Head Motion During fMRI in a Longitudinal Stroke Recovery Study

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Despite many advances, motion artifacts remain a serious problem in fMRI of some clinical populations. To characterize head motion in stroke patients, retrospective motion estimates were examined from the fMRI sessions of a large, ongoing longitudinal study of somatosensory and motor recovery. Preliminary results suggest age, low motor function, and fMRI inexperience may be associated with increased motion. A significant interaction was also observed between functional task type and the side of the body examined. As the longitudinal study unfolds, this analysis will be used to guide task design, monitor data quality, and select candidates for fMRI.

Introduction

Head motion artifacts can obscure the small intensity changes that are used to infer neuronal activation, frequently leading to fMRI examination failure [1]. Motion is especially problematic in recovering stroke patients who are often elderly and have sensorimotor deficits resulting from brain lesions. In a longitudinal stroke recovery study currently involving more than 125 patients, functional tasks, assistive aids, and behavioural measurement devices are being designed to minimize task-correlated head motion. To guide and evaluate this effort, motion estimates used for retrospective functional image correction were examined for a subset of these patients. The summarized motion estimates were compared with patient characteristics (session number, Chedoke-McMaster Stroke Assessment arm or hand motor function score, age, time since stroke) and task parameters (task side = affected side, task side = dominant side, sensory or motor task).

Methods

Functional MRI data were available for 35 patients (13 female, 22 male; mean age 60.1 years at first visit) out of an initial cohort of 57 patients. For these patients, the data from about 43 fMRI runs were incomplete, leaving 268 runs available for analysis. All studies used a 1.5 T Signa scanner and quadrature birdcage head coil (G.E. Medical Systems, Milwaukee, WI). A single-shot spiral sequence was used for fMRI, with TE/TR/flip angle = 40 ms/2000 or 1500 ms/80 degrees, matrix 64 x 64, FOV 20 cm, slice thickness 5 mm, and 26 slices. Most runs were either 308 or 315 s long and involved a manual somatosensory (vibrotactile) or motor (gripping) task in a 20 or 30 s on/off block design. After reconstruction, data were motion-corrected by AFNI software [2] that employs an iterative least squares fitting algorithm to estimate motion [3].

These motion estimates were normalized, linearly interpolated to a common 500 ms time base, and trimmed to 288 s starting at 18 s into the run to allow time for magnetization equilibration. To quantify motion in each run, the sample standard deviation was calculated after linear detrending of each motion component. These values were log-transformed to account for positive skewness and kurtosis before outlier screening by recursive removal of runs containing any one rotation or displacement statistic greater than four standard deviations from the mean for that statistic. Finally, the transformed, screened motion data were merged with patient characteristics and task parameters for analysis with the partial correlation and multivariate general linear model (GLM) modules of the SPSS statistical analysis software (SPSS, Chicago). An initial multivariate GLM was performed with a full factorial design in the fixed variables (Side is Affected, Side is Dominant, Task Type) and the remaining predictors (Patient ID, Session Number, CMSA Motor Function Score, Age, Days Post-Stroke) entered as covariates.

Results

Outlier screening removed two runs, both belonging to the same person (male), leaving 266 runs and 34 patients for analysis. The outliers had unusually high motion in all directions but contained especially large amounts of L-R axis rotation and I-S axis displacement (consistent with nodding). A partial correlation controlling for patient ID revealed marginally significant correlations between age and I-S axis rotation, $r(58) = .21$, $p = .08$; age and L-R displacement, $r(58) = .23$, $p = .06$; age and A-P displacement, $r(58) = .21$, $p = .08$; motor function score and A-P displacement, $r(58) = -.23$, $p = .06$; and session number and A-P displacement, $r(58) = -.21$, $p = .08$. The multivariate GLM revealed a significant main effect of Age, $F(6, 52) = 2.45$, $p = .04$, and a significant Side is Affected x Side is Dominant interaction, $F(52, 6) = 4.07$, $p = .002$, qualified by a Side is Affected x Side is Dominant x Task Type interaction, $F(52, 6) = 3.27$, $p = .008$. This three-way interaction is illustrated in Figure 1 with plots of the log-transformed standard deviation of detrended A-P displacement marginal means.

Discussion

The results, although preliminary, suggest that head motion during an fMRI study is linked to patient characteristics and task parameters. Both the GLM analysis and the partial correlation indicated that older patients moved more than younger patients. Additionally, patients may have moved slightly more if they had low motor function and little fMRI experience (number of sessions). The significant three-way interaction in the GLM analysis is intriguing: During somatosensory tasks, motion was greater when stimuli occurred on the dominant versus the nondominant side if that *was not* the affected side, while motion was less when stimuli occurred on the dominant versus the nondominant side if that *was* the affected side. During motor tasks, this pattern was essentially reversed. Perhaps most importantly, however, the range of motion seen in most runs was small enough that current motion correction algorithms should perform adequately (added in quadrature, the mean range was .72° and .55 mm, standard deviation .60° and .41 mm, respectively; see Figure 2).

Further work is needed to characterize correlates and patterns of motion in fMRI subjects, including expansion of this analysis to all stroke patients in the study. However, these results show that extra care is needed when studying elderly and impaired patients. One possibility is to build fMRI experience with practice sessions in a simulator prior to a real fMRI study. Our laboratory is exploring the use of such a simulator as well as more sophisticated motion data analysis techniques.

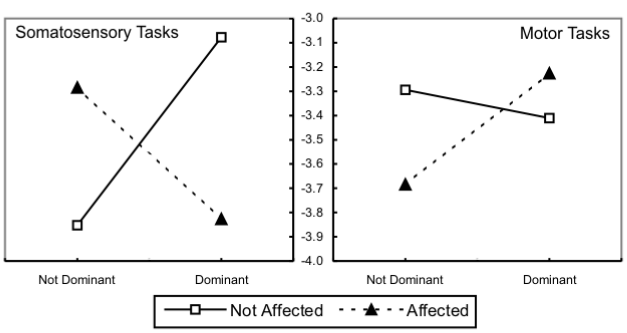

Figure 1. Marginal means of log-transformed A-P displacement SD for somatosensory and motor tasks.

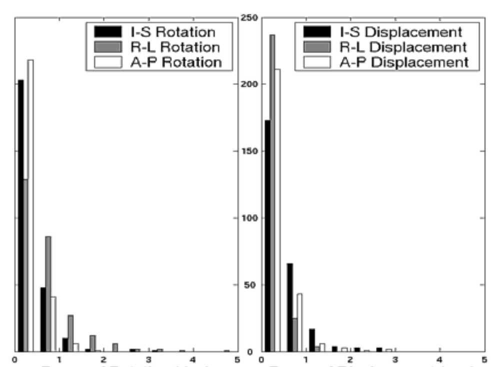

Figure 2. Histogram of range of motion (rotation and displacement in three axes).

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