PsychNology Journal, 2003
Volume 1, Number 2, 164 - 175

Testing Driver's Comfort in Virtual Environments

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ABSTRACT

In this study, the comfort of the tools available to the driver are evaluated through the virtual simulation of a car interior on a Tanorama[TM] Powerwall. In a series of couple comparisons, 20 participants have been asked to judge both the visibility and the aesthetic pleasantness of a set of hazard buttons, differing in their coloration parameters. The results show that "visibility' has a direct influence on the perceived comfort, while aesthetic pleasantness has none. The easiness with which different prototypes can be produced and evaluated in an immersive simulation adds another argument to the application of virtual environments to vehicle engineering.

Keywords: *car prototyping, vehicle evaluation, driver comfort*

Received 10 March 2003; received in revised form 13 May 2003; accepted 16 May 2003.

1. Introduction

The technological equipment of a car tries to meet the customers' needs in terms of communication, safety and on-board comfort, aiming at a multi-sensory harmony between the driver and its environment [Gilardi, 2002]. To achieve this goal, ergonomics represent a powerful aid with its focus on efficiency and comfort and with 'user-centeredness' [Norman, 1986] as the fundamental design principle [Buxton, 1998].

In particular, in order to evaluate different car interiors a parametric "vehicle system" has been devised, consisting of a mechanical frame (i.e. *seating-buck*) which varies the position of seating and commands, and of a virtual rendition of the car interior,

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integrated with specific software for the ergonomic analysis [Monacelli, 2001]. This simulator creates an environment for the manipulation and evaluation of physical (posture, visibility, approachability), cognitive (attentional demands [Lamble, 1999]) and perceptual aspects (directional motion, graphic patterns) of the driver's experience [Falkmer, 2000]. It provides an interactive, multi-modal environment in which researchers can study *in situ* the user's behaviour ("sensory labs", Gilardi, 2002).

In this paper we will describe a research carried out with a virtual simulator to evaluate the impact of different factors on the driver's perceived comfort.

2. Methodological guidelines

For the evaluative setting to be created, the following aspects have to be defined.

- *the object of study;*
- *the human factors of concern;*
- *the type of user (*Zhang, 1999*) (to be identified via market research);*
- *the experimental task;*

Figure 1 details these four aspects, highlighting in red those considered in the present study.

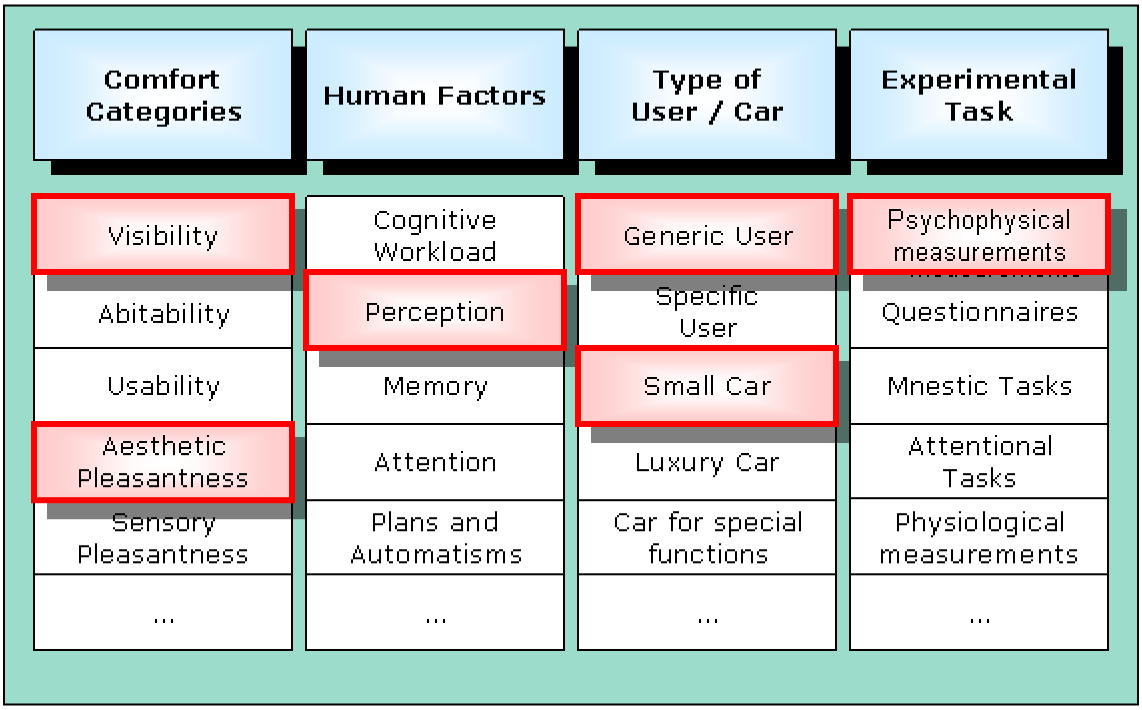

Figure1

Other aspects include:

- *the type of multi-modal environment;*
- *the impact of the technology with which the task is realized* (a training session before the actual evaluation task is highly recommended to allow participants' familiarization with the experimental setting and equipment);
- *comparison between real and virtual environments;* even though not strictly aimed at measuring the driver's comfort, it can be considered as a method for increasing the validity of the evaluation with the simulator;
- *use of anthropometrical data:* software specialized on calibrating posture, motion and access space of the occupants of the car is currently adopted in vehicle engineering and has been integrated in the virtual simulator.

3. Experiment

The object of the experiment presented here is to study the *immediate visibility* and *aesthetic pleasantness* conveyed by the color of the 'hazard buttons' of a car (namely the button to be pushed in case of emergency to activate the four external blinking lights of the car). As it is shown in figure 1, those aspects represent two components of the driver's perceived comfort. In a previous study (Pretto, 2002) a significant difference in the relative importance of these aspects was found, the former being more directly correlated to safety and comfort. Quite surprisingly, it is quite overlooked in the guidelines adopted by the major Italian car manufacturer.

The visibility of a button may derive from:

1. *relative position*: indicates the position of a button with respect to the adjacent objects;
2. *dimensions* of the active area, i.e. of the portion of a button that, when pressed, can activate the related function;
3. *shape* (squared/ rounded, regular/ irregular);
4. *jag*: on the assumption that the minimum jag of the button from the frame containing it ('filo incasso' level) has to be of about 2.5 mm;

5. *color*: usually, hazard buttons come in red, because of the conventional meaning associated to this color; however, there is no agreement yet on the adequacy of this color.

6. *approachability limits of the 'center of selection'* (namely the central point in the active area of the button*)* depending on its function, any button should be placed in easily reachable places, such as pre-defined areas of the dashboard or the door panel.

In this study we will operationalize it as 'color'.

3.1 Participants

Twenty persons participated to the experiment, all members of the research center responsible for the project (for confidentiality reasons), aged 21 to 45, with either normal eyesight or eyeglasses. Even though participants were only presented with static images, they were asked to sign in the informed consent form alerting on all possible side-effects of a dynamic, immersive session [Gamberini, 2002].

3.2 Technical Apparatus

The experiment was conducted at the Virtual Reality Room of Elasis Research Center in Italy using the following equipment:

- *Tanorama*™ *Powerwall*: a huge multi-channel rear projection screen 7.5m wide and 2.5m high (Fig. 2). Light reflection and surface dispersion can be analyzed as good as with real finished models. Product designers in the automotive industry have a suitable capability to visualize a complete car in a 1:1 scale. The Tanorama™ Powerwall consists of 3 segments, each one projected by one or two graphic channels, which in turn are powered by 1 or 2 projectors. Therefore, in addition to 3 channels mono displays and 6 channel stereo displays, it is also possible to have a 6 channel mono display. By using double projection for each segment, strong light-intensity and high brilliance is achieved.

Figure 2 Tanorama® PowerWall in the 'Virtual Reality Room' at Elasis Research Center

- *StereoGraphics – CrystalEyes3*™: glasses with polarized LCD lenses (*Shutter-glasses*) (Fig. 3) providing stereoscopic visualization (more information available at http://www.stereographics.com/products/crystaleyes/body_crystaleyes.html);

Fig. 3 Shutter Glasses

- *SGI Onyx 3400 InfiniteReality*: a graphic server able to generate real time 1:1 scale visualizations of different vehicles (Fig. 4) (more information available at SGI products site);

Fig. 4 SGI Onyx

Division MockUp (v. 6.2) has been used in order to create and customize the presentation algorithm of the stimuli. *3D Studio Max* (v. 4.2) has been used to modify the components (the creation of single objects from the mathematics of the car).

Presentation sequence, data collection and the entire experimental progress were controlled from a console located behind the participants. The execution of the experiment required the constant presence of two people: one working with the computers and the other handling the subjects.

3.3 Stimuli

The stimuli consisted of the virtual dashboard of a car, currently on the market, projected on a PowerWall, in which the colour of the hazard button could vary among five equidistant levels: from the darkest one, in which the colour equalled the dashboard shade, to the reddest one, identical to the tint used in many car models currently on the market. Tab. 1 reports the parameter values.

Stimuli	(power = 21.160)			
	Parameter	Red	Green	Blue
1	ambient	0.5	0.5	0.5
	diffuse	0	0	0
	specular	0.1	0.1	0.1
	emissive	0	0	0
2	ambient	0.5	0.5	0.5
	diffuse	0.1	0	0
	specular	0.1	0.1	0.1
	emissive	0.1	0	0
3	ambient	0.5	0.5	0.5
	diffuse	0.2	0	0
	specular	0.1	0.1	0.1
	emissive	0.2	0	0
4	ambient	0.5	0.5	0.5
	diffuse	0.3	0	0
	specular	0.1	0.1	0.1
	emissive	0.3	0	0
5	ambient	0.5	0.5	0.5
	diffuse	0.4	0	0
	specular	0.1	0.1	0.1
	emissive	0.4	0	0

Tab. 1 colour variations parameters in the experimental stimuli

The ‘paired comparison indirect scaling method’ was chosen for stimuli presentation. This method considers all the *n(n-1)/2* possible couples of *n* stimuli. It provides the possibility of comparing the variation of a certain physical variable with that of the sensorial or psychological variable on the basis of the concept of *discriminal dispersion* [Torgerson, 1958] and of Thurstone’s *law of comparative judgments* [Guilford, 1954]. It is assumed that it is possible to transform the judgments, provided on an ordinal scale, in values on an intervals scale (expressed in z points) representing the distance between the stimuli.

Each couple of stimuli has been presented four times to the participant: two times in a certain order and two times with the order inverted (group scaling) Furthermore, the ten possible couples have been presented two times in a certain sequence and two times with the sequence inverted. Overall, each participant was requested to express judgement on forty couples of stimuli. Each sequence of ten couples has been balanced according to Ross's criterions (1934) [Purghé, 1995].

3.4 Procedure

Participants sat on a chair, placed at 1.80 m in front of the projection screen and at 2.50 m from its left border. That position reflects the corresponding position of a driver seating inside a real car in accordance with the screen size. The viewpoint was customized at the height of the eyes of a virtual manikin positioned inside the digital mock-up, in conformity with the ergonomic criteria expressed by the software adopted (called 'Jack'). Fig. 5 shows a picture of the environment, as it appeared to the immersed participant. The participant wear a pair of shutter glasses (over regular eyeglasses if the participant needed them). The experiment was performed without environmental light, in order to avoid a distortions of the colour perception.

Fig. 5 Subjects' view during the experiments

The experimenter presented the first couple of stimuli, whose elements appeared in sequence for 5 seconds each. Afterwards, participants expressed their preference aloud by saying either "*primo (first)*" or "*secondo (second)*" depending on which stimuli they preferred in terms of "visibility" and "aesthetic pleasantness". The experimenter wrote both preferences and proceeded to the subsequent couple of stimuli, repeating this procedure for the 40 couples of stimuli.

Each experiment was preceded by a training phase of a few minutes, where stimuli were adopted that differed from the experimental ones in colours and objects, but not in their coloration parameters. Participants familiarized with the whole experimental procedure (including the expression of preference) so that during the experiment they would express their preference after the presentation of each couple of stimuli without any solicitation on the experimenters' part. The instructions, provided before the training phase, are reported in the Appendix.

3.4 Data analysis and results

The main purpose of the data analysis is to obtain a set of scalar values that indicates, in an interval scale, the position assumed by each stimulus along the psychological continuum representing the evaluated characteristics (Fig. 6). In this way, every scalar value will express, in *z points*, the distance of a stimulus from the others.

The mathematical transformations have been performed on data under the assumptions of *case V* of the Thurstone's *comparative judgements law*.

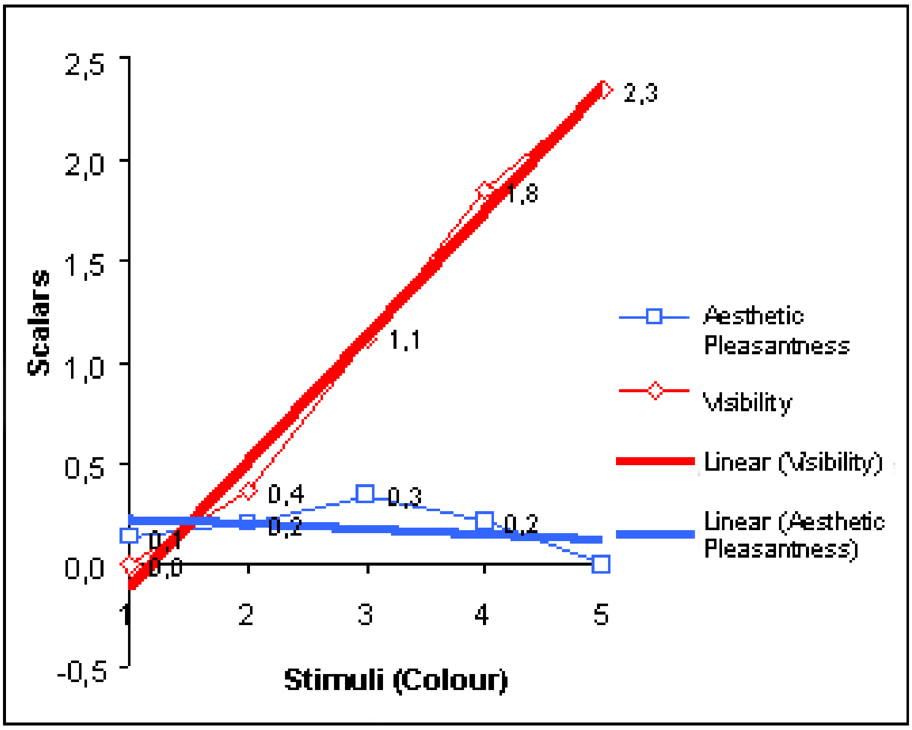

Fig. 6 trend of scalars S_j for aesthetics and visibility of stimuli

The data collected show a good adaptation to the model of mono-dimensional scale assumed by case V, because, for both characteristics, the calculated χ^2 is lower than critical χ^2, as shown in Tab. 2.

Characteristic	**χ^2 calculated**	**df**	**χ^2 critical (α= .05)**
Visibility	0,949	6	12,592
Aesthetics	0,023	6	12,592

Tab. 2 Data adaptation to the model of scale

The effect of colour on visibility and pleasantness preference can be statistically verified by applying the 'simple linear regression' model to the scalars, using the variations of colour as the independent variable. A regression equation assesses the average value of the dependent variable for a given value of the independent variable, i.e. the value that it would assume if it were not liable to the action of incidental factors [Camussi, 1995].

It is possible to verify whether the angular coefficient of the regression straight line significantly differs from 0. Tab. 3 reports the results of this test, along with the regression coefficient (*b*), the significance level (*F*), the correlation coefficient (*r*) and the determination coefficient (r^2).

Characteristic	**b**	**F(*gdl*1,4)**	**Sig.**	**r**	**r^2**
Visibility	0,422	76,695	0,001	0,975	0,95
Aesthetics	0,044	3,676	0,128	0,692	0,479

Tab. 3 Significance Tests for the adaptation to the simple linear regression model

With respect to visibility, it is possible to accept the alternative hypothesis H_1: $\beta \neq 0$, according to which the angular coefficient of regression equation (regression coefficient) is significantly different from 0. This implies that the chromatic variations have an effect on the preference judgement; in particular: the more the red tint increases, the more the perceived visibility of the hazard button increases. With respect to aesthetics pleasantness, we can not reject the null hypothesis H_0: $\beta = 0$, i.e. the chromatic variations do not have any effect on the aesthetic pleasantness of the stimulus, which remains almost constant through all stimuli.

4. Conclusion

The results of the experiment show a clear trend: the increase in the red tint of the button correlates directly with the visibility judgments. Since visibility has been assessed as the most important factor influencing the perceived comfort inside a car (Pretto, 2002), we can reasonably suppose a direct correlation of the red tint with the perceived comfort as well. The experimental results show on the other hand that the aesthetic pleasantness of the button is not significant. Therefore, we are allowed to consider that a button that is strictly associated with emergency is not appraised for its aesthetic quality as it is for the easiness with which it can be located.

These results should be always read with respect to the type of car in which the experiments have been conducted, i.e. a small car. However, even in a luxury car that cannot show unusual colours, the designer's choice must be based not only on aesthetic appearance, but on ergonomics as well; an emergency command needs special characteristics relating to visibility, approachability and perceptual salience.

Appendix

"*Tra poco le presenterò in questa plancia virtuale una serie di coppie di pulsanti di emergenza. Ogni pulsante presenterà una colore diverso dall'altro, alcune volte la differenza sarà notevole, altre volte appena percepibile. Dopo avere visto una coppia di pulsanti le chiederò di esprimere due giudizi: il primo riguarderà quale dei due pulsanti che ha visto le è sembrato il più visibile; il secondo le chiederà invece quale pulsante le è sembrato più gradevole. Risponda indicando soltanto 'primo' o 'secondo' se preferisce, rispettivamente, il primo o il secondo pulsante della coppia presentata. Tenga presente che i giudizi dovranno essere espressi in riferimento alla vettura in cui si trova e alla plancia che ha di fronte. L'esperimento durerà in tutto circa 10 minuti. Domande?*"

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Other images are available at
http://weblearn.psy.unipd.it/ergonomia/Virtual%20Reality%20for%20Car%20Prototyping.php