Quantitative evaluation of two marker fixation systems for prospective motion correction

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Purpose: To investigate two different marker fixation systems and to evaluate their performance in a prospective motion-correction MRI setup.

Background: Motion in magnetic resonance imaging remains one of the main sources of image degradation. Motion correction overcomes this problem by updating the MRI system in real time according to the movement of the subject in the scanner. The movement is followed by a device which detects the position of a marker attached rigidly to the patient's head. For few years, promising results are obtained[1]. However, the results are sensitive to the marker position and finding a sensitive measure to quantify the effectiveness of the correction has been elusive. In this work, we evaluate two fixation techniques and we propose a quantitative approach to compare the effectiveness of motion correction.

Methods: Five healthy subjects were scanned at 3T with T1w MRI imaging (3T Siemens Skyra, MPRAGE, .7mm isotropic, 2 Averages, 19min). The high-resolution and the long scanning time increased the sensitivity to motion artifacts. The subjects were asked to remain still. A motion tracking system[2] and the XPACE library were used for prospective motion correction[3]. The same protocol was repeated with 3 different configurations: no correction (NoMPT), correction with the marker attached to the nose bridge (NoseBridge) and correction 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[4]. To evaluate the image quality, two indexes were investigated: 1) Edge strength[5] (ES) to quantify image clarity, 2) Entropy of intensity co-occurrence (Haralick 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). The NoMPT, NoseBridge and MouthGuard images were compared by computing the mean of the ES. To further compare the 2 fixation systems, the Kullback-Leibler divergence (D_{KL}), a statistical measure for comparing distributions, was used to quantify differences in ES 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 marker positions, 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 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 ES (Fig. D). In every subject, the motion correction increases the mean ES 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 benefits the image quality even in healthy subjects used to remain immobile in MRI scanners. 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.

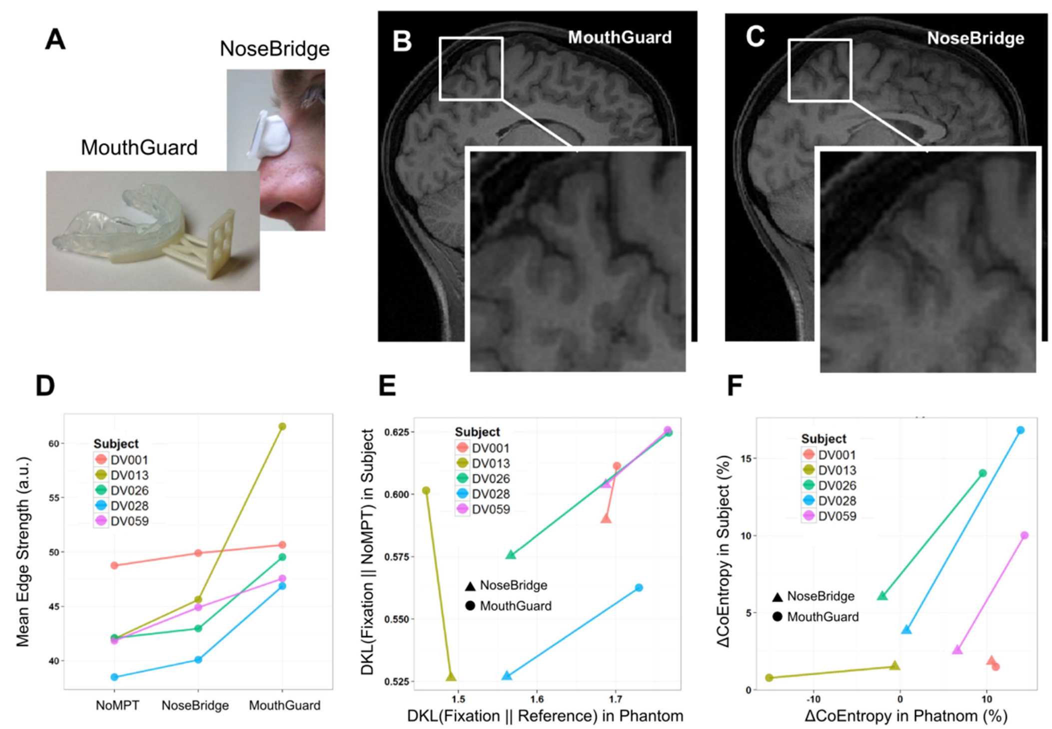

Figure. A) Illustration of the fixation systems. BC) Example of MPRAGE images acquired with the MouthGuard and NoseBridge. D) Evolution of the mean edge strength *vs* fixation systems. Colors code for different subjects. E) D_{KL} between fixation systems and NoMPT in Subject vs D_{KL} between reproduced motions and reference image in phantom. F) Variation of the entropy of the co-occurrence matrix between fixation systems and NoMPT in Subject vs in Phantom.