A New Method to Record 2D- Movement Kinematics during Functional Magnetic Resonance Imaging (fMRI)

T. Kushnir[1], B. Hauptmann[2], R. Sosnik[3], O. Smikt[3], E. Okon[3], T. Flash[3], A. Karni[1,4]

[1]Dept. of Diagnostic Imaging, MRI Unit, The Chaim Sheba Medical Center, Tel Hashomer, Israel, [2]Department of Neurology,Charité, Humboldt, University Berlin, Berlin, Germany, [3]Department of Applied Mathematics and Computer Science, The Weizmann Institute of Science, Rehovot, Israel, [4]The Brain-Behavior Research Center, Haifa University, Haifa, Israel

Introduction: Quantitative biomedical research related to complex motor control and motor learning mechanisms is based on the ability to record and analyze point-to-point movements in detail (kinematics). 2D (Digitizer tablets) and 3D (e.g., optoelectronic or electronic devices) digital recording systems afford the recording of movement kinematics with high temporal and spatial accuracy. However, the implementation of these systems for functional MR imaging is limited due to the constraints imposed by the magnetic environment, and by the introduction of elecro-magnetic noise.

Purpose: To develop a system for high-resolution 2D-movement recording that fulfills the needs to record sequential point-to-point hand (writing and drawing-like) movements simultaneously with fMRI measurement of brain function.

Methods: *Movement recording system:* The movement recording system was used for behavioral studies without imaging as well as during fMRI sessions. It consists of a stylus (i.e., a plastic pen) connected via fiber optics to a halogen light power source, a translucent plastic board, a CCD camera, a video monitor and a PC with a special video processor for light detection. The two potential electro-magnetic noise sources are the light power source and the camera. The former was positioned outside the magnet room, and the latter 3m away from the front of the magnet bore (2T version) or outside the magnet room recording through the window (3T version). A commercially available Video camera (Pulnix TM-300, 1/2 inch CCD sensor, nominal resolution 752H x 582V, video format analog CCIR) was used. The video signal was transferred to the control room where a video monitor and a PC were placed for on-line monitoring. The PC had a proprietary video card for data recording at sampling rate of 50 Hz. The translucent plastic board, semicircular, was clamped with scotch strips to the inside of the magnet bore at an individually convenient distance for hand-writing movements. Writing-like movements during the imaging experiments were recorded using a stylus of comparable size and weight to the one used in a previous behavioral study wherein a digitizing tablet was used [1]. A fiber optic cable leading from the halogen light source was inserted into the stylus, ending at the tip and resulting in a small bright dot well seen by the camera, which was placed in front of the translucent pad. The fiber optic cable was taped to the subject's wrist to prevent the generation of torque during the writing movements.

fMRI measurements: were conducted using either a 1.9T (2T prestige, Elscint) or a 3T (GE) scanner, with a standard head coil. T1-weighted images served to determine the anatomical landmarks: TR/ TE/ FA = 11.4 ms /4.4 ms/ 15° FOV 256×256 mm2, matrix size 200×256, 128 sagital slices, SW 1.33 mm. For BOLD contrast fMRI, T2*-weighted gradient-echo echo-planar images (TR/TE/FA 3000/ 45 ms/90^o, FOV 38.4×19.2 mm^2, matrix size 128×72, 3×2.7×5 mm^3 resolution, SW 5 mm) were collected; 12 axial slices (no gap) and 6 slices (1 mm inter-slice gap covering the cerebellum) oriented parallel to the bi-commissural (AC-PC) plane with the uppermost slice aligned 5 mm below the vertex (approximately covering the whole brain).

The test paradigm: Was as in [1]. The kinematics data recorded in the magnet during brain imaging was compared to data recorded using a standard digitizing tablet (Intuos) obtained in several consecutive sessions during a training program [1]. Stylus point movements were recorded during fMRI data acquisition using an event related design, where a baseline phase was followed by 4 alternating movement (2 scans) and resting (6 scans) intervals. Participants were asked to connect 4 target points (ABCDA) 'as rapidly and as accurately as possible'. The movement sequence was executed while viewing the translucent plastic board (target screen) using prism glasses.

Results: There was no difference between trials recorded in the behavioral study and trials recorded with the optical recording system inside the Magnet. The kinematics data acquired before and after extensive training on the target movement sequence[1] is shown in the Figure: a) at the beginning of the training, the movement pattern consisted of a series of single bell-shaped velocity profiles. b) With continued practice, the trajectories for the first and second pairs of segments became partially curvilinear with double-peaked velocity profiles. c) By the end of training, the prototypical straight paths disappeared and two curved paths emerged, the first with a bell-shaped velocity profile and the second with a double-peaked velocity profile. No added noise was found in the gradient echo-EPI images acquired while the movement recording system was on.

Discussion: The system for digital recordings of 2D-upper limb movement kinematics can be effectively used concurrently with fMRI data acquisition affording the correlation of cortical activation with accurate movement kinematics. It affords on-line tracking of conventional CCD camera with no interference with the magnetic field and image quality.

References: 1. Sosnik et al., Exp. Brain Research, 2004;156(4):422-38.