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Visuomotor strategies using driving simulators in virtual and pre-recorded environment

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Abstract

Drivers fix their gaze where they are planning to go. It is considered that steering is based on optic flow, the formation of visual motion at the moving eye. Different studies have analyzed the impact of visuomotor strategies on steering but, to our knowledge, few studies have compared visual strategies using similar urban video-projected environments. The aim of this study is to compare subjects' visuomotor strategies on similar video-projected environments in a fixed-base driving simulator. Experienced car drivers are exposed to two visual environments: a real traffic urban scenario pre-recorded on video; and the 3D simulation of the same scene. The visual environment represents a district of the center of Paris, between the Louvre and the Opera. Subjects' visual strategies are recorded using a binocular eye tracking system (Eyelink II). It is supposed that visuomotor strategies depend on the degree of similarity between both environments. The results indicate that eye movements differ between pre-recorded and virtual environment. Integration of information in the saccade buffer and visual attention control may explain these results.

Keywords – Binocular eye movement recording, driving simulator, visual environment, visuomotor strategy

1. Introduction

Steering a car is a complex cognitive task, which necessitates the integration of various information such as visual, auditory, proprioceptive, motor, and spatial essentially. The aim of the present study is to examine visuomotor strategies when people are exposed to two similar visual environments.

The effect of visual strategies on driving has been studied from various viewpoints [1]-[5]. However, their role in car driving tasks is still poorly understood [5]. In road driving, driver directs his/her gaze where s/he intends to go [6]. Studies show that with changes in driving parameters i.e., an increase in speed, gaze links more tightly to the driver's intended goal [7], [2], [5], [3]. Visuomotor strategy is thought, therefore to, depend on optic flow properties [8]-[10].

Using two contrasted visual environments, e.g., traffic of the same road presented in real situation or in pictures, authors show [11] that eye-movements were significantly

different. But when experimental conditions are similar this result is inverted. Drivers' visual strategies have been investigated in real and virtual intersections using an HMD in a driving simulator [12]. It has been found that drivers tended to make longer left-right glances in virtual reality that they did in reality but there was no difference in the number of glances between both experimental situations. Using a monocular tracking system, researchers [13] have recently revealed that eye fixation time for traffic signs, e.g., information signs or road markings, was quite comparable between watching a video and actual driving. However, to our knowledge, the binocular recording of eye movement have never been investigated in pre-recorded and virtual environments.

The above data suggest that the similarity of visuomotor strategies could depend on the the similarity between visual environments.

In order to examine this hypothesis, drivers aged 25 to 35 years were exposed to two visual environments in a fixed – base simulator: the first one was a pre-recorded scene of real urban traffic scenario; the second was the 3D simulation of same scene. Their visuomotor strategies were recorded using a binocular eye tracking system (eyelink II).

2. Method

2.1. Subjects

Twenty-six experienced car drivers (13 men and 13 women) were examined. Their average age was 30 years (SD 3 years). All were licensed to drive in France for 5 years or more and have driven at least five times a week. None of the subjects had more than 10 hours of driving experience on a simulator. All had normal or corrected-to-normal vision and no history of neurological disease. An additional number of four subjects participated but excluded owing to technical problems (one subject) or of simulator sickness (three subjects). Before the experiment all subjects signed an informed consent form. Study approved by local ethic committee and conform Helsinki convention.

2.2. Simulator

The INRETS' (MSIS-SIM^2) driving simulator, which is a fixed-based simulator, was used for this experiment. This simulator was composed of a vehicle (Xantia), fully functional pedals, speedometer, manual gearshift and three large flat screens. The screens stimulated 150 deg of subject visual field (120 deg horizontally and 37.5 deg vertically around). Three, IRIS BarcoGraphics 808s projectors, one for each screen, were used. Each projector runs 900 x 1600 pixels at 90 Hz refresh. Two visual environments, which correspond to two visual conditions, were used. A computer (AMD Athlon (tm) 64x2 Dual; Core Processor 5400+ 2.81 GHz, RAM 3.00 Go) controlled both environments.

2.3. Visual conditions

Two visual environments were compared: the first one was a real traffic urban scenario pre-recorded on video; the second was the virtual representation of the same scene.

Both scenes represented a district in the center of Paris between the Louvre and the Opera (the 1st district of Paris).

The beginning of the scene was the Pyramid's square. The traffic scene comprised the Pyramid's street until the intersection with St Honoré's street, turning right, in the direction of Palais' Royal Square; continuing down to the Rohan's street and again turning right to Rivoli's street, and continuing straight ahead until the Pyramid's square. In both conditions the vehicle of the simulator was put on normal steering position, the same procedure was used.

The subject was equipped with the eye tracker. They were installed on driver position. They were on passive driving situation. The subjects were informed that scenes of a Parisian district were presented on the screens. To incite the subjects to have an active research of visual information, they were asked to use the steering wheel of the simulator as they do in the real driving situation.

2.4. Procedure for a trial

When the subject was entered the simulator, only the computer's desktop background was projected on the three scenes.

A typical trial proceeded as follows. The subject's back and shoulders were in contact with the vehicle's seat back. The subject was asked to orient the head and gaze straight ahead. As soon as the head and the gaze were correct and after the subject declared that s/he was ready, the visual environment was presented on the screens. The presentation of the visual environment (pre-recorded or virtual) was the beginning of the experiment. The subject correctly installed on the simulator was in the middle of the street and had a direct vision of the traffic scene. The experimenter asked the subject "*to use the steering wheel of the simulator as s/he did in the real situation*".

The subject's visuomotor strategies were recorded during the whole trajectory. After that, a new trial was started. Each trial lasted around 3 minutes; the inter-trial interval was around 20 seconds. In each visual condition, each subject performed four trials. Two standard 2D calibrations of the eye tracker took place: the first one at the beginning of the trial; the second one after the first four trials. The order of the trials was randomly assigned to each subject. Each subject was given eight valid trials.

2.5. Eye movement recording

The eye movements were recorded with the Eyelink II. This video system was set to acquire eye position at 250 Hz. The apparatus consisted of video cameras that are mounted on a headband.

2.6. Experiment organization

Prior to visual exposition in the fixed-base driving simulator, a visual oculomotor clinical examination was performed for each subject. This examination was composed of visual acuity, heterophoria and vergence movement measures. In addition, a part of the French version neuropsychological battery VOSP (visual and object spatial perception [14]) was also used to evaluate subjects' spatial perception of objects. At the end of the visual exposition, the subjects were asked to verbalize their sensations and impressions and to represent in a graphic way, using a paper – pencil test, the traveled trajectory.

2.7. Dependant variables and analysis

The dependant variable was the eye movement. After standard calibration, the conjugate eye position, which corresponds to the left and right eye position divided by two, was computed. Four components of eye movement were analyzed: time and number of fixations, latency and amplitude of saccades (see results).

All statistical analyses were performed with R 2.2.1 software [15].

3. Results

The results are presented in three sections. In the first section, the results of visual oculomotor and neuropsychological examination are exposed; in the second the data of the comparison of eye movement between the visual environments are explained; in the third the verbalizations and graphic reproduction of the traveled trajectory given by the subjects are described.

3.1. Visual and neuropsychological examinations

The description of the population according to the visual oculomotor examination revealed that all the subjects presented a normal profile of visual acuity (10/10 for right eye visual acuity and 09/10 for left eye visual acuity).

The subjects had no obvious problem of vergence and heterophoria. In the same vein, the description of the population according to their results to the neuropsychological test showed that the subjects had no difficulties to detect objects (20/20); to identify objects independently of the degree of perceptual modification of their form (19/20); or to perceive their position in space i.e., (23/30) for silhouettes and (8/20) for progressive silhouettes.

3.2. Comparison between visual environments

Under the hypothesis that the visual strategies depend on the degree of the similarity between the environments, eye movements were expected to be different between the pre-recorded and the virtual environment.

The comparison of eye movements between pre-recorded and virtual environments is investigated in terms of a) time of fixations (in ms); b) number of fixations; c) latency of saccades (in ms); and d) amplitude of saccades (in deg $^{-1}$).

Within each of the defined visual condition, the observed individuals distribution of each of the above dependant variables approximates a J-shaped one. The same J-shaped distribution is preserved when data are pooled within each of the visual conditions. With such distribution shapes, the median has been chosen as a central index of each variable.

In order to compare the time and number of fixation, the latency and amplitude of saccades, the differences between medians have been intra-individually computed between the two visual conditions. The statistical comparisons have been conducted with the Wilcoxon matched-pairs signed-ranks test.

These comparisons show that:

a) the median time of fixation is longer in pre-recorded than in virtual environments ($T = 15$, $n = 26$, two-tailed $p < .0005$). The groups' median time was 267 and 258 ms in the pre-recorded and virtual scene respectively (fig. 1).

b) the median number of fixation is higher in the pre-recorded than in the virtual environments ($T = 78$, $n = 26$, two-tailed $p < .01$). The groups' median number was 429.5 and 425.2 in the pre-recorded and virtual scene respectively (fig. 2).

c) the median latency of the first saccade upon starting of the video is longer in pre-recorded than in virtual environments ($T = 1$, $n = 25$, two-tailed $p < .0005$). The groups' median latency of saccades was 307 and 291 ms in the pre-recorded and virtual scene respectively (fig. 3).

d) the median amplitude is bigger in pre-recorded than in virtual environment ($T = 6$, $n = 25$, two-tailed $p < .0005$). The groups' median amplitude were 5.1° and 4.2° in the pre-recorded and virtual scene respectively (fig. 4).

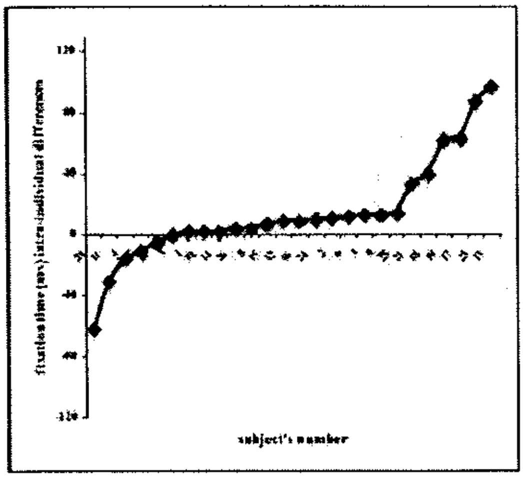

Fig. 1 – Differences between median fixation time (pre-recorded minus virtual)

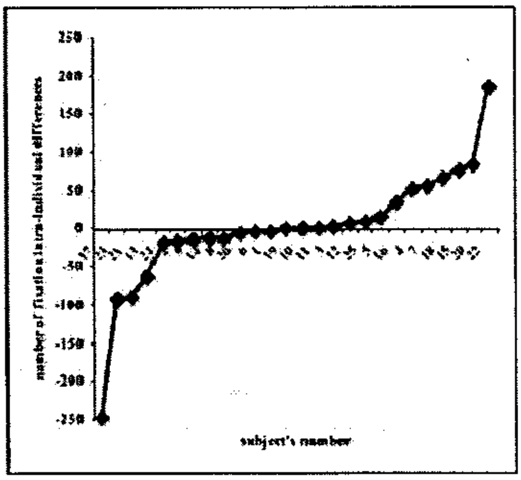

Fig. 2 - Differences between median number of fixation (pre-recorded minus virtual)

3.3. Subjects' verbalizations and graphic representations of the traveled trajectory

Twenty-four of the twenty-six subjects declared that they were completed immersed in both visual environments. Twenty of them reported that immersion was better in the pre-recorded environment. Subjects also found that both environments were rather different. They declared that the pre-recorded environment was dynamic, gives more sensations and gave better raise to actions than the virtual one. All the subjects were able to represent graphically the traveled trajectory. They also gave several details, which concern the road, the buildings, the traffic lights, the pedestrians, and the cars. As the subjects declared, the most of the details they remembered were from the pre-recorded environment.

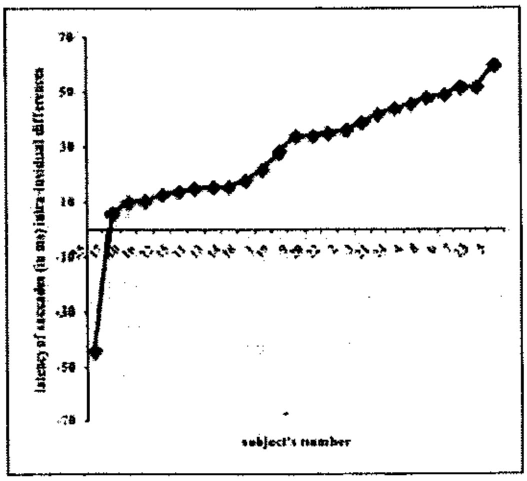

Fig. 3 - Differences between latency of saccades (pre-recorded minus virtual)

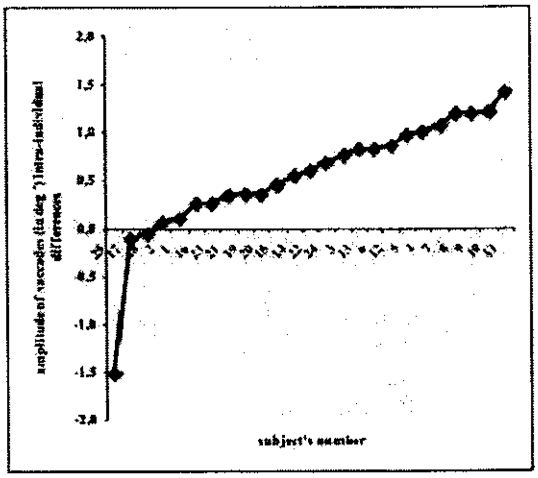

Fig. 4 - Differences between median amplitude of saccades (pre-recorded minus virtual)

4. Discussion

To our knowledge this is the first study which examined eye movements using a binocular apparatus in pre-recorded and virtual urban environments. Urban environments are rather rich in visual information and necessitate constant and continuous treatment. Consistent with our hypothesis, the present study indicates that the eye movements differ between the pre-recorded and virtual environments. In particular, the fixation times were shorter in the virtual environment than in the pre-recorded environment; the number of fixation was higher in the pre-recorded environment. In addition, the latency of the first saccade was longer in the pre-recorded environment; the amplitude of saccades was bigger in pre-recorded than in virtual environment.

It may be contradictory that both the frequency and duration of fixation are higher in the pre-recorded environment. This observation reveals that eye movements such as pursuit and OKN were involved and should be analysed in another study.

These results aren't consistent with previous data reporting that drivers' visuomotor strategies do not differ between virtual and real environments [12] or pre-recorded and actual environments [13]. The differences between those studies and our study can be explained from a methodological viewpoint.

In our study, we used an urban scenario, which is extremely rich in information. We also used a binocular eye tracker to record drivers' eye movements. In the above studies the authors not only used "partly rural" and "totally rural" areas, which are obviously less rich on information, but they also recorded drivers' visuomotor strategies using an HMD or a monocular eye tracking system.

In addition, we completed a preliminary clinic screening of our subjects. This screening revealed that the differences between both conditions cannot be explained neither by oculomotor nor by neuropsycho-logical problems. Technical limits could explain our data. In the pre-recorded condition there are limits due to the resolution of the cameras, in the virtual condition there are limits due to the computer's capacities. In both situations there are limits owing to the resolution of the projection. However, these limits cannot totally explain the results.

The higher number of fixations in pre-recorded environment may mirror subjects' need to renew their perception. This is classically the case in real situations [8].

The difference of fixation time between both environments may be explained by the fact that in the pre-recorded environment the subjects are more attentive than in the virtual environment, because it's "real". The larger saccade amplitude and latency in the pre-recorded than in the virtual environment is consistent with these interpretations.

To better understand this hypothesis, it should be reminded that eye movements are strongly linked to visual attention: the more eye movement the more the attention [16]. As the pre-recorded environment is richer in information than the virtual one, making more fixations and saccades implies higher attention control. In other words, the exposition of subjects to a pre-recorded environment necessitates more cerebral activity than to the virtual environment. This is also corroborated with the declaration of subjects that "the details they were able to recall during graphic representation of the scene came from the pre-recorded scene".

The above declarations could account for the comprehension of the results. Information recall is a genuine memory process, which necessitates storage in visuo-spatial working memory, in our case.

Different explanations, such as integration in saccade memory buffer or the fact that perception is renewed with each fixation and saccades are coherent with this hypothesis. Neuroimaging data also suggest the presence of common cortical areas for attention and memory processes [17]. Our results underline the ecological validity of the simulator.

To valid all these interpretations, additional studies are required with normal and clinical groups of drivers.

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