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A compatibility test for tactile displays designed for fMRI studies

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Abstract. The purpose of this document is to provide a compatibility test for mechatronic devices to be used within a diagnostic MR environment. In order to design new devices that can produce tactile stimuli of different nature inside the MRI environment, compatibility tests with several materials and mechatronic devices are reported. Results of these experiments are analyzed in order to evaluate artefacts caused by the presence and actuation of the devices.

1 Introduction

Functional brain exploration methodologies, such as functional Magnetic Resonance Imaging (fMRI), are at present used to study perceptual and cognitive processes. To develop more complex experimental fMRI paradigm, researchers are interested in realizing active interfaces, using electrically powered actuators and sensors to be used inside the MRI environment. The use of non-ferromagnetic metals with higher stiffness and rigidity compared to plastic facilitates the design of smaller devices [1]. Several reports provide criteria for MR compatible devices [2]. In this work we propose a method for MR compatibility testing by using gradient echo sequences that are often employed in fMRI studies. These sequences are sensitive to inhomogeneities of the magnetic field caused by devices located in the scanner bore or within the scanner room. We suggest a t-test on image sequences between different experimental conditions in order to evaluate changes in SNR values and time domain standard deviations.

2 Materials and Methods

Three non-ferromagnetic metals and two types of active motors were examined during MR image acquisition (Signa Horizon 1.5T, GE Medical Systems). We used cylindrical hollow tubes from three different materials (aluminium, brass, copper). Then we examined two types of servo motors: a DC motor and an ultrasonic motor (piezo-motor, D6060, Shinsei Corp., Japan). Moreover, we tested a shielded cable that is intended to be used with a linear potentiometer. Across all experiments, we scanned a spherical phantom of $CuSO_4$ solution, using a GE-EPI (gradient echo, eco planar imaging) with the following parameters: TE/TR 40/3000 msec, bandwidth 62.5 kHz, FOV 24 cm, resolution 64x64 pixels, Flip angle 90°, Slice thickness 5 mm, number of slices 25, 25 volumes acquired. The Signal to Noise Ratio (SNR):

$$SNR = Pcentre / SDcorner \quad (1)$$

[Pcentre: mean value of a 11x11 pixels area at the centre of the image, and SDcorner: standard deviation of a 10x10 pixels area at the higher right corner [3]], and the standard deviation (SD) of each voxel signal in time domain were calculated. We looked for differences between image sets acquired in different experimental conditions and image sets acquired with no device (reference images) to look for changes due to temporal instabilities. A t-test was used to detect parameter differences calculated for two sets of images. The Student t-test is a parametric one (the hypothesis are based on the distribution parameters, i.e. mean and variance) that assesses whether the means of two groups are statistically different from each other.
The hypothesis can be summarized this way:

-null hypothesis $H_0 = \mu_1 = \mu_2$
-monodirectional alternative hypothesis $H_1 = \mu_1 > \mu_2$
-bidirectional alternative hypothesis $H_1 = \mu_1 \neq \mu_2$

where μ_1 and μ_2 are the means of the two populations.
In order to decide whether the null hypothesis must be rejected or not, we must fix a critical value for the indicator t: it is possible to associate the critical value for the probability of the null hypothesis to be true, given the number of degrees of freedom and the kind of alternative hypothesis (in our case the alternative hypothesis is bidirectional), with the critical value for t.
If we choose that the significance level equals to 0.05 (this means that five times out of a hundred you would find a statistically significant difference between the means even if there was none) and considering that in our case the number of degrees of freedom is 38, we get a t critical value of about 2.021.
If we apply the t test in order to evaluate significant differences between acquired sequences with the devices under test and reference images and we find a $|t|$ value greater than 2.021, we can assert that the relative experiment created significant artefact in the images.
We hypothesized that the parameters' variance in each set could be different due to the motion of the objects, or to the motors or currents being turned on and off to simulate the devices' working conditions.

3 Results

The results indicated that reference images acquired in the same day showed no statistically significant differences. Images in the same conditions but acquired on different days showed a statistical difference in SNR values, with no difference for standard deviations. Results for aluminium, copper and brass seemed to indicate no differences with reference images acquired the same day, both for SNR and SD values. Experiments with these materials moved by an operator led to the same conclusions. Statistical differences were found for the electric cable with the potentiometer plugged both with current flowing (0.25 mA) and with no current. Experiments were performed with motors in two conditions: turned alternatively on and off for 15 seconds intervals, and always off. The ultrasonic motor showed no differences with reference images in both conditions (see Table 1) while the DC motor showed significant differences, even if placed in the corner of the MRI room at about 3 meters from the scanner (see Table 2).

Table 1. t value obtained for the images sequence of the ultrasonic motor on with high load respect to the reference images sequence (t critical value = 2.021)

	Slice n° 1	5	10	20
t SNR	-0.3799	-0.0254	-1.15	0.0652
t SD	-0.5689	0.0053	0.1244	-0.0286

Table 2. t value obtained for the images sequence of the DC motor on with high load respect to the reference images sequence (t critical value = 2.021)

	Slice n° 1	5	10	20
t SNR	-3.2284	3.3528	3.7272	3.7317
t SD	-20.1791	-14.0852	-20.9847	-18.1793

4 Conclusions

We proposed a compatibility test for mechatronic devices to be used within a diagnostic MR environment in order to evaluate artefacts caused by their presence and actuation. Three non-ferromagnetic metals and two types of active motors were examined during MR image acquisition: aluminium, brass, copper, a DC motor and an ultrasonic motor. Results for aluminium, copper and brass seemed to indicate no differences with reference images acquired the same day; the ultrasonic motor don't cause artefacts in the images while the DC motor showed significant differences. (Supported by IST-2002-6.1.1 FET Presence)

References

1. Moser, R., Gassert, R., Burdet, E., Sache, L., Woodtli, H. R., Erni, J., Maeder, W., Bleuler, H.: An MR Compatible Robot Technology. Proc. IEEE Intern. Conf. Rob. Autom., (2003)
2. Chinzei, K., Kikinis, R., Jolesz, F.A.: MR Compatibility of Mechatronic Devices: Design Criteria. Proc MICCAI '99, Lecture Notes in Computer Science, 1679 (1999) 1020-31
3. GE Medical System (ed): MR Safety and MR Compatibility: Test Guidelines for Signa SP™ Version 1.0, http://www.gehealthcare.com/rad/mri/pdf/safety1.pdf (1997)