Design of an fMRI-compatible analogue and digital joystick

Jonathan Howard[1], and Rexford Newbould[2]
[1]*Imanova Ltd, London, United Kingdom,* [2]*Imanova Ltd, London, London, United Kingdom*

Introduction. A wide variety of fMRI experiments benefit from the use of an MRI-compatible joystick. For example, this response system is used in functional examinations of movement-related areas such as the primary sensorimotor cortical and the dorsolateral prefrontal cortex in Parkinson's disease (PD)[1]. To this end, several commercial models are available, most relying on fibre-optic position and switch detection[2,3]. Fibre-optic devices are complex and expensive, require electronic components which can generate RF interference, and often contain a small number of fiber-optic sensor components, which results in a dramatically reduced resolution of the analogue signal. In this work, an inexpensive 2-degree of freedom (DOF) analogue joystick for neuroscience studies in an MRI/fMRI environment is designed. The joystick is fabricated using non-magnetic materials and contains two sensor stages in order deliver both analogue and digital position and response data.

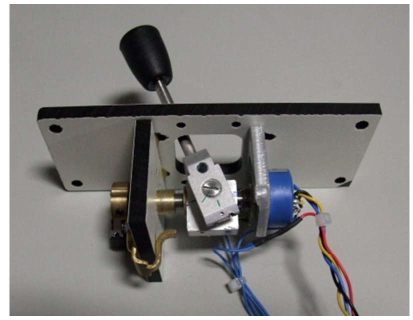

Figure 1. Joystick Construction.

Materials and Methods. An inexpensive, off-the-shelf industrial potentiometer-based joystick was purchased (Apem Joysticks, UK) and disassembled. The return-to-centre springs were replaced with beryllium copper springs (Mortimer Springs, UK), and any ferro-magnetic steel pins and screws were replaced with brass (Fig. 1). Vishay conductive plastic potentiometers were used, with bushing mounts and continuous rotation. These potentiometers have a linear response and provide an output smoothness of 0.1 % over a lever travel of +/-27.5°. This translates to a digital representation of over 2500 discrete points of measurement on each axis, resulting in a very sensitive and precise response. The joystick was mounted with a nylon frame to the scanner bed of a Siemens 3T Tim Trio (Siemens Healthcare, Erlangen, Germany) at the level of the subject's hand. In most cases, this was within the bore. The joystick was connected to a ribbon cable that exited the scanner room via a standard 15 way, 5600pF penetration panel filter, to an inexpensive game port to USB adaptor (RS Components, UK).

Data was acquired on a uniform sphere phantom with and without the presence of the joystick using a 3D spoiled gradient echo sequence with two complex echoes (7.38ms and 9.84ms) to create a field map. An fMRI session that will be used to analyze movement responses in PD patients was also collected on the same phantom with and without the joystick (2D GE-EPI, 38 slices, 140 repetitions, TR=2200ms, TE=31ms, PI=2, BW= 2298Hz/pix, matrix=64x64, FA=80°). The PD subjects will be required to perform a task presenting movement cues: A black fixation point and four arrows are present continuously throughout the scan. On 'movement' trials, the fixation point changes colour to green for 2 seconds, followed by one of the arrows turning green, which indicates the direction of movement to be performed (see Fig. 2). A volunteer moved the joystick through its full range of positions and joystick responses were recorded each millisecond outside the scan room and in the scanner bore without scanner activity and during both sequences. fMRI data series were high-pass filtered through the volume dimension in order to check for spiking, as well as independent component analysis using FSL melodic[4].

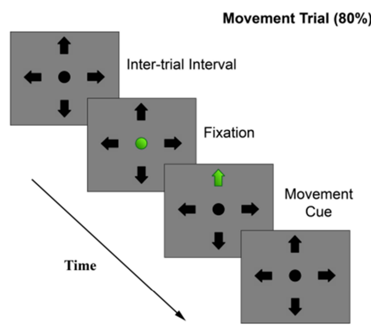

Figure 2. Design of the movement task

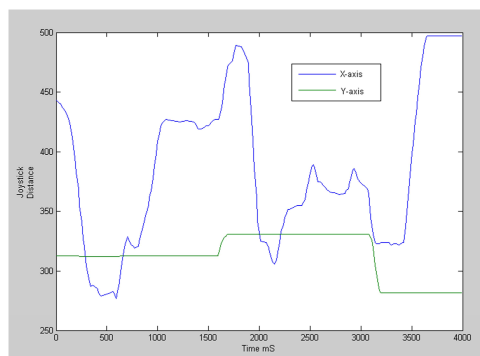

Figure 3. Recorded joystick position during scanner activity. X-axis position is in blue, Y-axis in green.

Results. No visible differences could be appreciated on the B_0 field maps with and without the presence of the joystick. Responses from the joystick appeared smooth and did not show evidence of induced currents from gradient activity (Fig 3). Positional information remained calibrated when inside the scanner bore as well as outside the scan room. Neither spikes nor differences in the component basis sets of the fMRI data series could be found. Therefore, it was likely that the joystick produces no detectable interference. In addition, the joystick was not affected by the scanners magnetic field, switching gradient fields or RF pulses.

Conclusions. An inexpensive 2-DOF analogue joystick has been developed for neuroscience studies that can be readily replicated at other research centres. All the experimental results described in this paper were generated in an MRI environment, with care taken to ensure full MR compatibility. The joystick was specifically designed to deliver a smooth analogue signal with a high-resolution to digital conversion that is often required for fMRI.

References. 1. Samuel, *Neuroreport*, 12(4),821-828, 2001. 2. I Melnyk - US Patent App. 09/995,708, 2001 3. Harja, *Intl Jnl of Medical Robotics and CAS*, 3(4), 365–371, 2007. 4. Beckmann, *Philosophical Transactions of the Royal Society*, 360(1457):1001-1013, 2005.