Behavioural Brain Research 345 (2018) 104–113

Contents lists available at ScienceDirect

Behavioural Brain Research

journal homepage: www.elsevier.com/locate/bbr

Research report

Older adults reveal enhanced task-related beta power decreases during a force modulation task

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ARTICLE INFO

Keywords:
Fine motor control
Precision grip
EEG
Alpha and beta power
Aging

ABSTRACT

Older adults (OA) compared to young adults (YA) reveal deteriorated fine motor control. However, it remains unknown whether this age difference is reflected on the central level, i.e., in electrophysiological correlates such as EEG task-related power (TRPow) in alpha (8–13 Hz) or beta band (13–30 Hz). Furthermore, we were interested in the association between age and alpha/beta power at rest as a potential determinant for TRPow changes. Twenty-five YA (19–29 years) and 45 OA (67–83 years) performed a force modulation (FM) task requiring to match a sinusoidal target force by exerting an isometric force with thumb and index finger. EEG was measured at rest and during FM task. YA outperformed OA in the FM task. For alpha, OA demonstrated less frontal power at rest than YA. For beta, OA revealed more power than YA in frontal, central, and parietal areas at rest. TRPow results depended on whether analyses were controlled for power at rest. When analyses were controlled, OA showed higher TRPow decreases than YA in beta in parietal and occipital areas during FM performance. TRPow decreases for beta were stronger in the contralateral than in the ipsilateral frontal hemisphere in OA than in YA. Decreases in TRPow indicate increased cortical activity to accomplish the FM task. Our findings suggest higher parietal and occipital processing demands while performing the FM task in OA than in YA. This study further confirmed the importance of controlling for EEG power at rest when investigating TRPow during motor performance to account for interindividual variability.

1. Introduction

Countless daily activities require precise force control and modulation of thumb and index finger under visual control, e.g., tying laces or using a smart phone. Fine motor control declines with increasing age, indicated by less precise performance, a higher performance variability or over-/undershooted forces ([1,2] for reviews). Further, older adults seem to have a higher need for (cognitive) processing resources than young adults when performing motor tasks in general [3–6] and precision grip force modulation (FM) tasks in specific [7,8]. However, less is known about electrophysiological age-related differences during FM task performance.

Visuomotor FM tasks require continuous control of an extensive brain network including the visual and sensorimotor system as well as frontal and parietal brain areas [9–11]. Studies using electroencephalography (EEG) in young adults revealed neural desynchronization, i.e., reduced oscillatory power, in the alpha (8–13 Hz) and beta (13–30 Hz) frequency ranges during the performance of FM tasks compared to a rest condition in frontal, central, parietal and occipital areas [9,12,13]. It is assumed that such task-related power (TRPow) decreases reflect enhanced cortical activation and active task processing [14,15]. More specifically, TRPow decreases of alpha oscillations of the sensorimotor cortex (central area) were interpreted as a marker of sensorimotor processing [14,16]. TRPow decreases of beta oscillations seem to reflect online control and feedback processes of the motor system [17,18] and changes in corticospinal output [15,19].

To date, no studies have investigated TRPow changes during precision grip FM tasks in older adults. In simple motor tasks (like self- or audio-guided finger pressing/tapping tasks in which continuous visual feedback was not provided) older adults revealed stronger TRPow decreases than young adults over motor and parietal areas in alpha [20–22] and beta band [21–23], indicating higher cerebral activation and enhanced active task processing with increasing age. In line with these findings, beta desynchronization was increased in the ipsilateral primary motor cortex in older adults during an FM power grip task in a magnetoencephalography (MEG) study [24].

However, TRPow values do not provide information about network oscillations at rest. This might be problematic as results associating age

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https://doi.org/10.1016/j.bbr.2018.02.028
Received 27 October 2017; Received in revised form 16 February 2018; Accepted 20 February 2018
Available online 24 February 2018

with alpha or beta power at rest are controversial: Several studies reported alpha power decreases with increasing age in general ([25,26] for reviews) or specific to the parietal and occipital area [27]. Others claimed that alpha power is diminished only in cognitively declined older adults ([28,29] for reviews) and revealed no decline in alpha power in healthy older adults [21,30–33].

Alpha power reflects oscillating activity of thalamic neurons in absence of sensorimotor information, and is defined as the dominant rhythm on the human cortex during a relaxed awake state [34]. Furthermore, alpha oscillations are thought to indicate a state of active inhibition and attentional readiness, and are linked to cognition and memory [28,35]. Especially in the frontal cortex, alpha oscillations seem to reflect cognitive top-down processes [36,37].

Relative to alpha, the origin and functional meaning of beta oscillations is less well understood. Beta oscillations occur during an awake state and are usually related to sensorimotor behavior, top-down processing, long-range communication, and preservation of the current brain state [15,38]. Several studies demonstrated higher beta power at rest in older than young adults in general [33], or specifically in central [21,24,32] or occipital regions [32]. Only one study reported no difference between young and older adults in beta power in any brain area [27]. However, the functional role of a potential age-related beta increase has not yet been determined. Taken together, these diverse findings require one to control for possible age-related power differences at rest when conducting TRPow analyses in aging studies.

Furthermore, older adults seem to reveal de-lateralization of brain activation (i.e., a less focused and more homogenous activation over both hemispheres), when compared to young adults, for example in motor areas during finger/key pressing tasks [20,39] or FM tasks [40]. This is also a common finding in cognitive aging research in prefrontal ([41,43] for reviews) and parietal areas [41–44], leading to the HAROLD (hemispheric asymmetry reduction in older adults) theory of aging [41,45].

Besides reduced lateralization, cognitive aging research also discusses a posterior-to-anterior shift in aging (PASA) [46], referring to a decrease in posterior activity combined with an increase in frontal activity in older adults (named frontality in the following). Accordingly, older adults revealed reduced event-related alpha desynchronization (ERD) over the parietal cortex relative to young adults [47]. Due to enhanced cognitive load during FM tasks in older adults [7,8], increased lateralization and frontality might also be reflected in alpha and beta power during FM tasks.

Activation (i.e., TRPow decrease) in the beta band over the contralateral sensorimotor cortex was associated with better motor performance in young and older adults [21]. Graziadio et al. [48] reported the same association for alpha (mu), but restricted to the age group of older adults. Others, however, reported no association between alpha/beta TRPow and behavioral performance in (visuo)motor tasks for young adults [13,24,39] or did not relate electrophysiological to behavioral data.

The aim of the current study was to investigate the association of age with fine motor control, EEG power at rest as well as TRPow during a precision grip FM task. In line with earlier studies, we hypothesized diminished fine motor control in older adults compared to young adults. Regarding EEG power at rest, we expected no difference in alpha power between young and older adults, but higher beta power in older than young adults. We further hypothesized that older adults revealed stronger alpha and beta TRPow decreases than young adults indicating enhanced active task processing. This stronger decrease may be a function of potential age-related differences of alpha or beta oscillations at rest. Due to heterogonous findings with respect to particular brain areas, we further examined whether possible age differences were consistent across brain regions of interest (frontal, central, parietal, and occipital, for rest and TRPow separately). Furthermore, based on findings from cognitive aging literature, we assumed that older adults should reveal less lateralization in frontal, central and parietal areas as well as a more pronounced frontality than young adults. Finally, we assumed higher activity (i.e., higher TRPow decreases) in the contralateral sensorimotor cortex to be associated with better FM performance.

2. Method

2.1. Participants

In total, 88 women took part in the study, subdivided with respect to their age in 55 older adults (OA) between 67 and 83 years of age ($M = 74.51$, $SD = 4.25$) and 33 young adults (YA) between 19 and 29 years of age ($M = 22.97$, $SD = 2.76$). All OA participated in a previous study of our research group, 18 months earlier. They agreed to store their contact data in a participant database, so that they were re-recruited via phone. YA were recruited with flyers and mailing lists of two local universities. The study was approved by the Faculty of Humanities of Saarland University (4.3.13). All participants took part voluntarily in the study and provided informed consent about general study information and EEG testing.

Furthermore, they completed a questionnaire assessing demographic information, health status and physical activity level (adapted version of the Baecke Physical Activity Questionnaire) [49], the Edinburgh handedness questionnaire to determine hand dominance [50] as well as a questionnaire to determine subjective hand use [51]. OA were screened for dementia by use of the Montreal Cognitive Assessment test (MoCA) [52] with a cutoff < 23 [53]. Also participants with a low MoCA score of 23 or 24 performed the FM task within a normal range, i.e., no trials of these participants were regarded as outlier. Furthermore, there was no significant association between performance in the FM task and MoCA score ($r = -.175$, $p = .250$), so that they were included in the analyses. Clinical manual dexterity was assessed using the Purdue Pegboard test (Purdue Pegboard test, model 32020, Lafayette Instruments, Lafayette, IN, USA) [54]. The mean number of pins placed with the dominant hand was calculated. YA revealed a significantly better performance than OA (see Table 1). OA received 6 € per hour as monetary compensation, YA got chocolate as well as an analysis of their cardiorespiratory fitness.

Several participants had to be excluded from data analysis as they did not meet the inclusion criteria (left-handers: n = 2 YA; MoCA score < 23: n = 4 OA) or due to technical problems with the EEG (n = 6 YA, n = 6 OA). Therefore, 45 OA between 67 and 83 years of age ($M = 74.73$, $SD = 4.39$ years of age, all female and right-handed) and 25 YA between 20 and 28 years of age ($M = 23.24$, $SD = 2.47$ years of age, all female and right-handed) were included in the analyses.

Table 1
Participant characteristics of young (YA) and older adults (OA).

	YA (n = 25)		OA (n = 45)				
	M	*SD*	*M*	*SD*	*F*(1, 68)	*p*	η^2
Age	23.24	2.47	74.73	4.39	2911.29	< .001*	.98
Education	16.36	1.94	12.90	2.59	34.02	< .001*	.33
Subj. health	3.88	0.78	3.71	0.70	0.87	.355	.01
MoCA	–	–	26.38	2.14	–	–	–
Subj. hand usage	17.88	2.92	16.69	5.33	1.07	.306	.02
Manual dexterity	16.44	1.42	13.04	1.30	102.85	< .001*	.60
MVC	45.97	12.79	39.20	9.27	6.51	.013*	.09

Note. *YA* = young adults; *OA* = older adults; *Age* = age in years; *Education* = years of education; *Subj. health* = self-rated health status in a Likert scale from 1 (poor) to 5 (excellent); *MoCA* = sum score of the Montreal Cognitive Assessment; *Subj. hand usage* = self-reported hand use (sum score of 9 items, 5-point scale); *Manual dexterity* = Purdue Pegboard test, mean score of three trials with the right hand; *MVC* = maximum voluntary contraction of index finger and thumb with the right hand, maximal value out of three trials.

* = Significant effect ($p < .05$).