Quantitative evaluation of prospective motion correction for various marker fixations

Nicolas Pannetier[1,3], Theano Stavrinos[1,3], Peter Ng[1,3], Michael Herbst[2], Maxim Zaitsev[2], Gerald Matson[1,3], Norbert Schuff[1,3]
[1] *Department of Radiology and Biomedical Imaging, University of California San Francisco, San Francisco, CA, USA*
[2] *Department of Radiology, University Medical Center Freiburg, Freiburg, Germany*
[3] *Centre for Imaging of Neurodegenerative Diseases, Veteran Affairs Medical Centre, San Francisco, CA, United States*
nicolas.pannetier@gmail.com

Aim: To investigate different marker fixation systems and evaluate their impact on the performance of a prospective motion-correction system.

Background: Motion during MR imaging of the brain remains one of the leading sources of image degradation and artifacts. Prospective motion correction overcomes this issue by updating the MRI system in real time according to the motion of the subject in the scanner. The motion is tracked by a device that records the position of a marker attached rigidly to the patient's head. Promising results have been obtained recently[1]. However, results are sensitive to the position of the marker. Furthermore, finding a sensitive metric for quantifying the effectiveness of the correction has been elusive. In this work, we evaluate two fixation techniques and we propose a quantitative approach to compare effectiveness of motion correction.

Methods: Five healthy subjects underwent 3T MRI high-resolution imaging (3T Siemens Skyra, MPRAGE, .7mm isotropic, 2 Averages, Time scan: 19min). The high-resolution and the long time scan assured a high sensitivity to motion artifacts. The subjects were asked to remain still throughout the experiment time. An MRI-compatible motion tracking system[2] and the XPACE library was used for prospective motion correction[3]. The same protocol was repeated with 3 different tracking configurations: the motion tracking off (NoMPT), the motion tracking on with the marker attached to the nose bridge (NoseBridge) (Fig.A) and the motion tracking on with the marker attached to the mouth guard (MouthGuard) (Fig.A). The same MRI protocol was acquired on a static phantom with the motion reproduced artificially by uploading the tracking files recorded during the in vivo scans as introduced in Herbst et al[4]. To evaluate the image quality, two indexes of image quality were investigated: 1) Edge strength[5] to quantify image clarity, 2) Entropy of intensity co-occurrence (Haralick texture features[6]) to measure image texture. To avoid corruption of intrinsic motions (neck, mouth), the analysis was limited to brain regions only (FSL Brain Extraction and subsequent manual corrections). The NoMPT, NoseBridge and MouthGuard images were compared by computing the mean of the edge strength. To further compare the two fixation systems, the Kullback-Leibler divergence (D_{KL}), a statistical measure for comparing distributions, was used to quantify differences in edge strength distributions between the corrections using the MouthGuard or NoseBridge within the same subject. To account for the possibility that improvements simply occurred because subjects moved less with one or the other placement, variations captured in the phantom data vs a motionless image of the phantom were used as reference in the D_{KL} analysis. The same analysis strategy was also used to evaluate entropy of the image intensity co-occurrences.

Results: Qualitative inspection of the images shows that the MouthGuard outperforms the NoseBridge fixation system (Fig. BC). Specifically, the images appear sharper at the white/gray matter boundaries and finer structures can be detected (e.g. meninges layers). This trend is confirmed quantitatively in the evolution of the mean of the edge strength (Fig. D). In every subject, the motion correction increases the mean edge strength and the largest improvement is observed with the MouthGuard fixation system whereas the NoseBridge performs only slightly better than without correction. This trend is unlikely related to a reduction in the motion when using the MouthGuard as shown when using D_{KL} of the phantom data as reference. (Fig. E). In 4 subjects out of 5, even though the amplitude of the motion was greater during the MouthGuard scan than during the NoseBridge scan (D_{KL}(fixation||reference)), the MouthGuard system still produces the best image quality. The same trend was found for the entropy of the 3d co-occurrence matrix.

Conclusion: These results demonstrate that the motion tracking clearly benefit the image quality even in healthy subjects used to undergo MRI scans and to remain immobile. In all instances, the best image quality was obtained using the MouthGuard system. The inferiority of the NoseBridge is probably related to complications with interfering motions such as wrinkling or sneezing that create marker motion independent of head motion. No discomfort with the MouthGuard system was noticed, however further investigations are required on a larger and more diverse population. In conclusion, the MouthGuard setup currently appears as an efficient system to provide motion free images that could clearly benefit clinical protocol in motion sensitive population such as elderly and young.

References: 1 Maclaren J et al. MRM 2013, 1;69(3):621-36. 2 Maclaren J et al. PLoS ONE 2012; 7:e48088. 3 Zaitsev M et al., Neuroimage 2006; 31:1038-1050. 4 Herbst M. et al., MRM 2013, e24645. 5 Aksoy M. et al., MRM 2012, 64:1237-1251. 6 Haralick R. Proc. of the IEEE 1979, 64:5 786-809.

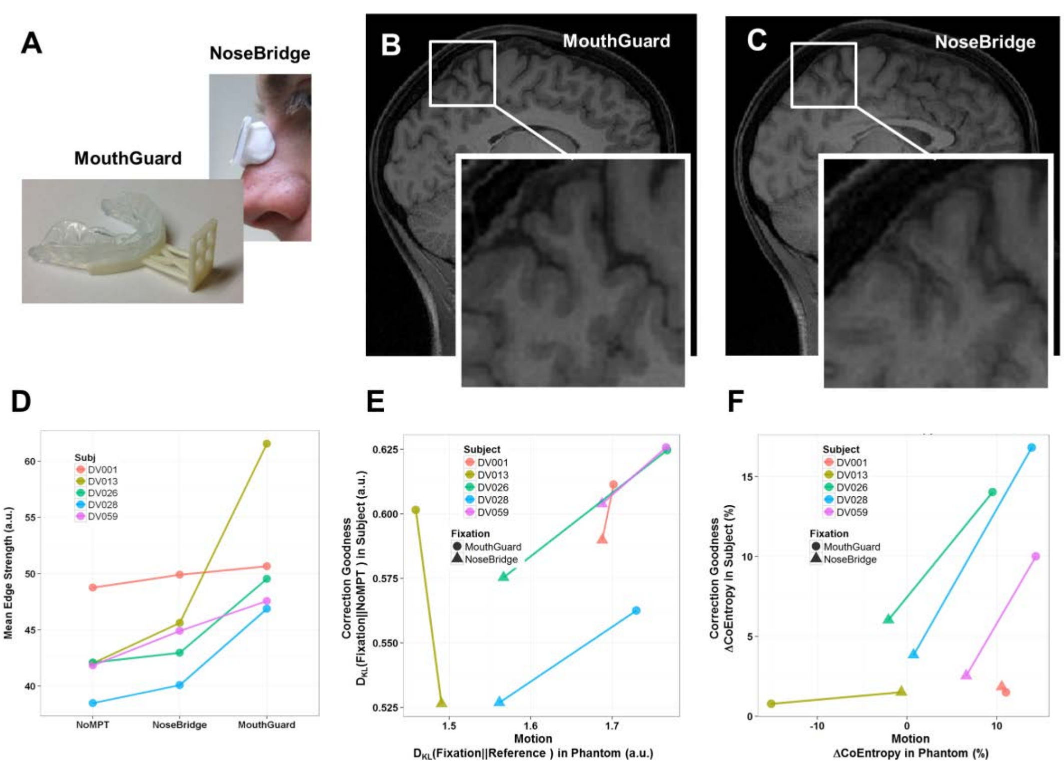

Figure. A) Illustration of the fixation systems. BC) Example of MPRAGE images acquired with the MouthGuard and NoseBridge. D) Evolution of the mean edge strength *vs* fixation systems and subjects. E) Kulback-Leibler divergence between fixation systems and NoMPT in Subject vs in Phantom. F) Variation of the entropy of the co-occurrence matrix between fixation systems and NoMPT in Subject vs in Phantom.