The Effect of Behavioral Performance during Multistep Cognitive Processing on the Extraction of Age-Related Changes from Resting State Network Activation

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Introduction

Age-related changes of brain activation may be observed, even if no behavioral performance difference was observed between elderly and young subjects. It has been reported that the activities of resting state networks (RSN), are also affected by aging (Andrews-Hanna JR, 2007; Chen ASH, 2013) and the decrease of default mode network (DMN) connectivity is correlated with structural and cognitive decline (Vidal-Pineiro D, 2014). In comparison with young subjects, the inclusion of a population of elderly subjects will provide more variability and heterogeneity due to differences in physical and cognitive ability. This will allow us to understand the dynamics of age- related cognitive changes based on this variability. Therefore, a pertinent question here would be to identify a good index with more specific RSN map corresponding to the neurological target of interest in the elderly. In this study, we investigated the potential of applying two different phases of behavioral performance data, which were obtained from one complex task. A virtual performance of object transfer using turnkeys was employed as the reference to evaluate the RSN. Based on the task demands, we focused on the RSNs of DMN and sensorimotor (SMN) network.

Material and Methods

Functional imaging data were obtained from 24 elderly (61 -75, 12 females) and 23 young (20 - 36, 12 females) healthy volunteers who gave written informed consent approved by the institutional IRB. Functional imaging data was acquired on a 3T-MRI scanner using a T2*-weighted GRE-EPI sequence (TR = 3000 ms, TE = 30 ms, FA = 90 deg, 39 axial slices, 3 mm thick, 0.75 mm gap, matrix = 64 x 64, FOV = 192 mm). Subjects kept their eyes open during the 7 minutes' RSN imaging session. The functional images were pre-processed with SPM8 and the RSN analysis was performed using GIFT toolbox and 25 independent components (ICs) were obtained (Infomax / ICCASO). The resultant T-statistics maps for each subject were imported to SPM8 for 2nd level analysis (random effect model) using SPM8 ($p<0.001$, uncorrected). Components of interest were identified from the 25 ICs by spatial correlation with Shirer's template (Shirer RW, 2011). Behavioral data from another fMRI session in the same experiment [1] were used as covariates. The task, virtual bean transfer test (VBTT), was modified from the bean transfer test (BTT), a subtest of the physical test protocols for elderly in Japan (Shigematsu R, 2001). This consisted of three operations; 1) a small, round object (a bean) on the left side of the monitor is clipped with two sticks representing chopsticks, 2) the object with chopsticks is moved to a round target (pot) on the right side, 3) it is dropped into the target. The success rate of clipping and transfer throughout the session was obtained for each subject as an index representing difficulty of task performance, and introduced as the covariates for the 2nd level (group) analysis of RSN.

Results

The correlation ratios between the success rate of clipping and that of transfer operation were $r = 0.56$ in the elderly, $r = 0.71$ in young and $r = 0.63$ in the whole subjects group, suggesting that these two operations may partially share the same neuronal basis. Nineteen ICs among the 25 were assigned to be RSN components and of which dorsal DMN (IC9, IC14), ventral DMN (IC17) and SMN (IC2) RSNs were selected for further analyses.. By introducing the success rates of these two operations as covariates, the following differences were detected. IC9 (Fig.1): left caudate head (x y z = [5 17 -1], T = 5.5, k = 255) by clipping covariate (CC); left BA7 ([-11 -49 54], 4.8, 226) by transfer covariate (TC) in the contrast of elderly – young (E-Y). Left caudate body ([-2 8 8], 4.4, 56) by TC, but no significant differences by CC for the contrast of young – elderly (Y-E). IC17: left BA40 ([-48 -47 51], 6.1, 284) and left Putamen ([-21 1 11], 4.7, 158) by CC; left caudate body ([-12 -5 21], 5.2, 175) and right caudate tail ([23 -25 22], 4.5, 162) in E-Y. Right BA7 ([5 -46 62], 4.4, 277) by CC; left BA7 ([-21 -64 41], 4.7, 277) by TC in Y-E. IC2 (sensory motor network): right caudate head ([5 18 1], 4.6, 63) and right BA6 ([62 -14 44], 4.1, 119) by CC; right BA31 ([15 -53 36], 4.8, 415) and right BA33 ([6 13 23], 4.5, 342) by TC in Y-E. Right BA39 ([50 -58 14], 4.5, 92) and right Putamen ([24 16 -5], 4.4, 119) by CC; left BA3 ([-20 -31 50], 5.7, 2404) and right BA4 ([26 -24 47], 4.9, 877) by TC in Y-E. However, no significant differences were detected by any covariate or contrast in IC14 (posterior DMN).

Discussion and Conclusion

The DMN and sensory motor network were targeted in this analysis, since the task performance included motor imaginary of the actual movements to hit the turnkeys for operation. The age-related decline observed in the DMN and increase in SMN was compatible with previous findings (Chen ASH, 2013). By introducing covariates representing performance level of different cognitive steps but continuously performed towards one goal, age-related change of RSN activity could be differently characterized in several nodes, although such difference was not detected in the posterior node of DMN. The latter observation may be related to the specific property of this elderly sample wherethe members are more healthy and active in the community then the general elderly population. Although this study was retrospective correlation between the performance level of the subjects and age-related changes of RSN activity, it may potentially suggest that classification of RSN activities in the elderly reflects the performance level of the subjects.

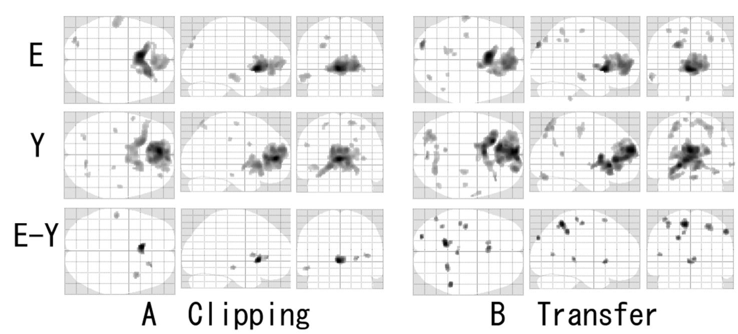

Fig.1 The contrasts of elderly (E) and young subjects (Y), and their difference (E=Y) obtained using an ANCOVA. Covariates of success rate of clipping the object (A) or transferring it to the target (B) were introduced.

[1] Nakai T et al., Neuro Informatics 2014, Leiden, doi: 10.3389/conf.fninf.2014.18.00012