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Changes in cortical activation during single-session sensorimotor training: young versus elderly adults

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Abstract—**People of advanced age experience changes in the brain structure, which cause motor and somatosensory systems' decline. To prevent and improve impaired functioning of the aged brain different intervention strategies are proposed. Sensorimotor training, encompassing both sensory and motor brain functions, seems to be one of the most accessible approaches. In this short report, we focus on the age-related effect of short-term training on cortical activation, particularly on the task-related low-frequency rhythms of electrical neural activity. We demonstrate the differential brain-wide changes in theta-band spectral power in considered age groups between the early and late stages of a training session.**

Index Terms—**aging, sensorimotor integration, training, EEG**

I. Introduction

Healthy aging affects structural and functional organization of the human brain [1], [2]. It causes inevitable negative behavioral outcomes in advanced age, such as reduced reaction time, delayed motor skills, slow speech, etc. [3]–[6].

Training of sensorimotor integration, a neural process encompassing sensory and cognitive functions, may be considered as a promising strategy for intervention or diagnostics of mild cognitive impairments [7]–[10]. While the attention is mostly focused on the outcomes of long-term training [11], [12], less is known about short-term effects. We suppose that particularly short session is an accessible way for patients in advanced age to improve their basic cognitive functions, or to detect abnormalities of the brain plasticity and learning.

Here, we report the results of neurophysiological study aimed at identifying age-related changes in cortical activation in the course of sensorimotor training. We witness a differential effect of a single-session sensorimotor training on cortical theta-band oscillations in the groups of young and elderly adult subjects. Our results suggest that considered age group may develop different sensory processing strategies during training session.

II. Materials and Methods

Participants. The groups of 11 elderly adult (aged 64.2±5.3 SD, 4 females) and 13 young subjects (aged 25.5±5.3 SD, 4 females) were recruited for this study. The participants had no history of brain trauma and neurological disorders. The study on the human subjects was approved by the local ethics committee and conducted according to the Declaration of Helsinki.

Task. The volunteers from both age groups underwent a single sensorimotor training session consisting in repetitive execution of a fine motor task paced by auditory command. Specifically, one had to perform left- or right-hand movement, if the presented auditory signal was short (250 ms) or long (750 ms). Overall number of repetitions was $N = 60$ (30 per hand). The same experimental design was previously reported in [6].

EEG acquisition and preprocessing. The whole-scalp multichannel EEG were acquired throughout the session using EEG recorder Encephalan-EEGR-19/26 (Medicom MTD, Russia). 31 Ag/AgCl sensors were applied in accordance with extended 10-20 layout. EEG signals were recorded at sampling rate $f_s = 250$Hz and additionally filtered within the range $[1, 100]$ Hz. Physiological artifacts were removed via independent component analysis (ICA) [13] using MNE package for Python [14]. Artifact-free EEG signals were segmented into task-related epochs according to experimental protocol containing 2.5s prestimulus and 1s poststimulus activity and centered at stimulus presentation. For further analysis, we used the first 10 epochs (5 per stimulus) to capture Early stage of training. The last 10 epochs (5 per stimulus) were considered as Late stage of training.

Time-frequency analysis. Using Morlet wavelets, we estimated spectral power (SP) in theta, lower-alpha1, lower-alpha2, and upper-alpha bands, anchored to the individual alpha frequency [15]. For each band, we computed the difference in pre- and poststimulus SP between Late and Early stages of training. Than, we compared corresponding SP differences between groups using a non-parametric statistical test [16] to reveal a significant interaction between Training and Age. Finally, cluster-averaged SPs were compared via a mixed-design ANOVA using JASP software [17].

III. Results

Prestimulus spectral power. A significant cluster-level effect

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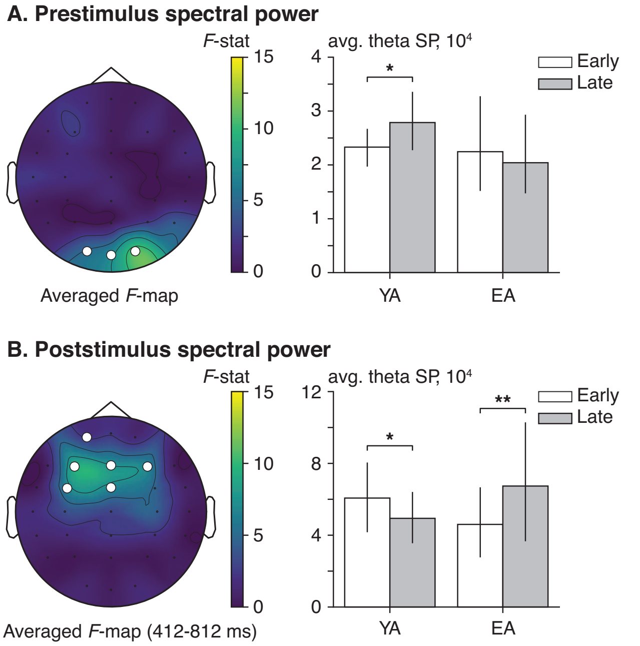

Fig. 1. Differential age-related effect of training on prestimulus (A) and postsimulus (B) theta-band SP. Left panels shows between-group F-maps, and right panel presents group means and standard deviations of theta-band SP.

was evaluated in theta-band (Fig. 1A). The cluster comprised of occipital sensors was found at $\alpha_{cl} = .05$, $F_{cl}(1, 22) = 4.30$. A mixed-design ANOVA of cluster-averaged SP demonstrated a significant interaction between Training and Age ($F(1, 22) = 9.54$, $p = .005$, $\eta^2 = .30$). Young participants experience a significant increase of prestimulus theta-band SP from Early to Late stages ($t(12) = 2.82$, $p = .016$, $d = .78$).

Poststimulus spectral power. A significant cluster-level effect was evaluated again in theta-band at 412-812 ms (Fig. 1B). The cluster comprised of frontal and frontal-central sensors was found at $\alpha_{cl} = .015$, $F_{cl}(1, 22) = 6.96$. A mixed-design ANOVA of cluster-averaged SP demonstrated a significant interaction between Training and Age ($F(1, 22) = 12.79$, $p = .002$, $\eta^2 = .37$). Young participants showed a significant decrease of poststimulus theta-band SP from Early to Late stages ($t(12) = -2.75$, $p = .018$, $d = -.76$). In turn, elderly adult subjects experienced a growth of poststimulus theta-band SP ($W = 4.0$, $p = .007$).

IV. Conclusions

A significant effect of sensorimotor training on pre- and poststimulus theta-band SP was demonstrated. While young participants increase prestimulus theta-band SP in occipital sensors and decrease frontal theta-band SP, elderly adults exhibit growth of frontal theta-band SP 412-812 ms post stimulus. Obtained results may indicate differential sensory processing strategies developed in considered age groups in the course of training.

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