BILATERAL FUNCTIONAL CONNECTIVITY FOR COMPLEX FINGER MOVEMENTS DECLINES AS AGING: AN FMRI AND SEM EXPLORATION

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Purpose: In daily activities, it is essential to coordinate one's finger movements in tune with visual information from the environment, namely, a kind of visuo-motor coordination. Recent neuroimaging investigations utilizing structural equation modeling (SEM) suggest necessity of functional connectivity within motor cortices for the successful visuo-motor coordination.[1-3] Whereas these studies have targeted younger adults, it is also assumed that the elderly's decline in bimanual finger movements derives from age-related differences of the functional connectivity, as well as that of activation in each region itself. The present study attempted to seek age-related declines of functional connectivity within the motor cortices, with particular focus on the effect of movement complexity. To address this objective, we utilized fMRI and SEM to compare neural activity between younger and elderly groups during the visually-guided bimanual finger movement task with easier in-phase (symmetrical) mode and complex anti-phase (asymmetrical) one.

Methods: Twenty healthy right-handed younger adults (10 males, age 25±6) and 20 healthy right-handed elderly adults (11 males, age 68±4) participated in the experiment on a 3T MR scanner (Siemens Trio/Tim) in accordance with the local ethics regulations. *Data acquisition*: The in-phase (symmetrical) and anti-phase (asymmetrical) modes of bimanual multiple finger movement task were administered in tune with visual pacing cues. In addition, in order to seek salient behavioral age differences which will be selected for SEM, we set the pacing cues for both of the modes at three levels of 1.0, 1.5 and 2.0 Hz frequencies. The task included 3 runs, each of which consisted of alternating blocks of rest (9 blocks lasting 20 seconds each) and visual cue presentations for the two kinds of mode (8 blocks lasting 20 seconds each). The 3 runs differed in the pacing cue frequency. As for fMRI data, T2* weighted GRE-EPI sequences were acquired with the following parameters: TE = 30 ms, TR = 3000 ms, flip angle = 90°, matrix 64 × 64, field of view = 192 mm, 39 axial slices, slice thickness = 3mm, and distance factor = 25%. We also acquired a three-dimensional MPRAGE high-resolution T1-weighted image for anatomical detail. *fMRI data analysis*: First-level contrasts for each condition of the task were entered into second-level, random effects analyses of variance (ANOVA) on the basis of the general linear model (GLM) with SPM 8 (Wellcome Department of Cognitive Neurology, London, UK). *Functional connectivity analysis with SEM*: Following a previous SEM study of bimanual finger movement[2], we specified 10 a priori ROIs (regions of interest) in bilateral primary motor area (M1), bilateral supplementary motor area (SMA), bilateral dorsal premotor area (PMd), bilateral primary somatosensory motor area (S1), and bilateral superior parietal lobule (SPL). The parameter estimates of the ROIs were extracted and adopted as observed variables of SEM. AMOS ver. 21J (SPSS, Chicago, IL, the USA) was used for the analysis.

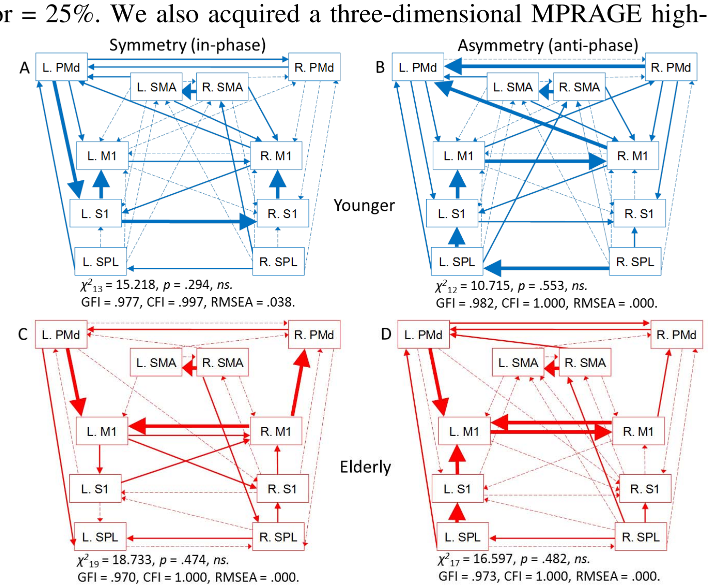

Fig. 1. Models for functional connectivity among the a priori 10 ROIs within motor cortices during the bimanual multiple finger movement task on the symmetrical and asymmetrical modes with 1.5Hz frequent visual pacing cues by younger (n = 20) and elderly (n = 20) groups. The ROIs applied to SEM as observed variables are presented in rectangles. Measurement error terms are not shown. Goodness-of-fit indices are presented below the models (all meet the conventional requirements). MNI coordinates of centers of the ROIs are as follows: M1, ±32, -32, 65; S1, ±33, -37, 68; PMd, ±37, -16, 54, SMA, ±6, -3, 60; SPL, ±33, -45, 59. The thickness of the arrows represents the absolute magnitude of standardized path coefficients (β) among the mean parameter estimates of the ROIs as follows: ↑ >0.6 ↑ <0.6>0.3 ↑ < 0.3.

Results: As behavioral data indicated salient age differences at 1.5Hz pacing cue frequency, fMRI data at the 1.5Hz pacing frequency was utilized for SEM of the a priori 10 ROIs within motor cortices. The SEM provided adequate fits between our data and each of the assumed models for the symmetrical and asymmetrical modes by younger and elderly groups (Fig.1). Younger group's asymmetrical mode (model B, Fig.1), compared with the symmetrical one (model A), exhibited increased bilateral connectivity within PMd, M1, and SPL as revealed in the thick arrows (β > .06). Contrarily, elderly group did not show such increased bilateral connectivity when compared the asymmetrical mode (model D) with the symmetrical one (model C), although a strong bidirectional connectivity was found within bilateral M1.

Discussion and conclusion: The present fMRI and SEM exploration detected age-related declines in functional connectivity within bilateral PMd and that between bilateral SPL during the visually-guided bimanual finger movement task with the complex anti-phase (asymmetry) mode. It is considered that PMd reflects motor planning before its execution[4], while SPL is crucial for visio-motor control that involves updating ongoing hand location in space[5]. The elderly adults presumably suffer a decline in such an optimization process of visuo-motor coordination, resulting in their inaccuracy of the complex bimanual finger movements.

References: [1] Rowe et al. 2006, NeuroImage 61, 464-477. [2] Walsh et al. 2008, NeuroImage 43, 540-553. [3] Zhuang et al. 2005, NeuroImage 25, 462-470. [4] Churchland et al. 2006, J. NeuroSci 26, 3697-3712. [5] Granek et al. 2012, PLoS ONE 7 e46619.