VISUAL PERFORMANCE DURING NIGHT DRIVING

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Paper Number 98-S2-P-23

ABSTRACT

Driving by night is known to be more dangerous than during daytime. In addition, a lot of drivers complain about vision during night driving. This is the first cause of driving restriction for seniors.

The needs for lightning systems improvement concern safety and comfort. This relies on a certain knowledge about visual performance of the driver.

The characteristics of the visual environnement of night driving and the physiology of vision at low photopic luminance level give cleues to the improvements to reach. A specific experimental set-up is developped in ordrer to measure the visual performance and fatigue while driving and without interrupting it. This test is based on the measure of visual acuity and contrast sensitivity. The visual fatigue is estimated from the evolution of the results to the tests versus time.

Average drivers are asked to drive at early night (avoiding drowsiness) on open roads in order to compare several frontlight systems. Experiments lasted 3 hours of driving. Each driver tested three lighting systems, and then drived 9 hours in three nights.

A classification of the systems is obtained in terms of visual performance of the drivers.

INTRODUCTION

Driving by night is a distinctive and non-physiologic situation that induces numerous accidents. In France, it represents 20% of traffic but it provoks 50% of death. Actually, night driving has many sights starting from casual driving to professionnal and continuous night driving of lorries. Many factors can have an influence upon night driving :

- atmosphere (monotony, repetition, tiredness, ...)
- toxicology (alcohol, tobacco, drugs, ...)
- vision (visual performance, glare sensitivity, optical illusion, ...)
- psychology (euphoria, fear, ...)

From an ergonomic approach, night does not exist by itself. In fact, it is a mental representation, specific for each person, linked to the weak performance of his senses, his visual potential and his psychological background. As human is blind at night, he cannot build his own previous experience of that kind of vision. Thus, each night image is immediately convert then interpreted as a daylight image following a complex conversion scheme. The pertinency of this transformation straightly relies from previous experience of the driver ; insofar as visual function is defined as being a psychophysiological feeling acquired deriving from a previous experience. Then, it is possible to consider that the night driver with his frontlight system has a lowered photopic vision and not a enhanced night vision and all the lighting systems have been made in order to bring night vision closer to daylight vision.

Improvements of front-light systems become important in terms of quality and intensity of light, shape of the beam. A better knowledge about vision during night driving is needed concerning safety and front-light improvement. Experiments on open road, with ordinary drivers, testing pertinent visual indicators are an approach to some of these problems.

Methodology

The complexity of the visual system pulls the experimental set-up. It starts with the eyes and ends in specific areas of the brain. Vision results from an optical processing, a transform from light waves to nerve impulse, then parallel processes for pattern, movement and colour recognition all refering to memory informations. Any change in the luminance of the scene induces modifications in the first optical stimulation and in all the processing. The visual system adjusts continuously to the luminance, the distance to objects, ... Then, any attempt to evaluate the visual performance of someone in a defined situation (i.e. a driver) will be significant only if the subject don't have to adjust his vision in terms of luminance nor of distance and if he don't have to interrupt his actual task (i.e. : driving).

Many prameters can be measured concerning vision. Acuity versus contrast is known to be very sensitive to the luminance level, to the age of the subject and to his fatigue. Many studies have been done in hospital or laboratories environnements and also for ergonmic purposes (Gur, 1992 ; Kluka, 1993 ; Koskela, 1998 ; Quant, 1992 ; Phillips, 1992). The subject is asked to look at a network or series of letters or symbols (Landolt rings or Snellen E) of variable sizes, drawn in a scale of gray levels generaly over a white background (other way a black background). The contrast sensitivity function is the limit of visible contrast for all spatial frequencies (fig 1.).

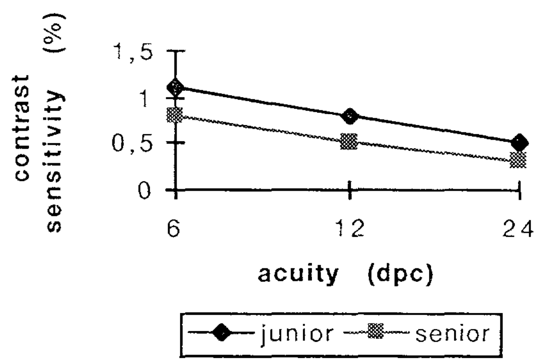

Figure 1. contrast sensitivity function for both junior and senior population at 200 cd/m^2.

Driver's visual performance is correlated to the luminosity of the observed scene, the contrast of scene's targets and driver acuity. For this reason, the sensitivity contrast function test to control visual performance during experiences seemed to be a suitable starting point for the driver vision evaluation.

The main difficulty of such experiments concerns the adaptation of a pertinent visual test in driving context, without any perturbation for the driving task. Results in laboratories context must be transposed in a real car context. First, driver's vision has to be evaluated in laboratory environnement in order to detect possible pathology and to check that the driver has a correct vision versus his age and others physiological parameters. All the drivers who participated to the experiments had a standard vision (with or whithout glasses) without any pathology except presbyopia for seniors.

The standard visual test uses networks with constant acuity at decreasing contrasts. For safety reason, only still images could be projected in front of the car. Letters were prefered to symbols because they involved a identification/recognition process and not only detection, that is closer to the driving task. In order to avoid luminance adjustement, the background of the test had the luminance of the road surface lightened by the low beam of the car. The contrast levels were calculated from this background. This luminosity corresponded to a low photopic level. The delay of answers was never measured as it also relies on traffic conditions.

The integration in the car is made within a Head Medium Display, without helmet, which showed letters generated by a display (fig2). The path of light was controlled by mirrors, strip and which ensured a projection at 1.8 meters from the driver's eyes. Thus the driver kept in far vision during the test. The image luminosity depended on light intensity of the screen (100 cd.m^2), coefficient reflection of the mirrors (90%) and strip (4%).

In this field of illuminance the maximal spatial frequency is about 4 Degree Per Cycle (dpc) and looks like a bandpass filter. For display size reasons, only spatial frequency beginning from 3 dpc could be studied. To have a good representation of the contrast sensitivity function, four spatial frequencies between 3 and 24 dpc were measured. This range, integrating visibility and lisibility, is important because useful in a driving context. The thresholds of contrast were between 0.8 and 6% corresponding to known contrasts detected at identical luminance.

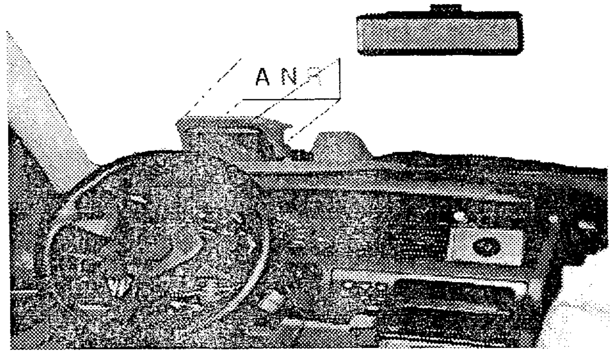

Figure 2. Experimental set-up : Letters of decreasing contrast projected via a head-up display.

Practically, letters of the same size but of decreasing contrast are displayed at the same time. The driver is asked to read loudly what he sees. Two series of four sizes of letters are shown without interrupting the driving.

Visual fatigue

Protocol

10 ordinary drivers, aged under 40 years, with correct acuity (10/10) were selected after undergone an acuity clinical control. To avoid drowsiness, experiments held in winter and each driver was asked to drive at early night on open roads (motorways and trunk roads) in order to compare three front-light systems. The journey lasted three hours. Four spatial frequencies were recorded and repeated twice to ensure statistical interpretation. The recording was realised every 45 min. The evolution of the contrast sensitivity function can be interpreted as a visual fatigue indicator.

Each driver tested only one front-light system a night and waited about two weeks the next experiment.

The devices differed by their luminance (689 cd/m^2 ; 1552 cd/m^2 ; 6325 cd/m^2).

Driver behavior is estimated by measures on the car, and physiological measures. Each driver, had to answer a questionnaire about perception of the beam, for every front-light system. Only the visual aspect is presented here.

Results from the contrast sensitivity function

First, the driving task was not perturbed and the test was well accepted by the drivers. The contrast sensivity function could be established at any time with homogeneous results with regards to the reference in laboratory.

No statistical difference between two measures for every spatial frequency was shown : this prove that the number of measures taken was adequate.

During driving, no evolution of the contrast sensitivity function could be observed, thus, there was no degradation of visual performance for a long night drive, whatever the front-light system used.

The perception of the contrast classified the light systems, whatever the spatial frequency tested. However, the frequency 6.08 dpc was the less discriminant. The results were correlated with the luminance of front-light system.

Global visual performance was also measured using a Ergovision from Essilor before and after the journey. The Ergovision is of commun use in occupational medecine. Results were correlated to those in laboratory but no effect of the front-light systems could be noticed as the driver visual system adapted to the luminance of the Ergovision. This shows the interest of such study in real visual context which avoid problems of estimation about : luminance range, front heads-light illuminance, beam pattern and road reflection.

Results from the questionnaire

Drivers were asked about visual sensation before and after the course, perception of visual fatigue, judgement of beam in staight line and curve configuration.

Each driver performed the test at night after a working day ; but they were not physically tired. However, they felt visual fatigue after the course. This observation could be noticed moretheless for the more luminous light. However, the drivers found confortable all the devices tested and the only one noted as very confortable was the most luminous front light system.

Age and night vision

Protocol

33 drivers aged between 20 and 40 years, and 27 drivers aged over 55 years were selected to participate to a night driving experiment. Each driver passed an optical clinical control. Only correct acuity vision were accepted to insure good homogeneous of the driver population. The age of 55 years old was decided as the limit for the senior group because presbyopia is then stabilised.

The test consisted of two 20 minutes of night journey on a winding road with correct horizontal signalisation. Half of the drivers first drove with halogen lamps and drove again on the same road with xenon lamps. The other half tested the lamps in the counter order. Since long journey didn't altered visual performance, the journey duration was fixed in function of visual time adaptation to new luminance. At the end of the journey a control of the contrast acuity was realised twice. In order to avoid misunderstanding problems of the test, it was explained and realised before the journey.

For this experiment three spatial frequency between 6 to 24 dpc were controlled, with two front light luminances (halogen : 2162 cd/m^2 ; xenon : 2327 cd/m^2).

Results from the contrast sensitivity function

The results confirmed that younger drivers had better acuity than older drivers. However, no difference of acuity could be noticed versus luminance for both populations (fig 1). The increase of luminance of xenon lamps was not suffisant enought to give seniors the same acuity as junior using halogen lamps.

Results from the questionnaire

Xenon lamps were always estimated as the most confortable front light system. The sharpened cut-off of xenon lamp was noticed but did not induced any discomfort.

Front-lights were also judged in terms of colour temperature. For this experiment, drivers were more confortable using higher temperature light (xenon : 3903K ; halogen : 3100K), which was more similar to the natural light. Seniors were less sensitive to the whiter wenon lamps probably because of a decrease of perception of short wavelenght lights due to age.

CONCLUSION

Improvement of front-light systems needs, to be efficient, a better knowledge of the links between visual performance and the devices provided. The use of a head-up display to perform ophtalmic tests allows the assesment of in situ visual performance without any perturbation induced by visual adaptation.