# Characterization of Head Motion in the MR Environment

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## INTRODUCTION

Magnetic Resonance Imaging (MRI) and spectroscopy (MRS) scans are susceptible to subject motion. Therefore, methods for adaptive motion correction are needed (Figure 1). MR-based and external tracking systems are in development, particularly those for brain scans. While movement characteristics of motion disorders are well documented, little is known about the properties of head motion in the restricted MR environment. Knowledge of possible head movements will aid in the development of motion compensation systems. The purpose of this study is to determine if similar tremor frequencies found in movement disorders and significant velocities are reproducible in the restricted MR environment.

## METHODS

Four participants (male, ages 27 – 36 years) performed a series of 8 pre-determined head movement patterns within an MRI head coil. These patterns included slow and fast left-right lateral oscillations (intentional tremor), slow and fast superior-inferior oscillations, fast motion from approximately 45 degrees off center left to right lateral and hold, fast motion from 45 degrees superior to inferior and hold, center position cough, and center position without motion. An infrared stereovision system (A.R.T. Track3, Germany, Figure 2) was installed in an MR scanner room and used to track head motion in a quadrature head coil (Siemens Trio), using 4 infrared reflective markers mounted on customized mouthpieces (Figure 3). Six degrees of freedom data (X, Y, Z translations and rotations) were collected over 10 s at 60 Hz. The homogeneous transform between A.R.T. tracking and MRI coordinate spaces was determined by performing a calibration using a structural phantom with attached tracking bodies [1]; all

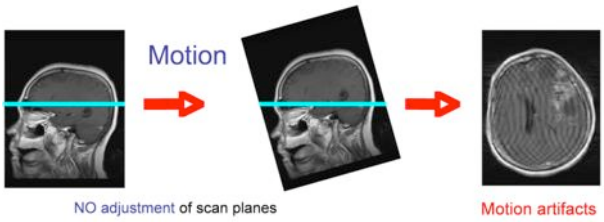


**Figure 1**: Motion during MRI scanning causes motion artifacts in reconstructed images.

**Figure 2**: A.R.T. Track3 stereovision system and Siemens 3T scanner located in the MRI room.

**Figure 3**: Custom mouthpiece / bite-bar for use in the MR environment.

values reported are relative to MRI isocenter. Collection and analysis of tracking data were performed using custom C++ and MATLAB functions [1].

## RESULTS

Major results of the motion study are summarized in Table 1. *Slow oscillatory movements (left-right lateral* or *superior-inferior),* performed at an average frequency of 0.4 Hz, resulted in typical velocities of 0.1 m/s and 75 degree/s (about the Z/superior-inferior axis). *Fast oscillations* (as fast as possible voluntary tremors left-right lateral or superior-inferior) showed power in a frequency range of 3 to 11 Hz *(Figure 4, Table 1)*. Typical maximum velocities were 0.05 - 0.1 m/s and 50 - 90 degree/s, and average maximum accelerations were approximately 0.3 *g* and 2000 degree/s$^2$ (*Figure 5)*. *Sharp transient movements* resulted in average maximum velocities of 0.57 m/s and 300 degree/s (*left-right lateral*), and 0.21 m/s and 400 degrees/s (*superior-inferior*). Average accelerations were approximately 0.5 - 1 *g* and 3000 degree/s$^2$, with maximum g-forces up to 2.0 *g* (on a single axis).

*Simulated "coughing"* led to translational values of 0.02 - 0.03 m/s and 0.1 *g*, and rotational velocity of about 10 degree/s.

## DISCUSSION

Voluntary tremors involved frequencies similar to those observed in movement disorders (4 – 12 Hz) [2,3]. Although MR coils substantially restrict head movements, significant rotational and translational velocities can be achieved during fast head movements. Accelerations appear to be limited at 1 to 2 *g,* but velocities may reach close to 1 mm/ms and 0.5 degree/ms. Velocities during simulated coughing were surprisingly small. These movements may induce motion artifacts even for fast MR acquisitions in the 10 ms range.

## REFERENCES


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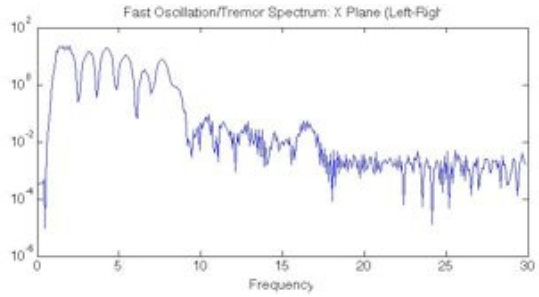


**Figure 4**: Fast left-right lateral (tremor) frequency spectrum.

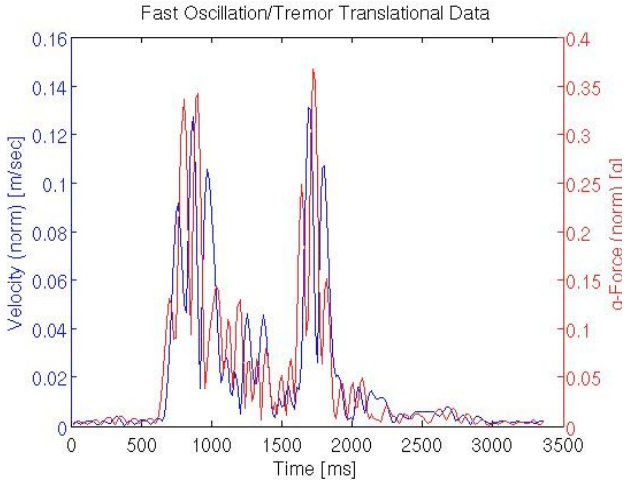


**Figure 5**: Fast left-right lateral (tremor) velocities (blue) and g-forces (red).

| *Summary of Motion Data* | | | | | |
|---|---|---|---|---|---|
| | | *Velocities*** | | *g-Force**** | *Freq.* |
| | *X (*) [m/s]* | *Y (*) [m/s]* | *Rz (*) [0/s]* | *(*) [g]* | *[Hz]* |
| Slow L-R Osc. | 0.14 (0.014) | 0.07 (0.007) | 74 (6) | 0.1 (0.02) | 0.3 - 0.5 |
| Fast L-R Osc. | 0.12 (0.027) | 0.04 (0.007) | 52 (10) | 0.3 (0.06) | 3.3 - 11 |
| Sharp L to R | 0.57 (0.086) | 0.24 (0.052) | 312 (47) | 0.7 (0.12) | --- |
| Cough | 0.02 (0.003) | 0.03 (0.008) | 9 (2) | 0.1 (0.02) | --- |
| | *Z (*) [m/s]* | *Y (*) [m/s]* | *Rx (*) [0/s]* | | |
| Slow S-I Osc. | 0.11 (0.005) | 0.11 (0.015) | 171 (8) | 0.2 (0.04) | 0.3 - 0.9 |
| Fast S-I Osc. | 0.07 (0.003) | 0.09 (0.019) | 90 (2) | 0.3 (0.05) | 4.6 - 8.6 |
| Sharp S to I | 0.21 (0.008) | 0.26 (0.011) | 409 (9) | 0.5 (0.04) | --- |

L-R = Left-Right Lateral, S-I = Superior-Inferior, Osc. = Oscillation
* +/- Standard Error
** Average Maximum Values
*** g-Forces represented in translational magnitude (norm)

**Table 1**: Summary of average maximum velocities, g-forces and range of frequencies.