Vehicle's motion detection: Influence of road layout and relation with visual drivers assessment

Jorge Santos, Paulo Noriega, & Pedro Albuquerque.

Department of Psychology, I.E.P., University of Minho, Campus de Gualtar, 4719 Braga Codex, Portugal.

ABSTRACT

The vehicle’s motion detection with concurrent self motion is an important dynamic task concerning vehicle’s collision avoidance. In this paper we present empirical data relating this task with environmental and individual factors such as: (a) different kinds of road pavements (bituminous, concrete and bituminous pavement with chromatic bands); (b) several measures traditionally used in driver's assessment, e.g. vision parameters and reaction times; (c) age and sex of drivers. One hundred and six persons participated in this study. Using computer generated images with realistic textures, we simulated a situation where participants had to detect a vehicle’s motion. All participants were also tested in several measures used traditionally in drivers’ assessment such as vision and reaction time tests. The vehicle’s motion detection was more impaired in the situation of a pavement with chromatic bands, which is the pavement with the higher optical flow density. These results showed that the optical flow played a more important role than the contrast between the object (vehicle) and the background (road) for visual motion detection tasks. Concerning the drivers assessment we point out the need of giving more importance to visual dynamic tests, contrast acuity and dazzling recovery time. Traditional tests of static visual acuity and reaction times should have less weight. Relatively to the sex and age variables the results showed that the relation between age and the vehicle’s motion detection is different for females and males. Females give fewer errors than males, but with age increment they need more time to detect the vehicle’s motion. Males need less time to detect a vehicle’s motion but with age they give more errors than females. From an ecological point of view, both behaviours reveal a negative effect of age on the vehicle’s motion detection because a wrong detection could be as dangerous as a slow detection.

1. INTRODUCTION

Through several fundamental and applied studies [1-3] we know that the object's motion detection is impaired by two concurrent causes: subject self motion; and the optical flow around the target object (visual motion of the visual scene that is generated when we move). One of this study aims was to understand this effect applied to vehicle guidance. Therefore we created a simulated situation where drivers had to detect the vehicle’s motion on different kinds of pavements that generated different densities of optical flow.
As the vehicle’s motion detection is important in the driving task, we decided also to study the relation of this task with some variables used in driver assessment (vision and reaction time tests). The traditional vision testing for driver assessment such as the Snellen optotypes is still in use. Nonetheless the traditional visual acuity measures have a relation with the reading task, the relation with the driving task is not so direct [4]. We tried to understand the relation of a specific driving task with tests used in the assessment of drivers, and tried to validate some of the tests currently in use.

The third question addressed in this study is about the relation of the vehicle’s motion detection task and the sex and age of participants. This is an important question if we think that the average age of drivers is increasing.

2. METHOD

2.1. Participants

One hundred and six subjects, 49 female and 57 male, all with a driving licence and a minimum driving experience of two years, participated in this study. The age was from 20 to 57 years with an average age of 35 and a standard deviation of 11.5.

2.2. Procedure

Participants were tested in three different kinds of tests to evaluate vision, reaction times and a vehicle’s motion detection. The visual parameters were evaluated through an Ergovision [5], we measured: (1) monocular far vision acuity; (2) binocular near vision acuity; (3) kinetic vision; (4) contrast acuity; (5) dazzling recovery time. Reaction times and the vehicle’s motion detection were measured using stimuli generated by a graphic station and presented through a video projector.

We measured the simple reaction time (SRT) and the choice reaction time (CRT). In the SRT the participants had to press a mouse button when a white vehicle appeared in a black background. In the CRT they had to press the left or the right mouse button when the same vehicle appeared in the left or the right side of the screen. For both tests the reaction times were registered in milliseconds.

For the vehicle’s motion detection task we used the method of constant stimuli, combined with a two forced choice indicator of response (2FC). Using computer generated images with realistic textures, we simulated a situation where participants, at a speed of 50 km/h, had to detect another vehicle’s motion. Participants had to press the left or the right mouse button, as quickly as possible, but trying to make no mistakes, to detect respectively approaching or receding vehicle motion. The detection time and kind of response (correct, wrong or omission) were registered. The target vehicle initial distance was 20 meters with five relative speeds (RS), that is the difference between participant’s speed and the other vehicle’s speed. Three kinds of road pavement were used: concrete (Fig. 1), bituminous (Fig. 3) and bituminous with chromatic bands (Fig. 5).

2.3. Stimuli

The stimuli constituted a white vehicle in a straight, 1 x 2 road, with a central broken line and an edge of carriageway marking, in a green field and with a sky background. A model of a 1992 VW Polo was used as an image of the rear of the car. The vehicle image was centred in the screen.

The luminance of the stimuli was adjusted to the luminance measured in a real situation. First we measured the luminance in a specific pavement and simultaneously of a large white card, the contrast between the pavement and the card was calculated. We replicated those contrast values in the experimental setting, the equivalent of the white card was the back of the target vehicle. The contrast between the three kinds of pavement and the vehicle is
presented in the table of figure 7. The contrast values were calculated using the Michelson equation\(^1\). The luminance was measured with a luminance meter (Minolta LS-110).

The global optical flow, i.e., the visual motion, was measured with a specific software developed for this kind of research [6]. Figure 7 shows the values of the optical flow mean density measured 16 degrees around the focus of optical expansion, i.e., the centre of the image from which all the points diverge. We can also see the optical flow representation of the three kinds of pavement used in figures 2, 4 and 6.

The stimuli and the experimental sequences were programmed with GL (Graphic Library) in C, and processed in real time at 30 images per second. The graphic station was a Silicon Graphics, model Onyx Reality Engine 2 (D-45802-RB), with a Rack (Biprocessor) of 2 CPU's 4400 at 150 MHz. The view was provided by a Barco 801s digital video projector with the resolution adjusted to 1025*768, at 60 Hz, on a 320*240 centimetres screen. The distance of participants to the screen was 650 cm. The visual field was 28 degrees horizontally and 21∞ vertically. This visual field is enough for the study of the task of object motion detection because the main optical flow interferes over a central vision area (at least inside 16 ∞) and not peripherally [3].

3. RESULTS AND DISCUSSION

3.1. Road pavements study

Concerning the study of road pavements we analysed the number of wrong detections in the vehicle’s motion in the approaching situations. Thus, the independent variable was the kind of road pavement, this independent variable has been manipulated in a within subjects experimental design, our dependent variable in this study was the average wrong detections for the approaching situation.

Table 1 and Figure 7 show the results of wrong detections with the three kinds of road pavement. The participants failed more in the bituminous pavement with chromatic bands. A non-parametric test for related samples (Friedman) revealed significant differences between groups (\(\chi^2=14.957, \ df=2, \ p=0.0006\)). The Wilcoxon test for related samples revealed significant differences between: the bituminous and the bituminous with chromatic bands (\(z=-3.98, \ p=0.0001\)), the concrete and the bituminous with chromatic bands (\(z=-4.72, \ p=0.0001\)). For the bituminous and concrete groups there was not a significant difference between the number of wrong detections (\(z=-1.60, \ p=0.1088\)).

These results are consistent with previous studies on vehicle motion detection. Santos [3] described how the visual motion (global optical flow) surrounding the target object (local optical flow) impairs the motion detection. The bituminous with chromatic bands generate a higher global optical flow mean density around the vehicle than the bituminous and concrete pavement, thus the motion detection is in that case more difficult. These results also show that the visual motion (optical flow) is more important than the contrast between the object (vehicle) and the background (road) for visual motion detection tasks. In figure 7 it is clear that the impairment of motion detection is due to the optical flow. The higher contrast is measured in the bituminous pavement; the concrete and the bituminous with chromatic bands had almost equal average contrasts. So it seems that the higher contrast of the bituminous relative to the concrete did not aid detection, because there was no significant difference between them.

---

\(^{1} C = \frac{(\text{max. luminance}-\text{min. luminance})}{(\text{max. luminance}+\text{min. luminance})}\)
Figure 1*. Stimulus for concrete pavement

Figure 2. Global optical flow representation, concrete pavement.

Figure 3*. Stimulus for bituminous pavement.

Figure 4. Global optical flow representation, bituminous pavement.

Figure 5*. Stimulus for bituminous pavement with chromatic bands.

Figure 6. Global optical flow representation, bituminous pavement with chromatic bands.

* images represented in black and white and with the vehicle initial distance of 20 meters
With these results we do not want to deny the importance of chromatic bands concerning their role in signalling for instance the cross walk or as a speed reducer. Chromatic bands impair the motion detection task because they generate a higher optical flow. This task is important in traffic control and avoiding vehicle collisions, thus we underline the importance of the detail around the vehicle, that is mainly generated by the road environment, e.g., pavement road design or vertical and horizontal traffic signs. Nonetheless a signalised road is very important, an over signalised road could be dangerous, concerning the impairment of the motion detection task.

Table 1
Three kinds of pavement, wrong detections, average and s.d.

<table>
<thead>
<tr>
<th>Pavement</th>
<th>Average</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous</td>
<td>1.54</td>
<td>1.78</td>
</tr>
<tr>
<td>Bituminous with chromatic bands</td>
<td>2.38</td>
<td>2.51</td>
</tr>
<tr>
<td>Concrete</td>
<td>1.29</td>
<td>1.50</td>
</tr>
</tbody>
</table>

3.2. Vision and reaction times study

The data concerning visual acuity, reaction times and the vehicle’s motion detection (wrong detections for the approaching and receding situations) were treated with a factor analysis. Table 2 shows the varimax-rotated factor matrix. The factor extraction determined three factors with an eigenvalue greater than 1 and a cumulative percentage variance of 67.1%. The first factor accounts for 32.6% of the variance and is saturated in decreasing order by the variables: contrast acuity, kinetic vision, dazzling recovery time, vehicle’s motion detection and by the binocular near vision acuity. The second factor accounts for 20.3% of the variance and is saturated by the reaction times (SRT and CRT). The third factor accounts for 14.1% of the variance and is saturated by the far vision acuity (left and right eye).

Considering the parameters we evaluated, vehicle’s motion detection is the one that best represents the driving task, once it is a component of that task. Thus, the variables closest to driving are: contrast acuity, kinetic vision and dazzling recovery time. Near vision acuity is related with factor one, but in the correlation matrix of the factor analysis it’s correlation with the vehicle’s detection is weak (r=0.171, p<0.05). However, it is related with factor one because the tests of contrast acuity and kinetic vision require near vision. In the correlation matrix of the factor analysis the correlation of near vision with contrast acuity and dynamic acuity is higher (respectively: r=0.45, p=0.001 and r=0.38, p<0.001). Reaction times and far vision acuity, respectively are responsible for factor two and three and are not related with the motion detection task. The practical implications of this study with regard to drivers’ assessment stress the need to give more importance to dynamic tests, contrast acuity and dazzling recovery time because those measures are closely related with a vehicle’s motion detection; a skill that is undoubtedly necessary and decisive to safe driver behaviour. Traditional tests of static visual acuity and reaction times should have less weight. The future tests for driver assessment should include more dynamic tasks such as the vehicle’s motion detection.
3.3. Age and sex study

In this study we compared the detection time (DT) and wrong detections in the vehicle’s motion detection task as a function of gender and age. We used participants’ answers for the approaching and receding situations. The omissions were considered as wrong detections. Female did not show a significant Spearman correlation coefficient between the number of wrong detections and age ($r=-0.1246$, $p=0.394$) but was found a significant positive correlation between the age and DT ($r=0.6120$, $p=0.001$). For males a significant positive correlation between the number of wrong detections and age ($r=0.4401$, $p=0.001$) was found. No significant correlation between the age and DT ($r=0.2224$, $p=0.206$) was found. The average and standard deviation of errors for females were 6 and 5.09 and for males were 7.86 and 6.95. The average and standard deviation of DT in milliseconds for females were 888 and 191 and for the males were 740 and 125 (Figure 8 and 9). These results show that the relation between age and the vehicle’s motion detection is different for female and male. Females gave fewer errors than male participants, but with increasing age they need more time to detect a vehicle’s motion. Males need less time to detect vehicle’s motion but with age they produced more errors than females. From an ecological point of view both behaviours reveal

<table>
<thead>
<tr>
<th>Values of:</th>
<th>Optical Flow</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3%</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>5%</td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>19%</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Figure 7. Three kinds of pavement, average wrong detections, optical flow and contrast.
a negative effect of age on the vehicle’s motion detection because a wrong detection could be as dangerous as a slow detection.

Table 2.
Varimax-rotated factor matrix.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far vision acuity right eye</td>
<td>0.24</td>
<td>-0.18</td>
<td>0.86</td>
</tr>
<tr>
<td>Far vision acuity left eye</td>
<td>0.06</td>
<td>0.13</td>
<td>0.89</td>
</tr>
<tr>
<td>Near vision acuity (monocular)</td>
<td>0.59</td>
<td>0.35</td>
<td>-0.12</td>
</tr>
<tr>
<td>Kinetic Vision</td>
<td>0.81</td>
<td>0.18</td>
<td>-0.02</td>
</tr>
<tr>
<td>Contrast Acuity</td>
<td>0.82</td>
<td>-0.01</td>
<td>0.24</td>
</tr>
<tr>
<td>Dazzling recovery Time</td>
<td>0.70</td>
<td>-0.03</td>
<td>0.17</td>
</tr>
<tr>
<td>Vehicles motion Detection</td>
<td>0.63</td>
<td>-0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Simple reaction Time (SRT)</td>
<td>0.01</td>
<td>0.88</td>
<td>0.04</td>
</tr>
<tr>
<td>Choice reaction Time (CRT)</td>
<td>0.05</td>
<td>0.86</td>
<td>-0.05</td>
</tr>
</tbody>
</table>

Figure 8. Average wrong detections for females and males.  
Figure 9. Average detection time in milliseconds for females and males.
References


5. Essilor Ergovision, manuel de rÈfÈrence. CrÈteil: Essilor (s.d.).