could affect cognitive performance

Exclusion criteria:

- Comorbidities with psychiatric disorders or other neurological diseases
- History of developmental learning disorders
- Inability to provide written informed consent

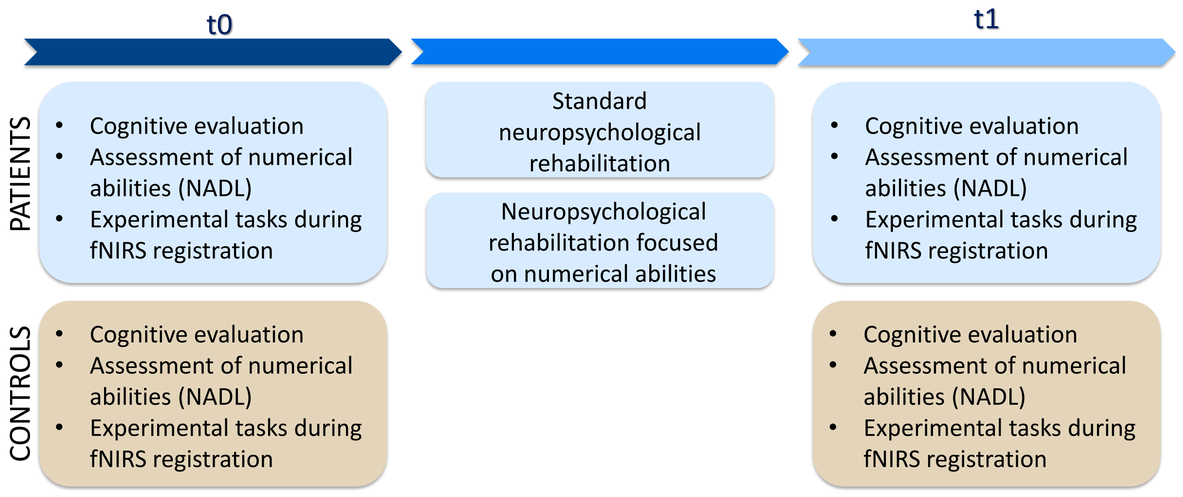
Procedure

Participants will be assessed for cognitive and numerical performances using a comprehensive neuropsychological battery which will include the Numerical Activities of Daily Living - short (NADL) test.

Afterward, participants will complete two computerized experimental tasks on a computer during fNIRS registration.

Cognitive evaluations and experimental sessions will be conducted at t0 and after one month (t1).

Between measurements, patients will be randomized to undergo i) standard neuropsychological rehabilitation or ii) rehabilitation focused on numerical abilities.



fNIRS data acquisition

Two tasks implemented on Psychopy software will be executed during the recording of cerebral activity through fNIRS. The tasks will be administered in a randomized order. Before the tasks, participants will complete 5 minutes of resting-state fNIRS registration.

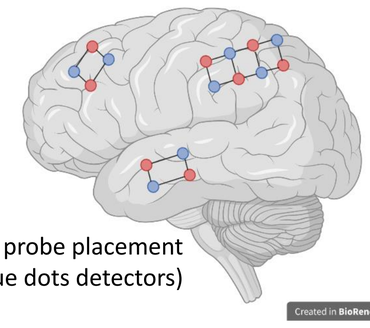
Experimental tasks:

- Calculation: mental calculation of addition and subtraction, 8 blocks of 5 items each
- Reading of non-words (control task): 2 or 3 syllables, 8 block of 5 items each

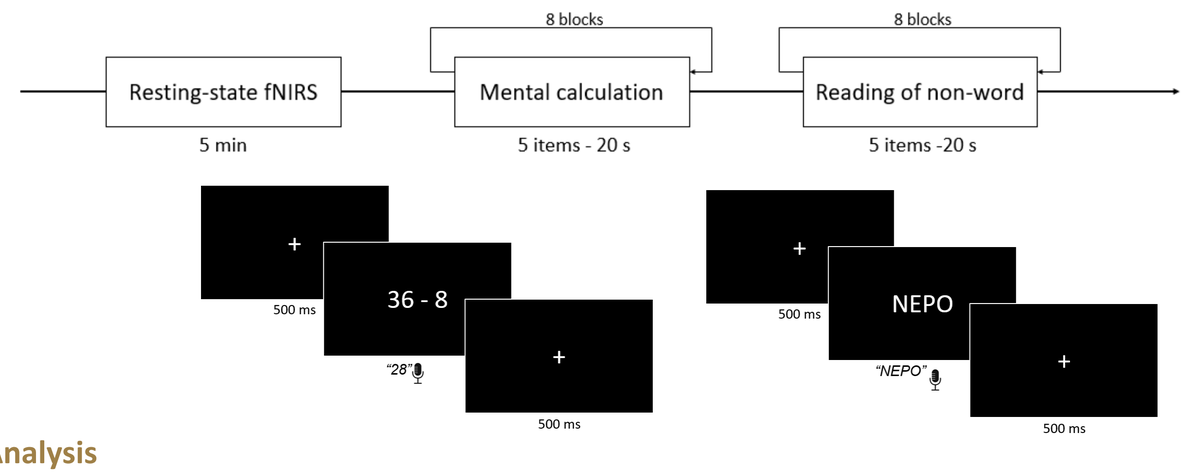
Accuracy and reaction times of oral responses will be recorded.

Probe placement (contralesional hemisphere)

- intraparietal sulcus (10 channels)
- Dorsolateral prefrontal cortex (4 channels)
- temporal lobe – control site [5] (4 channels).



Schematic illustration of probe placement
(red dots indicates sources, blue dots detectors)



Analysis

Behavioural: Mixed-effects models will be run. Group (patients; healthy control), Task (calculation; reading), Time (t0, t1) and NADL scores (continue) will be considered as independent variables. Accuracy and RTs at the two tasks will be considered as dependent variables.

fNIRS data: ANOVA will be conducted with Group (patients; healthy control), Task (calculation; reading), Time (t0, t1) and ROI (IPS; dlPFC, temporal lobe) as independent factors. The amplitude of the hemodynamic response will be considered as dependent variable. Hemodynamic responses of correct vs wrong behavioural responses will be also compared.

Delta values of fNIRS parameters and NADL scores between T1 and T0 will be calculated and correlated using Spearman correlations.

Expected results

- At t0, we expect to find no differences in the parietal/prefrontal hemodynamic responses between patients and controls.
- Consistently with fNIRS literature about motor recovery [2, 3], at t1 patients with numerical difficulties are expected to exhibit a larger activity (increased levels of oxyhemoglobin) in the contralesional parietal/prefrontal areas when performing the calculation task, compared both to healthy controls and patients without numerical deficits.
- A positive association between increased activity in parietal and frontal areas and better behavioral performance at t1 as compared to t0 is expected, as reflecting compensatory processes for the deficit.
- Patients that underwent the rehabilitation for numerical abilities are expected to exhibit larger pattern of functional reorganization in parietal and prefrontal regions at t1 compared to patients that underwent standard rehabilitation.

Future steps

- Association with structural MRI data to take into account the bimodal balance-recovery model: the increase of activity in the contralesional hemisphere could be adaptive or maladaptive depending on the residual resources of the ipsilesional hemisphere [6]
- Comparison of left stroke vs right stroke patients: lesions in both hemispheres could impair number processing [7] and affect the recovery process

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