Eye and Body Movements Characterised by Synchronised Sampling

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Introduction

The ANNIE project (Application of Neural Network to Integrated Ergonomics) – an EC project (Brite Euram) - aims at integrating mannequins and neural network techniques for simulating human movements. The neural net will control a mannequin to replicate human motion patterns to test the ergonomic suitability of virtual work places. Training data for the neural network are recorded from real workplaces.

It is cost-efficient and ergonomics will be used better with this type of simulations since it constitutes a powerful tool for integrating ergonomics in the design process in the early virtual design phase.

The study presented in this paper was made to record mannequin training data from drivers of a car mock-up.

Another goal with this pilot project is to obtain an orientation about stress and driver behaviour when performing extra tasks. We also tested a combination of equipment and the possibility to synchronise data from it.

Data collection

Recordings from eight subjects, all students between 20 and 30 years old, were performed. All drivers hold a driving license. The car mock-up was built from components from several cars, and the simulator also included a computer game and a video projector. Figure 1 shows this set-up.

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Figure 1: The car mock-up and auxiliary equipment.

The modern car computer game, controlled from the car mock-up, produced a fairly realistic moving 3D image of the road environment, which was presented on a screen placed in front of the driver.

A variety of data collection equipment was used on the human subjects, in addition to video.

- The SMI iView eye-tracker, which operates with the so-called pupil-corneal reflex method in the IR spectrum.
- Right and left hand wrist angles and movements (i.e. flexion and deviation) were measured with a Penny and Giles goniometer, M110. Data was sampled with a frequency of 20 Hz. The goniometer was located at the dorsum of the hand; from the knuckle of middle finger, straight back over the wrist to the forearm.
- Head, back and both upper arms were equipped with inclinometers. The inclinometers used were tri-axial accelerometers, using the gravitational acceleration of earth as a line of reference for inclination angles.
- Heart rate was assessed from electrocardiography (ECG) recorded by Ag/AgCl surface electrodes (Medicotest, Q-35-E).
- Activity of the right and left trapezius muscle was assessed by electromyography (EMG), recorded by Ag/AgCl surface electrodes (Medicotest, E-10-VS). A reference contraction (arm raised to 90∞ in the scapula plan) was used for normalisation.
- ELITE, an optoelectronic system for movement analysis, was used in the experiment. 26 passive markers placed on the body and whose 3D co-ordinates were recorded with a sampling rate of 50 Hz. Four TV-cameras (two on each side of the subject) were placed at 3 meters distance from the driver's seat.

We took care to record our simulation data so that they could be synchronised. The video recording included both a miniature of the eye tracker recording (allows video to eye-tracker synchronisation), and a small lamp that was lit when events were recorded onto the body movement files (allowed synchronisation between video and body movement data).

Driving task

Subjects were driving the car simulator with all data collection equipment mounted and running. The ELITE system recorded only during motion tasks.

The experiment was divided in two parts – conditions. In the first, subjects were asked to drive, and to perform the following tasks on command: answer a cellular telephone placed in the glove compartment, adjust the temperature, insert a cassette located on the dashboard into the car stereo, and eject the cassette. The same tasks were then recorded in the second condition, in which subjects did not drive.

The number of tasks performed by each driver varied in the first condition, depending on how many we managed to start before the driver had reached the end of the race (after about 13 to 50 minutes).

Results and discussion

Synchronisation of data from the different equipment was possible. The wrist angles as measured with two separate systems, ELITE and goniometers, showed good agreement but for extreme wrist angles. Further studies and refinements are needed to remedy this problem. Sources of error are artefacts from noise and skin motion for the ELITE system, and buckling and rotation errors for the goniometers.

On the basis of their driving style, we picked out two careful and two competitive drivers for a more detailed analysis. Three of these are males (subjects 1, 3 and 4), one is a female (subject 2). The difference between careful and competitive driving style was striking. Careful drivers (1 and 2) drove at a maximum speed of 90-100 km/h and had few or no accidents. They both ended up last in their races. Both competitive drivers (3 and 4) won their races, after often exceeding 300 km/h and having had uncountable accidents.

Car driving gave a high static load. For the right trapezius muscle the load was comparable to the reference contraction: arms up in scapula plane. The left trapezius muscle was about half as active as the right one. Steering movements were obviously performed with the right arm, while the left arm served just as support.

Our data indicate that during driving, the left hand is, for more than 50% of the time, outside the comfortable zone, defined as more than a 10 degree flexion/extension from the neutral position (Judic et al, 1993). Holding the car steering wheel in the normal 'ten to two' position is thus uncomfortable.

Arm movements were slower but took a more tortuous route (with higher angular velocity) when driving. When not driving, drivers could devote their full attention to the task and perform movements straight to the goal. Tasks which require high precision, i.e. insert cassette, required longer time to perform than low precision job, e.g. ejecting the cassette.

When performing tasks while driving, subjects tilted sideways, keeping the head in a fixed vertical position with the face towards the traffic. Instead of head movements subjects perform a large saccade towards the glove compartment. In this way they could maintain a good overview of the road in case they would have to quickly move their attention back. In contrast, Land (1992) shows that when approaching upcoming intersections drivers rather make head than eye movements.

When subjects did not have to drive, they looked at what they were doing with their hands. When able to look, they fixated their task six times longer, on the average.

Note however, that the possibility to gather information by sight and not to be disturbed by the driving task also influenced the duration of movements. Total performance time for the cellular telephone task was almost 25% shorter in the no-driving condition compared to when subjects drive.

Individual differences in gaze behaviour were also evident. For instance, the competitive driver 4 twice managed to get the telephone without looking at it at all, while the careful driver 2 always looked twice or three times. The competitive drivers 3 and 4 looked 250 ms on the average, while the careful drivers 1 and 2 looked for 1230 ms, i.e. almost five times as long. Drivers 3 and 4 therefore have to rely more on tactile information, which takes longer because the movements are explorative. Driver 2 made smooth movements in an environment that is already known by vision.

No driver managed to insert the cassette without looking. The average glance time is 700 ms (competitive driver) versus 933 ms (careful driver), with a total gaze time of 1120 ms (competitive) versus 1680 ms (careful). The data from our careful drivers agree with results of a study of cassette tape handling during driving (Wierwille, 1993).

A rough rule of thumb says the driver should not look away from the road ahead for 2 s or more at a time (Gale, 1997). The cassette insert task which required most visual attention had a fixation time of 1,7 s, i.e. somewhat below the thumb rule limit.

The Zwahlen guide (Zwahlen et al,1988), a proposal for evaluating visual attention required for operations in a car, placed three (2 competitive and one careful driver) of our subjects in the acceptable area. One driver - a careful driver - was placed in the grey zone, the uncertain area representing possibly dangerous visual behaviour.

The study showed the possibility and importance of using simultaneous measurements of movements, sight and loads.

Especially, the study showed that eye tracking gives important information about safety in car driving. Eye tracking also gives information of importance for trajectories of human movements when performing tasks.

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