Potential to Volunteer Testing Using a Driving Simulator with Motion Capture and EMG Data Acquisition

Fabian Kempter, Lorena Lantella, Norman Stutzig, Jörg Fehr, Tobias Siebert

I. INTRODUCTION

The occupants' active behaviour becomes more and more important in developing safety concepts for future mobility and interior concepts. Current active human body models (HBMs), which are calibrated and validated with averaged data of volunteer tests using sleds, allow occupant posture stabilisation. In contrast, the simulation of arbitrary motion using HBMs and realistic human-vehicle interaction is not yet possible. This is partly due to the lack of experimental data, particularly with regard to the passenger movement and muscle activity when driving autonomously, i.e., in non-standard situations where seats or heads are rotated. Experiments with driving simulators tests can contribute to these additional aspects by providing experimental data which cannot be investigated in standard laboratory sled tests. Simulator tests allow putting the occupant into new (virtually) interior concepts and to investigate the interaction under external loading. In this contribution, a setup of a driving simulator is presented. Its potential for studying occupants behaviour in non-standard postures is outlined using results of new experiments conducted with pre-rotated passengers' head postures.

II. METHODS

In a volunteer study, approved by the University of Stuttgart's ethical committee, 17 healthy subjects (3 female and 14 male, 72 ± 10 kg, 24 ± 2 years, 180 ± 12 cm) were tested. Surface electromyografic (SEMG) data were recorded from the left and right sternocleidomastoid (SCMl and SCMr) and the upper part of the trapezius (TRPl and TRPr) muscles using bipolar electrodes. SEMG electrodes were located based on the recommendations of [1]. After detecting maximum voluntary contraction (MVC) levels in isometric flexion and extension, the tests on the simulator were performed. Additional to the EMG signals, the kinematics of the motion platform and the volunteer were tracked (Fig.1). The virtual environment of a road intersection in a small city was visualised using head-mounted displays. The subjects were exposed to an automated braking event performed by the motion queuing algorithm of the platform using longitudinal translation and pitch motion. The subjects were asked to hold a specific head posture throughout the scenario of whether a nominal view (nom), i.e., looking straight ahead, or a shoulder view to the right (sho), typically performed prior to a lane change or if conversating with a

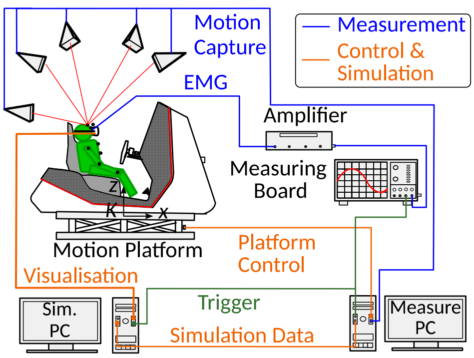

Fig. 1. Driving simulator setup with controls and measurement paths of SEMG, motion capture and synchronisation.

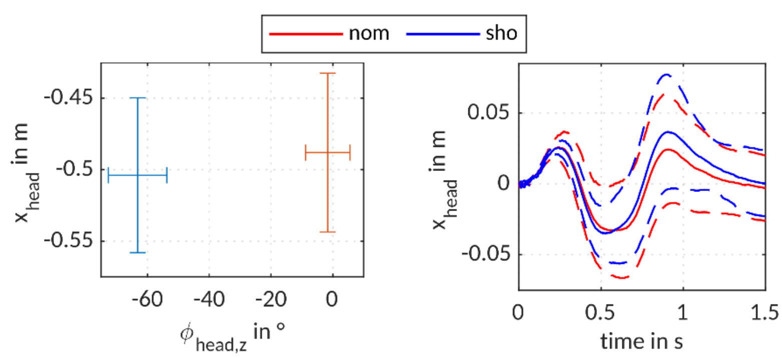

Fig. 2. Initial head postures (left) shown as initial yaw angle and longitudinal position for nominal view (red) and shoulder view (blue) as mean ± standard deviation. Head longitudinal displacement during braking event (t=0) with mean values (solid) ± standard deviation (dashed)(right).

F. Kempter (fabian.kempter@itm.uni-stuttgart.de, +49 711 685-66201) is a Research Associate and Doctoral Student at the Institute of Engineering and Computational Mechanics (ITM), L. Lantella is a Master's Student, N. Stutzig is a PD working at the Institute of Sport- and Movement Science (INSPO), J. Fehr and T. Siebert are Professors, working at the ITM or INSPO at the University of Stuttgart, Germany.

person sitting on the passenger seat. The experimental plan ensured a randomised order of the head postures. The subjects' kinematics were transformed to the moved platform coordinate system allowing the investigation of subject kinematics performed relative to the moved platform [2]. SEMG data were recorded using a Biopac MP160 system and a sampling frequency of 2000 Hz. All SEMG signals were preamplified by 2000 and filtered from 10 - 500 Hz using a bandpass filter. Subsequently, the signals were processed as in the study of [3] by rectifying them, applying a 4^{th} order Butterworth filter with a cutoff frequency of 20 Hz [4], and then smoothing the signals by a moving average of ±100 samples. To determine the reflex amplitude according to [3], first all local maxima and minima within 20 ms to 300 ms after the onset were determined. The first local maximum was then searched which was not followed by a local minimum for more than 10 ms. If there were two separate reflex components, only the first was considered. This local maximum is separated in a baseline signal (base) and peak value (peak) to differ between activity induced by holding the desired posture and induced by external excitation (Fig.3).

III. INITIAL FINDINGS

In the following section, nominal head orientation is compared to the shoulder view experiments. The results show inter- and intrasubject variability in initial head postures in yaw angle and in the longitudinal position related to the chosen seating position (Fig. 2 on the left). The head longitudinal displacement during the scenarios show large variability and no relevant difference between the two scenarios (Fig. 2 on the right). However, the preprocessed SEMG data show a significant influence of head posture on the ground muscle activity. The shoulder view to the right leads to increased muscle activity. Its significance can be shown in a paired t-test ($p < 0.001$) for the muscles of the left side (SCMl and TRPl). The braking event resulted in obvious reflex activity in all muscles observed, while the peak activation shows similar mean values for nominal view and shoulder view (Fig.4).

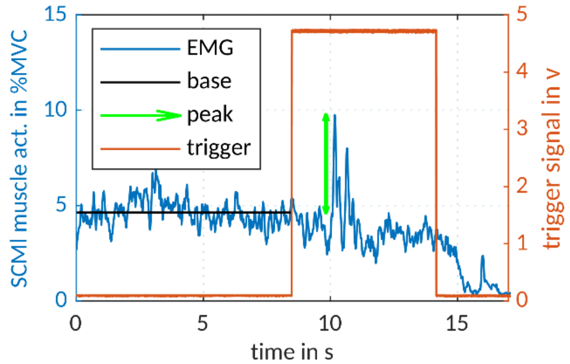

Fig. 3. Processing SEMG signals to obtain ground activity (base) and peak activation value (peak) exemplarily shown on a sternocleidomastoid signal as percentage of MVC in a shoulder view experiment with trigger signal.

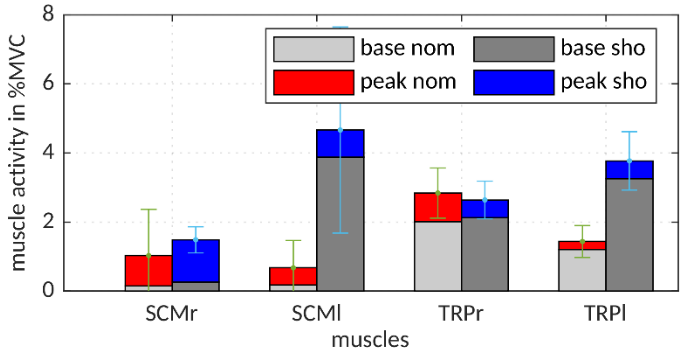

Fig. 4. Processed SEMG data with mean values of base activation (grey boxes), reflex peak value (colored boxes) and its standard deviation (error bars) for nominal head posture (left bars, nom) and shoulder view (right bars, sho).

IV. DISCUSSION

In this contribution, a setup is presented enabling the investigation of occupant behaviour in a virtual environment with different initial head postures. The results show that changes in head posture are accompanied by changed ground activation. The additional reflex induced (peak) muscle activity initiated by the platform motion during the braking event does not show relevant differences. This could be explained by the limited kinematic excitation. The approach of obtaining data inside a driving simulator is promising in the field of newly designed seating positions. Especially, the behaviour, as well as the level of perceived safety and comfort, can be investigated in a safe environment. This study’s results serve as input data for HBM development, i.e., muscle control strategies, and as additional data to validate active HBMs.

V. REFERENCES

[1] Barbero, M., et al., Springer, 2012.
[2] Kempter, F., et al., IMSD, 2018.
[3] Mühlbeier, A., et al., PLoS ONE, 2018.
[4] De Luca C.J., et al., JBiomech, 2010.