Age-related differences of brain activation patterns upon imaginary walking

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Introduction:

In elderly people the steadiness of walking decreases with advancing age while the probability of falls increases. Since some neuronal diseases, e.g. Parkinson or Normal Pressure Hydrocephalus (NPH), primarily affect the elderly we became interested whether or not fMRI-detectable patterns of brain activity due to walking or imaginated walking do change with age or remain constant irrespective of lifetime. Two groups of volunteers - healthy young and healthy elderly - were asked to execute imaginary walking tasks while measuring the BOLD response with fMRI. These imaginary walking tasks had been trained just before. In order to assess the cooperativeness of the volunteer, a well observable foot-movement task and its imaginary equivalent were added to the task list.

Methods:

Functional MRI was performed on 10 young (m/f=3/7, mean age=32.3±3.8y) and 9 elderly subjects (m/f= 6/3, mean age= 65.6±5.5years). Immediately before MR scanning, subjects were asked to walk with closed eyes (i) freely and (ii) guided by a supporter for about 40m. Subsequently in the magnet, they were instructed to perform notionally the following tasks: (A) move the right foot; (B) imagine moving the right foot; (C) imagine walking freely and (D) imagine guided walking as trained just before. Task and rest periods lasted 15 seconds. During the course of one run, each task was repeated five times. Younger subjects performed one run, whereas elderly subjects performed two runs (11min). Individual brain morphology was obtained by T1-weighted structural data sets (3D-MPRAGE, 1x1x1mm voxel size). Measurements were performed at 3T on a Siemens head scanner (Allegra; Siemens, Erlangen/Germany) with a conventional EPI-sequence covering the whole brain (TE/TR=30/2600 ms, 64x64 matrix, 45 slices, 3x3x3mm voxel size). Data were preprocessed (realignment, normalization to standard MNI-template, 8 mm spatial smoothing) and analyzed with SPM5 [1]. Artifacts in individual slices and in volumes due to larger (>0.7mm) head movements were removed by interpolation using the ArtRepair toolbox [2]. Statistical maps of brain activation were calculated for all conditions separately. However, in this work both imaginary walking conditions (i.e. C+D) were averaged together. Differences between younger and elderly subjects were assessed by an interaction analysis for age groups (ANOVA).

Results:

Imaginary walking caused different activation patterns for young (Fig. 1a) as compared to elderly (Fig. 1b) subjects: Young and old subjects exhibit positive BOLD signal changes in the following areas: pre- and supplementary motor cortices, cerebellum, putamen, inferior frontal gyrus and inferior parietal gyrus. As compared to young subjects, elderly subjects exhibited generally not only larger areas (see Fig. 1a&b) but also better agreements with the used model functions. This is most obvious in the inferior parietal lobules, especially on the left, where the threshold for FWE correction was undercut (see arrows in Figs 1b&c). Another difference between young and old subjects is that areas exhibiting negative BOLD signal changes (i.e. medial fronto-polar, superior temporal gyrus, posterior cingulate and precuneus) during imagined walking tasks were almost exclusively observed in younger subjects (Fig. 1a). The interaction analysis for age (Fig 1c) reveals significant differences between both groups regarding the areas with positive, but not for those areas with negative BOLD signal changes.

Discussion and Conclusions:

Larger positive BOLD signal changes in elderly, previously described as 'age-related overaction' [3] mainly for memory and other higher cognitive functions, has been demonstrated in this study for motor tasks. Furthermore, areas exhibiting negative BOLD signal changes have been associated with the default mode brain network which is more prominent in younger than in older subjects [4]. Most strikingly, however, is the strong 'activation' in the elderly of the inferior parietal lobule (IPL, arrows in Fig 1b&c), a region which is considered to contribute to spatial attention and multimodal sensory integration [5-7]. Although it is very intriguing to interpret our observations as 'age-related overaction' [3] to the control of eye and limb movements [7-9], this has to be corroborated with more detailed data.

References:

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Fig. 1: BOLD signal changes upon imaginated walking. Warm colors = positive, cold = negative BOLD signal. Threshold: $p<0.001$
a) Younger subjects (T-test: task > baseline) **b)** Elderly subjects (T-test: task > baseline) **c)** Difference between young and elderly. Warm colors = elderly > young (T-test: positive effect of age). Arrows indicate p-Values below FWE threshold