Measurement of Fast, Goal-Directed Head Motions in Humans

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I. INTRODUCTION

Human body models (HBMs) are evolving towards having the capability to simulate active muscle behaviour in pre-impact automotive events, and during the impact itself. It is important for the biofidelity of these active models that the muscle control behaviour is both robust and accurate across a wide array of human motions and responses, not just calibrated to unique loading conditions. Part of developing a reliable and generalised muscle control model for HBMs is validation with data collected from volunteers performing basic human motions. While several human subject studies have been performed to study voluntary head motions [1-3] and muscle responses [4-5], only one study has characterised goal-directed head movements, and that was limited to motions in the axial plane [6]. The objective of the current study is to collect basic, goal-directed head motion data from subjects with the anatomy representing a 50th percentile male. Kinematics data have been gathered for head rotations along the sagittal, transverse and frontal planes with the intension of providing a useful validation dataset for future neck muscle control studies.

II. METHODS

The volunteer study was approved by the University of Virginia Institutional Review Board and involved eight healthy male human subjects (average age: 29 years, average height: 179.7 cm, average weight: 85 kg). The subjects were screened for any physical condition, including auditory and visual issues, that could affect the head kinematics required for the study.

Testing protocol

The subjects were seated in an automobile seat facing a wall that was approximately 155 cm away. Several photo targets were placed on the walls corresponding to specific target head angles (neutral, 20^o extension, 30^o extension, 20^o flexion and 30^o left axial rotation) (Fig. 1(a)) using a laser level (Bosch GLL2-80) and a digital protractor (PRO360, Level Development ltd, Chicago, Il). Instrumented headgear was placed on the seated subjects, which incorporated a laser pointer (Class 3R, wavelength – 642 nm, power – 2 mW) that created a laser extending from the forehead and aligned with the intersection of the mid-sagittal and Frankfort planes. The laser was visible on the wall in front of the seated volunteer and the subjects were asked to practice positioning the laser to different photo targets using only the motion of their head (keeping the thorax still and minimising out-of-plane motion). For testing, the volunteers were asked position the laser to a specified marker (marker 1) for the initial head position, and then move the laser dot as fast as possible to a second target (marker 2) upon hearing an auditory signal. The sound would go on for 4 s and the subjects were instructed to move their head to back to marker 1 as soon as the sound ended.

Instrumentation

The head kinematics were measured by a three-axis gyro sensor (IES 3103-600, Braunschweig, Germany) with a maximum range of 600 ^{o}/s and mounted on the rear of the headgear (Fig. 1(b)). Data from the sensor were collected at 1000 Hz using a DTS slice data acquisition system (DTX Seal Beach, CA). Vicon markers were installed on the headgear, and the volunteer was surrounded by an array of Vicon cameras.

III. INITIAL FINDINGS

Data for an individual trial were collected for 10 s: from 2 s before the beep sound to 4 s after the sound ended. The signals measured by the gyro sensor were debased by the mean of the measurements 500 ms

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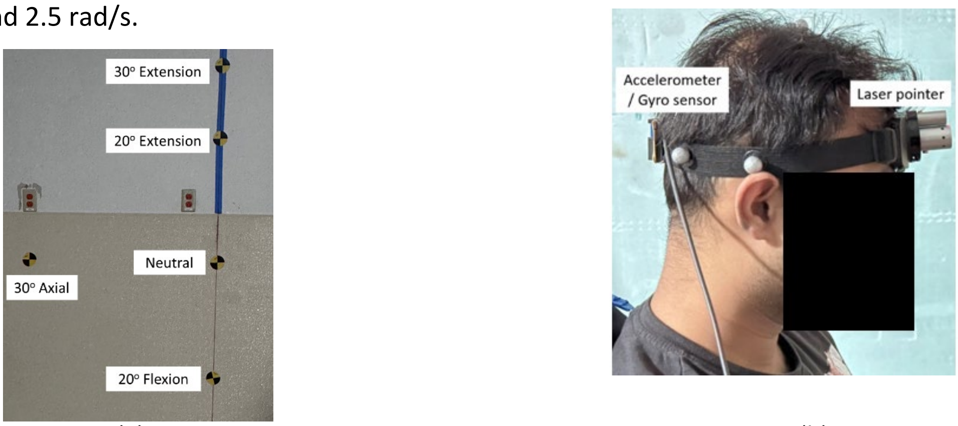
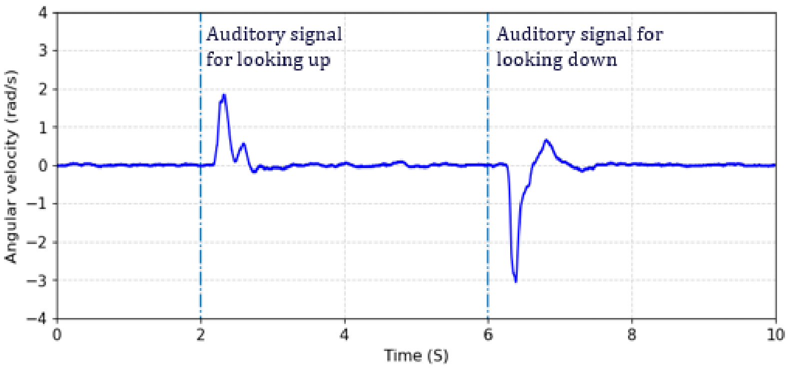
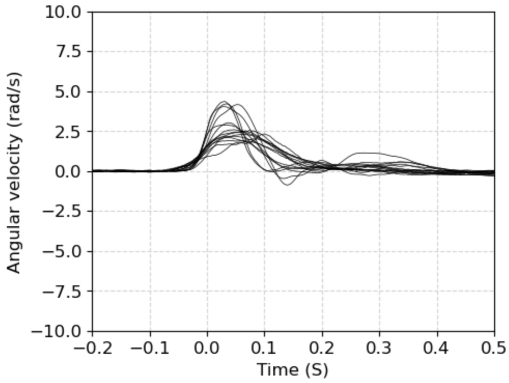
before the start of the motion. Figure 2(a) displays an average velocity measured by the sensor for neutral (marker 1) to 20° extension (marker 2) head motion. After reaching the initial extension target, the head stabilised before the beep signal ended, signalling the volunteer to move back to the neutral position. Each movement was isolated from the onset of auditory signal to 1 s after the onset and analysed. Analysis of the velocity temporal histories show a latency of 150–250 ms between the auditory signal and the initiation of recording of data by the sensor. Figure 2(b) shows the velocity profiles of test subjects adjusted such that the head rotates 2° at time 0 s. The timing of the peak angular velocities and the time taken to reach the target marker differed between the volunteers and ranged between 100 ms and 300 ms. The head velocities were fastest for axial rotations, with average peak velocities around 4 rad/s. The rotations in the sagittal plane had average peak velocity between 2.5 rad/s and 3 rad/s. It was also observed that the movements from extremities to neutral had higher peak velocities, and the neutral to 20° flexion movement had the lowest average peak velocity at around 2.5 rad/s.



(a) (b)

Fig. 1. (a) The targets for goal-directed head movements. (b) Volunteer with headgear containing the laser pointer and sensors.





(a) (b)

Fig. 2. (a) Example velocity-time curve of head angular velocity for neutral to 20° extension and back. (b) Debased velocity profiles of volunteers for neutral to 20° extension, adjusted for latencies.

IV. DISCUSSION

The present study characterises the goal-directed head rotations in eight male volunteers in sagittal and axial planes. The volunteers were asked to rotate their heads between a set of markers as fast as possible by reacting to an auditory signal. Even though the volunteers were instructed to move their head immediately on hearing the beep sound, latencies were observed before the sensors started recording any data. The velocity data gathered by the study can be used to obtain the angle time profile for each head rotation and can be used as a validation set for active HBM development of a head and neck muscle control model [7-8].

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