Report on design for LED Applications: human factor

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INtelligent Renewable Optical ADvisory Systems (INROADS)

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1 Introduction

The INROADS project aims at developing "active road markings", which encompasses road studs, white lines and other surface mounted intelligent lighting applications, tools and methods. The underlying idea is to provide intelligent lighting systems and enhanced information or guidance to drivers wherever this is needed. This should improve safety and service level and enable more effective operation, planning, design, repair and maintenance of the road network. Also it should minimise both the vulnerability of road networks to incidents and to CO2 emissions by optimising the use of the existing assets and reducing the need for additional construction.

In the course of a stakeholder meeting in Brussels on 23 February 2012, a comprehensive list of potential applications for the intelligent lighting was presented to national authorities, road operators and transport research institutes in order to discuss their usability and refine some of the ideas presented (for a complete list, see Deliverable 2.3, October 2012). Some applications were discarded due to their low priority in the eyes of the stakeholders, leaving the remaining applications to undergo a vote by the project team. The outcome encompassed four scenarios that represent the potentially most interesting employments of the intelligent road studs:

1. Active lane delineation on country roads – LED automatically turned on when a vehicle has been detected to enhance the lane edges and outline a curve on unlit roads (off when there is no traffic).
2. Smart pedestrian crossings – illuminates only when vehicles approach the crossing (e.g. highlighting stop bars); could be used near schools only during school's activity hours.
3. Stationary Vehicle Ahead – Warning LEDs which are on (flashing, etc.) when there is an obstacle or a stationary vehicle ahead (broken down, accident, queue in the fog, etc.) on driving lanes and/or on the shoulders – known flash points.
4. In pavement signage – Patches of flush mounted lights conveying useful information for the road users such as a variable speed limit, lane closure (accident ahead, debris, etc.), traffic jam, advanced warning for queues ahead, mandatory exit, etc.

One key issue of the project is the evaluation of the proposed applications, in terms of human factors. Considering the signalling applications, among the most useful questions are, for example, if the new equipments are visible enough, both in daytime and nighttime; do the drivers understand the messages, and do they behave accordingly? In other words, one needs some insights about the perception and about the behavioural reaction of the drivers, in presence of such systems. As result, human factor studies were carried out in WP6 to provide recommendations on the photometric, colorimetric and geometric design for the various proposed embedded LED applications. These recommendations will be based on data from both photometric and psycho-visual evaluations.

The remainder of this deliverable is organised as follows. Section 2 reports the IFSTTAR contribution which investigates visibility and discomfort glare produced by a road stud during daytime and nighttime. Recommendations are provided according to the external illumination and the road surface condition. Then, in Section 3, CIDAUT provides a state of the art of guidance and standards available for lighting and signalling road systems in order to identify photometric recommendations for LED-road studs based on these documents. Section 4 focuses on a smart pedestrian crossings application. A human factor study conducted by CIDAUT, to determine the most preferable configuration ensuring acceptance and hazard awareness, is detailed. Finally, discussion and conclusions of the report are presented in Section 5.

2 Visibility study of road studs

2.1 Context and previous work

The relevance of road illuminated installations needs a good understanding of the message by road users. To study this question, literature mainly focuses on the road user behaviour depending on the situation (Styles 2004, Reed 2006). However, others topics such as the visibility of the road illuminated marking have to be considered.

Indeed, road illuminated marking installations are relevant if the visibility of the devices is ensured without drawback, such as glare that affect driver performances (Theeuwes et al. 2002, Bullough et al. 2008). Both issues have to be addressed whatever the external condition (daytime/nighttime, various weather conditions) (Munehiro et al. 2007; Wu et al. 2012). Some previous work already investigated these questions. For example, Wu et al. (2012) conducted an experiment to collect subjective evaluations of legibility and glare feeling produced by LED signroads, under three different ambient conditions (bright (30klux), dark (5klux) and night (10lux)). Evaluations were first carried out at short (9.8m) and long (57m) distance from the signboards, using a 5-point scale. Then, subjects judged their comfort and glare perception while moving forward. Authors found no difference in subjective evaluation near or distant from signboard without background. In addition, the brighter the ambient condition, the lower the glare level. Finally, LED signboards with 3:1 contrast between LED and background led to the lowest glare level and uncomfortable feeling.

Other previous work focuses on specific environmental conditions (Alferdinck 2004, Bacelar 2006, Hagiwera et al. 2001, Munehiro et al. 2007). Hagiwera et al. (2001) studied the visibility of road delineators under blowing snow during daytime and nighttime. Based on photometric measurements conducted during 30 days, they introduced a model predicting the luminance of an illuminated delineator and the background luminance under blowing snow. Munehiro et al. (2007) conducted an experiment about visibility and glare of three LED road delineators under clear and foggy conditions during daytime and nighttime in a real-world street. The intensity and colour of the LED road delineators were fixed. Judgments of 20 women about visibility, discomfort glare and safety feeling were collected at 50, 100, 150 and 200m from the delineators. In addition, photometric measurements were recorded at two-minute intervals (luminance, horizontal illuminance). As a result, recommended luminous intensity for each tested LED delineators depending on the weather condition and the time of the day (day or night) were proposed. For example, for amber LED delineators, 1000cd was recommended during clear daytime and 70cd during clear nighttime (i.e. without fog). Findings suggest that visibility decreases with the observation distance (but is still high at 200m); whereas level of discomfort glare seems not to depend on the observation distance either during day or night. Models of subjective visibility assessment value (between 1-poorly and 7-sufficiently) and subjective discomfort glare assessment value (between 1-imperceptible and 5-intolerable) depending on the luminous intensity level were determined through linear regression of judgment mean values for each observation distance, each weather condition and each time of the day.

Focusing on road studs, Bacelar (2006) carried out subjective experiments to compare three LED road studs with fixed intensity and one conventional stud during nighttime. Participants drove in a closed track along 200 m and assessed the visibility, the legibility of the trajectory and the glare level on semantic scales, and their preference between studs, streetlighting and nothing. The LED road studs with the medium maximal intensity (around 4 cd) make it possible to ensure good visibility and legibility and low discomfort glare level.

Alferdinck (2004) conducted an experiment in a closed track to identify the intensity levels required to ensure that road studs are perceived by road users during daytime (maximum road luminance 5000 cd/m^2) and nighttime (road luminance 0.02 cd/m^2). For various inter-distance between road studs (from 1m to 7m), seven participants set the stud intensity to reach a given visual performance objective. Six intensity levels were recorded for each subject (from detectable to disturbing). Findings suggest that the minimal required luminous intensity is dependant of the inter-distance between the road studs. From collected data and photometric measurements, a model is proposed to estimate the required intensity level according to the road luminance for a given visual performance objective and a given inter-distance. In a larger study about dynamic marking system with road studs, Alferdinck (2007) recorded judgments of four experts about the brightness of three different models of road studs, standing at 50 m from the stud and driving. In addition, the experts judged if they were able to distinguish the switched on studs (from "very easily" to "with very difficulty") from the switched off ones. Data were collected during daytime, twilight and nighttime.

As a conclusion, in previous studies about visibility and discomfort glare feeling of road markings, few ones are related to LED road studs. From the previous work, the importance to adapt the luminous intensity of the road studs depending on the external conditions is highlighted. Various illumination conditions (e.g. daytime, nighttime) and weather conditions (e.g. fog, snow) have been studied. However, even if wet condition was already explored by Gibbons et al. (2004) for conventional pavement markings, we did not find previous work related to visibility of LED road studs in such condition. In addition, small panel size (lower than 20 participants) was found in previous work, which limits the validity of the results especially during daytime while illuminance conditions are changing from one participant to another (e.g. seven participants in (Alferdinck 2004)).

2.2 Focus of the study

In this context, the present study aims at studying the visibility and discomfort glare produced by LED road stud during daytime (under varying illumination conditions) and nighttime for a dry and a wet road surface by collecting data from larger panel than in previous work (>30 participants). According to the INROADS project partner decision, the study was conducted with one amber-coloured road stud provided by DSTA. Measured characteristics of the tested amber-coloured stud are detailed in Section 3.3. Two experiments were conducted; the first one is related to daytime (called "Daytime" Experiment) and the second one to nighttime condition (called "Nighttime" Experiment). The experiments were designed in order to test the following hypotheses:

- The visibility of the stud changes with the illuminations conditions;
- The visibility of the stud increases with the stud intensity level;
- The discomfort glare level increases with the stud intensity level.

First, based on the hypotheses, the "Daytime" Experiment will try to answer the following questions:

- How does the visibility of the stud change depending on the illumination conditions?
- Does the visibility of the stud change depending on the road surface condition (dry *vs.* wet)?
- Does the visibility of the stud change depending on the road user characteristics?

The "Daytime" Experiment is presented in Section 3.4 and results are detailed in Section 3.5.

Second, the "Nighttime" Experiment and the corresponding results, respectively presented in Section 3.6 and 3.7, focuses on discomfort glare in dark conditions potentially produced by the road stud.

Results of these experiments led to threshold-range recommendations on stud intensity levels to ensure visibility and avoid glare whatever the external conditions (see Sections 3.5.2.5, 3.7.5 and 3.8).

2.3 Photometric properties of the road stud

The experiments were carried out with one amber-coloured road stud provided by DSTA. Intensity measurements were conducted in the IFSTTAR-LEPSIS laboratory to determine the distribution of intensity of the stud. For these measures, the stud intensity was set at the maximum available, but the distribution shape is the same whatever the dimming. Figure 2.1 presents the intensity distribution of the stud determined from measured data. Moreover, Figure A1 in Annexe A provides additional information about the intensity distribution in vertical range between -0.5° and -1°.

The stud intensity is controlled by a DSTA software interface. The intensity level was varied with software input between 0 (corresponding to the stud switched off) to 255 (corresponding to the maximum available luminous intensity). Laboratory measures were conducted to establish the response curve between the value i input in the software and the luminous intensity I provided by the stud. Figure 2.2 presents the relation between the software input i and the intensity I provided at [H: 0°, V: -1°]. The relation is polynomial whatever the observation angle. Equation 1 expresses the relation for -1° vertical observation:

$$I\ (cd) = -10^{-5} i^2 + \ 0.0109\ sv + 0.0864 \qquad (1)$$

Considering a fixed height of the road user eye, vertical angle of observation varies according to the distance from the stud. For 1m20 height, Figure 2.3 reports the maximum available stud luminous intensity (i =255) at 0° horizontal observation angle according to the distance from the stud.

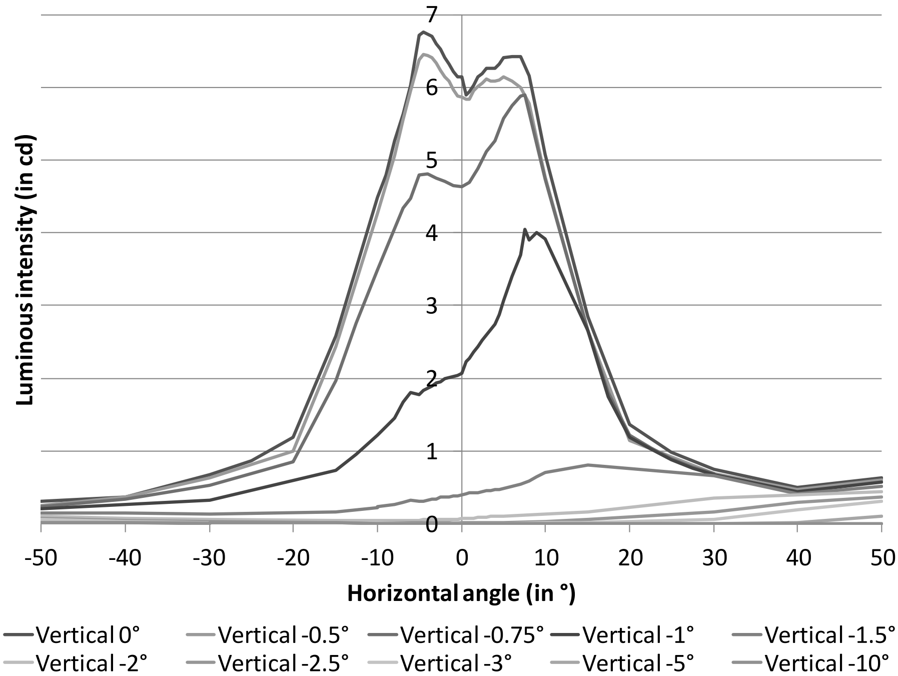

Figure 2.1: Intensity distribution of the amber coloured road stud, at various vertical angles

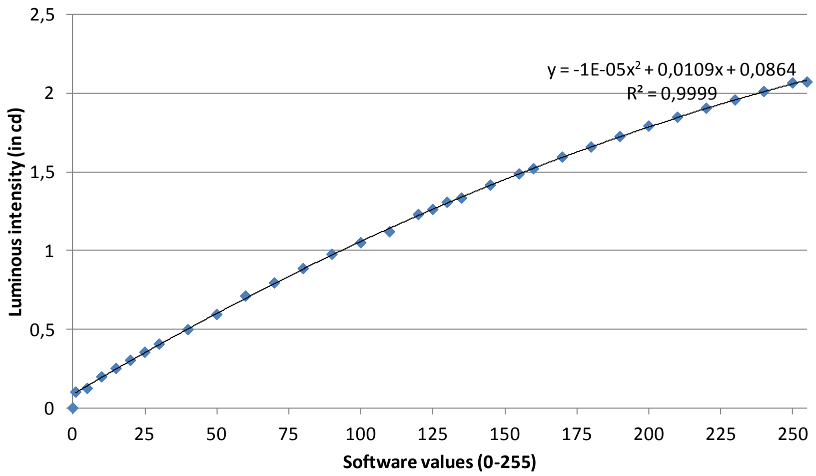

Figure 2.2: Software input values vs Luminous intensity (horizontal angle 0°, vertical angle -1°)

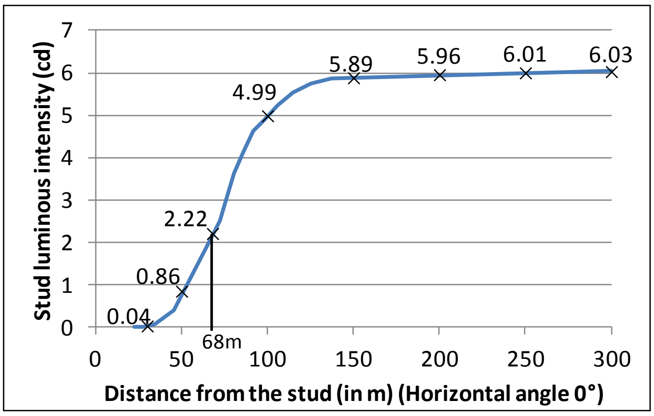

Figure 2.3: Stud luminous intensity for 0° horizontal angle according to the observation distance (1m20 height)

2.4 Presentation of the "Daytime" Experiment

2.4.1 Panel

42 participants were involved in this study. All participants were aged from 21 to 57 years old, with 57% of men and 43% of women. Characteristics of the panel are presented in Table 2.1.

Table 2.1: Characteristics of the panel – "Daytime" Experiment

Characteristics of the panel	Type	Panel
Gender	Male	57.00%
	Female	43.00%
Age	<25	10.00%
	25-34	43.00%
	35-44	24.00%
	45-54	17.00%
	>54	7.00%
Driving License	Yes	95.24%
	No	4.76%
Corrected vision	Yes	47.62%
	No	52.38%

In addition, the following visual characteristics of the participants were collected by conducting a vision test with an ErgoVision:

- Visual acuity in binocular vision;
- Visual acuity in mesopic vision in binocular vision;
- Contrast sensitivity (assessed with the number of errors to read letters under various contrasts);
- The time of recovery after glare feeling.

Table 2.2 reports the vision characteristics of the panel.

2.4.2 Experimental conditions

The "Daytime" Experiment was carried out on a closed track in Guerville (IFSTTAR). Participants were seated at 68.75m from the stud to ensure 1° of observation towards WNW direction, corresponding to an azimuth of 120°. 52 intensities from 0 to 2.2cd (see Figure 2.3) (from 0 to full intensity) of the stud were randomly presented. The experiment was conducted during various time of day. Horizontal illuminance on the road surface did vary during the experiment. In addition, depending on the time of the day, the sun position varied. The experiment lasted around 45 minutes for each participant.

Table 2.2: Vision characteristics of the panel – "Daytime" Experiment

Visual characteristics	**Type**	**Panel**	**Visual characteristics**	**Type**	**Panel**
Visual acuity	12/10	79%	Mesopic acuity	12/10	0%
	10/10	10%		10/10	5%
	8/10	5%		8/10	47%
	6/10	0%		6/10	31%
	4/10	6%		4/10	12%
	2/10	0%		2/10	5%
Contrast sensitivity	Very good (0 errors)	55%	Time Recovering after glare	<25s	36%
	Good (≤2 errors)	24%		25-50s	31%
	Medium (3-4 errors)	7%		>50s	33%
	Bad (>5 errors)	7%		Good recovery	86%
	Very Bad (>10 errors)	7%		Bad recovery	14%

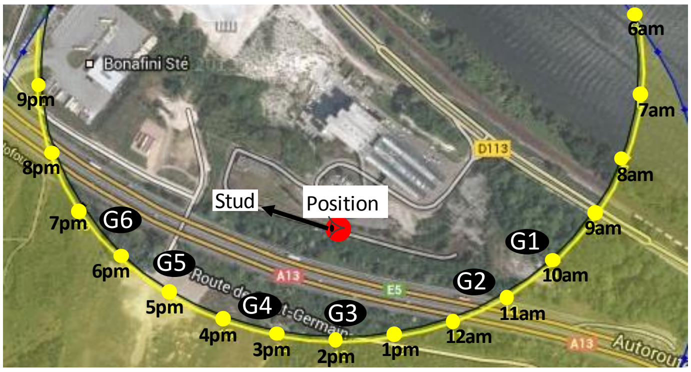

Figure 2.4: Sun position depending on each group
(from http://www.sunearthtools.com the July 9th 2013 at 48° 58' 10.702" N 1° 44' 17.637" E)

Table 2.3: Sun position during the experiment in sunny conditions (July 9th 2013)

Day	Group	Hour	Elevation	Azimuth	Sun position related to the user (Azimuth 120°)	
Sunny day July 9th 2013	G1	10am	45.97°	110.89°	-9.11°	Behind
		10am30	50.26°	119.48°	-0.52°	
	G2	11am	54.54°	128.07°	8.07°	Behind
		11am30	57.74°	139.71°	19.71°	
	G3	2pm	60.66°	210.12°	90.12°	Side
		2pm30	57.38°	221.56°	101.56°	
	G4	3pm	54.09°	233.00°	113.00°	Side
		3pm30	49.77°	241.45°	121.45°	Front
	G5	5pm	35.87°	263.21°	143.21°	Front
		5pm30	30.96°	268.94°	148.94°	
	G6	6pm	26.04°	274.66°	154.66°	Front
		6pm30	21.20°	280.00°	160.00°	
Cloudy Day Sept. 20th 2013	G7	10am	30.23°	129.78°	9.78°	Hidden
		10am30	33.53°	137.88°	17.88°	

Participants were split in one of seven groups: six groups (G1 to G6) during sunny day and one group (G7) during cloudy day. Characteristics of participants within each group are detailed in Table A1 in Annexe A. Figure 2.4 presents the sun position for each group during the sunny day. In addition, elevations and azimuths of the sun during sunny and cloudy days are reported in Table 2.3.

Figure 2.5: “Daytime” Experiment

2.4.3 Experimental protocol

Each group of six participants first assessed the visibility of the stud on dry road surface. Then, pavement was watered to reproduce the wet condition, as illustrated in Figure 2.5(b). The same protocol was repeated to collect data in case of wet road surface. The experiment is illustrated in Figure 2.5.

For each intensity, the participants were asked to rate the visibility of the stud answering the following question: “For you, the road stud looks”:

- 0: switched off;
- 1: switched on, barely visible;
- 2: switched on, uneasy to see;
- 3: switched on, visible enough;
- 4: switched on, with glare.

The stud was set at the tested intensity during four seconds after what fifteen seconds were left to the participants to write an answer. The illuminance of the road surface was recorded for each stimulus.

2.5 Results of the “Daytime” Experiment

Data were analysed to study the variation of visibility with the intensity of the stud and the external conditions. First, preliminary analyses conducted on illuminance and on participants data are presented (Section 3.5.1). Then, statistical analyses are carried out on the visibility ratings and recommendations are provided (Section 3.5.2). Finally, a model is proposed (Section 3.5.3) that determines the required intensity of the stud depending on the illumination conditions.

2.5.1 Preliminary analyses

As experimental conditions varied during the whole experiment, preliminary analyses were required before studying the visibility ratings. First, preliminary statistical analyses have been conducted on the horizontal illuminance data in order to highlight the various illumination conditions met during the experiment (Section 3.5.1.1). Then, participant data are examined (Section 3.5.1.2).

2.5.1.1 Preliminary analysis of illuminance data

Horizontal illuminance closed to the stud was recorded for each judged intensity, i.e. for 52 tested intensities*2 road surface condition*7 groups of participants. Figure 2.6 and Table A2 in Annexe A shows the range of illuminance for each group of participants and each road surface condition (dry or wet). During the whole experiment, horizontal illuminance varied between 14klux and 100klux. As highlighted in the box plots in Figure 2.6, in each group, 80% of the tested intensities were judged under a range of 10klux (50% for Group 4 on dry or wet road surface and for Group 5 on dry road surface). In addition, sun azimuth (respectively sun elevation) ranges from 5 to 11° (respectively from 3° to 5°) depending on the group (see Table 2.3). It can be considered that each group was exposed to stable illumination conditions. However, in some groups (G3, G4, G5), extreme illuminance values (illustrated with blue points in Figure 2.6) could bias visibility ratings because there are not in the same range as 80% of met illuminance values.

Thus, to ensure constant condition for each group, visibility ratings collected under illuminance values not included between the lower and the upper bounds of the box plots in Figure 2.6 will be removed in further statistical analyses (Sections 3.5.2.2 and 3.5.2.3).

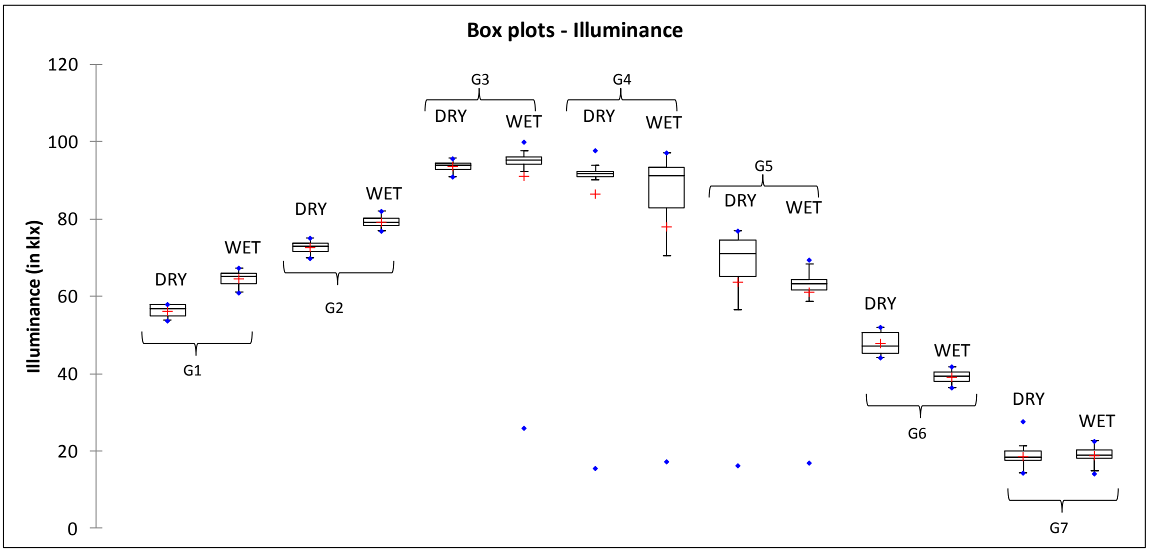

Figure 2.6: Box plots of recorded illuminance for each group of participants

Table 2.4: Repeated measures ANOVA with one inter-subject and one intra-subjects factors (DV=illuminance)

	Sum of squares	DOF	Mean squares	F	p-value	η^2-partial
Total	2825488	1	2825488	21290.03	0.0000	0.9835
Group	389624	6	64937	489.30	0.0000	0.8916
Error inter-subjects	47379	357	133			
Road surface condition	190	1	190	1.71	0.1919	0.0048
Road surface condition *Group	6957	6	1159	10.46	0.0000	0.1495
Error intra-subjects	39583	357	111			

This preliminary analysis aims at studying the difference in illuminance between the groups of participants, and at identifying which groups can be considered as being exposed to the same illumination conditions. To that purpose, a repeated measures ANOVA (Howell 1997) was conducted on recorded illuminance data, with the factor “Group” (inter-subjects factor with seven modalities) and the factor “Road surface condition” (intra-subjects factor with two modalities “dry” or “wet”). Repeated measures ANOVA results are presented in Table 2.4. The main findings are:

- Globally, no statistically significant difference was found between illuminance met during experiment on dry road surface and on wet road surface. Thus, we will be able to compare, in Section 3.5.2, the whole collected visibility ratings on dry road surface with those on wet road surface.
- There are significant differences between illuminance recorded for each group (significant effect of the “Group” factor). The post-hoc Tukey test results, reported in Table A3 in Annexe A, highlight that illuminance varies across groups, except between Groups 1 and 5. However, according to Figure 2.3, the sun was in opposite position between these two groups (behind participants for G1 and in front view for G5). In the following, the illumination conditions of each group will be described with an illuminance range and a sun position.
- There are significant differences between the two road surface condition within a given group of participants (significant effect of the interaction “Group*Road surface condition”). Table A3 in Annexe A highlights for which groups the illuminance conditions are not significantly different between dry and wet road surface. These preliminary results will be employed in Section 3.5.2 to study the visibility changes between wet and dry road surface. The visibility ratings between wet and dry road surface will be compared for Groups 2, 3, 5 and 7.

As a conclusion, this preliminary study highlights two main findings:

- Intra-group analysis will allow to test the hypothesis that the visibility of the stud increases with its intensity level, because horizontal illuminance and sun position were roughly constant within most groups (see Figure 2.6);
- Inter-group analysis will allow to test the hypothesis that the visibility of the stud changes with the illumination conditions, because horizontal illuminance was significantly different across groups.

2.5.1.2 Preliminary analyses on visibility ratings

2.5.1.2.1 Validity of collected data on the judgment scale

In this research one of the tested hypotheses is "the visibility of the stud increases with the stud intensity level". To study the good understanding and use of the judgment scale, a Spearman correlation test was carried out between visibility ratings of each participant and tested intensity levels, based on the assumption that each participant was in constant experimental conditions (validated from findings of Section 3.5.1.1). According to Table A4 in Annexe A, strong correlation (p-value<0.0001) was found whatever the participant.

2.5.1.2.2 Cluster analysis

Then, cluster analysis was carried out to find out potential outliers. Hierarchical clustering (Gordon 1999) was employed using the percent disagreement distance with average linkage (STATISTICA) for each group. Results are presented as dendrograms in Figure A2 in Annexe A. Two outliers (participant 5 (visual acuity of 4/10 and 28 contrast sensitivity errors) and participant 9 (83% of ratings 1)) were identified and their data was removed from statistical analyses.

2.5.1.3 Findings of preliminary analyses

As a conclusion, preliminary analyses lead to the following findings:

- The judgment scale was correctly understood and employed by the participants;
- Data of two participants (S5 & S9) are removed for statistical analysis;
- The whole visibility ratings on dry road surface can be compared with those on wet road surface;
- Each group was exposed to a given illumination condition defined with an illuminance range and a sun position, and therefore will be considered separately in statistical analyses of visibility ratings.
- The collected visibility ratings between wet and dry road surface can be compared for Group 2, 3, 5 and 7.

2.5.2 Analyses of the visibility ratings

Statistical analyses on visibility ratings were carried out in this section based on the findings of the preliminary analyses. First, the distributions of collected data are presented (Section 3.5.2.1). Then, analyses are conducted to study if the visibility of the stud changes according to the illumination conditions (Section 3.5.2.2), the road surface condition (Section 3.5.2.3), and the observer's characteristics (Section 3.5.2.4). Finally, recommendations about the required intensity to ensure visibility are provided (Section 3.5.2.5).

2.5.2.1 Global view of the ratings

Mean value of the whole set of visibility ratings and 95% confidence intervals were computed for each tested intensity and are represented in Figure 2.7. As expected, the higher the intensity, the better the stud visibility. This result is confirmed by Spearman correlation test that highlighted a strong positive correlation between the mean visibility ratings and the stud intensity level (S=0.985, p-value<0.0001).

In addition, Figure A3 in Annexe A represents the percentages of participants that answered a given rating according to the intensity of the stud. Results for dry (respectively wet) road surface are displayed in blue (respectively in red). For example, in Figure A3(a), the stud is mostly judged switched off for the small intensity values. Thus, the global data confirms that the visibility of the stud increases with the stud luminous intensity level.

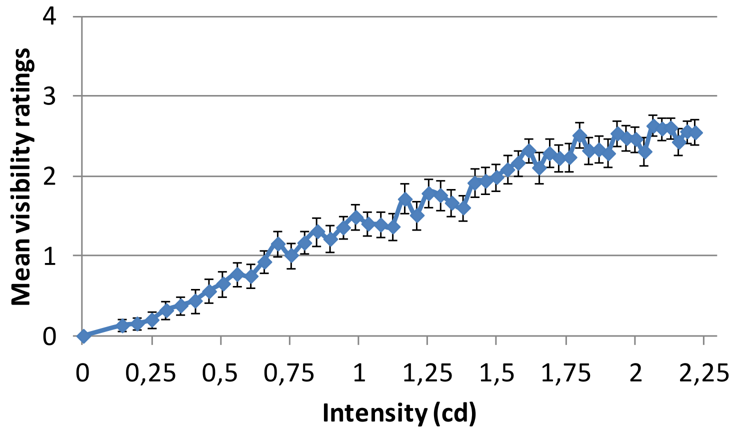

Figure 2.7: Mean visibility ratings (and 95% confidence intervals) as a function of the stud intensity (cd)

2.5.2.2 Does the visibility of the stud change depending on the illumination conditions?

According to Section 3.5.1, each group is associated to a given illumination condition (see Table 2.3 and Figure 2.6), described by:

- the sun position (azimuth, elevation);
- a given range of horizontal illuminance.

Figure 2.8 presents the mean values of the ratings collected for each group and each road surface condition. Average illuminance and qualitative sun position are also reported in Figure 2.8 for each group. As highlighted in Figure 2.8 and attested by a Kruskal-Wallis test (Dry road surface: $H(6,N=1920)=164.63$, $p\text{-value}<0.0001$, Wet road surface: $H(6,N=1920)=368.07$, $p\text{-value}<0.0001$), ratings are significantly different depending on the group. Thus, the visibility ratings depend on the illumination condition.
From Section 3.5.1.1, recorded illuminance for Groups 1 and 5 are not significantly different but the sun was respectively behind and in front of the participants. According to post-hoc test results, reported in Table A5 and A6 in Annexe A, no significant difference between ratings of these two groups was found on dry road surface. However, for wet road surface, ratings are significantly different. According to Figure 2.8, participants judged in average less visible the stud when the sun was in front view than behind them for equivalent level of road surface illuminance. This result could be explained by the difference in luminance, and has to be confirmed in future work.

Thus, as already highlighted in previous work (see Section 3.1), stud visibility during daytime vary depending on the horizontal illuminance and the sun position, the latter being significant especially for wet road surface.

2.5.2.3 Does the visibility of the stud change depending on the road surface condition (dry or wet)?

According to the illuminance data analyses conducted in Section 3.5.1.2, the visibility ratings of wet and dry road surface can only be compared for Groups 2, 3, 5 and 7, and for the whole set of data together. As highlighted in Table 5, there are statistical significant differences between judgments on dry and wet road surface (except for group 2, when the sun is behind). This result could be explained by the difference of daylight reflexion on the same dry and wet road surface during a sunny or cloudy day.

2.5.2.4 Does the visibility of the stud change depending on the road user characteristics?

As 95% of participants have a good visual acuity, correlation test was not carried out for this characteristics. According to Table A7 in Annexe A, no correlation between personal and visual characteristics (e.g. gender, age, etc) of participants and their judgments was found. Thus, luminous intensity level required to ensure visibility will be recommended without distinction of gender or age.

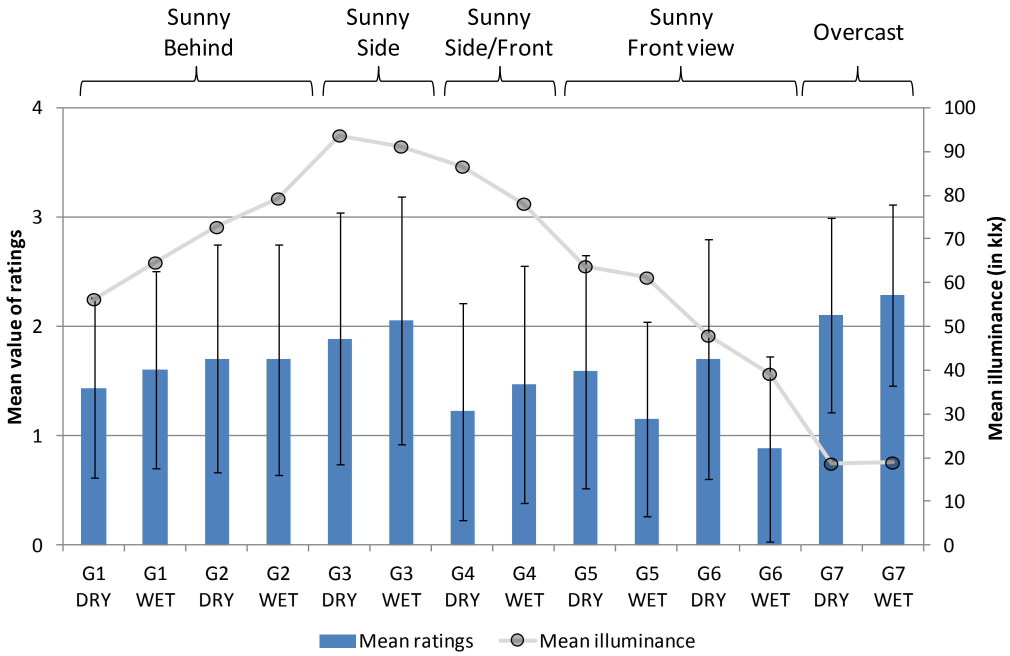

Figure 2.8: Mean value and standard deviation of ratings for each group of participants

Table 2.5: Wilcoxon signed-rank test results

	Statistics	p-value
Global DRY/ Global WET	V=169933.0	<0.0001
G2 DRY / G2 WET	**V=1869.00**	**0.67481**
G3 DRY / G2 WET	V=1539.00	0.00031
G5 DRY / G5 WET	V=7487.00	<0.0001
G7 DRY / G7 WET	V=990.000	<0.0001

2.5.2.5 Recommendations

Recommendations of required luminous intensity level to ensure the visibility of the stud can be expressed from the collected data. According to the previous sections, recommendations will differ depending on the illumination condition and the road surface condition.

To identify recommended intensity level, data obtained for the same range of illuminances were taken into account (e.g. judgments given in G4 for illuminance lower than 80klux were not considered). Figure 2.9 and 2.10 presents for each group the percentage of ratings "2 (barely visible)" and "3 (visible enough)" given by the participants for each tested intensity1. By taking into account the difference of ratings depending on the illumination conditions and the road surface condition, Table 2.6 reports the minimum intensity required to ensure 100% of participants see the stud (with difficulty or correctly). According to Table 2.6, the maximum available luminous intensity of the tested stud is required (i.e. 2.2cd) when the sun is in the field of vision of the observer (the angle describing the sun position related to the observer, ranges from 120 to 240°). However, if the road surface is wet and the sun has low elevation (e.g. at the end of afternoon), the stud is not powerful enough to be 100% visible. On the contrary, when the sun is behind the observer, the intensity could be lower (between 1.5cd and 2.1cd). It can also be noticed that recommended intensities are higher when the sun elevation is lower than 55°.

Globally, under sunny day, intensity has to be higher than 1.5cd, such as more than 70% of available luminous intensity of the stud. Under cloudy day, 55% of the available stud luminous intensity is enough to ensure visibility.

[1] Recommendations to ensure 100% of participants that correctly see the stud (that only answered "3 visible enough") are not given here

However, these recommendations are addressed for one stud. As in most applications a set of studs is employed, recommended intensity could be lower, but would be related to the situation. In addition, as highlighted in Figure 2.3, available luminous intensity of the stud increases with the distance observation.

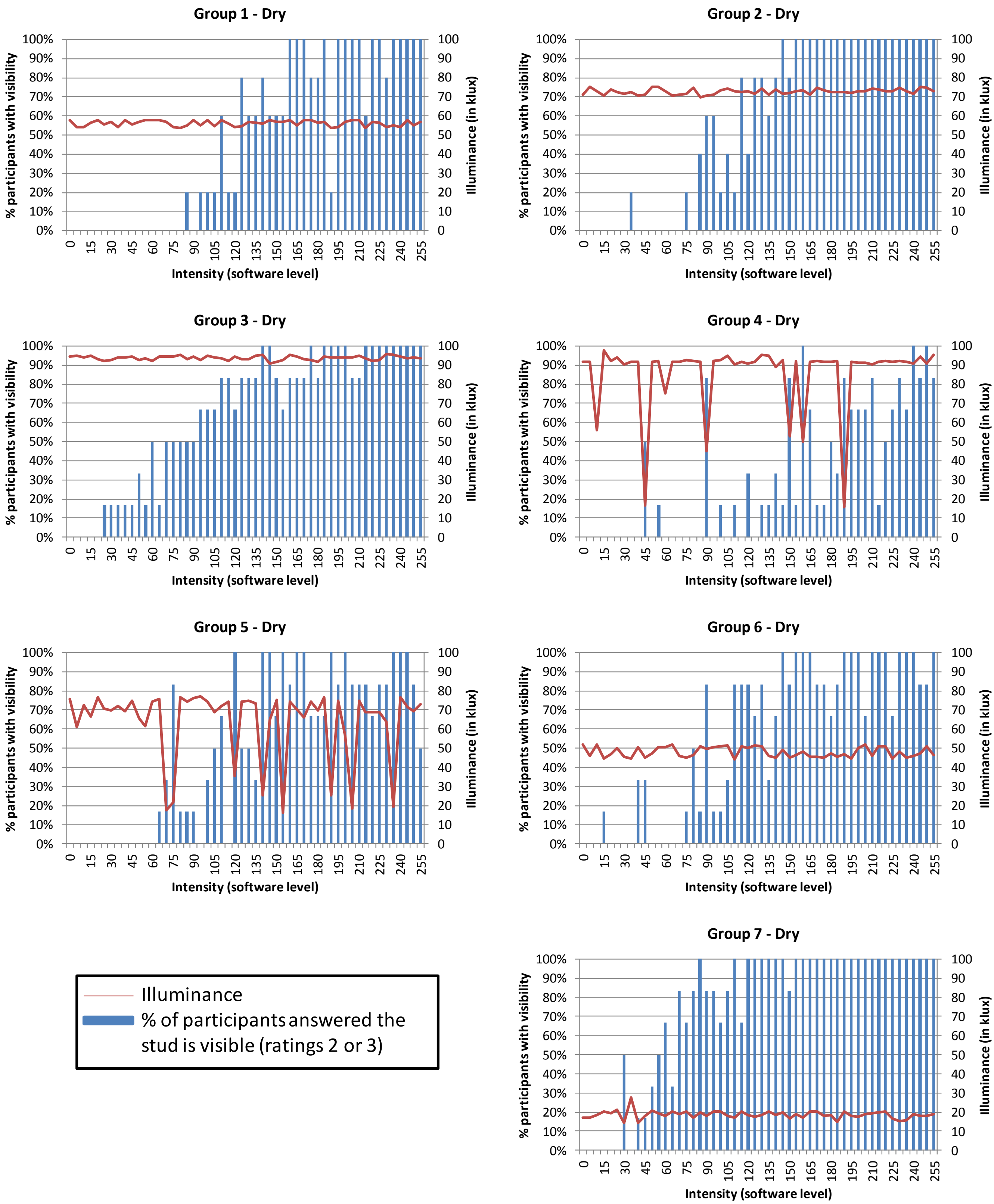

Figure 2.9: Percentage of ratings "2" and "3" for each group – Dry road surface

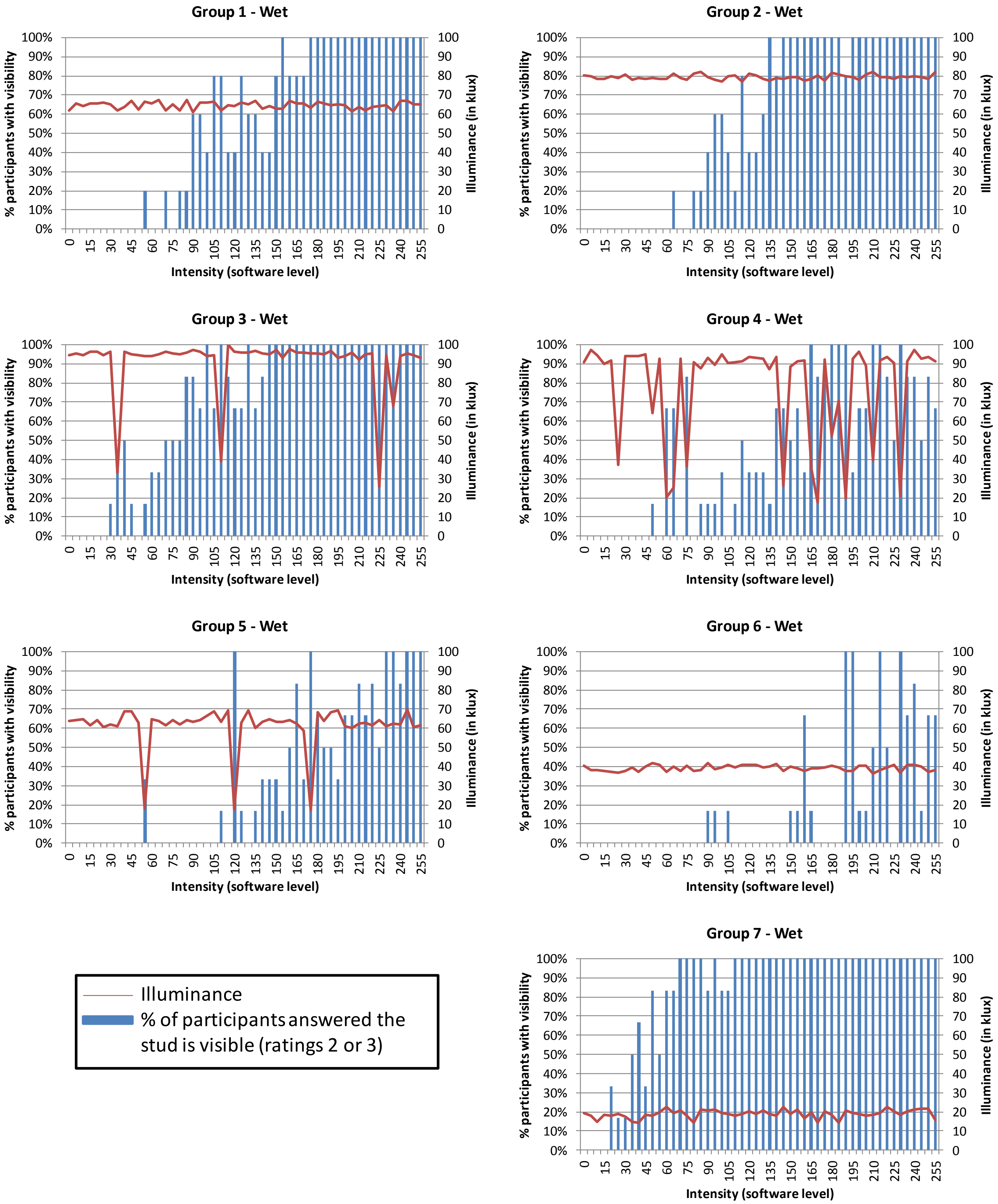

Figure 2.10: Percentage of ratings "2" and "3" for each group – Wet road surface

Table 2.6: Recommendations to ensure 100% of visibility

Sun position		Horizontal illuminance	Recommended intensity	
Elevation	Position for the user		Dry surface	Wet surface
Medium 46-50°	Behind (0°)	55-65klux	2.1 cd (92.2%)	1.7 cd (68.6%)
High 54-58°	Behind (8-20°)	70-80klux	1.6 cd (56.9%)	1.5 cd (56.9%)
High 57-60°	Side (90-102°)	90-100klux	1.9 cd (82.4%)	1.5 cd (56.9%)
Medium 50-54°	Side/Front (113-121°)	90-100klux	2.2 cd (100%)	Not reached
Low 31-36°	Front view (143-148°)	60-75klux	2.2 cd (100%)	2.2 cd (96.1%)
Very Low 21-26°	Front view (154-160°)	40-50klux	2.2 cd (100%)	Not reached
Hidden		15-30 klux	1.3 cd (47.1%)	1.1 cd (43.1%)

2.5.3 Visibility model

Going further, a visibility model can be proposed from experimental data. To that purpose, given that ordinal data was collected, a logistical regression was used. Model estimation (Section 3.5.3.1), model validation (Section 3.5.3.2) and model utilisation (Section 3.5.3.3) are presented in this section.

2.5.3.1 Model estimation: Logistic regression

From ordinal collected data, a binary relationship between each step of the judgment scale (e.g. 0/1234, 01/234, 012/34, 0123/4) can be assumed. Based on the assumption employed for recommendations in Section 3.5.2.5 that the visibility is ensured if the observers gave ratings ≥ 2, ordinal collected data can be transformed into binary data as presented in Table 2.7. In this way, logistical regression can be employed on binary data to estimate a visibility model. This visibility model will provide the percentage of participants for who the visibility is ensured (percentage of binary answer "1") according to the intensity level of the stud, the horizontal illuminance on the road surface, the sun position according to the observer and the road surface condition. In order to limit the model complexity (and ensure better accuracy), according to results of Section 3.5.2.2, the sun position will only be quantified with the angle between the sun azimuth and the observation direction; the sun elevation will not be taken into account in this model.

Table 2.7: Data transformation in binary data

Ratings	Binary
0 switched off	0: insufficient visibility
1 barely visible	
2 uneasy to see	1: ensured visibility
3 visible enough	
4 with glare	

The logistical model provides both the predicted proportion Pr of positive answers "1" about visibility and a predicted binary value for a given situation (from the values of each independent variable). Predicted binary values are deduced from predicted proportion according to a proportion threshold. This threshold is usually set at 0.5 (Rakotomalala 2013). As a result, the model predicts a positive answer "1" if the predicted proportion is higher than 0.5, otherwise it predicts the negative answer "0".

Model expression is given in Equation (1). Parameter values, obtained with XLSTAT, are reported in Table 2.8.

$$Pr = \frac{1}{1 + \exp\left(-\left(a_0 + a_1 * Intensity + a_2 * Illuminance + a_3 * Sun\ position + a_{4\ (DRY\ or\ WET)}\right)\right)} \quad (1)$$

The residual deviance (-2*log-likelihood -2LLM= 5749.19 > -2LL0=3369.31) and the pseudo-R^2 of McFadden (RMF=0.414) were computed to quantify the interest of the model through the significant link between the set of independent variables and the dependent variable (Rakotomalala 2013). In addition, Wald test (Rakotomalala 2013) was conducted to study the contribution of independent variables to the model. Wald test results are reported in Table 2.8. Compare to findings of Section 3.5.2, it confirms that the intensity, the horizontal illuminance of the road surface, the sun position and the road surface condition, taken into account in the regression, all have a significant contribution to the model. Especially, it highlights that "Intensity" is the variable that most affects the visibility of the stud; the second one being the variable "sun position" related to the observer (quantified by the angle between the sun azimuth and the observation direction). The "road surface condition" is the less significant factor.

To illustrate the model, Figure 2.11(a) (respectively Figure 2.11(b)) shows, with triangles, the predicted proportions obtained for each illumination condition according to the intensity level for dry road surface (respectively for wet road surface). Matching observed proportions computed from experimental data are represented with circles. Confidence intervals size (Upper bound – Lower bound) of predicted proportions ranges from 0.005 to 0.108.

Table 2.8: Logistical regression: Parameter estimation and Wald test

Independent Variable	Unit	Parameter name	Parameter value	Khi^2 of Wald	p-value
Constant	-	a0	-2.2735	241.459	< 0.0001
Intensity	cd	a1	3.2797 cd^{-1}	1150.516	< 0.0001
Illuminance	lx	a2	-0.0128 lx^{-1}	56.482	< 0.0001
Sun position	deg°	a3	-0.0109 deg^{-1}	208.315	< 0.0001
Road surface condition - DRY	-	a4	0.1518	12.237	0.0005
Road surface condition - WET	-	a4	-0.1518	12.237	0.0005

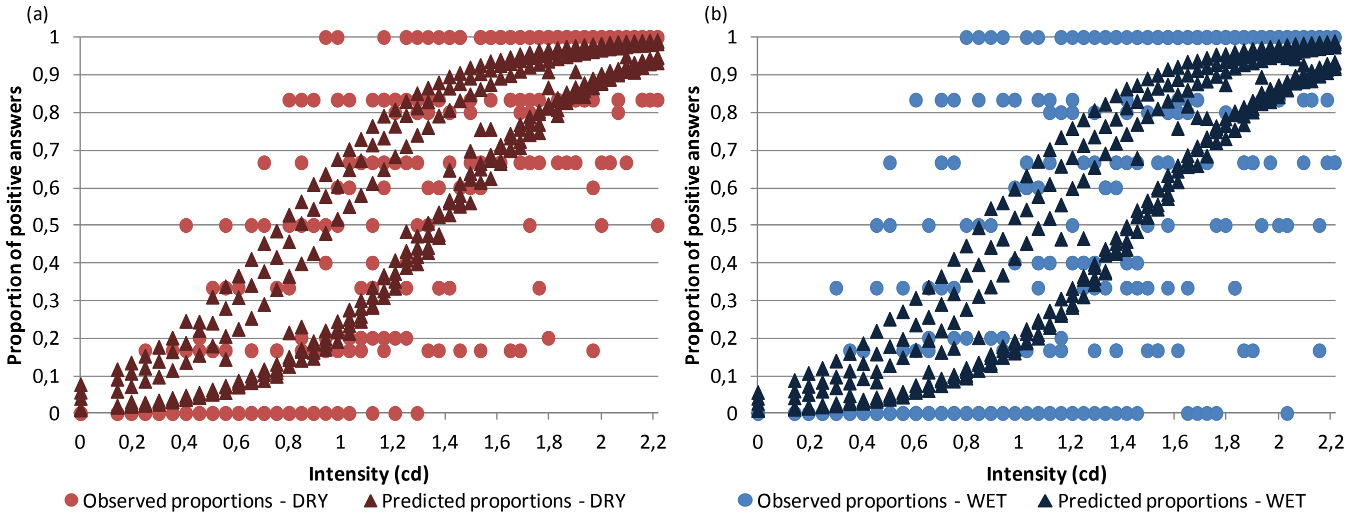

Figure 2.11: Predicted & observed proportions from experimental data (a) Dry road surface (b) Wet road surface

2.5.3.2 Model validation

To validate the model, comparisons of observed and predicted values were needed. Comparisons were related to both:

- Observed and predicted binary values;
- Observed and predicted proportions of positive answer (*i.e.* answer "1").

First, confusion matrix in Table 2.9 presents the comparison results of observed and predicted binary answers, deduced from the 0.5 threshold. The confusion matrix provides the number of false positive ("1") and negative ("0") answers and true positive and negative answers. The present model has an error rate of 18.46%, i.e. an 18.46% chance to predict a wrong answer. Then, the ROC Curve was computed to study the quality of the model based on predicted proportions (see Figure A4 in Annexe A). Performances of prediction, measured by the Sensitivity (number of true positive) and the number of false positive (1-Specificity), are computed by varying the threshold between 0 and 1 (not only 0.5 as in confusion matrix). The AUC (Area Under Curve) of the ROC curve provides a quantitative indication of the relevance of the prediction. It expresses the probability of the model to place a positive answer before a negative one. The proposed model has AUC=0.896, which suggests an excellent discrimination, according to Hosmer and Lemeshow (2000). Finally, in order to quantify the quality of predicted proportions, the Hosmer-Lemeshow test was employed: C(2)=14.861, p-value=0.06>0.05. The model is accepted because the critical probability is higher than the selected risk of 5% (Hosmer and Lemeshow 2000, Rakotomalala 2013).

Table 2.9: Confusion matrix

Obs \ Pred.	0	1	Total	% correct
0	1536	408	1944	79.01%
1	360	1856	2216	83.75%
Total	1896	2264	4160	81.54%

2.5.3.3 Use of model predictions

The proposed model can predict the proportion (and its confidence interval) of positive answer about road stud visibility, or predict the answer of a road user about visibility of the stud, for a given situation defined by:

- A given luminous intensity level of the stud (for 0° horizontal and 1° vertical observation angles);
- A given illumination condition defined by:
    - An given horizontal illuminance of the road surface, ranged from 10 to 100 klux only;
    - A given angle between the azimuth of the sun and the observation direction, ranged from 0° to 180°, *i.e.* the sun moving from behind to front view through the left side of the observer. Prediction for angle ranges from -180° to 0° (right side) can be deduced afterwards with symmetry assumption;
- A road surface condition: dry or wet.

Conversely, the required intensity of the stud for a given illumination condition and a given road surface condition can be computed with the model, to ensure that a given percentage of road users will judged the stud visible.The estimated model assumes a linear relation between the independent variables. For a given proportion of positive answers, the required intensity increases as the sun moves from the back to the front view of the observer, increases with the horizontal illuminance on the road surface, and is higher for wet road surface than dry road surface. For example, Figure 2.12 presents the intensity level required to ensure visibility (rated 2 or more) for 95% of the road users as a function of the illumination, for dry road surface (in red) and wet road surface (in blue). Corresponding luminous intensity values are reported in Table A8 and A9 in Annexe A. The linear relations are highlighted in Figure 2.12. The model allows proposing recommendations for situations not explored during the visibility tests. For example, if the sun is in front of the road user and horizontal illuminance on the road surface is around 100klx (e.g. sunny day, midday), the required intensity is 2.53 cd, which is higher than the maximum available with the current DSTA road stud.

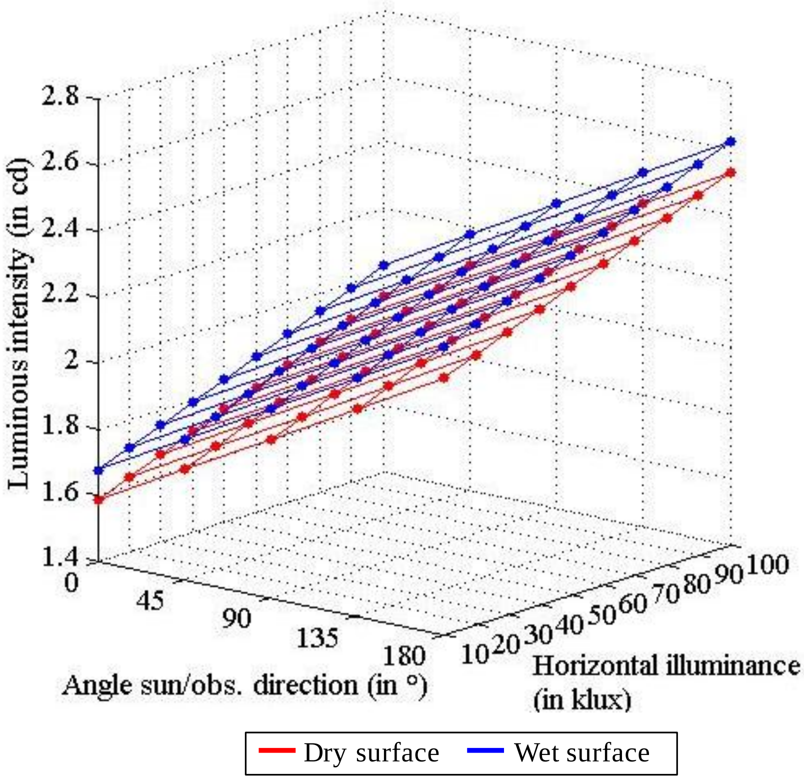

Figure 2.12: Recommended luminous intensity to ensure 95% of positive answers (i.e. ratings ≥2) depending on the illumination condition

2.5.4 Conclusions of "Daytime" Experiment

In the "Daytime" Experiment, the visibility of a LED road stud was investigated and a visibility model was proposed. In accordance with previous work, the findings suggest that the luminous intensity of the road stud has to be tuned to the illumination conditions. The latter can be defined by horizontal illuminance on the road surface and the sun position. According to the proposed model, the required stud intensity increases with the horizontal illuminance, and as the sun comes in the field of view of the observer. Besides, additional knowledge was obtained. Especially, to ensure visibility, the road surface condition (dry or wet) also needs to be taken into account. Indeed, the visibility of the stud is significantly different for dry and wet road surface. From the model estimation, a higher luminous intensity is required for wet road surface (especially when the sun is in front of the road user).

As a result, for 1° observation in the axis of the stud (corresponding to 68.75m and 0° horizontal angle) and a dry road surface, luminous intensity of 1.3cd is recommended for cloudy days, and intensities ranging from 1.7cd (sun behind the observer) to 2.6cd (sun in front view) during sunny days. From the proposed model, recommended luminous intensities in case of wet road surface can be deduced by adding 0.09cd to the ones recommended for dry road surface. In discussion, it could relevant to study the interest of using weather station to vary the intensity depending on the hygrometry for energy savings (see Section 3.8).

However, the experiment presents limits. First, findings are limited to one vertical angle observation (1°), so then to one distance from the stud. Recommendations are given from data collected in static position. Moreover, even if data was collected for cloudy day (15-30klux), overcast sky with lower illuminance (<15klux) was not investigated in this study. Finally, the accuracy of the model is limited to the restricted number of data (six) collected for each external condition and do not take into account sun elevation. In future work, visibility will be investigated at various distances. In addition, previous work investigated the visibility of a set of studs but no findings are currently available to compare the visibility of one stud or of a set of studs. Thus, in future work, data could be collected with a set of studs in order to investigate this question.

2.6 Presentation of the "Nighttime" Experiment

During nighttime, preliminary test suggested that the stud was visible at 300m even with the minimum available intensity. Therefore, the main question to address during nighttime is related to discomfort glare. In addition, according to preliminaries test, road surface reflexion properties do not seem to influence glare perception. Thus, wet road surface was not investigated during the nighttime experiment. As a result, the "Nighttime" Experiment focused on discomfort glare potentially produces by the road stud in dark conditions.

2.6.1 Panel

36 participants were involved in this study. All participants were aged from 21 to 57 years old, with 53% of men and 47% of women. The characteristics of the panel are presented in Table 2.10.

Table 2.10: Characteristics of the panel – "Nighttime" Experiment

Characteristics of the panel	Type	Panel
Gender	Male	53.00%
	Female	47.00%
Age	<25	8.00%
	25-34	42.00%
	35-44	28.00%
	45-54	14.00%
	>54	8.00%
Driving License	Yes	94.44%
	No	5.56%
Corrected vision	Yes	47.22%
	No	52.78%

In addition, the following visual characteristics of the participants were collected by conducting a vision test with the ErgoVision (see Table 2.11):

- Visual acuity was tested in binocular vision;
- Visual acuity in mesopic vision in binocular vision;
- The contrast sensitivity (assessed with the number errors to read letters under various contrasts);
- The time of recovery after glare feeling.

Table 2.11: Vision characteristics of the panel – "Nighttime" Experiment

Visual characteristics	Type	Panel	Visual characteristics	Type	Panel
Visual acuity	12/10	78%	Mesopic acuity	12/10	0%
	10/10	8%		10/10	3%
	8/10	6%		8/10	47%
	6/10	0%		6/10	33%
	4/10	6%		4/10	11%
	2/10	0%		2/10	6%
Contrast sensitivity	Very good (0 errors)	53%	Time Recovering after glare	<25s	33%
	Good (≤2 errors)	25%		25-50s	28%
	Medium (3-4 errors)	6%		>50s	39%
	Bad (>5 errors)	8%		Good recovery	83%
	Very Bad (>10 errors)	8%		Bad recovery	17%

2.6.2 Experimental conditions

The experiment was carried out indoor in order to reproduce nighttime photometric conditions. Participants were seated at 30m from the stud with 1° of observation. 13 intensities from 0.1 to 0.6cd (i = 1 to 49, at 1° of vertical observation) of the stud were randomly presented. Corresponding luminance levels are provided in Table 2.12. The average horizontal illuminance on the road surface was controlled at 1lx (AFE 2002).

Table 2.12: Tested intensity level of the stud and corresponding luminance level at 1° observation

Software input	Intensity(cd)	Luminance (cd/m^2)	Software input	Intensity (cd)	Luminance (cd/m^2)
1	0.10	422.31	29	0.39	1705.47
5	0.14	610.66	33	0.43	1882.06
9	0.18	797.33	37	0.47	2056.97
13	0.23	982.32	41	0.51	2230.19
17	0.27	1165.63	45	0.55	2401.73
21	0.31	1347.26	49	0.59	2571.60
25	0.35	1527.21			

2.6.3 Experimental protocol

For each intensity, the participants were asked to assess their glare feeling answering the following question: “Do you feel glare from the road stud?”:

- 1: No, not at all;
- 2: No, it is just acceptable;
- 3: Yes, it is disturbing;
- 4: Yes, it is unbearable.

The participant observed the stud during two seconds before he answered, and two minutes of dark adaptation was left between two stimuli.

2.7 Results of the “Nighttime” Experiment

Data collected during “Nighttime” Experiment are analysed in this section. First, cluster analysis is performed (Section 3.7.1). Then, statistical analyses are carried out on glare ratings to study the influence of the intensity (Sections 3.7.2 and 3.7.3) or of the observer’s characteristics (Sections 3.7.4). Finally, recommendations about relevant intensity to avoid glare are provided (Section 3.7.5).

2.7.1 Cluster analysis

First, cluster analysis was carried out to highlight potential outliers. Hierarchical clustering (Gordon 1999) was employed using the percent disagreement distance with average linkage (STATISTICA). Results are presented in Figure A5 in Annexe A. According to (Nakache and Confais 2004), in the dendrogram, no break in aggregation distance between nodes is obtained and the whole data was kept for further statistical analyses.

2.7.2 Frequency of ratings

Second, frequencies of ratings given by participants for each intensity were computed (see Figure 2.13). The answers “Not blinded at all” and “Just acceptable” (represented by the first and second bars in Figure 2.13) correspond to no glare feeling in front of the stud, whereas the answers “Distrurbing” and “Unbearable” (represented by the third and fourth bars in Figure 2.13) correspond to glare feeling. According to Figure 2.13 and Figure 2.14, to ensure 100% of “no glare” answers, the stud luminous intensity has to be set at the minimum available value, i.e. 0.1cd. It corresponds to 422.31cd/m^2 at the observation point of view of 1°. With others settings more than 5% of observers were disturbed by the stud at 1° observation during nighttime (see Figure 2.14).

2.7.3 Friedman non-parametric test

Third, a non-parametric Friedman test and a non-parametric post-hoc test were performed. The Friedman test result (Q(12)=100.74, p-value<0.0001) highlights significant differences in producing glare between the tested luminous intensities. Table 2.13 groups together the intensities for which the glare feeling is not significantly different (according to comparisons of mean ranks with non-parametric post-hoc test). According to Table 2.13, the intensities for which the stud is judged the less disturbing are ranged from 0.1cd to 0.27cd (0.1cd being not significantly different from 0.14, 0.18, 0.23 and 0.27cd). The threshold of I<0.3cd will therefore be recommended to limit discomfort glare.

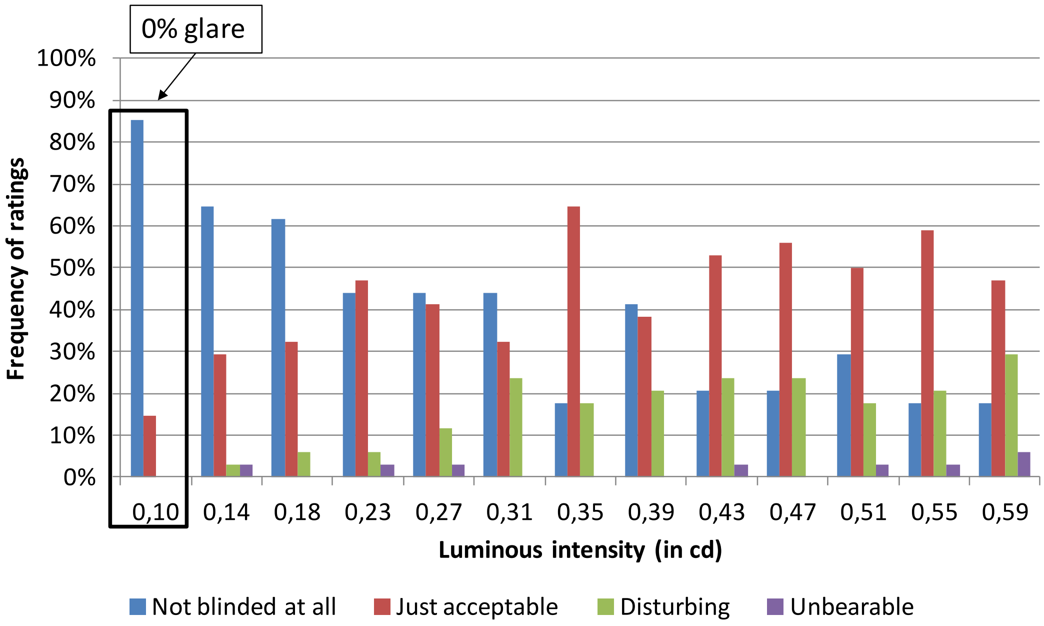

Figure 2.13: Frequency of glare ratings according to the tested intensity

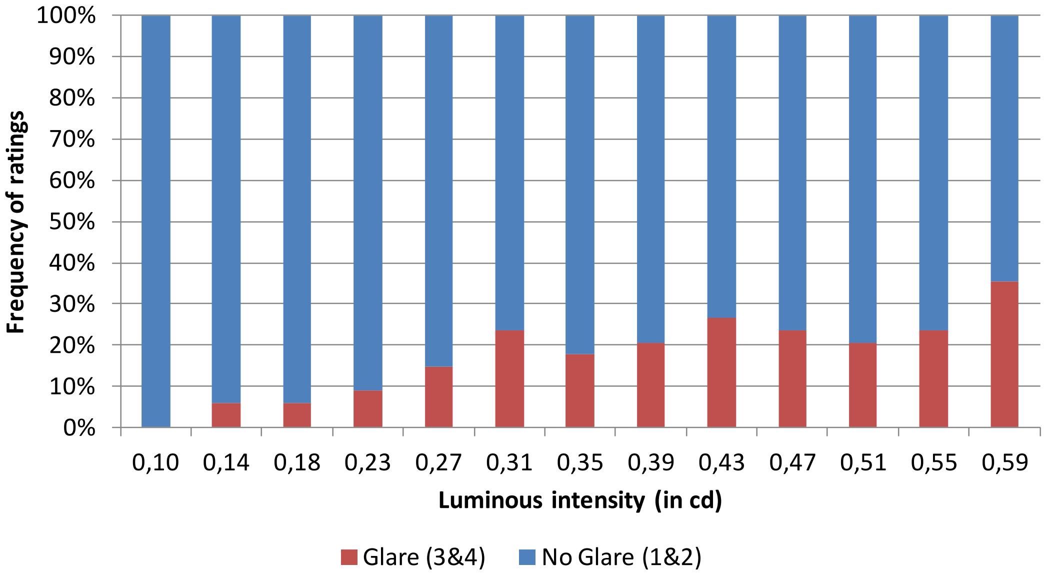

Figure 2.14: Proportions of glare/no glare ratings

Table 2.13: Classes of non-significantly different intensities for glare feeling

Intensity	Mean rank	Classes		
0.10 cd	3,736	A		
0.18 cd	5,111	A	B	
0.14 cd	5,125	A	B	
0.23 cd	6,333	A	B	C
0.27 cd	6,528	A	B	C
0.31 cd	6,778		B	C
0.39 cd	7,056		B	C
0.51 cd	7,944		B	C
0.35 cd	8,069		B	C
0.43 cd	8,222			C
0.47 cd	8,306			C
0.55 cd	8,583			C
0.59 cd	9,208			C

2.7.4 Correlation with vision characteristics

As 95% of participants have a good visual acuity, correlation test was not carried out for this characteristics. According to Table A10 in Annexe A, no correlation between characteristics (e.g. gender, age, etc) and visual performance of participants and their judgments was found. Thus, the luminous intensity level required to avoid glare is recommended without distinction of gender or age.

2.7.5 Conclusions and recommendations

The "Nighttime" Experiment was conducted in order to investigate the discomfort glare potentially produced by the stud. It was highlighted that at 1° observation the luminous intensity of the stud has to be set lower than 0.30cd to limit discomfort glare, and preferably at the minimum 0.1cd (corresponding to L=422cd/m^2) to ensure that less than 5% of road users are disturbed by the stud. Thus, based on this latter recommendation (4.70% of maximum available intensity of DSTA stud), Figure 2.15 presents the resulting luminous intensity that would be provided during nighttime according to the distance from the stud at 1m20 height. The luminous intensity increases with distance (for a given height) because of geometry stud. Thus, in future work, it is planned to supplement the present findings about discomfort glare by collecting data at various distance, relevant in driving conditions.

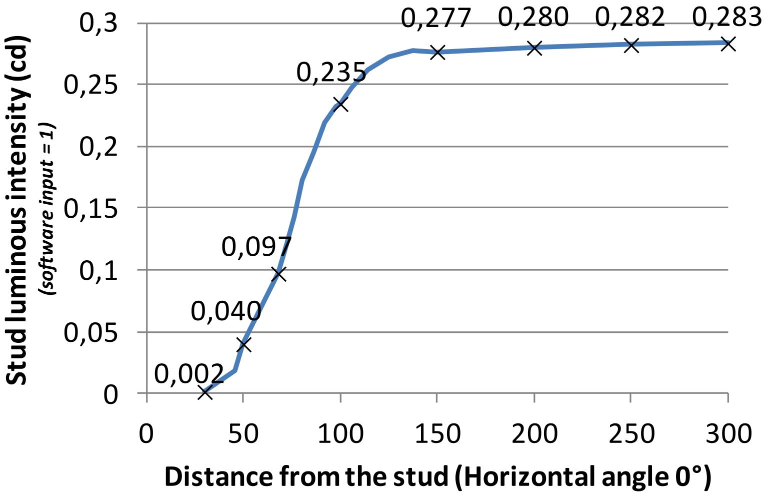

Figure 2.15: Luminous intensities (as the function of the distance) to avoid glare at 1° observation

2.8 Discussion: Dimming and Energy savings

Based on the recommendations provided for daytime (see Section 3.5) and nighttime (see Section 3.7), luminous intensity of the stud can be reduced depending on the external conditions while ensuring visibility and avoiding discomfort glare. As a result, dimming the stud according to the external conditions may allow to energy savings, compared to providing the maximum available luminous intensity level.

In order to quantify the benefit of stud dimming, energy saving (ES) can be calculated according to Equation (2). Equation (2) is based on findings obtained in "Daytime" Experiment and "Nighttime" Experiment:

$$ES(\%) = 1 - \left[w_{night} * P_{night} + w_{day} * \left(w_{cloudy} + w_{sunny} * \left(w_{dry} * P_{dry} + w_{wet} * P_{wet}\right)\right)\right] \qquad (2)$$

with

$$\begin{cases} w_i : weight\ for\ the\ external\ condition\ i \\ P_i : \%\ power\ demand\ to\ provide\ required\ intensity\ for\ the\ external\ condition\ i \end{cases}$$

As examples, energy saving that can be reached in Paris (France) and Tel Aviv (Israel), with various road orientation, was calculated. Characteristics of the weather in both cities are given in Table 2.14.

Table 2.14: Weight for power demand calculation – Examples of Paris and Tel Aviv

	Weather characteristics	Weights for calculations
Paris (France)	Year mean Daytime: 12h Days of rain/year: 111 days Sun: 1725 h/year	50% day / 50% night 30% wet / 70% dry 40% sunny / 60% cloudy
Tel Aviv (Israel)	Year mean Daytime: 12h Days of rain/year: 111 days Sun: 3227 h/year	50% day / 50% night 11% wet / 89% dry 74% sunny / 26% cloudy

Table 2.15: Energy saving estimation for various road orientations in Paris (France) and Tel Aviv (Israel)

Road orientation	Energy savings – Paris			Energy savings – Tel Aviv		
	Global	Daytime	Sunny	Global	Daytime	Sunny
N/S	61.15%	27.00%	0.00%	53.50%	11.7%	0.00%
S/N	63.37%	31.43%	11.08%	57.89%	20.5%	11.85%
E/W	61.85%	28.41%	3.52%	54.90%	14.5%	3.79%
W/E	61.98%	28.66%	4.15%	55.13%	15.0%	4.42%
SE/NW	62.99%	30.68%	9.19%	57.19%	19.1%	9.96%
NW/SE	61.51%	27.71%	1.78%	54.26%	13.2%	2.05%
NE/SW	61.38%	27.46%	1.15%	54.03%	12.8%	1.42%
SW/NE	62.99%	30.68%	9.19%	57.19%	19.1%	9.96%

In order to determine the required intensity levels during sunny days, the day was split into three periods (35% of morning, 30% midday, 35% afternoon/evening), for which mean horizontal illuminance was considered (respectively 70klx, 100klx and 60klx). Moreover, the sun position related to the road user differently varies depending on the road orientation. To make it easier, fixed sun positions were defined for the three periods (South-Est in morning, South at midday and South-West in afternoon/evening). Mean sun positions for each road orientation used for energy saving calculation are reported in Table A11 in Annexe A. Intensity required for each situation was then deduced from the model prediction in Tables A8 and A9 in Annexe A. According to previous work (Ice 2002, Masson 2012, Juntunen et al. 2013), light output can be considered proportional to power demand2. Therefore, percentages of power demand were calculated by making ratio between the required intensity over the maximum intensity (see Table A12 in Annexe A). Finally, energy saving was computed from Equation (2).

Table 2.15 reports energy savings computed for Paris (France) and Tel Aviv (Israel). As highlighted in Table 2.15, taking into account external conditions lead to around 61-63% energy savings in Paris and 53-58% in Tel Aviv, compared to providing the maximum luminous intensity all the time. The saving is mostly due to large dimming during nighttime (98% ES). Nevertheless, during daytime 27-30% energy savings (respectively 11-20% ES) is reached in the example of Paris (respectively of Tel Aviv), of which 0 to 11% during sunny days, depending on the road orientation. In addition, 0-0.57% energy in Paris and 0-1.34% energy in Tel Aviv are saved by taking into account the road surface condition. For a stud maximal power demand of 5W, it corresponds to save around 600Wh. As a weather station costs around 40€, corresponding to 300kWh according to the energy cost3, it could be not relevant to take into account the hygrometry for energy savings. However, a more detailed cost analysis is required to confirm this consideration.

2.9 Conclusions

Two experiments were conducted in order to study the visibility and discomfort glare produced by an LED amber-coloured road stud. Results highlight that during daytime the visibility of the stud vary according to the illumination conditions: horizontal illuminance on the road surface and sun position. In addition, stud visibility significantly differs on wet and dry surfaces. Various luminous intensity levels were therefore recommended depending on these factors. Lowest levels are required under cloudy sky. The maximum available intensity is needed especially under sunny sky when the sun is in front view of the road user. During nighttime, the minimum available intensity level is recommended to avoid discomfort glare. Recommendations were expressed for 1° vertical observation in the axis of the stud. Intensities for other observation angles can be deduced from the intensity distribution of the stud measured in laboratory. Based on these recommendations, the stud can be dimmed while ensuring good visual conditions to road users. To quantify the benefit of dimming, energy saving calculation was proposed. The examples of Paris and Tel-Aviv highlight that more than 50% energy savings can be reached by dimming the stud according to the time of the day, the illumination conditions and the surface condition.

However, the study was conducted for a fixed point of view (and consequently a fixed viewing distance). In future work, it would be relevant to study the distance effect, especially for wet road surface (which was not already study in previous work). Moreover, results about discomfort glare during nighttime are limited in this study. Further investigations are required, in order to analyse similarities between discomfort glare variation provided by studs and by other light sources already investigated and modelled in previous work.

[2] Light output is proportional to forward current (Ice 2012) and there is a linear relation between current and provided luminous flux (Masson 2012 p151).

[3] 0.1311€ / kWh (www.edf.com)

3 Standards and visibility

3.1 Background

The aim of this document is to determine the criteria and the procedure to evaluate the performance of LED-made road studs in-use, as they are seen by a standard driver.

To achieve this goal, three steps have been proposed: First, study of the standards and scientific papers about the evaluation of LEDs and any other road signaling elements. Second, identification of the necessary physics magnitudes. And third, define the criteria and procedure for evaluating road studs in-use by using the physics magnitudes selected in the previous stage.

3.2 State of the art

The starting point of this phase is the search of information in all documents based on lighting information for guidance, reporting, requiring, demarcating or alerting to road users. This search also includes optical studies (in the physical sense), vision and visual perception

The traffics elements studied in this document are:

- Led-made road studs.
- Road Studs.
- Horizontal marks.
- Traffic signs.
- Light signal heads.
- Variable message signs.
- Road lighting.
- Retroreflecting road studs.

The information was performed on one side from the European and national standards witch define the initial requirements, installation and even maintenance. Another source of information was obtained from the International Committee of Illumination (CIE), which includes multiple references on visual perception studies, driving process models (visual perception), etc. Finally, a third source of information was Scientifics papers, publications in journals, dissertations, etc. many of them available in the network.

3.2.1 LED-made Road Studs

At present time there are no specific standards of these elements and is still under development. Steve Jenkins (Chairman of the Technical Committee CIE 4-47) said "*it is in the process of writing a new document about LEDs in the transport environment and, if there were enough information about LED pavement markers that they can gather, then there will be section which addresses this. This is likely to be published within the middle of 2013*".

The draft standard prEN1463 part 3 is based on luminous intensity. This draft classifies those LED-made road studs by their properties as size, durability, light emission, etc. This standard defines these elements depending on the uptake of energy (solar, cable, etc.), depressibility (degree of embedding in asphalt), permanent or temporary elements, with and without retroreflective elements and dimensions.

This draft standard includes criteria of visibility both day and night, and also procedures for how to test them, all of them based on luminous intensity, in static way and in ideal laboratory conditions.

3.2.2 Road marking materials

The European standard EN-1436-2009+A1 defines the photometric performance of white and yellow road markings, both in terms of retroreflection as diffuse lighting.

Road markings have different luminance depending on the incident light: diffuse illumination (daytime) or retroreflection due to the own vehicle headlights (nighttime). Under diffuse illumination the standard establishes the coefficient of luminance Qd as main criteria for road mark evaluation. This coefficient defines the luminance perceived by a user on a road mark under diffuse illumination E. Its units are mcd•m-2•lx-1. The minimum values are defined in the following table:

Table 3.1 Minimum values of Q_d for road marking under diffuse illumination

Colour of the road marking	Class of pavement	Class	Minimum value of Q_d
White	Asphalt	Q_2	$Q_d \geq 100$
		Q_3	$Q_d \geq 130$
		Q_4	$Q_d \geq 160$
	Cement concrete	Q_3	$Q_d \geq 130$
		Q_4	$Q_d \geq 160$
		Q_5	$Q_d \geq 200$
Yellow		Q_1	$Q_d \geq 80$
		Q_2	$Q_d \geq 100$
		Q_3	$Q_d \geq 130$

Supposing an average sunny day (50 klx over a road marking) the luminance would vary between 4000 and 10000cd/m2 (depending on the Qd value). The luminance of the pavement seen by a driver in the same geometry (2.29° in accordance with Appendix A of the standard with respect to the plane of the road) would be approximately 1.100cd/m2 (assuming a reflection coefficient ρ= 0.07, diffuse lighting luminance is $L = \rho \cdot E/\pi$) obtaining a contrast ratio of 4:1 in the worst case and 10:1 at best.

Translating these results to road studs LED-made, the luminance levels for a sunny day should be able to reach at least the luminance values calculated with respect to the pavement. Due to the small size and their high emission LED light, these values are easily achievable.

Under night condition, the standard establishes the coefficient of retroreflection RL, as main criteria for road mark evaluation.

Coefficient of retroreflection RL is calculated.

$$R_L = \frac{L}{E}$$

Equation 1 Coefficient of retroreflection

where *L* is the luminance and *E* is the illuminance.

The minimum values of retroreflection over road markings are detailed in the Table 3.2.

According to our experiences, the luminance of a retrorreflective road marking due to the illumination of a standard passenger has a value close to 300 mcd•m^{-2}•lx^{-1} , with a luminance 15 times higher than the luminance measured in the pavement. Assuming a 10m distance with respect to the driver and with a measuring geometry of retroreflection as defined in the standard and an illuminance of 200lx, luminance on the road caused by passenger car headlights is 4cd/m^2 against the 60cd/m^2 over the road marking.

In the worst scenario (from the table above), in which the value of retroreflection is 80mcd·m^{-2}·lx^{-1}, **the luminance of the road marking perceived by a driver compared to the luminance of the pavement is at least 4 times greater**.

Table 3.2 Minimum value of the coefficient of retroreflection on a road marking.

Class of Road Marking and Colour		**Class**	**Minimum value od the coefficient of retroreflection R_L mcd·m^{-2}·lx^{-1}**
Permanent	White	R_2	$R_L \geq 100$
		R_3	$R_L \geq 150$
		R_4	$R_L \geq 200$
		R_5	$R_L \geq 300$
	Yellow	R_1	$R_L \geq 80$
		R_3	$R_L \geq 150$
		R_4	$R_L \geq 200$
Provisional		R_3	$R_L \geq 150$
		R_5	$R_L \geq 300$

3.2.3 Retroreflected and illuminated traffic signs

Generally, this type of traffic signs presents information based on legend and symbols. There are two different types of traffic signs: Retroreflective and illuminated. In illuminated signs, whether internally or externally illuminated, they require minimum levels of luminance and contrast with the environment, in order to be visible and legible from a safe distance.

For retroreflective signs, a minimum level of retroreflectivity is required depending mainly on the road class and on the speed limit. Since passenger cars have similar luminous intensity distribution, the luminous intensity over a retroreflective sign in a typical geometry (angle of observation □ = 0.33°) is fairly limited. Giving a value of illuminance over a traffic sing and the coefficient of retroreflection of the sheet, a luminance can be calculated, which is the optical magnitude what the human eye perceives. At least, for a retroreflection value ensures a luminance levels and appropriate contrasts similar to an illuminated traffic sign.

Studies on retroreflective signs (CIE TC 4-40 Performance evaluation of retroreflective traffic signs 2009) concluded that for a 75% percentile of the population, the minimum luminance required for a traffic sign to be readable is 3cd/m2 for rural settings and it is 6 for environments of high complexity without illumination. Visibility processes need lower luminance with respect to the legibility processes.

Table 3.3 Subjective rating response

Rating Scale	**Subjective response**	**Luminance cd/m^2**
1	Too Bright not Recognizable	3000
2		600
3	Bright Recognizable	300
4		70
5	Optimal Luminance	25
6		7
7	Dark Recognizable	2
8		0.7
9	Too Dark, not recognizable	0.3

Other studies performed at the University of Darmstadt (Frank, 1990) confirm the above results in a brighter environment or in the presence of glare from oncoming vehicles, the required sign luminances are increased by a factor 4, as can be seen in the Figure 3.1.

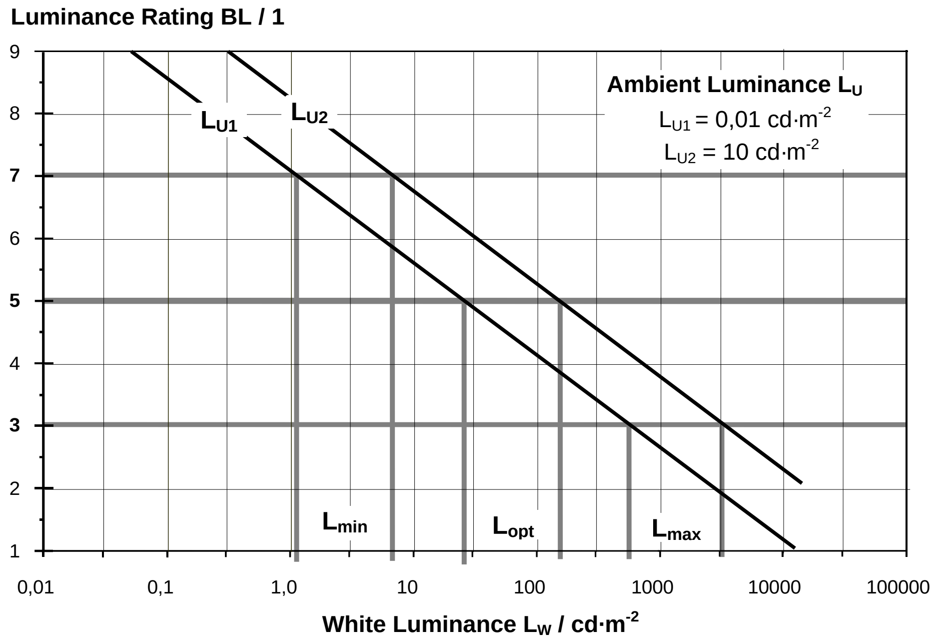

Figure 3.1 Luminance Rating of Test Signs

Two discrete ambient luminances of 0.01 cd/m2 and 10 cd/m2 are shown with an observation distance of 70 m and without glare.

The step from the optimum luminance to the maximum luminance (bright, still legible) is again a factor of 10. Minimum contrast required for the legend/symbol for retroreflective materials are:

Table 3.4 Contrast range for white letter on background

Background colour	Ratio	
	Minimum	Maximum
Blue	0.03	0.35
Green	0.05	
Dark green	0.03	0.15

Minimum coefficients of retroreflection for class 1 and 2 of retroreflective sheets, and their colorimetric ranges are standardized (UNE-EN-12899-1). This standard includes also the values of luminance and luminance contrast for every internally illuminated signs. The luminance contrast between the background and the text has to be between 5 and 15, while the luminance, depending on class and colour has different values. For example, for the white sheet the minimum luminance values have to be between 40 and 150 cd/m2 for Class 1, 150 and 300 for class 2 and from 300 to 900 cd/m2 for class 3.

The decision to install internally illuminated traffic signs has to be done in any of these scenarios: 1. - High degree of condensation, which disables the retroreflection effectiveness or 2. - High complex scenarios where the luminance over a retroreflection sheet due to the passenger car headlights luminous intensity is not enough, especially on overhead signs.

Table 3.5 Luminance ranges for internally illuminated traffic sings

Colour	Class L1	Class L2	Class L3
White	40 ≤ L ≤ 150	150 ≤ L ≤ 3000	300 ≤ L ≤ 900
Yellow	30 ≤ L ≤ 100	100 ≤ L ≤ 300	300 ≤ L ≤ 900
Red	6 ≤ L ≤ 20	20 ≤ L ≤ 50	50 ≤ L ≤ 110
Blue	4 ≤ L ≤ 10	10 ≤ L ≤ 40	40 ≤ L ≤ 80
Green	8 ≤ L ≤ 20	20 ≤ L ≤ 70	70 ≤ L ≤ 180
Dark Green	4 ≤ L ≤ 10	10 ≤ L ≤ 40	40 ≤ L ≤ 80
Brown	4 ≤ L ≤ 10	10 ≤ L ≤ 14	40 ≤ L ≤ 80

Table 3.6 Luminance contrast for lited vertical sing

Colour	Blue	Green	Dark Green	Brown
Color Contrast	**White**	**White**	**White-Yellow**	**White**
Luminance contrast	5 ≤ K ≤ 15	5 ≤ K ≤ 15	5 ≤ K ≤ 15	5 ≤ K ≤ 15

3.2.4 Variable message signs

EN 12966-1:2005 + A1: 2009 standard defines the minimum and maximum levels of luminance and luminance contrast (luminance ratio, LR) of a variable message sign, to get a correct legibility at a sufficient distance so that road users have a reasonably large time to maneuver or act safely.

Variable message signs are classified into several groups depending on their visual performance. These groups are sorted by colour, luminance limits, contrast between on and off LEDs and LED emission (light distribution on a transversal plane-cut on the road).

Luminace ratio LR is calculated:

$$LR = \frac{L_a - L_b}{L_b}$$

Equation 2 Luminance ratio

where L_a and L_b are the luminance values of lit and unlit LED respectively, over an external illumination.

Table 3.7 Luminance limits for white LEDs on its reference axis for class L1, L2 y L3

External illuminance (lx)	Luminance (cd/m²)			
	Minimum			**Maximum**
	L1	**L2**	**L3**	**L1, L2, L3**
40 000	12 4000	6 200	3 100	62 000
10 000	12 400	-	-	-
4 000	2 200	1 100	550	11 000
400	600	300	150	3 000
40	250	200	100	1 250
≤ 4	75	60	30	375

Minimum luminance relation for an external illumination between 400 y 40 000lx has to be as follows:

Table 3.8 Luminance relation for different colours

Colour	Luminance ratio					
	R3		**R2**		**R1**	
	Reference axe	**Out ref. axe**	**Reference axe**	**Out ref. axe**	**Reference axe**	**Out ref. axe**
White	16.7	8.35	10	5	5	3
White/Yellow	14.2	7.1	8.5	4.25	4.25	2.55
Yellow	10	5	6	3	3	1.8
Green	5	2.5	3	1.5	1.5	0.9
Red	4.2	2.1	2.5	1.25	1.25	0.75
Blue	1.7	0.85	1	0.5	0.5	0.3

where R1, R2 y R3 is a variable message sign classification with respect to their luminance relation.

Variable message signs encrypt information (legend and/or symbol). This means that the drivers must have enough time to read and understand the information. In addition, those messages must be legible during daylight conditions and in a overhead emplacement, where the complexity of the scene and the external illuminance levels are high. These assumptions explain the high levels of luminance required for this type of sign.

Legibility distance from these signs depends on the beam divergence of the LED emission and the sign height. For a typical height of 7 meters it can be legible from 200 or 300 meters away on high speed roads (text size range D and E) and between 90 and 150 for the rest roads (text size range B and C). Legibility times are shown in the following table:

Table 3.9 Ellapse time to read the message at different speed values.

Class of Sign	**Dist. (m)**	**Ellapse time to read the message**						
		40Km/h	**50Km/h**	**60Km/h**	**80Km/h**	**100Km/h**	**110Km/h**	**130Km/h**
A	60	5.5	4.3	3.5	3	2	-	-
B	90	8.2	6.5	5.4	4	3	-	-
C	150	13.6	10.8	9.0	6.8	5.6	4.9	4.1
D	200	18.2	14.4	12.0	9.1	7.4	6.5	5.5
E	300	27.3	21.6	18.0	13.6	11.1	9.8	8.3

3.2.5 Traffic control equipment: Signal heads

European standard 12368:2006 defines the behavior of these elements.

Signal heads are used to transmit optical messages by turning on and off light units where the information is color coded. As the information perceived in the visibility mode (do not exist any text or symbols) the main optical magnitude is the luminous intensity instead of the luminance (legibility requirements).

Luminous intensity determines the amount of luminous flux (photometric energy per unit of time) emitted in a solid angle. Although the luminous intensity is used to evaluate signal head, the driver only "sees" luminance. The luminance and the luminous intensity are related as follows:

$$L = \frac{I}{S_e}$$

Equation 3 luminance versus luminous intensity.

where I is the luminous intensity emited from the signal head to the driver and Se is the effective surface of the signal head.

Signal head diameter is normalized into two possible values: 300 and 600mm.

Same way as LED panels, there is a luminous intensity signal head classification as it can be seen in the next table that shows red, yellow and green signal heads luminous intensity vs its reference axis.

Table 3.10 Limits for luminous intensity in traffic signal heads

Class – luminous intensity level	**1**	**2**	**3**
I_{min}	100 cd	200 cd	400 cd
I_{max} clase 1 I_{max} clase 2	400 cd 1 100 cd	800 cd 2 000 cd	1 000 cd 2 500 cd

Depending on the beam divergence of the LED, the signal heads may decrease in intensity up to 40% when measured off-axis reference beam depending on its usefulness: very wide (E-type), wide (W-type) medium (M-type) and narrow (N-type) beam.

Luminance uniformity on signals heads is one of the most important magnitude. Usually it can be 1:10 or 1:15, depending on the emission beam divergence.

As the information is color-coded, these signal heads should be invariant to external lighting. Inner reflector in incandescent bulbs can mirror the sunlight to the driver, producing a ghost effect, similar to as if the lamp was lit.

The luminance at the reference axis goes from 354cd/m2 (class 1 - 600mm of diameter) to 400 000cd/m2 (class 2 - 300mm of diameter).

Keep in mind that these high values are justified by the fact that should be visible even during the day and in adverse conditions: direct sunlight just behind the signal head, sun reflector directly over the signal head, fog, heavy rain, etc. A light sensor may be incorporated in signal heads to regulate the luminous intensity with respect to the external light, although this solution is not typically used.

3.2.6 Road illumination

European standards, as EN-13201 and BS EN 16247-1:2012, define the requirements, benefits and methods of road lighting measurement. These standards aim to:

1-. Define, according to certain photometric requirements, different lighting classes for road lighting, based on the criteria of the visual needs of pedestrian and drivers, considering environmental aspects as green-house, efficiency, etc.
2.- Define mathematical methods to calculate the quality of road lighting.
3.- Define photometric measurements procedures and other parameters related to lighting installations.

Some road classes have been defined depending on the kind of use:

- Class **ME** is for roads for **high speed roads**.
- Class **CE** defines complexity roads as roundabout, intersections, etc.
- Class **S** and **A** is for **pedestrian and bicycles**.
- Class **ES** are those in which is necessary to identify persons and objects
- Class **EV** defines specially road where it is needed to **illuminate vertical surfaces** as toll road gates or similar.

Lighting requirements change from some classes to other: while the motor vehicle (ME) is based on luminance of the road surface, the rest are based on illuminance criteria. These differences of criteria, are based on the use of the road: while in high speed roadways lighting is designed to better identify the road itself, in other ways, its use is to identify what's on the road, pedestrians, roundabouts additions, lighting toll areas, etc..

Luminance criteria, establishes longitudinal uniformity criteria (ratio between the minimum and maximum luminance value on a rail center) and global criteria (ratio between the minimum and average luminance in an area of the road). The minimum average luminance values are maintained between 0.3 and 2 cd/m2 depending on the ADT (Average Daily Traffic) and road speed. The limits of minimum global uniformities are between 0.35 and 0.4, and 0.4 to 0.7 for the minimum longitudinal uniformities.

There are other criteria based on disabling glare (Threshold Increment) ranging between 15 and 10% of maximum value. This ratio is calculated from the veiling luminance produced by other light sources and disturbing the average luminance of the road.

Finally, the ratio criterion quantifies as disturbing environment lighting some other way.

The road lighting increases the luminance perceived by a user both the pavement as of road markings. Luminance of these road markings, retroreflective character generally, have been increased due to diffuse illumination. The luminance of road markings depends on the state and nature of the paintings.

These standards determine the minimum and maximum levels of luminance on the pavement that have to be taken into account when LED luminance levels were set. If a contrast of pavement/road studs of 3:1 is desired, LED luminance should be at least at angles 6cd/m2 α ≈ 1.33 ° (60m away and 1.4m in height, according to the method for measuring luminance of roads for motor vehicles).

3.2.7 Retroreflecting road studs

The goal of the retroreflecting road studs standard (EN-1463-1) is to specify the initial optical properties in a laboratory environment of the retroreflective sheetings, to be used as permanent o temporal road studs.

Retroreflecting road studs are classified by their size:

Table 3.11 Dimensions of retroreflecting road studs.

Class	Height (mm)		Large (mm)		Width (mm)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
H1	---	18	35	250	84	190
H2	18	20	75	320	90	230
H3	20	25	---	---	---	---

Retroreflective surface comes from 2940 to 47500 mm² for class H1 and from 6750 y 73600 mm² for class H2.

Night time visibility: Retroreflection values:

Standard Luminous intensity (cd· cd·lx^{-1}) minimun values

Table 3.12 Minumun values for retroreflecting road studs.

Entrance angle β_H β_V = 0º	Observation angle α	Minimum R' (mcd·lx^{-1}) Class		
		1	2	3
±15º	2º	2	2.5	1.5
±10º	1º	10	25	10
±5º	0.3º	20	220	150

Table 3.13 Colour factor for retroreflecting roads studs.

Colour	Colour Factor
White	1.0
Yellow	0.6
Ambar	0.5
Red	0.2
Green	0.2

The luminance perceived by a driver can be calculated as follows:

$$L = \frac{I}{S_e} = \frac{R' \cdot E}{S_e} = \frac{R' \cdot E}{S \cdot \cos(\alpha + \beta_H)}$$

Equation 4 Luminance of retroreflecting road studs

where R' is the coefficient of retroreflection in luminous intensity, E is the perpendicular illuminance over the surface, and Se is the effective surface observed by the driver. In Spain, as well as in other countries, class 2 and 3 are used depending on the road particular characteristics. Luminance perceived by a driver in a standard passenger vehicle can be up to 10cd·m-2.

In the following table all the angles corresponds to the exact geometry a driver in a standard passenger car with, seeing a retroreflecting road stud on the left lane over the pavement at the left of the vehicle, for different distances. The value measured at each simulated distance is the sum of retroreflecting road stud of each headlamps vehicle[4].

Table 3.14 Minimun retroreflecting values versus distance ("Driver Geometry")

Dist. (m)	Headlights	Obsev. α	Rot. ε	Entrance Ang. β1	Entrance Ang. β 2	Minimum R_l (mcd/lux)	Typical R_l (mcd/lux)
30	Right	0.95	19	-2.0	-1.6	40	80
	Left	2.91	-72	4.6	-2.9		
91	Right	0.35	24	-0.7	-0.5	350	500
	Left	0.90	-69	1.4	-1.0		
152	Right	0.22	24	-0.4	-0.3	600	1000
	Left	0.53	-68	0.8	-0.6		

Day time visibility: Luminance factor. It is the relation between the luminance of a retrorefecting road stud and a perfect lambertian over diffuse illumination. Luminance factor as to be greater or equal than 0.75 for white and green road studs, and greater then 0.45 for yellow sheeting.

3.3 Evaluation Criteria: Definition of parameters and physics manitudes

In general the above standards are written under a practical point of view in order to facilitate their manufacture and testing in a laboratory. These elements can be classified into two groups: those that emit light and those that retroreflect it.

1. **Emitting light signs** can be classified into two groups:

   - Lighting elements colour coded where **legibility is not required** (only visibility): criteria is based on the luminous intensity distribution. It **is not necessary** to distinguish details over the lighting surface. Typical examples are the signal head to control the traffic.
   - Lighting elements where **legibility is required** (information is based on symbols and/or text): criteria is based on luminance. It **is necessary** to distinguish details over the lighting surface. When legibility is required, a user has to unscramble the information by detecting every detail on it. The message is breaking up by different luminance over it.

2. **Retroflecting light elements**. These retroreflective elements can conform legibility messages (p.e. a speed limit over traffic sign) or visibility information (retroreflecting road stud). In any case, the evaluation criterion is the coefficient of retroreflection which is the data provided by the manufacturers. The minimum retroreflectivity values are based on the minimum required luminance criteria necessary to view/read signal by a driver when a sheeting is lit with the vehicle headlamps.

The point of view of in-use evaluation as they are seem by a driver, is different that the point of view of the manufacturer. The main magnitude for the in-use method is the luminance as well as it is the human eye perception.

[4] 3M Marker Series 290 Product Bulletin 290 March 2001. http://multimedia.3m.com/mws/mediawebserver?mwsId=66666UF6EVsSyXTtMXT_N8TEEVtQEVs6EVs6EVs6E666666--&fn=477.PDF

3.4 Procedure and criteria for evaluation of LED road studs

According to the analysis of all lighting and signaling systems used on roads, some conclusions can be considered:

- For lane delimiting, similar as retroreflective road marking, **luminance contrast has to be greater or equal to 4:1** in both diffuse and retroreflecting illumination.
- Coded messages for legibility (using text and/or symbols) have to be seen far away so the driver have time enough to decode and assimilate the information. Variable message vertical signs and traffic signs have a luminance contrast of (white or yellow text) **5:1 and 3:1 in and out of the reference axis respectively**. Letter size is quite important, because the legibility depends on the visual acuity (eye angle resolution) and the distance to the letter. **45cm is a typical size for text on overhead retroeflective traffic signs**. Pavement-Embedded Signage (PES) (as it were on coded message retroreflecting road marking) has to be enlarged to be read correctly due to the perspective.[5]

As a conclusion, luminance levels for LED-made road studs should be at least 4 times the pavement when used for guiding or delimitating lanes and 5 times for coded information.

Luminance levels should be adjustable with respect to the weather: sun, rain, fog, etc. to keep the luminance contrast without glare.

In-use evaluation of LED-made road studs should be done as in a dynamic way, similar to a driver in terms of luminance. Luminance measure of LED-made road studs and its environment (due to calculate luminance contrast), needs to have spatial resolution. This fact makes necessary the use of a luminance meter with spatial resolution. These devices are usually image sensor-made (CCD, CMOS, etc.), but need some specially properties, for example, the spectral sensitivity curve adapted to the CIE (2005) defined photonics, among others.

Dynamic luminance measurement encloses technical difficulties that have already been solved by certain equipment described in the scientific literature (Gutiérrez *et al.*, 2012).

[5] http://www.legislation.gov.uk/uksi/1994/1519/schedule/6/made

4 Smart pedestrian crossings experiment

4.1 Background

Collisions involving pedestrians in pedestrian crossings commonly result in fatalities (Chan and Ng, 2009). Nowadays, there are a high number of advanced warnings in order to increase the detection of a pedestrian crossing when a pedestrian is on it. These applications usually consist of a series of high-intensity luminaries buried in the pavement on both sides of the pedestrian crossing that direct light along road towards oncoming traffic. When activated, either by a pedestrian pressing a signal button or by some form of automatic pedestrian detection system, the lamps of the beacons switch on. The bright flashing warning lights lining the crosswalk draw driver's attention to the pedestrian crossing, raising the driver awareness and making these pay more attention to what is happening there and act appropriately.

In addition, this type of devices may constitute warnings that allow driver receive explicit information about the presence of pedestrians around the crosswalk.

When some of these treatments have been used to supplement signs and markings at crosswalks, the number of evasive conflicts between drivers and pedestrians have been reduced; the rate of motorists yield to pedestrian increases as well as the distance at which the drivers apply their brakes. In addition, this reduces motorist's approach speed and increases pedestrians' perception safety in both day and night-time driving

Nowadays, active studs are one of the most important factors in creating a safer, more controlled driving environment. The most obvious advantage of active studs is increased visibility (forward illumination can be increased from 100 metres to approximately 900m, irrespective of highlight intensity, Mole 2002).

Active studs can be used where conventional road marking is limited in use, for example, they can provide road layout guidance in daylight hours and in adverse weather conditions. Active studs can detect fading light levels, moisture on the road, fog, icy conditions, etc. and automatically active the required level of illumination. Some important benefits of using these studs are (Mole, 2002): a reduction in accident risk; increased driver visibility, alertness and awareness of potential hazards; avoidance of sudden braking and manoeuvres, for example, better control and improved delineation, especially in poor weather.

In addition, some possible applications of illuminated road studs to improve the safety of our roads are listed below (Boys and Green, 1997):

- Motorway ramp metering: studs can be sequentially activated to control merging;
- Motorway off-ramps to provide advance warning of exits;
- Vehicle-activated lights at sharp bends or hazards;
- Roundabout control;
- School bus stop-zones activated by time of day and buses;
- Pedestrian crossings emphasized by lanes of studs leading to the crossing. These studs can change colour and flash where required;
- Tidal flow control in urban areas, illiuminated studs can be used to divide the road;
- Advance warning for railway level crossings and,
- Replacing some pole-mounted traffic signals.

In this context, the colour and flashing are an important and common dimension of visual coding. Colour is particularly useful for memory coding and message recognition. The colour red, yellow and blue is frequently used in coding electrical and hydraulic equipment, and for marking safety hazards. International guidelines and standards are available for designers to follow when using colours (ISO 3864-1: 2002; and ANSI Z535.1-2002). Red identifies stop and danger and is used for it; yellow suggests physical hazard and caution and blue connotes caution against starting, using or moving equipment under repair or in use. However, it has been shown that cultural and geographical factors may have an effect on designer preferences and user perceptions for colours (Chan and Ng, 2009).

Notwithstanding, it has been shown that cultural and geographical factors may have an effect on designer preferences and user perceptions for colours. The results showed that Hong Kong, Chinese, Koreans and Thais did not generally share common colour concepts associations (Chan & Courtney, 2001). For example, Chinese and Thais associated red with potential hazard and radiation hazard; however, Korean associated orange with potential hazard and yellow with radiation hazard.

Research about associations of colours with concepts and conditions will provide industrial designers with knowledge about the meaning of color codes they use. Bergum and Bergum (1981) investigated population stereotypes relating to color using 12 concepts (safe, danger, cold, hot, go, stop, near, far, caution, radiation, on, off). From their side, Courtney (1986) found out that Chinese did not yield such clear-cut association as those found with US subjects. Red for stop and green for go, which have virtually perfect associations for American subjects, were not particularly strong associations for the Chinese subjects. For Chinese participants chose green for “on”, whereas US subjects, for this category, chose red. Although there are international standards (EN 60073, 1993) on the meanings of colours with respect to the safety of persons and the conditions and device positions, such standards seem not to be generally applicable for different populations. It was also suggested that extra care should be exercised when equipment and systems to be used in China are designed assuming the strong red and green stereotypes found in the west, and more work is necessary to understand the color associations.

Furthermore, Guillaume, Pellieux, Chastres & Drake (2003) showed that context of delivery might be a critical factor in judging the urgency of warning signals.

In this context the current study aims to determine the most preferable configuration, based on different colours and effects of advance warnings, targeted to provide information about the presence of pedestrians crossing on the crosswalk, according to the acceptance and hazard awareness perceived by the road users, when these approach this type of road configurations. Some of the hypotheses are collected below:

- The flashing-amber in-pavement LED is perceived as less dangerous than the rest of in-pavement LED modalities.
- The amber-flashing light is perceived more effective than the rest of modalities.
- The in-pavement LED modalities are more desirable than the OLEDs and Danger warning.
- The red-flashing effect raises more alertness than the rest of modalities.
- ....

4.2 Method

4.2.1 Sample

Thirty-three volunteers participated in this study. With the aim of having with a representative sample, 18 men of all ages and 15 women with the same distribution, except for motorcyclists women over 55 years who can not find. The objective of the study was to identify the most appropriate lighting application to provide warning to drivers about the presence of pedestrian on the crosswalk or near. The objective was not to study differences among groups of age or gender.

Table 4.1: Distribution of the sample as regards the gender, age and type of driver.

	18-34		35-54		over 55		Total
	Motorcyclists	Drivers	Motorcyclists	Drivers	Motorcyclists	Drivers	
Men	3	3	3	3	3	3	18
Women	3	3	3	3	0	3	15
Total	6	6	6	6	3	6	33

4.2.2 Instrument

Hellier et al (2000) examined the stability of the arousal strength of the three warning signal words: urgency, danger and unsafe. Danger was found to elicit higher arousal strength than unsafe and urgent, which had relatively similar ratings. However, Yu et al (2004) found that danger and urgent had the same perceived arousal strengths for Chinese subjects. In addition, no significant differences were found between these three ratings (ANOVA p>.05) and the ratings were highly correlated (r=0.962). Hence, the urgency, danger and unsafe ratings will be used in general as the perceived hazard rating in further analyses and discussions (Chang and Ng, 2008).

Subjects were asked to rate the perceived hazard level of the stimulus on a 9-point likert scale on the dimensions of danger (1=dangerous, 9=extremely dangerous), urgency (1=urgent, 9=extremely urgent), and unsafe (1=unsafe, 9= extremely unsafe) on the screen. These scales had already been used in previous studies to evaluate the perceived hazard level of various visual signals with or without simultaneous auditory alerts (Chan and Ng, 2009) (
Figure 4.1).

In addition, two additional variables, conspicuity and detectability, with respect to the beacon shown were included as well. Both variables were also measured on a 9-point Likert scale.

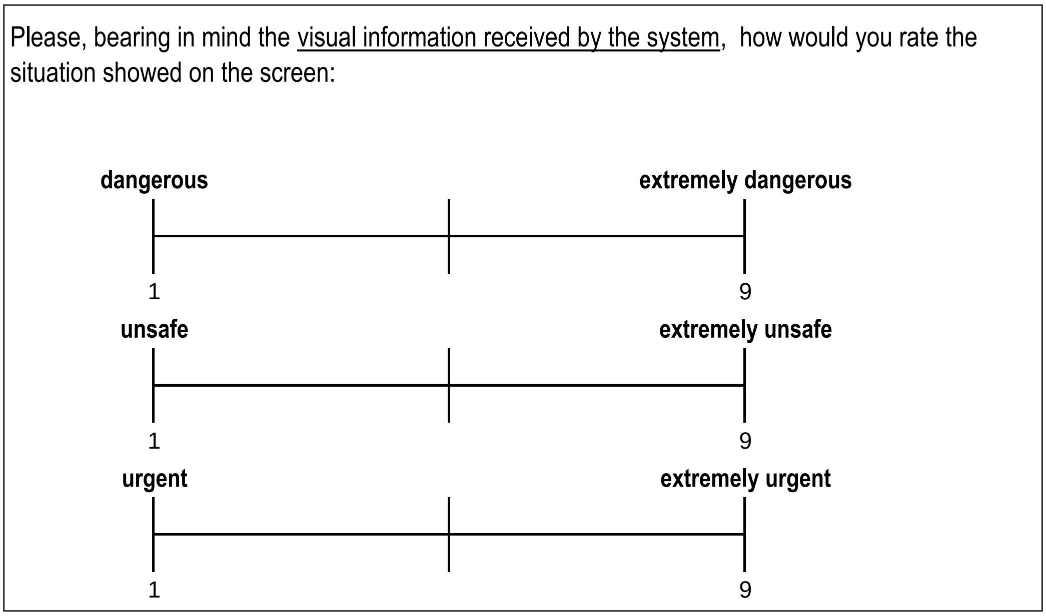

Figure 4.1: The perceived hazard level of the visual signals (Chang and Ng, 2009)

Furthermore, in order to know the acceptance of the different applications shown, a simple scale developed by Van Der Laan, Heino and De Waard (1997) was used (Figure 4.2). This scale is presented to the driver as nine 5-categories continuum (scored from 1 a 5) on various dimensions relating to the usefulness and satisfaction of the different systems assessed.

All scales and questionnaires used were applied in their Spanish versions (Acceptance scale by Van Der Laan, obtained from www.hfes-europe.org/accept/accept_es.htm and the perceived hazard level scales was translated from the study authors).

Please, what do you think about the **system** used to provide visual information when you approach a pedestrian crossing (remember, option 3 has a neutral meaning, neither one or other):

Useful	1	2	3	4	5	**Useless**
Pleasant	1	2	3	4	5	**Unpleasent**
Bad	1	2	3	4	5	**Good**
Nice	1	2	3	4	5	**Annoying**
Effective	1	2	3	4	5	**Superfluous**
Irritating	1	2	3	4	5	**Likeable**
Assisting	1	2	3	4	5	**Worthless**
Undesirable	1	2	3	4	5	**Desirable**
Raising Alertness	1	2	3	4	5	**Sleep-inducing**

Figure 4.2: The acceptance scale (Van Der Laan, Heino and De Waard, 1997)

4.2.3 Procedure

A series of video clips containing the targeted applications where different colours, effects and configurations could be tested were elaborated. 3D computer graphics and animation software was used for this purpose.

4.2.3.1 Configurations tested

Different configurations for the targeted application have been tested. These configurations consist of LEDs or pavement-embedded signage on either side of crossings or on the marking itself, that are illuminated when drivers approach and there are pedestrians crossing or near the pedestrian crossing. The three main configurations based on advanced warnings included in the study are the following:

1. The first one is "**in-pavement LEDs in pedestrian crossing**":

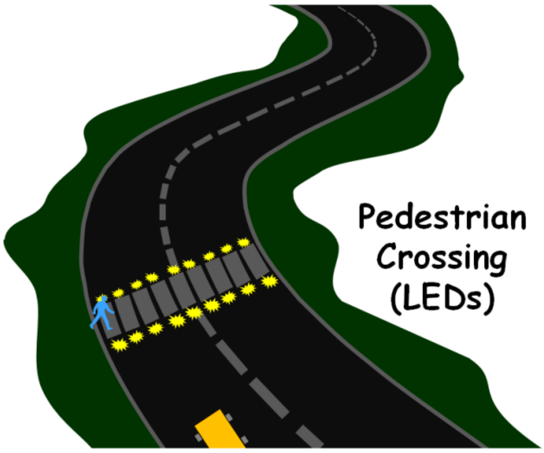

Figure 4.3: Pedestrian crossing LEDs modality

This main configuration has been included in eight different shapes taking the colour and the LEDs effect into account:

- Type of colour: yellow, amber, white and red.
- Type of the effects: flashing and steady effect.

As a result of the combination of the colour and effect of the LEDs, eight configurations have been defined: yellow-flashing mode; yellow-steady effect; amber-flashing shape; yellow-steady mode; white-steady effect; white-flashing mode; red-steady configuration and red-flashing mode.

2. The second configuration is "**PEs (Pedestrian crossing)**": the in-pavement danger warning provided to driver when a pedestrian is on and near the zebra crossing (Figure 4.4).

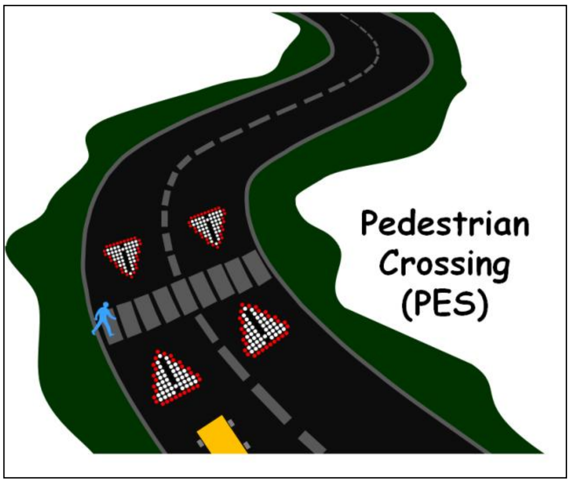

Figure 4.4 Danger warning modality

3. And the third configuration is "OLEDs (Pedestrian crossing)": this advanced warning consists of illuminating the pedestrian crossing markings when pedestrian is crossing (Figure 4.5).

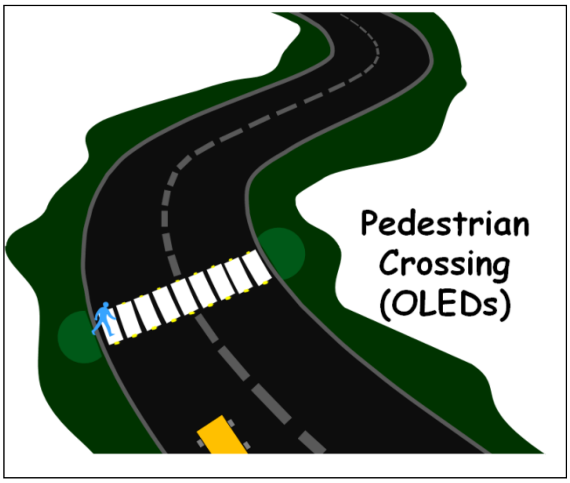

Figure 4.5 Pedestrian crossing (OLEDs)

All these treatments have been designed to alert motorists about the presence of pedestrians on the crosswalks or to make the crosswalk more conspicuous.

4.2.3.2 Variables identified

The independent and dependent variables studied are described below.

- <u>*The independent variables:*</u>

The independent variable *was the type of advanced warning* shown on the presence of a nearby pedestrian crossing when the motorists approach it, based on LEDs or in-pavement signage on either side of the pedestrian crossing or in-pavement embedded LEDs when the motorists approach the crosswalk. A total of 10 types of configurations were used in the study. These configurations are detailed below:

- Configuration 1: “in-pavement LEDs in either side of the pedestrian crossing”

  Based on the literature, the most effective combination of colour and effect of LEDs is the configuration with amber and flashing light/beacon (UNECE, 2002). However, there are some doubts about the preference of other different combinations. For that reason, we are going to show this configuration with several options based on four colours and two types of effect of LEDs: (1) flashing and (2) steady. Accordingly, we showed eight configurations in accordance with these combinations:

  - Configuration 1.1: Flashing-yellow effect.
  - Configuration 1.2: Steady- yellow effect.
  - Configuration 1.3: Flashing-amber effect.
  - Configuration 1.4: Steady-yellow effect.
  - Configuration 1.5: Steady-white effect.
  - Configuration 1.6: Flashing-white effect.
  - Configuration 1.7: Steady-red effect.
  - Configuration 1.8: Flashing-red effect.

- Configuration 2: PEs (Pedestrian crossing)”: embedded signage (“Danger warning”) activated when a driver approaches to pedestrian crossing.

- Configuration 3: OLEDs in the marking itself illuminate (a bit like in Michael Jackson's Billie Jean video)

As result of the configurations collected above, a total of 10 configurations were evaluated in order to find out if there are or not significant statistically differences among the effects indicated with regard to the perceived hazard level, the detectability and the acceptance.

- The dependent variables:

The three dependent variables considered in the study were:

- Perceived Hazard level on the dimensions of: danger, urgency and unsafe.
- Acceptance of the prototype system.
- Detectable and conspicuity of the advanced warning.

4.2.3.3 Procedure

In order to recruit the participants, an association of motorcyclists was contacted. In addition, an internal CIDAUT basedata was used for selecting the driver at random. First of all, information on age and gender, as well as mode of transport, was collected from all the candidates in order to select the proper sample, together with their availability to participate in the tests. Once the 33 participants were selected, they were asked to go to CIDAUT facilities individually at their most convenient date and time, and experimenters let them know beforehand that the test would take them about 1 hour and a half or 2 hours. The experimenters adapted to participants´ schedules.

Once in CIDAUT facilities, volunteers were welcomed, and experimenter thanked them for their participation. Before starting the test, volunteers were told briefly what is the objective of INROADS project, and they signed a consent form. Afterwards, the experimenter shot the 10 videos. After each video they were asked to fill in a form in order to find out their opinion on the different colours, effects, and configurations. Once they had watched and evaluated all the videos, experimenters showed them the videos again in order to find out their preferences (Figure 4.6).

Additional notes were taken reflecting any comments offered by the subject during the test. The experimenter was also attentive to non-verbal reactions of the participants to each of the videos, and she asked them to talk about their preferences and feelings after watching the videos. These comments or reactions were recorded in an attempt to identify any positive or negative characteristics of each individual configuration.

Figure 4.6 Participants watching INROADS videos

To test the validity of our hypothesis, the main and interaction effects of the modalities on perceived hazard rating were examined through an Analyis of Variance (ANOVA) and the Paired Sample T-Test to find out significant interactions among all possible pairs**.**

4.3 Results

4.3.1 Perceived Hazard Rating: danger, unsafe and urgent

As it has been indicated above, several multivariate tests were carried out in order to contrast the hypothesis. Regarding the perceived **"danger"** in each situation, Table 4.2 collects the descriptive statistics. The mean perceived danger rating of flashing in-pavement LED modalities and the advanced warning was much higher than for steady in-pavement LED modalities, except for the steady-yellow LED modality that showed a higher score. The steady-white in-pavement LED condition was the less dangerous condition.

To test our hypothesis, an Analysis of Variance (ANOVA) test was carried out. As the Table 4.3 collects, several significant effects were identified for flashing-red and flashing-yellow in-pavement LEDs warnings ($p < .05$). As regard the flashing-red in-pavement LED, this was found significantly more dangerous than OLEDs warning ($p=.044$), and the flashing-amber in-pavement LEDs was considered more dangerous than the steady-white effect ($p=.045$).

Table 4.2: Descriptive statistics for the variable "DANGER"

Measure: **Danger**

factor1	Mean	Std. Error	Interval Bound	Bound
White_Flashing	22,228	5,473	10,956	33,500
Amber_Flashing	**29,439**	6,667	15,709	43,170
White_Steady_	15,508	4,277	6,699	24,316
Warning	**30,176**	6,405	16,985	43,368
Yellow_flashing	**30,306**	6,298	17,335	43,278
Red_Steady	22,815	5,076	12,361	33,269
Amber_Steady	21,834	4,833	11,880	31,788
Yellow_Steady	28,970	5,853	16,915	41,025
OLEDs	21,225	4,802	11,335	31,116
Red_flashing	**33,387**	6,022	20,986	45,789

Table 4.3 ANOVA for the variable "DANGER"

Measure: Dangerous

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	1352,019	1	1352,019	1,364	,254
	White_Steady_ vs. Amber_Flashing	2772,263	1	2772,263	4,476	**,045**
	Warning vs. White_Steady	1575,554	1	1575,554	1,400	,248
	Yellow_flashing vs. Warning	926,156	1	926,156	1,608	,216
	Red_Steady vs.Yellow_flashing	191,858	1	191,858	,510	,482
	Amber_Steadyvs. Red_Steady	273,759	1	273,759	,878	,358
	Yellow_Steady vs Amber_Steady	493,079	1	493,079	,760	,392
	OLEDs vs. Yellow_Steady	402,413	1	402,413	,832	,370
	Red_flashing vs OLEDs	1952,099	1	1952,099	4,478	**,044**

In order to find more possible specific interactions, a paired sample T-Test was realized for the variable danger. The results showed significant differences for the steady-white in-pavement LED condition. For this condition, it has been found that the level of perceived danger is significantly lower than for the rest of conditions ($p < .05$), except for the OLEDs modality and flashing-white in-pavement LEDs, where no significant differences were found. As regards flashing-red effect, this modality was perceived as more dangerous than the steady in-pavement LED modalities and OLEDs ($p < .05$) (Table B1 in Annexe B).

As a result, we can not say that the flashing-amber effect is perceived as more dangerous than the rest of modalities of in-pavement LEDs, when there is a pedestrian going across or near the pedestrian crossing. Notwithstanding, the flashing-red effect is perceived as more dangerous than steady modalities and OLEDS warning. Furthermore, the use of the steady-white effect was considered significantly less dangerous than the rest of modalities, except the flashing-white and OLEDs.

With regard to perceived **"safety"**, the flashing-red (Mean=35, 98), the flashing-yellow (Mean=33, 09), the steady-yellow in-pavement LEDs (Mean=30,91) and danger warning (Mean= 31,42) were seen as the most unsafe situations (Table 4.4).

Table 4.4 Descriptive statistics for variable UNSAFE in each situation

Descriptive Statistics

	Mean	Deviation	N
White_Flashing	16,9081	22,99907	27
Amber_Flashing	26,2563	30,58080	27
White_Steady_	14,4930	13,81938	27
Warning	**31,4256**	30,02466	27
Yellow_flashing	**33,0996**	29,53063	27
Red_Steady	20,0730	19,10930	27
Amber_Steady	18,1122	17,38185	27
Yellow_Steady	**30,9163**	27,50554	27
OLEDs	14,0089	19,23119	27
Red_flashing	**35,9837**	26,29840	27

To contrast the hypotheses regarding "unsafe situation", the results of the ANOVA showed several significant main effects for the flashing-yellow, steady-yellow and the flashing-red in-pavement LEDs (analysis of variance P< .05). Specifically, the flashing-yellow LEDs was considered as a more unsafe situation than the danger warning (P< .044). Likewise, the steady-yellow LEDs modality was assessed as more unsafe than OLEDs warning (P< .016) and the flashing-red LEDs more unsafe than the OLEDs warning (P< .016) (Table 4.5).

Table 4.5 ANOVA for variable UNSAFE

Measure: Unsafe

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	2359,473	1	2359,473	1,354	,255
	White_Steady_ vs. Amber_Flashing	1356,955	1	1356,955	3,744	,064
	Warning vs. White_Steady	4022,910	1	4022,910	3,844	,061
	Yellow_flashing vs. Warning	3166,151	1	3166,151	4,459	**,044**
	Red_Steady vs.Yellow_flashing	514,097	1	514,097	1,858	,185
	Amber_Steady vs. Red_Steady	845,824	1	845,824	3,168	,087
	Yellow_Steady vs Amber_Steady	1730,858	1	1730,858	2,289	,142
	OLEDs vs. Yellow_Steady	2647,136	1	2647,136	6,684	**,016**
	Red_flashing vs OLEDs	4685,520	1	4685,520	9,389	**,005**

Furthermore, a paired sample T-test was carried out in order to find out whether differences might exist for the other conditions. As it can be seen in Table B2 in Annexe B, the flashing-red effect condition was considered as more unsafe than the rest of conditions (p< .05), except for the flashing-yellow, steady yellow and danger warning (p>.05). In the case of the flashing-yellow effect, this was also considered more unsafe than the rest of categories (p< .05), apart from the flashing-red effect, steady-yellow and danger warning (p> .05). And finally, the steady-yellow condition was considered more unsafe than the rest of options as well (p< .05), except for the flashing-red, the flashing-yellow, the danger warning and the flashing-amber (p> .05). In addition, the danger warning was assessed more unsafe than the rest of modalities (p< .05), except for the flashing-red, the flashing-yellow, the steady-yellow and the flashing-amber (p> .05). Hence, the situations significantly perceived as more unsafe by the drivers were the flashing-red, the steady-yellow, the flashing yellow and the danger warning.

Regarding the variable **"urgency"**, the Table 4.6 collects their descriptive statistics for each advanced warning. The mean rating of the flashing-amber (Mean=35, 70), the red-flashing LEDs (Mean= 36, 06) and even, the danger warning (Mean=33, 65) were quite higher than for the rest of warnings, while the OLEDs warning (Mean= 16, 43), the steady-white LEDs (Mean= 20, 37) and the steady-amber in-pavement LED (Mean= 23, 19) were considered as the less urgent warnings. However, the results of the ANOVA showed only significant main effects for the amber-flashing effect, the steady-red modality and the steady-yellow in-pavement LEDs (p <.05).

Table 4.6 Descriptive statistics for the variable URGENT

Measure: urgent

factor1	Mean	Std. Error	95% Confidence Interval Bound	Upper Bound
White_Flashing	**30,773**	6,187	18,003	43,544
Amber_Flashing	**35,707**	6,413	22,471	48,943
White_Steady_	20,371	4,750	10,567	30,175
Warning	**33,650**	5,339	22,631	44,669
Yellow_flashing	26,798	5,153	16,162	37,434
Red_Steady	**29,884**	5,691	18,140	41,629
Amber_Steady	23,198	5,165	12,539	33,857
Yellow_Steady	**31,078**	5,322	20,094	42,062
OLEDs	16,433	4,469	7,209	25,657
Red_flashing	**36,066**	5,416	24,888	47,245

As it can be seen in Table 4.7, the flashing-amber effect, the Steady-Red effect and Steady-yellow in-pavement LEDs were significantly more urgent than the steady-white effect (P< .014), the steady-amber effect (P< .052) and OLEDs warning (P< .001), respectively.

Table 4.7 ANOVA for the variable URGENT

Measure: Urgent

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	608,609	1	608,609	,576	,455
	White_Steady_ vs. Amber_Flashing	4140,536	1	4140,536	6,971	**,014**
	Warning vs. White_Steady	552,156	1	552,156	,557	,463
	Yellow_flashing vs. Warning	276,773	1	276,773	,956	,338
	Red_Steady vs.Yellow_flashing	4,506	1	4,506	,005	,944
	Amber_Steady vs. Red_Steady	1002,546	1	1002,546	4,190	**,052**
	Yellow_Steady vs Amber_Steady	150,266	1	150,266	,308	,584
	OLEDs vs. Yellow_Steady	3905,750	1	3905,750	14,293	**,001**
	Red_flashing vs OLEDs	1815,953	1	1815,953	3,722	,066

In addition, a paired sample T-Test was performed in order to find out other possible interactions of these modalities. In spite of the interactions above mentioned, the results of the T-Test indicated that the most significant differences were for the modalities OLEDs warning and the steady-white in-pavement LEDs. Both modes of presenting information about the presence of pedestrians on and near a pedestrian crossing were considered less urgent than the rest of conditions (p< .05). Furthermore, no significant differences were found neither among them nor with regard to the steady-amber condition (p>.05). Accordingly, the OLEDs warning and steady- white effect were significantly perceived as the less urgent situations (**Erreur ! Source du renvoi introuvable.** B3 in Annexe B).

4.3.2 Visibility variables

Two variables related to visibility were included in the study: conspicuity and detection. As for the "**conspicuity"** of the advanced warnings, the descriptive statistics for each of the modalities are collected in Table 4.8. As it can be seen in this table, the flashing-amber and flashing-yellow effects were considered highly conspicuous (Mean=55,53 y Mean= 52,28, respectively). In addition, other warnings such as the danger warning (Mean=47, 23), the flashing-red effect (Mean=46,49) and the Steady-yellow effect (Mean=45, 59) were also assessed as quite conspicuous.

Table 4.8 Descriptive statistics for the CONSPICUITY

Measure: Conspicuity

factor1	Mean	Std. Error	95% Confidence Interval Bound	Upper Bound
White_Flashing	43,423	6,643	29,875	56,970
Amber_Flashing	**55,535**	5,879	43,545	67,526
White_Steady_	38,043	5,537	26,750	49,335
Warning	**47,238**	6,031	34,938	59,539
Yellow_flashing	**52,285**	5,907	40,238	64,332
Red_Steady	40,246	5,730	28,561	51,932
Amber_Steady	39,088	5,603	27,661	50,516
Yellow_Steady	**45,599**	5,767	33,838	57,361
OLEDs	36,904	6,231	24,197	49,612
Red_flashing	**46,492**	6,019	34,216	58,768

In order to contrast the hypothesis regarding conspicuity, an ANOVA was realized and the main effects and interactions are collected in Table 4.9. The results of the ANOVA showed significant effects for flashing-amber and steady-red (P< .05). Specifically, the flashing-amber effect was significantly more conspicuous than the flashing-white effect (P< .006) and steady-white effect (P< .035). On the part of the steady-red effect, this was found significantly more conspicuous than steady-amber LEDs (p< .040).

In addition, a paired sample T-test was also performed for the variable conspicuity. As it can be seen in Table B4 in Annexe B, the flashing amber effect was significantly more conspicuous than the rest of modalities (p< 0.05), except for the flashing-yellow effect, the flashing-red and the danger warning (p>0.05). Consequently, the flashing-amber effect is significantly more conspicuous in order to perceive the presence of pedestrians on/near the pedestrian crossing.

Table 4.9 ANOVA for the variable CONSPICUITY

Measure: Conspicuity

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	4695,047	1	4695,047	8,811	**,006**
	White_Steady_ vs. Amber_Flashing	4185,324	1	4185,324	4,855	**,035**
	Warning vs. White_Steady	79,044	1	79,044	,059	,809
	Yellow_flashing vs. Warning	1240,145	1	1240,145	1,449	,238
	Red_Steady vs.Yellow_flashing	1594,318	1	1594,318	2,256	,143
	Amber_Steady vs. Red_Steady	1585,924	1	1585,924	4,611	**,040**
	Yellow_Steady vs Amber_Steady	7,273	1	7,273	,019	,891
	OLEDs vs. Yellow_Steady	2192,730	1	2192,730	2,525	,122
	Red_flashing vs OLEDs	159,093	1	159,093	,136	,715

Regarding the **variable "detectability"**, five modalities of the in-pavement LEDs were considered as highly detectable, such as: the flashing-white effect (Mean= 56, 87), the flashing-amber modality (Mean= 59, 83), Flashing-yellow effect (Mean= 57, 80), the steady-yellow modality and flashing-red (Mean= 50, 50) (Table 4.10).

Table 4.10 Descriptive statistic for the variable DETECTABLE

Measure: Detectable

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White_Flashing	**56,879**	6,803	42,985	70,772
Amber_Flashing	**59,833**	5,605	48,386	71,279
White_Steady_	42,826	5,792	30,997	54,655
Warning	47,816	6,780	33,970	61,662
Yellow_flashing	**57,803**	5,960	45,631	69,974
Red_Steady	47,204	5,939	35,075	59,332
Amber_Steady	42,033	6,059	29,660	54,406
Yellow_Steady	**54,372**	5,879	42,364	66,379
OLEDs	44,741	6,633	31,194	58,288
Red_flashing	**50,507**	6,319	37,602	63,412

The results of ANOVA showed significant interaction effects for the flashing-amber and steady-red effect. According to the ANOVA (Table 4.11), the flashing-amber effect was significantly more detectable by the users than the Steady-white effect ($P< .005$) as well as the Steady-red effect that was considered more detectable significantly than the Steady-amber ($P< .024$).

Table 4.11 ANOVA for the variable DETECTABLE

Measure: Detectable

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	270,486	1	270,486	,509	,481
	White_Steady_ vs. Amber_Flashing	7476,142	1	7476,142	8,997	**,005**
	Warning vs. White_Steady	891,726	1	891,726	,634	,432
	Yellow_flashing vs. Warning	1102,869	1	1102,869	2,144	,154
	Red_Steady vs.Yellow_flashing	1052,817	1	1052,817	1,521	,227
	Amber_Steady vs. Red_Steady	3116,589	1	3116,589	5,623	**,024**
	Yellow_Steady vs Amber_Steady	434,556	1	434,556	,910	,348
	OLEDs vs. Yellow_Steady	1251,935	1	1251,935	1,104	,302
	Red_flashing vs OLEDs	,429	1	,429	,000	,985

In order to find out other interactions, a paired sample T-test was carried out. The results of this test showed that the flashing-amber was also perceived as significantly more detectable than the steady-red, OLEds warning, steady white effect and the steady-amber effect ($p< 0.05$). In addition, the results of the T-test showed that the flashing-yellow was also more detectable than the steady-red, the steady-amber, the steady-yellow and the OLEDS warning ($p< 0.05$) (Table B5 in Annexe B). However, although the ANOVA showed a significant interaction with respect the steady-red modality, after carrying out the T-test, this interaction was found not to be significant, since the number of cases considered was different in both tests. As result of this, it can be said that the flashing-amber is perceived as more detectable than the steady in-pavements LEDs conditions and OLEDs.

4.3.3 Acceptance scale rating

Focusing on the acceptance scale, the first variable studied was **"usefulness"**. The Table 4.12 shows the descriptive statistics for the variable usefulness for all conditions. The flashing-amber in-pavements LEDs condition was considered the most useful (Mean=1,57), followed by the Steady-yellow and OLEDs warning, although all the options, in general, were considered useful to provide information about the presence of pedestrians on/near the pedestrian crossing.

Table 4.12 Descriptive statistics for the variable USEFUL

Measure: **Useful**

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White_Flashing	1,939	,168	1,597	2,282
Amber_Flashing	1,576	,131	1,309	1,842
White_Steady_	1,758	,138	1,477	2,038
Warning	2,333	,241	1,842	2,824
Yellow_flashing	1,848	,164	1,515	2,182
Red_Steady	1,939	,179	1,575	2,304
Amber_Steady	1,970	,182	1,599	2,340
Yellow_Steady	1,636	,136	1,359	1,914
OLEDs	1,788	,203	1,374	2,201
Red_flashing	1,758	,157	1,438	2,078

The results of the ANOVA showed significant interactions for the flashing–amber effect, flashing-yellow and steady-yellow effects. According to Table 4.13, the flashing-amber effect is significantly more useful to provide this kind of information than the flashing-white LEDs (P< .016). Likewise, the steady-white is also more useful in order to provide information regarding the presence of pedestrians crossing than the danger warning (P< .022) and the steady-yellow effect is significantly more useful than the steady-amber effect as well (P< .024).

Furthermore, a paired sample T-test was carried out in order to find out other interactions. As result of this test, it was also found that the steady-white was considered more useful significantly than the Steady-amber effect (p=.033). In addition, the steady-yellow effect and the flashing-red LEDs were considered more useful than the danger warning, p=.022 y p=-024, respectively (Table B6 in Annexe B). As result of this, the flashing –amber is more useful than the danger warning, the flashing-white effect, the steady-red effect and the steady-amber. As for the steady-yellow, this effect is more useful than danger warning and steady-amber.

Table 4.13 ANOVA for the variable USEFUL

Measure: **Useful**

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	4,364	1	4,364	6,454	**,016**
	White_Steady_ vs. Amber_Flashing	,000	1	,000	,000	1,000
	Warning vs. White_Steady	10,939	1	10,939	5,807	**,022**
	Yellow_flashing vs. Warning	,093	1	,093	,132	,719
	Red_Steady vs.Yellow_flashing	,078	1	,078	,162	,690
	Amber_Steady vs. Red_Steady	,165	1	,165	,241	,627
	Yellow_Steady vs Amber_Steady	2,455	1	2,455	5,654	**,024**
	OLEDs vs. Yellow_Steady	,250	1	,250	,215	,646
	Red_flashing vs OLEDs	,383	1	,383	,510	,480

The next variable is **"pleasant"**: the modality considered as the most pleasant in order to provide information about the presence of pedestrians on and near the pedestrian crossing was the OLEDs application (Mean=1.6), quite the opposite than the yellow conditions, in their both versions. But above all, the less pleasant condition was Flashing-red LEDs (Mean=2,18) whose punctuation was near "not pleasant, not unpleasant" (Table 4.14).

Table 4.14 Descriptive statistic for the variable PLEASANT

Measure: **PLEASANT**

factor1	Mean	Std. Error	Interval Bound	Bound
White_Flashing	**2,152**	,195	1,754	2,549
Amber_Flashing	2,333	,203	1,921	2,746
White_Steady_	**2,182**	,187	1,801	2,563
Warning	2,364	,203	1,950	2,778
Yellow_flashing	2,576	,195	2,179	2,972
Red_Steady	2,394	,179	2,029	2,759
Amber_Steady	2,515	,175	2,159	2,871
Yellow_Steady	2,515	,200	2,108	2,923
OLEDs	**1,606**	,162	1,275	1,937
Red_flashing	2,818	,224	2,362	3,274

For this variable, the ANOVA table shows significant main effects for the danger warning modality and OLEDs application. According to the results (Table 4.15), the danger warning is significantly considered more pleasant to provide this kind or information than the Flashing-yellow effect (P< .004). In addition, the OLEDs application was significantly perceived as more pleasant than the Steady-yellow LED application (P< .000) and Flashing-red modality (P< .022).

Table 4.15 ANOVA for the variable PLEASANT

Measure: **Pleseant**

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	1,091	1	1,091	,714	,404
	White_Steady_ vs. Amber_Flashing	,121	1	,121	,107	,746
	Warning vs. White_Steady	,660	1	,660	,426	,519
	Yellow_flashing vs. Warning	3,341	1	3,341	9,371	**,004**
	Red_Steady vs.Yellow_flashing	,175	1	,175	,166	,686
	Amber_Steady vs. Red_Steady	1,091	1	1,091	2,480	,125
	Yellow_Steady vs Amber_Steady	,801	1	,801	,896	,351
	OLEDs vs. Yellow_Steady	19,705	1	19,705	21,140	**,000**
	Red_flashing vs OLEDs	9,104	1	9,104	5,823	**,022**

Besides, the results of the Paired sample T-Test indicate that the OLEDs warning was significantly more pleasant than the rest of modalities (P<.05). In addition, the steady-white and the flashing-white effects both were considered significantly more pleasant than the flashing-red and the Flashing-yellow effect (P<.05) (Table B7 in Annexe B).

With regard to the variable **"goodness",** all the advanced warnings used to provide visual information when driver approaches a pedestrian crossing were considered quite good, above all the OLEDs modality (Mean=4) and the white LEDs conditions (both means= 3,93) (Table 4.16).

Table 4.16 Descriptive statistics for the variable GOOD

Measure: **Bad**

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
White_Flashing	**3,939**	,184	3,564	4,315
Amber_Flashing	**3,909**	,201	3,499	4,319
White_Steady_	**3,939**	,174	3,585	4,293
Warning	3,636	,234	3,160	4,112
Yellow_flashing	3,788	,198	3,384	4,192
Red_Steady	3,727	,201	3,318	4,136
Amber_Steady	3,758	,169	3,414	4,101
Yellow_Steady	3,636	,203	3,222	4,050
OLEDs	**4,000**	,218	3,557	4,443
Red_flashing	3,758	,185	3,381	4,134

The results of the ANOVA did not show any significant differences for the variable "goodness" regarding the modalities studied (Table 4.17). As the Table 4.16 indicates all conditions were considered quite good in order to provide information about the presence of pedestrians on and near the pedestrian crossing. Apart form the ANOVA test, a Paired Sample T-Test was carried out and there were not significant differences among the modalities regarding the variable good (Table B14 in Annexe B).

Table 4.17 ANOVA for the variable "GOOD"

Measure: **GOOD**

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	,030	1	,030	,026	,872
	White_Steady_ vs. Amber_Flashing	,008	1	,008	,010	,919
	Warning vs. White_Steady	2,832	1	2,832	1,737	,197
	Yellow_flashing vs. Warning	,153	1	,153	,292	,592
	Red_Steady vs.Yellow_flashing	,438	1	,438	,500	,485
	Amber_Steady vs. Red_Steady	,142	1	,142	,312	,581
	Yellow_Steady vs Amber_Steady	1,040	1	1,040	1,262	,270
	OLEDs vs. Yellow_Steady	1,432	1	1,432	1,040	,315
	Red_flashing vs OLEDs	,108	1	,108	,145	,706

Below, with respect to the variable **NICENESS,** the OLEDs application was considered as the nicest by the participants in order to present information about the presence of pedestrian on/ near the pedestrian crossing (Mean=1,65). Notwithstanding, all conditions studied were considered quite nice as well (Table 4.18).

Table 4.18 Descriptive statistics for the variable "NICE"

Measure: **NICE**

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White_Flashing	2,344	,209	1,918	2,769
Amber_Flashing	2,594	,205	2,175	3,012
White_Steady_	2,219	,189	1,833	2,604
Warning	2,344	,194	1,949	2,739
Yellow_flashing	2,625	,189	2,239	3,011
Red_Steady	2,719	,169	2,373	3,064
Amber_Steady	2,406	,200	1,998	2,814
Yellow_Steady	2,313	,208	1,888	2,737
OLEDs	1,656	,166	1,318	1,994
Red_flashing	2,875	,228	2,410	3,340

For the variable niceness, the results of ANOVA showed significant main effect for the conditions danger warning and OLEDs warning. With regard to the danger warning, this modality was considered nicer than the flashing-Yellow LED (P= .054). As regard to the OLEDs modality, this was also considered nicer than the Steady-yellow and flashing-red LED application (P= .000 and P= .022 respectively), as this can be seen in the Table 4.19.

Table 4.19 ANOVA for the variable NICE

Measure: **NICE**

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	2,000	1	2,000	1,192	,283
	White_Steady_ vs. Amber_Flashing	2,000	1	2,000	1,851	,184
	Warning vs. White_Steady	,056	1	,056	,035	,854
	Yellow_flashing vs. Warning	2,000	1	2,000	4,000	**,054**
	Red_Steady vs.Yellow_flashing	2,761	1	2,761	3,531	,070
	Amber_Steady vs. Red_Steady	,147	1	,147	,154	,698
	Yellow_Steady vs Amber_Steady	,737	1	,737	,562	,459
	OLEDs vs. Yellow_Steady	19,924	1	19,924	23,714	**,000**
	Red_flashing vs OLEDs	8,565	1	8,565	5,789	**,022**

For this variable, a paired sample T-test was carried out as well (**Erreur ! Source du renvoi introuvable.** B8 in Annexe B). According to the results of the T-test, the OLEDs warning was considered nicer as well than the flashing-amber, the steady-amber, the danger warning, the flashing-red and the flashing-white (P<.05). In addition, the Steady-white warning was nicer than the Flashing-red, the flashing-amber, the flashing-yellow and the flashing-red (P<.05)

In relation to the variable **EFFECTIVENESS,** all applications were considered effective in order to warn about the presence of pedestrians on/near pedestrian crossing, although the most effective were the flashing-amber LEDs (Mean=1,74) and Flashing-red in-pavement LEDS (Mean= 1,71) (Table 4.20).

Table 4.20 Descriptive statistics for the variable "EFFECTIVE"

Measure: EFFECTIVE

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White_Flashing	2,000	,180	1,633	2,367
Amber_Flashing	1,742	,139	1,458	2,026
White_Steady_	2,097	,163	1,764	2,430
Warning	2,677	,260	2,147	3,208
Yellow_flashing	2,065	,185	1,686	2,443
Red_Steady	2,097	,209	1,669	2,524
Amber_Steady	2,161	,161	1,832	2,491
Yellow_Steady	2,065	,160	1,737	2,392
OLEDs	2,065	,207	1,642	2,487
Red_flashing	1,710	,148	1,407	2,012

For this variable, the results of test ANOVA showed significant main effects for the steady-white effect and Flashing-red effect (P<.005) (Table 4.21). Specifically, the steady-white effect was considered more effective than danger warning in order to warn drivers about the presence of pedestrians on/near pedestrian crossing (P= .009). Likewise, the flashing-red effect was perceived as more effective than OLEDs warning as well (P= .007).

Besides, the paired sample T-test also indicated that most of the modalities were considered more effective than the danger warning (P<.05). In addition, the T-test found that the flashing-amber was more effective than the flashing-yellow effect, the steady-amber LEDs and the steady-yellow modality (p<.05). Last, according to Table B9 in Annexe B, the flashing-red modality was also perceived as more effective than the flashing-yellow, the steady-yellow and the flashing-amber effect.

Table 4.21 ANOVA for the variable "EFFECTIVE"

Measure: EFFECTIVE

Source	factor1	Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	2,065	1	2,065	1,939	,174
	White_Steady_ vs. Amber_Flashing	1,581	1	1,581	2,267	,143
	Warning vs. White_Steady	16,573	1	16,573	7,922	**,009**
	Yellow_flashing vs. Warning	,129	1	,129	,172	,681
	Red_Steady vs.Yellow_flashing	,012	1	,012	,009	,925
	Amber_Steady vs. Red_Steady	,073	1	,073	,141	,710
	Yellow_Steady vs Amber_Steady	,095	1	,095	,140	,711
	OLEDs vs. Yellow_Steady	,073	1	,073	,057	,814
	Red_flashing vs OLEDs	4,907	1	4,907	8,423	**,007**

As regards the variable **"Likeable"**, the flashing-amber LEDs (Mean=3,06) and the flashing-red LEDs (Mean=3,0) were considered neither likeable or annoying. The rest of conditions were considered likable in order to present information about the presence of pedestrians on and near the pedestrian crossing (Table 4.22).

Table 4.22 ANOVA for variable "LIKEABLE"

Measure: **Likeable**

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White_Flashing	3,129	,240	2,639	3,619
Amber_Flashing	3,065	,173	2,711	3,418
White_Steady_	3,677	,176	3,318	4,037
Warning	3,323	,182	2,951	3,694
Yellow_flashing	3,129	,190	2,742	3,517
Red_Steady	3,323	,199	2,916	3,729
Amber_Steady	3,484	,130	3,218	3,750
Yellow_Steady	3,290	,162	2,960	3,621
OLEDs	4,032	,205	3,614	4,450
Red_flashing	3,000	,207	2,576	3,424

As it can be seen in Table 4.23, the main interactions were for the steady-white effect and OLEDs warnings (p< .05). As regards the steady-white modality, this was considered more likeable than the flashing-amber effect (p=.015). Regarding the OLEDs warning, this condition was considered more likeable in order to warn about the presence of pedestrians on/near pedestrian crossing than the Steady-yellow LED effect (p= .000) and flashing-red condition (p= .043).

Taking into account the paired sample T-test, the OLEDs warning was more likeable significantly than the rest of modalities, except the steady-white effect where non-significant differences were found (p=0.239). As regards the steady-white effect, the results of the T-test showed that this effect is more likeable than the flashing-red, the steady-red, the flashing-amber, the flashing-white and the flashing-amber (p<.05)(Table B10 in Annexe B).

Table 4.23 ANOVA for the variable "LIKEABLE"

Measure: Likeable

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	,129	1	,129	,072	,790
	White_Steady_ vs. Amber_Flashing	10,452	1	10,452	6,664	**,015**
	Warning vs. White_Steady	,032	1	,032	,031	,861
	Yellow_flashing vs. Warning	,889	1	,889	,964	,334
	Red_Steady vs.Yellow_flashing	,105	1	,105	,091	,765
	Amber_Steady vs. Red_Steady	1,363	1	1,363	3,054	,091
	Yellow_Steady vs Amber_Steady	,006	1	,006	,007	,935
	OLEDs vs. Yellow_Steady	16,513	1	16,513	15,419	**,000**
	Red_flashing vs OLEDs	4,560	1	4,560	4,479	**,043**

Focusing on the variable **"ASSISTANCE"**, all modalities were considered quite assisting to provide information about the presence of pedestrians on and near the pedestrian crossing, above all, the flashing-amber LEDs (Mean=1,72) and flashing-red LEDs (Mean=1,87) (Table 4.24).

Table 4.24 Descriptive statistics for the variable "ASSISTANCE"

Measure: **ASSISTING**

factor1	Mean	Std. Error	Interval Bound	Interval Bound
White_Flashing	2,121	,183	1,748	2,495
Amber_Flashing	1,727	,164	1,392	2,062
White_Steady_	2,000	,157	1,680	2,320
Warning	2,576	,238	2,090	3,062
Yellow_flashing	2,030	,160	1,705	2,356
Red_Steady	2,000	,163	1,668	2,332
Amber_Steady	2,061	,150	1,754	2,367
Yellow_Steady	2,030	,127	1,772	2,289
OLEDs	2,000	,204	1,584	2,416
Red_flashing	1,879	,161	1,550	2,208

Regarding the significant effects of the variable "assisting", the results of ANOVA showed significant effect for the flashing-amber and the steady-white conditions (P< .005). As regards the first condition, the flashing-amber effect was considered more assisting then than flashing-white effect (p= .035) and the steady-white condition was considered also more assisting than the danger warning (p=.009) in order to provide information about the presence of pedestrians on/near the pedestrian crossing (Table 4.25).

Taking into account the results of the paired sample T-test, several modalities are significantly more assisting than the danger warning (P< .005), such as: the flashing-yellow, the flashing-red, the flashing-amber, the OLEDs warning anf the steady-red (p< .005) (Table B11 in Annexe B). Notwithstanding, the differences mentioned above on the variable assisting were not found in the T-test, since the number of subjects taken by both tests are different.

Table 4.25 ANOVA for the variable "ASSISTING"

Measure: **ASSISTING**

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	5,121	1	5,121	4,837	**,035**
	White_Steady_ vs. Amber_Flashing	,189	1	,189	,198	,659
	Warning vs. White_Steady	12,943	1	12,943	7,806	**,009**
	Yellow_flashing vs. Warning	,189	1	,189	,304	,585
	Red_Steady vs.Yellow_flashing	,273	1	,273	,464	,501
	Amber_Steady vs. Red_Steady	,008	1	,008	,013	,911
	Yellow_Steady vs Amber_Steady	,062	1	,062	,088	,769
	OLEDs vs. Yellow_Steady	,153	1	,153	,106	,746
	Red_flashing vs OLEDs	1,091	1	1,091	1,972	,170

Regarding the variable **"Desirability"** of these advanced warning applications in order to present information about the presence of pedestrians on and near the pedestrian crossing, all applications were considered quite desirable, above all, the OLEDs warning (Mean=4,03) and the steady-yellow LEDs (Mean=3,84). Quite the opposite, the steady and Flashing-red LEDs were considered less desirable, obtaining a punctuation near 3, considered as neither desirable nor undesirable (Table 4.26).

Table 4.26 Descriptive statistics for the variable "DESIRABLE"

Measure: **Desirable**

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White_Flashing	3,688	,198	3,284	4,091
Amber_Flashing	3,688	,171	3,340	4,035
White_Steady_	**3,813**	,158	3,490	4,135
Warning	3,500	,191	3,111	3,889
Yellow_flashing	3,594	,173	3,241	3,947
Red_Steady	**3,406**	,210	2,978	3,834
Amber_Steady	3,688	,122	3,438	3,937
Yellow_Steady	**3,844**	,143	3,553	4,135
OLEDs	**4,031**	,182	3,659	4,403
Red_flashing	**3,219**	,194	2,822	3,615

With regard to the ANOVA results, the OLEDS warning was more desirable than the Steady-yellow effect and more desirable than flashing-red LED effect, p= .011 y p= .004, respectively (Table 4.27).

Furthermore, a Paired sample T-test was carried out in order to find out other main interactions. As a result of this test, it can be said that the OLEDs warning is more desirable than the steady-red effect (p=.014) and the danger warning (p=.006) as well. In addition, the flashing-red was also considered more undesirable than the steady-amber effect, the flashing-yellow, the steady-white, the flashing-amber and the flashing-white in-pavement LEDs (p< .005). Last, it was also found that the steady-red effect was more undesirable than the steady-white and the steady-yellow LEDs applications (p< .005) (Table B12 in Annexe B).

Table 4.27 ANOVA for the variable DESIRABLE

Measure: **DESIRABLE**

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	,000	1	,000	,000	1,000
	White_Steady_ vs. Amber_Flashing	,500	1	,500	,508	,481
	Warning vs. White_Steady	1,681	1	1,681	1,499	,230
	Yellow_flashing vs. Warning	,195	1	,195	,455	,505
	Red_Steady vs.Yellow_flashing	2,000	1	2,000	2,050	,162
	Amber_Steady vs. Red_Steady	,170	1	,170	,444	,510
	Yellow_Steady vs Amber_Steady	1,531	1	1,531	2,303	,139
	OLEDs vs. Yellow_Steady	4,594	1	4,594	7,357	**,011**
	Red_flashing vs OLEDs	7,241	1	7,241	9,659	**,004**

The last variable studied is "**Raising alertness":** all advanced warnings were considered to raise awareness of the presence of pedestrians on/near the pedestrian crossings, above all, the Flashing-amber LEDs (Mean= 1,48) (Table 4.28).

Table 4.28 The descriptive statistics for the RAISING ALERTNESS

Measure: **Raising Alertness**

factor1	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White_Flashing	1,818	,160	1,493	2,143
Amber_Flashing	**1,485**	,138	1,203	1,767
White_Steady_	1,939	,162	1,608	2,270
Warning	2,121	,212	1,689	2,553
Yellow_flashing	1,606	,130	1,341	1,871
Red_Steady	1,758	,138	1,477	2,038
Amber_Steady	1,909	,186	1,529	2,289
Yellow_Steady	1,970	,160	1,644	2,295
OLEDs	1,697	,154	1,384	2,010
Red_flashing	1,636	,162	1,307	1,966

Focussing on the ANOVA for the variable "raising alertness", the flashing-amber condition was perceived as more raising alertness than flashing-white condition (p=.019) as well as the steady-white condition (p=. 045) (Table 4.29). The flashing-amber LED effect raises more alertness than the white LEDS conditions to provide information about the presence of the pedestrians on/near pedestrian crossing. Apart from these differences, according to the paired sample T-test (Table B13 in Annexe B), the flashing-amber raises more alertness than the Steady-yellow, the steady-amber, the steady-red and danger warning (p< .005). In addition, the flashing-yellow LED is significantly considered to raise more alertness than the Steady-white effect and the Danger warning (p< .005).

Table 4.29 ANOVA for the raising alertness

Measure: **Raising alertness**

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.
factor1	Amber_Flashing vs. White_Flashing	3,667	1	3,667	6,069	**,019**
	White_Steady_ vs. Amber_Flashing	2,735	1	2,735	4,372	**,045**
	Warning vs. White_Steady	4,609	1	4,609	3,290	,079
	Yellow_flashing vs. Warning	1,820	1	1,820	2,913	,098
	Red_Steady vs.Yellow_flashing	,044	1	,044	,075	,785
	Amber_Steady vs. Red_Steady	,485	1	,485	,814	,374
	Yellow_Steady vs Amber_Steady	,893	1	,893	1,635	,210
	OLEDs vs. Yellow_Steady	,547	1	,547	,714	,404
	Red_flashing vs OLEDs	1,012	1	1,012	1,609	,214

4.3.4 Appropriateness ranking test

Appropriateness ranking test consisted of asking the participants to put the alternatives in order according to how appropriate they thought the ten modalities were in order to inform the driver about the presence of pedestrians on and near the pedestrian crossing. The order established is shown Table 4.30 and Figure 4.7.

Table 4.30 Appropriateness raking test for the in-pavement LEDs effects

	Alternative	Scale value[6]
Most appropriate	Steady-white	1,24
	Flashing-white	1,13
	Flashing-amber	0,98
	Steady-yellow	0,74
	Steady-red	0,61
	Flashing-yellow	0,41
	Flashing-red	0
Least appropriate	Steady-amber	-2,58

As it can be seen in Table 4.30, the most appropriate alternatives to inform the driver about the presence of pedestrians on and near the pedestrian crossing are the steady-white, the flashing-white and the flashing –amber. These modalities clearly distinguish themselves from the rest of alternatives with their significantly higher scale values.

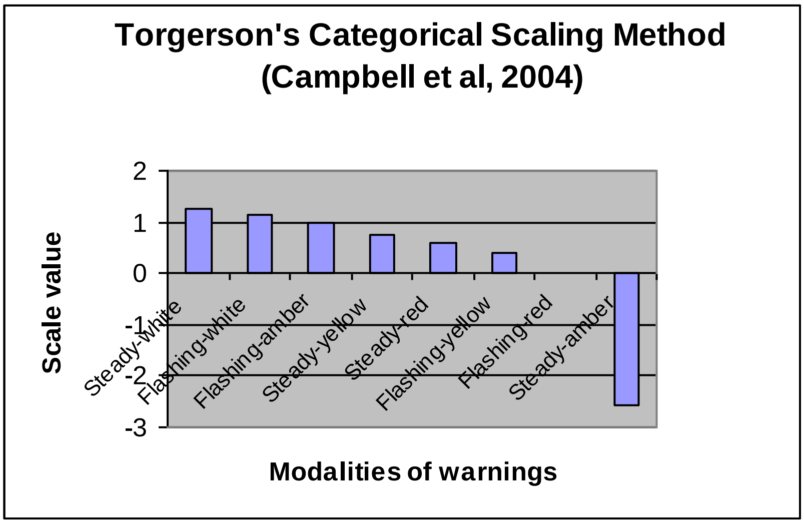

Figure 4.7 Torgerson's categorical scaling method

In addition, another appropriate ranking test was carried out for the three main type of modalities, such as OLEDs, the Flashing-amber in-pavement LEDs and the danger warning. As it can be seen in Table 4.31, the most appropriate alternative to inform the driver about the presence of pedestrians on and near the pedestrian crossing is the danger warning, although there are not clear differences among the three main types of alternatives according to the scale values.

Table 4.31 Torgerson's categorical scaling method for the three modalities

	Alternative	Scale value[7]
Most appropriate	Danger warning	0,11
	Flashing-amber	0
	OLEDs	0
Least appropriate	Steady-amber	-2,58

[6] According to Torgerson's Categorical Scaling method (based on Torgerson's Law of Categorical judgement), the higher value the higher ranking. Campbell et al. 2004.

[7]

4.4 Discussion

White is the colour most preferred by drivers in this study, both steady white and flashing white; and OLED´s is the most pleasant one, and significantly more likeable than the rest of modalities, except the steady-white effect (non-significant differences). Notwithstanding, the colours associated to an insecure situation are mainly flashing red, flashing as well as steady yellow, and Warning signal.

Open comments of participants in the current study point out that white provides more light, it seems it illuminates the object so that it can be seen. It is more appropriate when the problem is lack of visibility, but some of them think that white is too alarming and it causes glare. They argue that white is the colour best associated to a pedestrian crossing, but they also perceive it as “too much light”.

This result is consistent with the literature. In this sense, Karczenwski (2002), conducted a study in order to examine the effect that the color of emergency lighting has on other drivers, finding that while white was the most visible color, however drivers also indicated that it may not be the best choice for use in an emergency lighting display on a stationary vehicle at night, perceiving it as too powerful at close distances and temporarily blinding as they approached the stationary squad car that was displaying the flashing lights. This study suggested that the use of white light, on average, created an unsafe environment for emergency responders due to the distraction that it created as drivers approached an incident scene.
Steady burnt white effect is considered significantly less dangerous than the rest of modalities, except the flashing-white and OLEDs. In this regard, steady white and OLEDs are the configurations perceived as less urgent. This result may appear odd since flashing white is not included in the “less urgent” group together with the other white configurations. However, previous research has shown that the perceived hazard level for an alerting visual signal increases with its flash rate (Chan & Ng, 2009). Besides, as a redundant cue, flashing has been found to be superior to colour alone in attracting attention to objects in a display (Thackray & Touchstone, 1991), and in influencing the detectability of signal lights (Sanders & McCormick, 1993). Furthermore, attention is known to be captured by abrupt stimulus onsets (Krumhansl, 1982; Yantis & Jonides, 1990), with the same intensity, flashing LED is much more conspicuous than steady burning light.

In fact, through open comments participants indicated that flashing lights capture their attention and they are not disturbing. For them, flashing lights are most commonly associated to precaution, warning, danger. However, two drivers indicate that flashing is annoying, since it is distracting and alerts too much.

In addition, flashing red is significantly perceived as more dangerous than all the steady burning lights and OLEDs in the present study. This result is fully in line with previous research. In this regard, Chan & Ng, 2009) obtained that a red flashing light was perceived as the most effective hazard warning colour, with yellow and blue warning lights indicative of less hazardous situations.

Furthermore, this result agrees with the finding of a colour association study (Chan & Courtney, 2001) that red was the colour most frequently chosen to indicate the concept of danger and hazard.

A study that compared several treatments to improve motorist yielding to pedestrians at un-signalized intersections indicated that red signal or red beacon devices produced higher yielding behaviour than in-roadway signs, yellow overhead flashing beacons, pedestrian crossing flags, and in-roadway warning lights (Turner, Fitzpatrick, Brewer & Park, 2006). In the laboratory study of flashing lights at railway grade crossing, red flashing lights were found better in attracting subjects (Ruden & Coleman, 1979). The city of Los Angeles uses mid-block pedestrian signals that display a flashing red signal when activated (Fitzpatrick, Turner, Brewer, Carlson, Ullman, et al., 2006).

Interestingly though, in the present study, flashing-red is considered more undesirable than white (flashing and steady burnt), amber (flashing and steady burnt), and flashing yellow. Volunteers explain through open comments that red is more intuitive because it is usually the colour for danger: “we are used to it: for instance, in traffic lights, braking light, …”. Notwithstanding, participants also affirm that as red is related traffic lights, to stop, it creates a sense of danger that is unnecessary.

Flashing-amber is perceived as the most conspicuous as well as more detectable and raising alertness than other options. However, some participants commented that it reminds them road works. Interestingly, recovery operators and breakdown services have been found to consider that their use of amber beacons is poorly understood due to the proliferation of its use for other purposes and, in certain instances, may not be seen at all (UNECE, 2002).

Although OLEDs is perceived as the most pleasant configuration, for some of them it is annoying because it gives them the impression of movement, they tend to follow the light, so they finish looking to one of the sides. They argue that if a pedestrian entered the zebra crossing from the opposite side this could create a dangerous situation.

With respect to the "Warning signal" used in this study, it is considered less effective than any other modality, and less assisting than most of them, but open comments show that drivers feel that it gives them more time to react because it is separated from the zebra crossing, it is a pre-warning, and it is less aggressive. But for some of the participants the warning signal goes unnoticed while they are driving.

Additional research should be performed to determine the effects of inclement weather and the impact of daylight on the different colours and effects investigated in this study.

5 Conclusions

Deliverable 6.1 was dedicated to human factor analysis of LED road studs, in which IFSTTAR (Section 2) and CIDAUT (Sections 3&4) were involved.

The stud must be seen and then the message of the stud must be understood. Thus, bibliographic work and human factor experiments were conducted in order to provide recommendations that allow to ensure the relevance of the road studs through:

- a good visibility of the studs, *i.e.* studs are visible without drawback such as glare (Sections 2 and 3);
- a good understanding of the message by road users (Sections 3 and 4).

A state of the art of standards about various lighting and signalling systems used on roads was conducted (Section 3). Recommendations in luminance were proposed for the LED road studs from current standards of other systems by making an analogy depending on the application. Conclusions suggest that luminance levels for LED road studs should be at least 4 times the pavement luminance when used for guiding or delimitating lanes and 5 times for coded information. However, luminance measures of LED road studs and its environment should be done as in a dynamic way and needs to have spatial resolution, which encloses technical difficulties. In addition, luminance levels should be adjustable with respect to the weather to keep the luminance contrast without glare.

Therefore, the stud visibility was investigated under various external conditions. Two human factor experiments were carried out under daytime and nighttime conditions to assess the visibility of a DSTA amber-coloured road stud. During daytime, findings suggest that the luminous intensity of the road stud has to be tuned to the illumination conditions, defined by horizontal illuminance on the road surface and the sun position. A visibility model was proposed. It shows that the required stud intensity increases with the horizontal illuminance, and as the sun comes in the field of view of the observer. Besides, additional knowledge was obtained. Especially, the visibility of the stud is significantly different for dry and wet road surface. From the model estimation, a higher luminous intensity (+0.09cd) is required for wet road surface (especially when the sun is in front of the road user). Various luminous intensity levels were therefore recommended depending on these factors. Recommendations were expressed for 1° vertical observation in the axis of the stud: 1.3cd for cloudy days, from 1.7cd (sun behind the observer) to 2.6cd (sun in front view) for sunny days. During nighttime, the question was mainly on avoiding glare. Findings showed that the minimum available intensity level is recommended to avoid discomfort glare. Based on these recommendations, the stud can be dimmed while ensuring good visual conditions to road users. Examples showed that more than 50% energy savings can be reached by dimming the stud according to the time of the day, the illumination conditions and the surface condition.

Finally, the meaning and understanding of road stud colours were investigated based on a smart pedestrian crossing application. Findings show that flashing is understood as a warning. However, the level of hazard vary depending on the colour (red is interpreted as more dangerous than other colours). According to participants, red indicates too much danger for pedestrian crossings information. White road studs were preferred for this application, even if they are perceived more luminous than others colours. Thus, intensity must be dimmed to prevent discomfort glare. Results were relevant compared to previous work. However, as colour meaning may depend on the culture, the same experiment should be reproduced in different countries.

As a result, the studies conducted in this report allowed to provide recommendations to ensure relevance of the road stud installation:

- Stud visibility has to be ensured by varying the intensity level to external and road surface conditions based on a visibility model provided in Section 2 and luminance contrast recommendations provided in Section 3;
- Stud settings (intensity level, colour, flashing, etc) should avoid distraction and glare as recommended in Section 2 for nighttime and Section 4;

- The appropriate colour, settings of studs (Section 4) and luminance contrast (Section 3) should be employed to ensure the message is understood.

Further experiments would be interesting in order to supplement with recommendations about visibility of a set of studs, at various distances from the studs, and of various stud colours. Moreover, additional research should be performed to determine the effects of inclement weather and the impact of daylight on the different colours. Finally, a human factor experiment could confirm the recommended luminance contrasts.

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TABLES

FIGURES

DEFINITIONS

Angle of observation α (of a retroreflector): angle between the direction of observation of the retroreflector and the direction of the incident light

Glare: condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or to extreme contrasts

Lambertian surface: ideal surface for which the radiation coming from that surface is distributed angularly according to Lambert's cosine law

Luminous flux: Quantity of the energy of the light emitted per second in all directions, weighted with a standardized model of the sensitivity of the human eye to different wavelengths (lumen).

Luminous Intensity: Unit for luminous Intensity. It is the amount of luminous flux per steradian (Candela).

Illuminance: Amount of luminous flux that covers a surface (Lux).

Luminance: Luminous intensity emitted by the surface area (candela per square meter).

Retroreflection: reflection in which radiation is returned in directions close to the opposite of the direction from which it came, this property being maintained over wide variations of the direction of the incident rays.

Retroreflectivity: A property of some materials that reflects light back to its source with a minimum of scattering.

ACRONYMS

cd	Candela
CIE	International Committee of Illumination
LED	Light Emission Diode
lx	lux
lm	Lumen
m	Meter
VMS	Variable Message Sign

ANNEXES

A. Annexe A of Section 2 (IFSTTAR)

Annexes: Stud characteristics

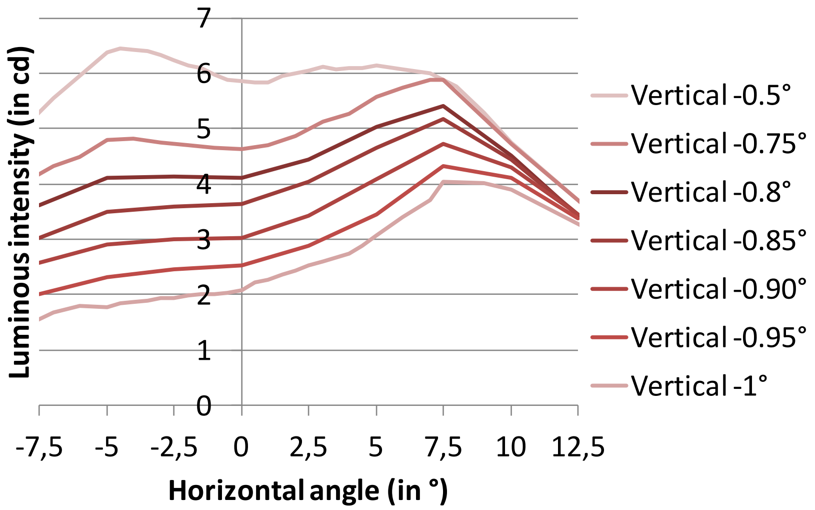

Figure A1: Further data on intensity distribution of the amber-coloured road stud

Annexes: "Daytime" Experiment

Table A1: Characteristics of participants per group

	Mean age	Men/Women
Group 1	33.3	4/2
Group 2	36.2	3/3
Group 3	37.0	2/4
Group 4	32.2	2/4
Group 5	35.8	3/3
Group 6	41.3	4/2
Group 7	34,5	5/1

Table A2: Frequency of illuminance for each group of participants

		0-15klux	15-30klux	30-45klux	45-60klux	60-75klux	75-90klux	90-105klux
G1	DRY	0%	0%	0%	100%	0%	0%	0%
	WET	0%	0%	0%	100%	0%	0%	0%
G2	DRY	0%	0%	0%	0%	92.3%	7.7%	0%
	WET	0%	0%	0%	0%	0%	100%	0%
G3	DRY	0%	0%	0%	0%	0%	0%	100%
	WET	0%	1.9%	3.8%	0%	1.9%	0%	92.3%
G4	DRY	0%	3.8%	0%	5.8%	0%	5.8%	84.6%
	WET	0%	11.5%	7.7%	1.9%	3.8%	11.5%	63.5%
G5	DRY	0%	13.5%	1.9%	1.9%	65.4%	17.3%	0%
	WET	0%	5.8%	0%	3.8%	90.4%	0%	0%
G6	DRY	0%	0%	15.4%	84.6%	0%	0%	0%
	WET	0%	0%	100%	0%	0%	0%	0%
G7	DRY	5.8%	94.2%	0%	0%	0%	0%	0%
	WET	11.5%	88.5%	0%	0%	0%	0%	0%

Table A3: Post-hoc Tukey test : mean values multiple comparisons

Group	Mean illuminance	No significant difference classes					
G7	18.8	A					
G6	43.6		B				
G1	60.5			C			
G5	62.5			C			
G2	76.0				D		
G4	82.3					E	
G3	92.4						F

Group	Road surface condition	Mean illuminance	No significant difference classes						
G7	DRY	18.7	A						
G7	WET	18.9	A						
G6	WET	39.2		B					
G6	DRY	47.9			C				
G1	DRY	56.3				D			
G5	WET	61.2				D	E		
G5	DRY	63.8					E		
G1	WET	64.6					E		
G2	DRY	72.7						F	
G4	WET	78.1						F	
G2	WET	79.3						F	
G4	DRY	86.6							G
G3	WET	91.2							G
G3	DRY	93.7							G

Table A4: Spearman correlation test between each subject rating and intensity level

Subject	Spearman	p-value	Subject	Spearman	p-value
S1	**0.853**	**< 0.0001**	S22	**0.880**	**< 0.0001**
S2	**0.912**	**< 0.0001**	S23	**0.829**	**< 0.0001**
S3	**0.925**	**< 0.0001**	S24	**0.918**	**< 0.0001**
S4	**0.885**	**< 0.0001**	S25	**0.792**	**< 0.0001**
S5	**0.693**	**< 0.0001**	S26	**0.786**	**< 0.0001**
S6	**0.880**	**< 0.0001**	S27	**0.844**	**< 0.0001**
S7	**0.812**	**< 0.0001**	S28	**0.923**	**< 0.0001**
S8	**0.889**	**< 0.0001**	S29	**0.915**	**< 0.0001**
S9	**0.638**	**< 0.0001**	S30	**0.717**	**< 0.0001**
S10	**0.878**	**< 0.0001**	S31	**0.621**	**< 0.0001**
S11	**0.836**	**< 0.0001**	S32	**0.734**	**< 0.0001**
S12	**0.795**	**< 0.0001**	S33	**0.712**	**< 0.0001**
S13	**0.689**	**< 0.0001**	S34	**0.747**	**< 0.0001**
S14	**0.730**	**< 0.0001**	S35	**0.791**	**< 0.0001**
S15	**0.703**	**< 0.0001**	S36	**0.817**	**< 0.0001**
S16	**0.881**	**< 0.0001**	S37	**0.857**	**< 0.0001**
S17	**0.784**	**< 0.0001**	S38	**0.865**	**< 0.0001**
S18	**0.788**	**< 0.0001**	S39	**0.860**	**< 0.0001**
S19	**0.922**	**< 0.0001**	S40	**0.867**	**< 0.0001**
S20	**0.895**	**< 0.0001**	S41	**0.869**	**< 0.0001**
S21	**0.921**	**< 0.0001**	S42	**0.821**	**< 0.0001**

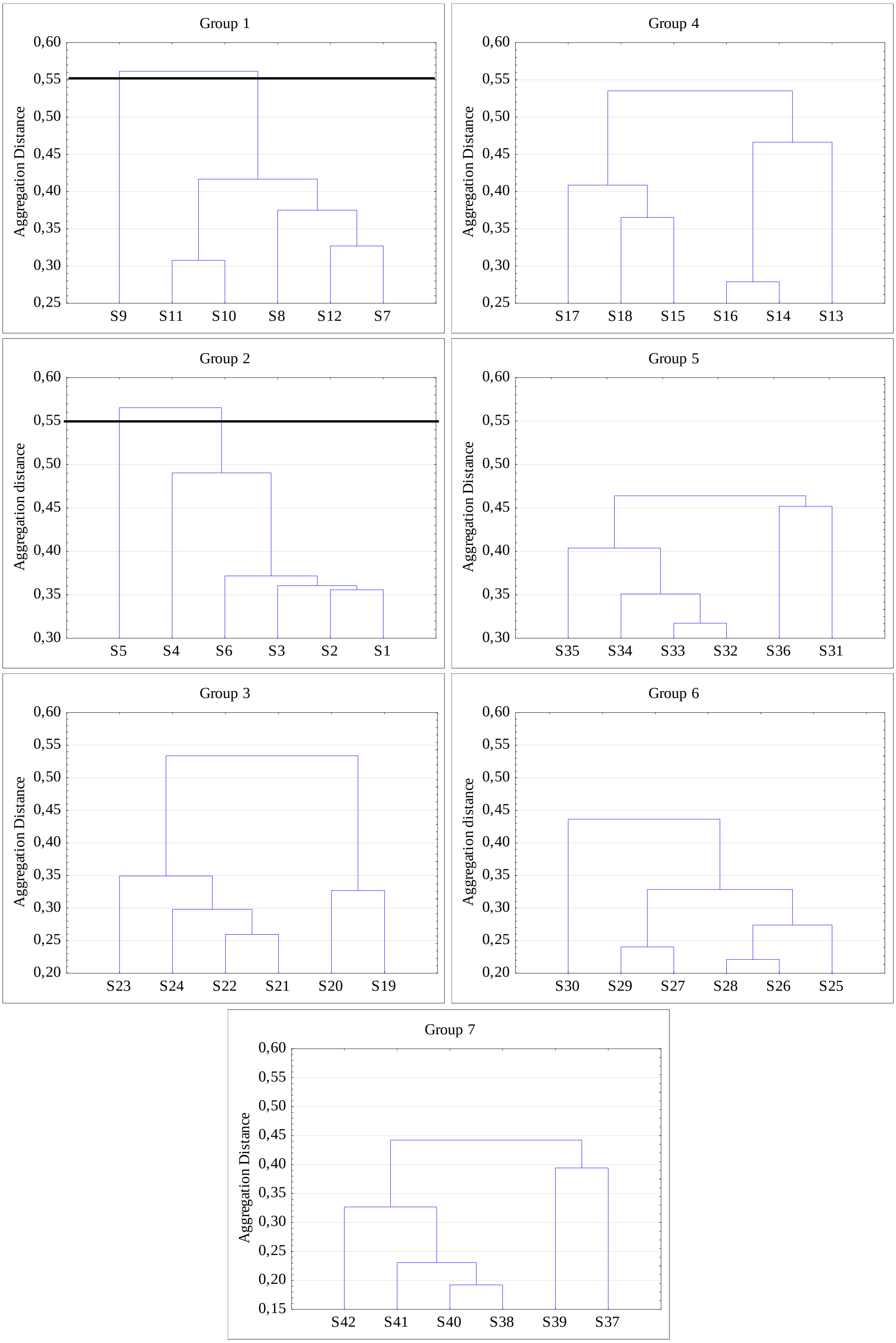

Figure A2: Hierarchical clustering results – Dendrogram for each group

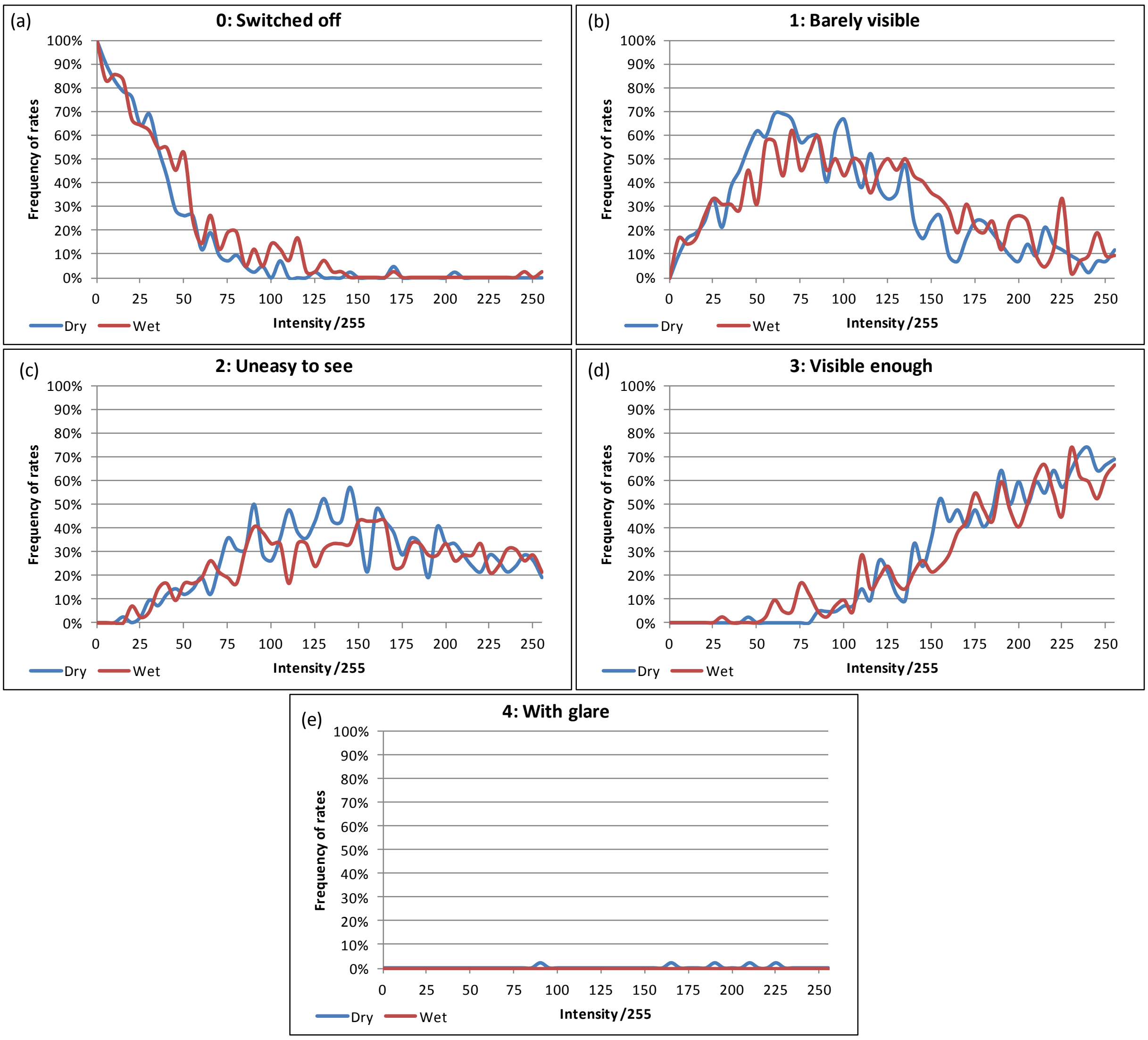

Figure A3: Data distribution for each possible answer according to the stud intensity (i=0-255): (a) Switched off, (b) Barely Visible, (c) Uneasy to see, (d) Visible enough, (e) Visible with glare

Table A5: Non-parametric post-hoc test on ratings data – Dry road surface

Group	Mean ranks	No significant difference classes			
G4	706.7	A			
G1	815.2	A	B		
G5	926.9		B	C	
G2	981.8			C	
G6	996.8			C	
G3	1048.7			C	
G7	1226.7				D

Table A6: Non-parametric post-hoc test on ratings data – Wet road surface

Group	Mean ranks	No significant difference classes			
G6	630.1	A			
G5	710.3	A			
G4	890.6		B		
G1	980.3		B		
G2	1001.8		B		
G3	1196.2			C	
G7	1324.3				D

Table A7: Spearman correlation test between participant's characteristics and ratings

Characteristics	Ratings	Spearman	p-value
Age	Mean rating	0.134	0.395
Gender	Mean rating	-0.254	0.104
Corrected vision	Mean rating	0.230	0.142
Contrast sensitivity	Mean rating	0.060	0.705
Mesopic acuity	Mean rating	0.078	0.621
Glare recovering	Mean rating	-0.037	0.814
Age	% of 2&3	0.171	0.279
Gender	% of 2&3	-0.256	0.102
Corrected vision	% of 2&3	0.242	0.122
Contrast sensitivity	% of 2&3	0.102	0.520
Mesopic acuity	% of 2&3	0.045	0.775
Glare recovering	% of 2&3	-0.136	0.389

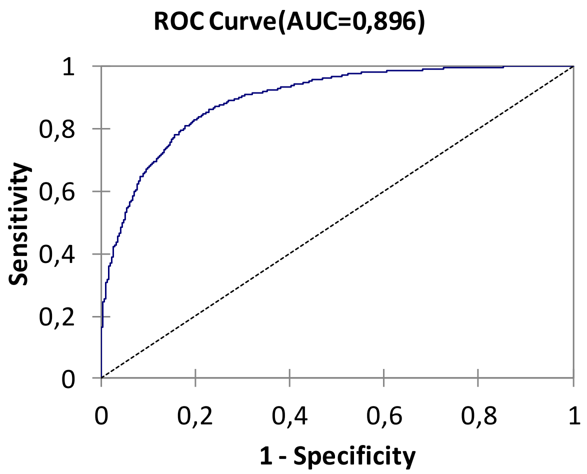

Figure A4: ROC Curve

Table A8: Recommended luminous intensity to ensure 95% of positive answers depending on the illumination condition – Dry road surface

Illuminance/Angle	0	45	90	135	180
10	1.58 cd	1.73 cd	1.88 cd	2.03 cd	2.18 cd
20	1.62 cd	1.77 cd	1.92 cd	2.07 cd	2.22 cd
30	1.66 cd	1.81 cd	1.96 cd	2.11 cd	2.26 cd
40	1.70 cd	1.85 cd	2.00 cd	2.15 cd	2.30 cd
50	1.74 cd	1.89 cd	2.04 cd	2.19 cd	2.34 cd
60	1.78 cd	1.93 cd	2.08 cd	2.23 cd	2.37 cd
70	1.82 cd	1.97 cd	2.12 cd	2.26 cd	2.41 cd
80	1.86 cd	2.01 cd	2.15 cd	2.30 cd	2.45 cd
90	1.90 cd	2.04 cd	2.19 cd	2.34 cd	2.49 cd
100	1.94 cd	2.08 cd	2.23 cd	2.38 cd	2.53 cd

Table A9: Recommended luminous intensity to ensure 95% of positive answers depending on the illumination condition – Wet road surface

Illuminance/Angle	0	45	90	135	180
10	1.68 cd	1.83 cd	1.97 cd	2.12 cd	2.27 cd
20	1.72 cd	1.86 cd	2.01 cd	2.16 cd	2.31 cd
30	1.75 cd	1.90 cd	2.05 cd	2.20 cd	2.35 cd
40	1.79 cd	1.94 cd	2.09 cd	2.24 cd	2.39 cd
50	1.83 cd	1.98 cd	2.13 cd	2.28 cd	2.43 cd
60	1.87 cd	2.02 cd	2.17 cd	2.32 cd	2.47 cd
70	1.91 cd	2.06 cd	2.21 cd	2.36 cd	2.51 cd
80	1.95 cd	2.10 cd	2.25 cd	2.40 cd	2.55 cd
90	1.99 cd	2.14 cd	2.29 cd	2.44 cd	2.58 cd
100	2.03 cd	2.18 cd	2.33 cd	2.47 cd	2.62 cd

Annexes: Experiment « Nighttime »

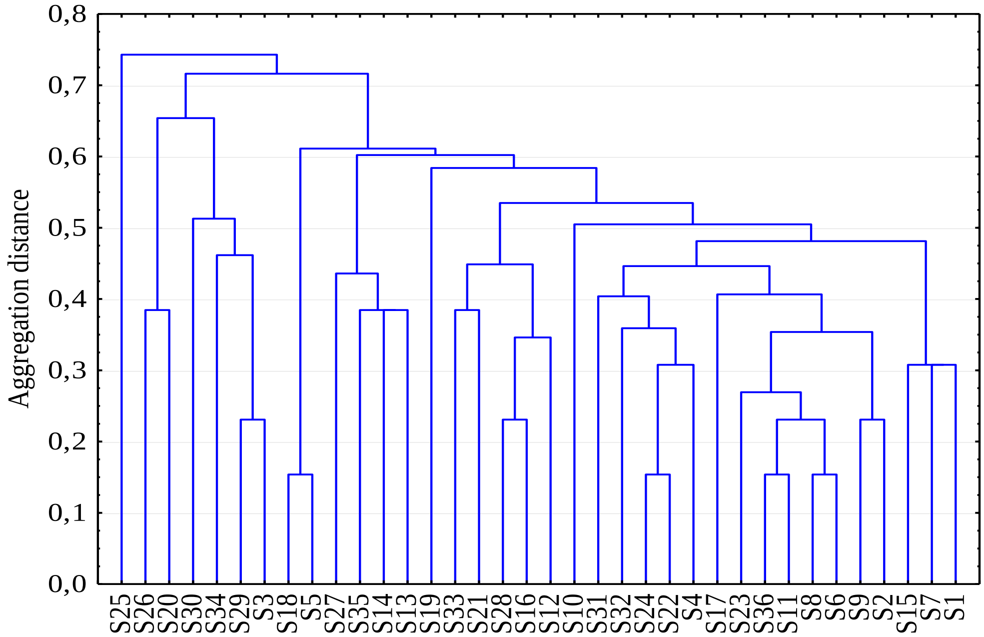

Figure A5: Results of hierarchical clustering - Dendrogram – Nighttime Experiment

Table A10: Spearman correlation test between participants characteristics and ratings - Nighttime

Characteristics	Ratings	Spearman	p-value
Age	Mean rating	-0.037	0.828
Gender	Mean rating	0.126	0.461
Corrected vision	Mean rating	-0.059	0.731
Contrast sensitivity	Mean rating	-0.104	0.546
Mesopic acuity	Mean rating	-0.072	0.674
Glare recovering	Mean rating	-0.294	0.082
Age	% no glare	0.097	0.572
Gender	% no glare	-0.126	0.461
Corrected vision	% no glare	-0.044	0.799
Contrast sensitivity	% no glare	0.218	0.200
Mesopic acuity	% no glare	0.030	0.863
Glare recovering	% no glare	0.246	0.147

Annexes: Discussion

Table A11: Mean sun position for the road user considered in energy saving calculation

Road orientation	Morning (70klx)	Midday(100klx)	Afternoon/Evening(60klux)
N/S	135°	180°	-135°
S/N	-45°	0°	45°
E/W	45°	90°	135°
W/E	-135°	-90°	-45°
SE/NW	0°	45°	90°
NW/SE	180°	-135°	-90°
NE/SW	90°	135°	180°
SW/NE	-90°	-45°	0°

Table A12: % of required power demand depending on the road orientation

Road orientation	% of power demand			
	Night	Cloudy	Sunny – Dry	Sunny – Wet
N/S	4.70%	55.00%	80.73%	84.16%
S/N	4.70%	55.00%	65.84%	69.27%
E/W	4.70%	55.00%	73.28%	76.72%
W/E	4.70%	55.00%	73.28%	76.72%
SE/NW	4.70%	55.00%	67.56%	70.99%
NW/SE	4.70%	55.00%	79.01%	82.44%
NE/SW	4.70%	55.00%	79.01%	82.44%
SW/NE	4.70%	55.00%	67.56%	70.99%

B. Annexe B of Section 4 (CIDAUT)

Table B1: Paired sample T-test for the variable "danger"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	-7,2	31,4	5,9	-19,4	4,9	-1,2	27,0	0,23
i_bla_A - f_bla_C	7,1	23,6	4,4	-1,9	16,0	1,6	28,0	0,12
i_bla_A - W_D	-7,4	40,2	7,6	-23,0	8,2	-1,0	27,0	0,34
i_bla_A - i_amar_E	-6,9	37,0	6,9	-21,0	7,1	-1,0	28,0	0,32
i_bla_A - f_rojo_F	-1,0	25,4	4,7	-10,6	8,7	-0,2	28,0	0,84
i_bla_A - f_ámb_G	1,2	25,4	4,7	-8,4	10,9	0,3	28,0	0,80
i_bla_A - f_amar_H	-5,6	26,3	5,1	-16,0	4,8	-1,1	26,0	0,28
i_bla_A - Mich_I	1,9	28,9	5,5	-9,4	13,1	0,3	27,0	0,74
i_bla_A - i_rojo_J	-13,7	28,7	5,3	-24,7	-2,8	-2,6	28,0	0,02
i_ámb_B - f_bla_C	16,4	33,9	6,3	3,5	29,3	2,6	28,0	0,01
i_ámb_B - W_D	3,4	42,3	8,0	-13,0	19,8	0,4	27,0	0,67
i_ámb_B - i_amar_E	2,7	27,5	5,1	-7,8	13,2	0,5	28,0	0,60
i_ámb_B - f_rojo_F	8,3	38,6	7,2	-6,4	23,0	1,2	28,0	0,26
i_ámb_B - f_ámb_G	10,6	36,5	6,8	-3,3	24,5	1,6	28,0	0,13
i_ámb_B - f_amar_H	2,8	27,0	5,1	-7,6	13,3	0,6	27,0	0,58
i_ámb_B - Mich_I	9,1	38,2	7,2	-5,7	23,9	1,3	27,0	0,22
i_ámb_B - i_rojo_J	-5,0	19,9	3,8	-12,8	2,7	-1,3	27,0	0,19
f_bla_C - W_D	-13,5	28,3	5,3	-24,2	-2,7	-2,6	28,0	0,02
f_bla_C - i_amar_E	-13,5	26,4	4,8	-23,4	-3,7	-2,8	29,0	0,01
f_bla_C - f_rojo_F	-7,8	13,8	2,5	-12,9	-2,6	-3,1	29,0	0,00
f_bla_C - f_ámb_G	-5,7	14,1	2,6	-11,0	-0,4	-2,2	29,0	0,04
f_bla_C - f_amar_H	-12,4	28,1	5,3	-23,3	-1,5	-2,3	27,0	0,03
f_bla_C - Mich_I	-5,6	16,4	3,1	-12,0	0,8	-1,8	27,0	0,08
f_bla_C - i_rojo_J	-20,8	29,3	5,4	-32,0	-9,7	-3,8	28,0	0,00
W_D - i_amar_E	-0,2	32,3	6,0	-12,4	12,1	0,0	28,0	0,98
W_D - f_rojo_F	6,5	28,1	5,1	-4,0	17,0	1,3	29,0	0,22
W_D - f_ámb_G	7,8	30,5	5,7	-3,8	19,3	1,4	28,0	0,18
W_D - f_amar_H	1,2	44,0	8,5	-16,2	18,6	0,1	26,0	0,89
W_D - Mich_I	8,4	34,3	6,6	-5,1	22,0	1,3	26,0	0,21
W_D - i_rojo_J	-5,6	35,9	6,6	-19,0	7,8	-0,9	29,0	0,40
i_amar_E - f_rojo_F	5,8	28,5	5,2	-4,9	16,4	1,1	29,0	0,28
i_amar_E - f_ámb_G	7,9	28,1	5,1	-2,6	18,4	1,5	29,0	0,14
i_amar_E - f_amar_H	1,7	32,4	6,1	-10,9	14,3	0,3	27,0	0,78
i_amar_E - Mich_I	8,6	32,6	6,2	-4,0	21,3	1,4	27,0	0,17
i_amar_E - i_rojo_J	-6,8	26,3	4,9	-16,8	3,2	-1,4	28,0	0,17
f_rojo_F - f_ámb_G	2,1	15,3	2,8	-3,6	7,8	0,7	29,0	0,46
f_rojo_F - f_amar_H	-4,3	32,4	6,1	-16,9	8,3	-0,7	27,0	0,49
f_rojo_F - Mich_I	2,8	21,9	4,1	-5,7	11,3	0,7	27,0	0,50
f_rojo_F - i_rojo_J	-12,4	31,4	5,7	-24,1	-0,6	-2,2	29,0	0,04
f_ámb_G - f_amar_H	-6,4	30,5	5,8	-18,2	5,4	-1,1	27,0	0,28
f_ámb_G - Mich_I	0,4	20,5	3,9	-7,5	8,4	0,1	27,0	0,91
f_ámb_G - i_rojo_J	-14,9	32,5	6,0	-27,3	-2,6	-2,5	28,0	0,02
f_amar_H - Mich_I	7,2	34,7	6,7	-6,5	21,0	1,1	26,0	0,29
f_amar_H - i_rojo_J	-5,7	23,2	4,5	-14,9	3,5	-1,3	26,0	0,21
Mich_I - i_rojo_J	-14,1	32,2	6,1	-26,6	-1,6	-2,3	27,0	0,03

Table B2: Paired sample T-test for the variable "safety"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	-10,2	41,2	7,8	-26,2	5,8	-1,3	27,0	,202
i_bla_A - f_bla_C	1,2	20,0	3,6	-6,3	8,7	0,3	29,0	,745
i_bla_A - W_D	-14,8	37,3	6,9	-29,0	-0,6	-2,1	28,0	,041
i_bla_A - i_amar_E	-16,5	38,4	7,0	-30,9	-2,2	-2,4	29,0	,025
i_bla_A - f_rojo_F	-5,0	30,0	5,5	-16,2	6,2	-0,9	29,0	,370
i_bla_A - f_ámb_G	-3,6	25,1	4,6	-13,0	5,8	-0,8	29,0	,438
i_bla_A - f_amar_H	-13,8	34,6	6,4	-26,9	-0,6	-2,1	28,0	,041
i_bla_A - Mich_I	0,9	20,8	3,9	-7,0	8,8	0,2	28,0	,816
i_bla_A - i_rojo_J	-21,5	33,8	6,2	-34,1	-8,9	-3,5	29,0	,002
i_ámb_B - f_bla_C	11,3	33,1	6,1	-1,3	23,9	1,8	28,0	,076
i_ámb_B - W_D	-5,0	42,6	8,0	-21,5	11,5	-0,6	27,0	,541
i_ámb_B - i_amar_E	-6,6	26,7	4,9	-16,7	3,5	-1,3	28,0	,193
i_ámb_B - f_rojo_F	4,7	32,1	6,0	-7,5	17,0	0,8	28,0	,432
i_ámb_B - f_ámb_G	7,7	34,9	6,5	-5,6	21,0	1,2	28,0	,244
i_ámb_B - f_amar_H	-4,0	27,5	5,1	-14,4	6,5	-0,8	28,0	,445
i_ámb_B - Mich_I	11,7	38,2	7,2	-3,1	26,5	1,6	27,0	,116
i_ámb_B - i_rojo_J	-10,9	22,5	4,2	-19,6	-2,2	-2,6	27,0	,016
f_bla_C - W_D	-16,2	28,3	5,2	-26,8	-5,7	-3,1	29,0	,004
f_bla_C - i_amar_E	-17,2	29,3	5,3	-27,9	-6,4	-3,3	30,0	,003
f_bla_C - f_rojo_F	-6,0	19,5	3,5	-13,1	1,2	-1,7	30,0	,097
f_bla_C - f_ámb_G	-4,6	15,7	2,8	-10,4	1,1	-1,7	30,0	,109
f_bla_C - f_amar_H	-14,8	29,2	5,3	-25,7	-3,9	-2,8	29,0	,010
f_bla_C - Mich_I	-0,6	16,2	3,0	-6,8	5,6	-0,2	28,0	,844
f_bla_C - i_rojo_J	-22,7	29,3	5,3	-33,6	-11,8	-4,3	29,0	,000
W_D - i_amar_E	-0,9	35,5	6,5	-14,1	12,3	-0,1	29,0	,889
W_D - f_rojo_F	11,4	28,7	5,2	0,7	22,1	2,2	29,0	,038
W_D - f_ámb_G	11,7	30,2	5,5	0,4	23,0	2,1	29,0	,043
W_D - f_amar_H	1,2	40,9	7,6	-14,4	16,7	0,2	28,0	,878
W_D - Mich_I	16,9	33,4	6,3	4,0	29,8	2,7	27,0	,012
W_D - i_rojo_J	-4,4	40,3	7,4	-19,5	10,6	-0,6	29,0	,551
i_amar_E - f_rojo_F	11,2	24,2	4,3	2,3	20,0	2,6	30,0	,015
i_amar_E - f_ámb_G	12,5	30,7	5,5	1,3	23,8	2,3	30,0	,030
i_amar_E - f_amar_H	3,1	35,0	6,4	-10,0	16,1	0,5	29,0	,636
i_amar_E - Mich_I	17,9	34,1	6,3	4,9	30,8	2,8	28,0	,009
i_amar_E - i_rojo_J	-5,0	27,0	4,9	-15,1	5,1	-1,0	29,0	,319
f_rojo_F - f_ámb_G	1,3	19,2	3,4	-5,7	8,4	0,4	30,0	,700
f_rojo_F - f_amar_H	-8,4	32,0	5,8	-20,3	3,5	-1,4	29,0	,160
f_rojo_F - Mich_I	6,0	24,4	4,5	-3,3	15,3	1,3	28,0	,197
f_rojo_F - i_rojo_J	-16,5	27,6	5,0	-26,8	-6,2	-3,3	29,0	,003
f_ámb_G - f_amar_H	-9,6	32,7	6,0	-21,8	2,6	-1,6	29,0	,119
f_ámb_G - Mich_I	4,8	19,5	3,6	-2,7	12,2	1,3	28,0	,199
f_ámb_G - i_rojo_J	-17,9	29,4	5,4	-28,9	-6,9	-3,3	29,0	,002
f_amar_H - Mich_I	14,7	34,8	6,5	1,4	27,9	2,3	28,0	,031
f_amar_H - i_rojo_J	-7,7	24,7	4,6	-17,2	1,7	-1,7	28,0	,103
Mich_I - i_rojo_J	-22,4	31,6	5,9	-34,5	-10,4	-3,8	28,0	,001

Table B3: Paired sample T-test for the variable “urgency”

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	-2,1	32,5	6,1	-14,7	10,5	-0,3	27,0	0,73
i_bla_A - f_bla_C	10,0	30,3	5,5	-1,3	21,3	1,8	29,0	0,08
i_bla_A - W_D	0,1	42,1	7,8	-15,9	16,1	0,0	28,0	0,99
i_bla_A - i_amar_E	3,8	28,5	5,3	-7,0	14,6	0,7	28,0	0,48
i_bla_A - f_rojo_F	-1,0	42,4	7,9	-17,2	15,1	-0,1	28,0	0,90
i_bla_A - f_ámb_G	9,4	33,8	6,3	-3,4	22,3	1,5	28,0	0,14
i_bla_A - f_amar_H	0,9	25,8	4,9	-9,2	10,9	0,2	27,0	0,86
i_bla_A - Mich_I	12,9	31,5	5,8	1,1	24,6	2,2	29,0	0,03
i_bla_A - i_rojo_J	-8,2	30,9	5,7	-20,0	3,5	-1,4	28,0	0,16
i_ámb_B - f_bla_C	9,8	33,1	6,2	-2,8	22,4	1,6	28,0	0,12
i_ámb_B - W_D	-1,2	39,6	7,5	-16,6	14,1	-0,2	27,0	0,87
i_ámb_B - i_amar_E	2,6	35,9	6,7	-11,1	16,3	0,4	28,0	0,70
i_ámb_B - f_rojo_F	-1,1	41,8	7,8	-17,0	14,8	-0,1	28,0	0,89
i_ámb_B - f_ámb_G	7,1	33,9	6,4	-6,1	20,2	1,1	27,0	0,28
i_ámb_B - f_amar_H	1,4	31,5	6,0	-10,8	13,6	0,2	27,0	0,82
i_ámb_B - Mich_I	18,2	29,2	5,5	6,9	29,6	3,3	27,0	0,00
i_ámb_B - i_rojo_J	-3,3	32,4	6,1	-15,9	9,2	-0,5	27,0	0,59
f_bla_C - W_D	-9,3	25,6	4,7	-18,9	0,3	-2,0	29,0	0,06
f_bla_C - i_amar_E	-6,0	16,7	3,0	-12,2	0,3	-2,0	29,0	0,06
f_bla_C - f_rojo_F	-10,6	25,0	4,6	-20,0	-1,3	-2,3	29,0	0,03
f_bla_C - f_ámb_G	-0,4	13,3	2,4	-5,3	4,6	-0,2	29,0	0,88
f_bla_C - f_amar_H	-9,6	25,1	4,7	-19,1	0,0	-2,1	28,0	0,05
f_bla_C - Mich_I	2,9	17,9	3,3	-3,8	9,6	0,9	29,0	0,39
f_bla_C - i_rojo_J	-18,2	27,6	5,1	-28,7	-7,7	-3,6	28,0	0,00
W_D - i_amar_E	5,3	31,4	5,7	-6,4	17,1	0,9	29,0	0,36
W_D - f_rojo_F	1,3	35,4	6,5	-11,9	14,6	0,2	29,0	0,84
W_D - f_ámb_G	9,1	26,0	4,8	-0,8	19,0	1,9	28,0	0,07
W_D - f_amar_H	0,7	35,1	6,6	-13,0	14,3	0,1	27,0	0,92
W_D - Mich_I	12,6	31,6	5,9	0,6	24,6	2,1	28,0	0,04
W_D - i_rojo_J	-5,5	37,3	6,9	-19,7	8,7	-0,8	28,0	0,43
i_amar_E - f_rojo_F	-4,6	30,3	5,4	-15,7	6,6	-0,8	30,0	0,41
i_amar_E - f_ámb_G	5,3	19,4	3,6	-2,1	12,6	1,5	28,0	0,15
i_amar_E - f_amar_H	-3,7	26,8	5,1	-14,1	6,6	-0,7	27,0	0,47
i_amar_E - Mich_I	10,6	23,7	4,4	1,5	19,6	2,4	28,0	0,02
i_amar_E - i_rojo_J	-11,7	29,0	5,3	-22,5	-0,9	-2,2	29,0	0,04
f_rojo_F - f_ámb_G	8,2	27,5	5,1	-2,2	18,7	1,6	28,0	0,12
f_rojo_F - f_amar_H	1,7	36,0	6,8	-12,3	15,7	0,3	27,0	0,80
f_rojo_F - Mich_I	15,4	26,5	4,9	5,3	25,5	3,1	28,0	0,00
f_rojo_F - i_rojo_J	-7,0	36,4	6,6	-20,6	6,6	-1,1	29,0	0,30
f_ámb_G - f_amar_H	-8,0	26,9	5,1	-18,4	2,4	-1,6	27,0	0,13
f_ámb_G - Mich_I	3,0	23,3	4,3	-5,9	11,9	0,7	28,0	0,49
f_ámb_G - i_rojo_J	-18,0	33,4	6,3	-30,9	-5,0	-2,8	27,0	0,01
f_amar_H - Mich_I	12,4	29,6	5,6	0,9	23,8	2,2	27,0	0,04
f_amar_H - i_rojo_J	-5,9	25,7	4,9	-16,0	4,3	-1,2	26,0	0,25
Mich_I - i_rojo_J	-22,6	26,9	5,0	-32,9	-12,4	-4,5	28,0	0,00

Table B4: Paired sample T-test for the variable " conspicuity"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	-12,3	22,8	4,0	-20,4	-4,3	-3,1	32,0	,004
i_bla_A - f_bla_C	4,5	34,2	6,0	-7,7	16,6	0,8	32,0	,458
i_bla_A - W_D	-3,7	43,9	7,6	-19,3	11,9	-0,5	32,0	,632
i_bla_A - i_amar_E	-10,8	40,0	7,0	-25,0	3,4	-1,5	32,0	,132
i_bla_A - f_rojo_F	3,2	40,2	7,1	-11,3	17,7	0,4	31,0	,658
i_bla_A - f_ámb_G	4,2	35,8	6,2	-8,5	16,9	0,7	32,0	,504
i_bla_A - f_amar_H	-3,2	29,8	5,2	-13,8	7,3	-0,6	32,0	,538
i_bla_A - Mich_I	5,5	39,3	6,8	-8,4	19,5	0,8	32,0	,424
i_bla_A - i_rojo_J	-3,8	37,5	6,5	-17,1	9,5	-0,6	32,0	,565
i_ámb_B - f_bla_C	16,8	28,3	4,9	6,7	26,8	3,4	32,0	,002
i_ámb_B - W_D	8,6	40,0	7,0	-5,6	22,8	1,2	32,0	,225
i_ámb_B - i_amar_E	1,6	33,8	5,9	-10,4	13,5	0,3	32,0	,794
i_ámb_B - f_rojo_F	15,3	33,5	5,9	3,2	27,4	2,6	31,0	,015
i_ámb_B - f_ámb_G	16,5	28,6	5,0	6,4	26,7	3,3	32,0	,002
i_ámb_B - f_amar_H	9,1	23,4	4,1	0,8	17,4	2,2	32,0	,033
i_ámb_B - Mich_I	17,9	38,6	6,7	4,2	31,5	2,7	32,0	,012
i_ámb_B - i_rojo_J	8,5	36,2	6,3	-4,3	21,4	1,4	32,0	,185
f_bla_C - W_D	-8,2	34,5	6,0	-20,4	4,1	-1,4	32,0	,183
f_bla_C - i_amar_E	-15,2	28,8	5,0	-25,5	-5,0	-3,0	32,0	,005
f_bla_C - f_rojo_F	-2,2	26,8	4,7	-11,9	7,4	-0,5	31,0	,645
f_bla_C - f_ámb_G	-0,3	22,4	3,9	-8,2	7,7	-0,1	32,0	,946
f_bla_C - f_amar_H	-7,7	27,1	4,7	-17,3	1,9	-1,6	32,0	,113
f_bla_C - Mich_I	1,1	37,3	6,5	-12,2	14,3	0,2	32,0	,870
f_bla_C - i_rojo_J	-8,3	41,8	7,3	-23,1	6,5	-1,1	32,0	,264
W_D - i_amar_E	-7,1	43,6	7,6	-22,5	8,4	-0,9	32,0	,359
W_D - f_rojo_F	7,0	35,5	6,3	-5,8	19,8	1,1	31,0	,274
W_D - f_ámb_G	7,9	31,2	5,4	-3,2	19,0	1,5	32,0	,155
W_D - f_amar_H	0,5	38,1	6,6	-13,0	14,0	0,1	32,0	,944
W_D - Mich_I	9,2	36,8	6,4	-3,8	22,3	1,4	32,0	,159
W_D - i_rojo_J	-0,1	46,6	8,1	-16,6	16,4	0,0	32,0	,991
i_amar_E - f_rojo_F	12,0	36,6	6,5	-1,2	25,2	1,9	31,0	,072
i_amar_E - f_ámb_G	15,0	33,5	5,8	3,1	26,8	2,6	32,0	,015
i_amar_E - f_amar_H	7,5	32,6	5,7	-4,0	19,1	1,3	32,0	,194
i_amar_E - Mich_I	16,3	36,5	6,3	3,4	29,2	2,6	32,0	,015
i_amar_E - i_rojo_J	7,0	43,9	7,6	-8,6	22,6	0,9	32,0	,368
f_rojo_F - f_ámb_G	1,2	21,5	3,8	-6,6	8,9	0,3	31,0	,762
f_rojo_F - f_amar_H	-5,4	28,6	5,1	-15,7	5,0	-1,1	31,0	,298
f_rojo_F - Mich_I	3,3	37,9	6,7	-10,3	17,0	0,5	31,0	,622
f_rojo_F - i_rojo_J	-6,2	38,2	6,8	-20,0	7,5	-0,9	31,0	,363
f_ámb_G - f_amar_H	-7,4	24,1	4,2	-16,0	1,1	-1,8	32,0	,086
f_ámb_G - Mich_I	1,3	29,8	5,2	-9,2	11,9	0,3	32,0	,799
f_ámb_G - i_rojo_J	-8,0	43,5	7,6	-23,4	7,4	-1,1	32,0	,299
f_amar_H - Mich_I	8,8	33,3	5,8	-3,1	20,6	1,5	32,0	,141
f_amar_H - i_rojo_J	-0,6	37,1	6,5	-13,7	12,6	-0,1	32,0	,932
Mich_I - i_rojo_J	-9,3	37,9	6,6	-22,8	4,1	-1,4	32,0	,167

Table B5: Paired sample T-test for the variable " detectability"

	Paired Differences					t	df	Sig. (2-tailed)
				Confidence Interval of the				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	-2,3	22,9	4,1	-10,6	5,9	-0,6	31,0	0,57
i_bla_A - f_bla_C	14,2	31,1	5,5	3,0	25,4	2,6	31,0	0,01
i_bla_A - W_D	10,1	42,9	7,6	-5,3	25,6	1,3	31,0	0,19
i_bla_A - i_amar_E	-1,8	33,3	5,9	-13,9	10,2	-0,3	31,0	0,76
i_bla_A - f_rojo_F	10,0	35,1	6,2	-2,7	22,6	1,6	31,0	0,12
i_bla_A - f_ámb_G	14,8	35,9	6,4	1,8	27,7	2,3	31,0	0,03
i_bla_A - f_amar_H	2,5	21,4	3,8	-5,2	10,2	0,7	31,0	0,51
i_bla_A - Mich_I	12,1	43,1	7,7	-3,7	27,9	1,6	30,0	0,13
i_bla_A - i_rojo_J	6,5	43,8	7,7	-9,3	22,3	0,8	31,0	0,41
i_ámb_B - f_bla_C	16,1	29,8	5,2	5,6	26,7	3,1	32,0	0,00
i_ámb_B - W_D	12,3	37,4	6,5	-1,0	25,5	1,9	32,0	0,07
i_ámb_B - i_amar_E	0,3	24,3	4,2	-8,3	9,0	0,1	32,0	0,94
i_ámb_B - f_rojo_F	12,0	32,8	5,7	0,4	23,6	2,1	32,0	0,04
i_ámb_B - f_ámb_G	16,7	30,7	5,3	5,8	27,6	3,1	32,0	0,00
i_ámb_B - f_amar_H	5,0	19,4	3,4	-1,9	11,9	1,5	32,0	0,15
i_ámb_B - Mich_I	14,8	38,8	6,9	0,9	28,8	2,2	31,0	0,04
i_ámb_B - i_rojo_J	8,7	37,4	6,5	-4,6	22,0	1,3	32,0	0,19
f_bla_C - W_D	-3,8	40,2	7,0	-18,1	10,4	-0,5	32,0	0,59
f_bla_C - i_amar_E	-15,8	27,8	4,8	-25,6	-5,9	-3,3	32,0	0,00
f_bla_C - f_rojo_F	-4,1	23,4	4,1	-12,4	4,2	-1,0	32,0	0,32
f_bla_C - f_ámb_G	0,6	26,9	4,7	-9,0	10,1	0,1	32,0	0,90
f_bla_C - f_amar_H	-11,1	32,7	5,7	-22,7	0,5	-1,9	32,0	0,06
f_bla_C - Mich_I	-1,7	37,0	6,5	-15,1	11,6	-0,3	31,0	0,79
f_bla_C - i_rojo_J	-7,4	40,2	7,0	-21,7	6,8	-1,1	32,0	0,30
W_D - i_amar_E	-11,9	38,8	6,8	-25,7	1,8	-1,8	32,0	0,09
W_D - f_rojo_F	-0,3	43,3	7,5	-15,6	15,1	0,0	32,0	0,97
W_D - f_ámb_G	4,4	37,2	6,5	-8,8	17,6	0,7	32,0	0,50
W_D - f_amar_H	-7,2	42,9	7,5	-22,5	8,0	-1,0	32,0	0,34
W_D - Mich_I	3,0	44,2	7,8	-13,0	18,9	0,4	31,0	0,71
W_D - i_rojo_J	-3,6	46,1	8,0	-19,9	12,8	-0,4	32,0	0,66
i_amar_E - f_rojo_F	11,7	27,7	4,8	1,8	21,5	2,4	32,0	0,02
i_amar_E - f_ámb_G	16,3	28,5	5,0	6,2	26,5	3,3	32,0	0,00
i_amar_E - f_amar_H	4,7	26,7	4,7	-4,8	14,2	1,0	32,0	0,32
i_amar_E - Mich_I	13,0	35,4	6,3	0,2	25,8	2,1	31,0	0,05
i_amar_E - i_rojo_J	8,4	42,7	7,4	-6,8	23,5	1,1	32,0	0,27
f_rojo_F - f_ámb_G	4,7	28,0	4,9	-5,3	14,6	1,0	32,0	0,34
f_rojo_F - f_amar_H	-7,0	30,3	5,3	-17,7	3,8	-1,3	32,0	0,20
f_rojo_F - Mich_I	2,5	40,4	7,1	-12,0	17,1	0,4	31,0	0,73
f_rojo_F - i_rojo_J	-3,3	32,9	5,7	-15,0	8,4	-0,6	32,0	0,57
f_ámb_G - f_amar_H	-11,7	31,8	5,5	-22,9	-0,4	-2,1	32,0	0,04
f_ámb_G - Mich_I	-2,5	33,2	5,9	-14,5	9,5	-0,4	31,0	0,67
f_ámb_G - i_rojo_J	-8,0	35,6	6,2	-20,6	4,6	-1,3	32,0	0,21
f_amar_H - Mich_I	9,2	42,6	7,5	-6,1	24,6	1,2	31,0	0,23
f_amar_H - i_rojo_J	3,7	37,8	6,6	-9,7	17,1	0,6	32,0	0,58
Mich_I - i_rojo_J	-5,7	47,1	8,3	-22,7	11,3	-0,7	31,0	0,50

Table B6: Paired sample T-test for the variable "usefulness"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	0,4	0,8	0,1	0,1	0,7	2,5	32,0	,016
i_bla_A - f_bla_C	0,2	1,0	0,2	-0,2	0,6	1,0	32,0	,325
i_bla_A - W_D	-0,4	1,5	0,3	-0,9	0,1	-1,6	32,0	,130
i_bla_A - i_amar_E	0,1	1,0	0,2	-0,3	0,4	0,5	32,0	,598
i_bla_A - f_rojo_F	0,0	0,9	0,2	-0,3	0,3	0,0	32,0	1,000
i_bla_A - f_ámb_G	0,0	1,2	0,2	-0,4	0,4	-0,2	32,0	,882
i_bla_A - f_amar_H	0,3	1,0	0,2	-0,1	0,7	1,7	32,0	,106
i_bla_A - Mich_I	0,2	1,4	0,2	-0,3	0,6	0,6	32,0	,530
i_bla_A - i_rojo_J	0,2	0,9	0,2	-0,1	0,5	1,1	32,0	,263
i_ámb_B - f_bla_C	-0,2	0,8	0,1	-0,5	0,1	-1,4	32,0	,184
i_ámb_B - W_D	-0,8	1,5	0,3	-1,3	-0,2	-3,0	32,0	,005
i_ámb_B - i_amar_E	-0,3	0,8	0,1	-0,6	0,0	-1,9	32,0	,071
i_ámb_B - f_rojo_F	-0,4	1,0	0,2	-0,7	0,0	-2,0	32,0	,050
i_ámb_B - f_ámb_G	-0,4	0,8	0,1	-0,7	-0,1	-2,7	32,0	,010
i_ámb_B - f_amar_H	-0,1	0,6	0,1	-0,3	0,1	-0,6	32,0	,535
i_ámb_B - Mich_I	-0,2	1,2	0,2	-0,6	0,2	-1,0	32,0	,315
i_ámb_B - i_rojo_J	-0,2	0,9	0,2	-0,5	0,1	-1,1	32,0	,263
f_bla_C - W_D	-0,6	1,5	0,3	-1,1	-0,1	-2,2	32,0	,033
f_bla_C - i_amar_E	-0,1	0,9	0,2	-0,4	0,2	-0,6	32,0	,572
f_bla_C - f_rojo_F	-0,2	1,0	0,2	-0,5	0,2	-1,1	32,0	,280
f_bla_C - f_ámb_G	-0,2	0,5	0,1	-0,4	0,0	-2,2	32,0	,033
f_bla_C - f_amar_H	0,1	0,6	0,1	-0,1	0,4	1,1	32,0	,292
f_bla_C - Mich_I	0,0	1,1	0,2	-0,4	0,4	-0,2	32,0	,872
f_bla_C - i_rojo_J	0,0	1,1	0,2	-0,4	0,4	0,0	32,0	1,000
W_D - i_amar_E	0,5	1,6	0,3	-0,1	1,0	1,8	32,0	,088
W_D - f_rojo_F	0,4	1,4	0,2	-0,1	0,9	1,7	32,0	,108
W_D - f_ámb_G	0,4	1,6	0,3	-0,2	0,9	1,3	32,0	,211
W_D - f_amar_H	0,7	1,7	0,3	0,1	1,3	2,4	32,0	,022
W_D - Mich_I	0,5	1,5	0,3	0,0	1,1	2,0	32,0	,051
W_D - i_rojo_J	0,6	1,4	0,2	0,1	1,1	2,4	32,0	,024
i_amar_E - f_rojo_F	-0,1	0,7	0,1	-0,3	0,1	-0,8	32,0	,447
i_amar_E - f_ámb_G	-0,1	1,1	0,2	-0,5	0,3	-0,7	32,0	,513
i_amar_E - f_amar_H	0,2	0,8	0,1	-0,1	0,5	1,5	32,0	,147
i_amar_E - Mich_I	0,1	1,3	0,2	-0,4	0,5	0,3	32,0	,797
i_amar_E - i_rojo_J	0,1	1,0	0,2	-0,3	0,4	0,5	32,0	,609
f_rojo_F - f_ámb_G	0,0	1,1	0,2	-0,4	0,4	-0,2	32,0	,872
f_rojo_F - f_amar_H	0,3	1,0	0,2	-0,1	0,7	1,7	32,0	,106
f_rojo_F - Mich_I	0,2	1,3	0,2	-0,3	0,6	0,6	32,0	,523
f_rojo_F - i_rojo_J	0,2	1,0	0,2	-0,2	0,5	1,0	32,0	,311
f_ámb_G - f_amar_H	0,3	0,6	0,1	0,1	0,6	3,0	32,0	,006
f_ámb_G - Mich_I	0,2	1,3	0,2	-0,3	0,6	0,8	32,0	,414
f_ámb_G - i_rojo_J	0,2	1,3	0,2	-0,2	0,7	0,9	32,0	,353
f_amar_H - Mich_I	-0,2	1,2	0,2	-0,6	0,3	-0,7	32,0	,465
f_amar_H - i_rojo_J	-0,1	1,1	0,2	-0,5	0,3	-0,7	32,0	,513
Mich_I - i_rojo_J	0,0	1,5	0,3	-0,5	0,6	0,1	32,0	,908

Table B7: Paired sample T-test for the variable "pleasure"

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Lower	95% Confidence Upper			
i_bla_A - i_ámb_B	-0,2	1,2	0,2	-0,6	0,3	-0,8	32,0	,404
i_bla_A - f_bla_C	0,0	1,2	0,2	-0,5	0,4	-0,1	32,0	,887
i_bla_A - W_D	-0,2	1,5	0,3	-0,7	0,3	-0,8	32,0	,408
i_bla_A - i_amar_E	-0,4	1,1	0,2	-0,8	0,0	-2,3	32,0	,028
i_bla_A - f_rojo_F	-0,2	1,5	0,3	-0,8	0,3	-1,0	32,0	,347
i_bla_A - f_ámb_G	-0,4	1,2	0,2	-0,8	0,1	-1,7	32,0	,097
i_bla_A - f_amar_H	-0,4	1,3	0,2	-0,8	0,1	-1,6	32,0	,110
i_bla_A - Mich_I	0,5	1,2	0,2	0,1	1,0	2,6	32,0	,014
i_bla_A - i_rojo_J	-0,7	1,5	0,3	-1,2	-0,1	-2,5	32,0	,018
i_ámb_B - f_bla_C	0,2	1,3	0,2	-0,3	0,6	0,7	32,0	,492
i_ámb_B - W_D	0,0	1,4	0,2	-0,5	0,5	-0,1	32,0	,899
i_ámb_B - i_amar_E	-0,2	0,8	0,1	-0,5	0,0	-1,9	32,0	,073
i_ámb_B - f_rojo_F	-0,1	1,3	0,2	-0,5	0,4	-0,3	32,0	,794
i_ámb_B - f_ámb_G	-0,2	1,0	0,2	-0,5	0,2	-1,0	32,0	,311
i_ámb_B - f_amar_H	-0,2	1,2	0,2	-0,6	0,2	-0,9	32,0	,395
i_ámb_B - Mich_I	0,7	1,4	0,2	0,2	1,2	3,1	32,0	,004
i_ámb_B - i_rojo_J	-0,5	1,4	0,3	-1,0	0,0	-1,9	32,0	,062
f_bla_C - W_D	-0,2	1,5	0,3	-0,7	0,3	-0,7	32,0	,488
f_bla_C - i_amar_E	-0,4	1,0	0,2	-0,8	0,0	-2,2	32,0	,035
f_bla_C - f_rojo_F	-0,2	1,1	0,2	-0,6	0,2	-1,1	32,0	,269
f_bla_C - f_ámb_G	-0,3	1,0	0,2	-0,7	0,0	-1,9	32,0	,062
f_bla_C - f_amar_H	-0,3	1,3	0,2	-0,8	0,1	-1,5	32,0	,140
f_bla_C - Mich_I	0,6	1,3	0,2	0,1	1,0	2,6	32,0	,014
f_bla_C - i_rojo_J	-0,6	1,6	0,3	-1,2	-0,1	-2,3	32,0	,025
W_D - i_amar_E	-0,2	1,2	0,2	-0,6	0,2	-1,0	32,0	,304
W_D - f_rojo_F	0,0	1,4	0,2	-0,5	0,5	-0,1	32,0	,899
W_D - f_ámb_G	-0,2	1,1	0,2	-0,5	0,2	-0,8	32,0	,443
W_D - f_amar_H	-0,2	1,4	0,2	-0,6	0,3	-0,6	32,0	,537
W_D - Mich_I	0,8	1,3	0,2	0,3	1,2	3,3	32,0	,002
W_D - i_rojo_J	-0,5	1,5	0,3	-1,0	0,1	-1,8	32,0	,083
i_amar_E - f_rojo_F	0,2	1,2	0,2	-0,2	0,6	0,9	32,0	,374
i_amar_E - f_ámb_G	0,1	0,7	0,1	-0,2	0,3	0,5	32,0	,625
i_amar_E - f_amar_H	0,1	1,0	0,2	-0,3	0,4	0,4	32,0	,721
i_amar_E - Mich_I	1,0	1,1	0,2	0,6	1,4	4,9	32,0	,000
i_amar_E - i_rojo_J	-0,2	1,3	0,2	-0,7	0,2	-1,1	32,0	,292
f_rojo_F - f_ámb_G	-0,1	1,1	0,2	-0,5	0,3	-0,6	32,0	,535
f_rojo_F - f_amar_H	-0,1	1,4	0,2	-0,6	0,4	-0,5	32,0	,613
f_rojo_F - Mich_I	0,8	1,3	0,2	0,3	1,3	3,4	32,0	,002
f_rojo_F - i_rojo_J	-0,4	1,4	0,2	-0,9	0,1	-1,8	32,0	,085
f_ámb_G - f_amar_H	0,0	1,0	0,2	-0,4	0,4	0,0	32,0	1,000
f_ámb_G - Mich_I	0,9	1,2	0,2	0,5	1,3	4,5	32,0	,000
f_ámb_G - i_rojo_J	-0,3	1,4	0,3	-0,8	0,2	-1,2	32,0	,238
f_amar_H - Mich_I	0,9	1,2	0,2	0,5	1,3	4,3	32,0	,000
f_amar_H - i_rojo_J	-0,3	1,8	0,3	-0,9	0,3	-1,0	32,0	,339
Mich_I - i_rojo_J	-1,2	1,4	0,2	-1,7	-0,7	-4,9	32,0	,000

Table B8: Paired sample T-test for the variable "niceness"

	Paired Differences							
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
i_bla_A - i_ámb_B	-0,2	1,3	0,2	-0,7	0,2	-1,1	32,0	,283
i_bla_A - f_bla_C	0,1	1,0	0,2	-0,2	0,5	0,7	31,0	,501
i_bla_A - W_D	0,0	1,5	0,3	-0,6	0,5	-0,1	32,0	,906
i_bla_A - i_amar_E	-0,3	1,0	0,2	-0,6	0,1	-1,6	32,0	,130
i_bla_A - f_rojo_F	-0,4	1,3	0,2	-0,9	0,0	-1,9	32,0	,060
i_bla_A - f_ámb_G	-0,1	1,3	0,2	-0,6	0,3	-0,5	32,0	,601
i_bla_A - f_amar_H	0,0	1,6	0,3	-0,6	0,5	-0,1	32,0	,914
i_bla_A - Mich_I	0,6	1,1	0,2	0,3	1,0	3,4	32,0	,002
i_bla_A - i_rojo_J	-0,5	1,3	0,2	-1,0	-0,1	-2,4	32,0	,022
i_ámb_B - f_bla_C	0,4	1,4	0,2	-0,1	0,9	1,5	31,0	,136
i_ámb_B - W_D	0,2	1,5	0,3	-0,3	0,7	0,8	32,0	,421
i_ámb_B - i_amar_E	0,0	1,0	0,2	-0,4	0,3	-0,2	32,0	,865
i_ámb_B - f_rojo_F	-0,2	1,3	0,2	-0,6	0,3	-0,8	32,0	,431
i_ámb_B - f_ámb_G	0,1	1,2	0,2	-0,3	0,5	0,6	32,0	,555
i_ámb_B - f_amar_H	0,2	1,4	0,2	-0,3	0,7	0,9	32,0	,386
i_ámb_B - Mich_I	0,9	1,5	0,3	0,4	1,4	3,4	32,0	,002
i_ámb_B - i_rojo_J	-0,3	1,3	0,2	-0,8	0,2	-1,3	32,0	,194
f_bla_C - W_D	-0,1	1,4	0,2	-0,6	0,4	-0,5	31,0	,613
f_bla_C - i_amar_E	-0,4	0,9	0,2	-0,7	-0,1	-2,4	31,0	,021
f_bla_C - f_rojo_F	-0,5	1,1	0,2	-0,9	-0,1	-2,5	31,0	,018
f_bla_C - f_ámb_G	-0,2	1,2	0,2	-0,6	0,2	-0,9	31,0	,374
f_bla_C - f_amar_H	-0,1	1,4	0,3	-0,6	0,4	-0,4	31,0	,712
f_bla_C - Mich_I	0,6	1,1	0,2	0,2	1,0	3,0	31,0	,006
f_bla_C - i_rojo_J	-0,7	1,6	0,3	-1,2	-0,1	-2,3	31,0	,031
W_D - i_amar_E	-0,2	1,3	0,2	-0,7	0,2	-1,1	32,0	,301
W_D - f_rojo_F	-0,4	1,2	0,2	-0,8	0,0	-1,9	32,0	,062
W_D - f_ámb_G	-0,1	1,4	0,3	-0,6	0,4	-0,4	32,0	,720
W_D - f_amar_H	0,0	1,6	0,3	-0,6	0,6	0,0	32,0	1,000
W_D - Mich_I	0,7	1,3	0,2	0,2	1,1	2,9	32,0	,007
W_D - i_rojo_J	-0,5	1,6	0,3	-1,1	0,1	-1,8	32,0	,081
i_amar_E - f_rojo_F	-0,2	1,1	0,2	-0,5	0,2	-0,8	32,0	,443
i_amar_E - f_ámb_G	0,2	1,2	0,2	-0,3	0,6	0,7	32,0	,465
i_amar_E - f_amar_H	0,2	1,4	0,2	-0,3	0,7	1,0	32,0	,332
i_amar_E - Mich_I	0,9	1,3	0,2	0,5	1,4	4,1	32,0	,000
i_amar_E - i_rojo_J	-0,3	1,3	0,2	-0,7	0,2	-1,2	32,0	,230
f_rojo_F - f_ámb_G	0,3	1,3	0,2	-0,2	0,8	1,3	32,0	,201
f_rojo_F - f_amar_H	0,4	1,5	0,3	-0,1	0,9	1,6	32,0	,130
f_rojo_F - Mich_I	1,1	1,2	0,2	0,6	1,5	5,2	32,0	,000
f_rojo_F - i_rojo_J	-0,1	1,1	0,2	-0,5	0,3	-0,7	32,0	,513
f_ámb_G - f_amar_H	0,1	0,8	0,1	-0,2	0,4	0,6	32,0	,540
f_ámb_G - Mich_I	0,8	1,3	0,2	0,3	1,2	3,5	32,0	,001
f_ámb_G - i_rojo_J	-0,4	1,6	0,3	-1,0	0,1	-1,6	32,0	,129
f_amar_H - Mich_I	0,7	1,3	0,2	0,2	1,1	3,0	32,0	,006
f_amar_H - i_rojo_J	-0,5	1,8	0,3	-1,2	0,1	-1,6	32,0	,111
Mich_I - i_rojo_J	-1,2	1,5	0,3	-1,7	-0,6	-4,4	32,0	,000

Table B9: Paired sample T-test for the variable "effectiveness"

	Paired Differences							
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
i_bla_A - i_ámb_B	0,2	1,0	0,2	-0,2	0,6	1,2	32,0	,243
i_bla_A - f_bla_C	-0,1	0,9	0,2	-0,5	0,2	-0,8	32,0	,458
i_bla_A - W_D	-0,7	1,7	0,3	-1,3	-0,1	-2,4	31,0	,021
i_bla_A - i_amar_E	-0,1	1,0	0,2	-0,5	0,2	-0,7	32,0	,501
i_bla_A - f_rojo_F	-0,1	1,3	0,2	-0,6	0,4	-0,5	32,0	,607
i_bla_A - f_ámb_G	-0,2	1,0	0,2	-0,5	0,2	-1,1	32,0	,296
i_bla_A - f_amar_H	-0,1	1,1	0,2	-0,5	0,3	-0,6	32,0	,535
i_bla_A - Mich_I	-0,1	1,4	0,2	-0,6	0,4	-0,3	31,0	,801
i_bla_A - i_rojo_J	0,2	1,1	0,2	-0,2	0,6	1,1	32,0	,281
i_ámb_B - f_bla_C	-0,3	1,0	0,2	-0,7	0,0	-1,9	32,0	,062
i_ámb_B - W_D	-0,9	1,5	0,3	-1,5	-0,4	-3,6	31,0	,001
i_ámb_B - i_amar_E	-0,3	0,9	0,2	-0,7	0,0	-2,1	32,0	,046
i_ámb_B - f_rojo_F	-0,3	1,3	0,2	-0,8	0,1	-1,5	32,0	,140
i_ámb_B - f_ámb_G	-0,4	0,9	0,2	-0,7	-0,1	-2,4	32,0	,021
i_ámb_B - f_amar_H	-0,3	0,9	0,2	-0,6	0,0	-2,2	32,0	,039
i_ámb_B - Mich_I	-0,3	1,3	0,2	-0,8	0,1	-1,4	31,0	,169
i_ámb_B - i_rojo_J	0,0	0,9	0,2	-0,3	0,3	0,0	32,0	1,000
f_bla_C - W_D	-0,6	1,5	0,3	-1,1	-0,1	-2,3	31,0	,030
f_bla_C - i_amar_E	0,0	1,0	0,2	-0,4	0,4	0,0	32,0	1,000
f_bla_C - f_rojo_F	0,0	1,3	0,2	-0,5	0,5	0,0	32,0	1,000
f_bla_C - f_ámb_G	-0,1	0,7	0,1	-0,3	0,2	-0,5	32,0	,645
f_bla_C - f_amar_H	0,0	0,9	0,2	-0,3	0,3	0,0	32,0	1,000
f_bla_C - Mich_I	0,0	1,3	0,2	-0,4	0,5	0,1	31,0	,895
f_bla_C - i_rojo_J	0,3	1,1	0,2	0,0	0,7	1,8	32,0	,078
W_D - i_amar_E	0,6	1,6	0,3	0,0	1,2	2,1	31,0	,044
W_D - f_rojo_F	0,6	1,5	0,3	0,0	1,1	2,2	31,0	,037
W_D - f_ámb_G	0,5	1,5	0,3	0,0	1,1	2,1	31,0	,048
W_D - f_amar_H	0,6	1,7	0,3	0,0	1,2	2,0	31,0	,057
W_D - Mich_I	0,6	1,4	0,3	0,1	1,1	2,4	30,0	,021
W_D - i_rojo_J	0,9	1,6	0,3	0,4	1,5	3,3	31,0	,002
i_amar_E - f_rojo_F	0,0	1,3	0,2	-0,5	0,5	0,0	32,0	1,000
i_amar_E - f_ámb_G	-0,1	1,0	0,2	-0,4	0,3	-0,3	32,0	,730
i_amar_E - f_amar_H	0,0	0,9	0,2	-0,3	0,3	0,0	32,0	1,000
i_amar_E - Mich_I	0,0	1,5	0,3	-0,5	0,5	0,0	31,0	1,000
i_amar_E - i_rojo_J	0,3	0,9	0,2	0,0	0,6	2,2	32,0	,039
f_rojo_F - f_ámb_G	-0,1	1,2	0,2	-0,5	0,4	-0,3	32,0	,778
f_rojo_F - f_amar_H	0,0	1,3	0,2	-0,5	0,5	0,0	32,0	1,000
f_rojo_F - Mich_I	0,0	1,3	0,2	-0,4	0,5	0,1	31,0	,893
f_rojo_F - i_rojo_J	0,3	1,2	0,2	-0,1	0,8	1,6	32,0	,117
f_ámb_G - f_amar_H	0,1	0,9	0,2	-0,2	0,4	0,4	32,0	,690
f_ámb_G - Mich_I	0,1	1,4	0,2	-0,4	0,6	0,4	31,0	,703
f_ámb_G - i_rojo_J	0,4	0,9	0,2	0,1	0,7	2,4	32,0	,021
f_amar_H - Mich_I	0,0	1,4	0,3	-0,5	0,5	0,0	31,0	1,000
f_amar_H - i_rojo_J	0,3	0,9	0,1	0,0	0,6	2,2	32,0	,032
Mich_I - i_rojo_J	0,3	1,4	0,2	-0,2	0,9	1,4	31,0	,176

Table B10: Paired sample T-test for the variable "likeable"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	0,1	1,4	0,2	-0,4	0,6	0,5	31,0	,607
i_bla_A - f_bla_C	-0,6	1,4	0,2	-1,1	-0,1	-2,3	31,0	,032
i_bla_A - W_D	-0,2	1,4	0,3	-0,7	0,3	-0,7	31,0	,462
i_bla_A - i_amar_E	0,0	1,5	0,3	-0,5	0,6	0,1	31,0	,905
i_bla_A - f_rojo_F	-0,1	1,6	0,3	-0,7	0,5	-0,2	31,0	,831
i_bla_A - f_ámb_G	-0,3	1,4	0,2	-0,8	0,2	-1,2	31,0	,256
i_bla_A - f_amar_H	-0,2	1,6	0,3	-0,8	0,4	-0,6	30,0	,582
i_bla_A - Mich_I	-0,8	1,6	0,3	-1,4	-0,3	-3,0	31,0	,006
i_bla_A - i_rojo_J	0,2	1,3	0,2	-0,3	0,6	0,7	31,0	,493
i_ámb_B - f_bla_C	-0,7	1,4	0,2	-1,2	-0,2	-2,7	32,0	,012
i_ámb_B - W_D	-0,3	1,2	0,2	-0,7	0,2	-1,3	32,0	,213
i_ámb_B - i_amar_E	-0,1	1,0	0,2	-0,5	0,2	-0,7	32,0	,488
i_ámb_B - f_rojo_F	-0,2	1,4	0,2	-0,6	0,3	-0,6	32,0	,530
i_ámb_B - f_ámb_G	-0,4	0,9	0,2	-0,7	-0,1	-2,5	32,0	,017
i_ámb_B - f_amar_H	-0,2	1,2	0,2	-0,6	0,2	-1,1	31,0	,293
i_ámb_B - Mich_I	-0,9	1,4	0,2	-1,4	-0,4	-3,8	32,0	,001
i_ámb_B - i_rojo_J	0,0	1,1	0,2	-0,4	0,4	0,2	32,0	,879
f_bla_C - W_D	0,4	1,2	0,2	0,0	0,8	1,9	32,0	,068
f_bla_C - i_amar_E	0,5	1,3	0,2	0,1	1,0	2,4	32,0	,024
f_bla_C - f_rojo_F	0,5	1,4	0,2	0,0	1,0	2,1	32,0	,045
f_bla_C - f_ámb_G	0,3	1,2	0,2	-0,2	0,7	1,3	32,0	,203
f_bla_C - f_amar_H	0,4	1,1	0,2	0,0	0,8	2,0	31,0	,056
f_bla_C - Mich_I	-0,3	1,3	0,2	-0,7	0,2	-1,2	32,0	,239
f_bla_C - i_rojo_J	0,7	1,4	0,3	0,2	1,2	2,8	32,0	,009
W_D - i_amar_E	0,2	1,3	0,2	-0,3	0,6	0,7	32,0	,492
W_D - f_rojo_F	0,1	1,5	0,3	-0,4	0,6	0,5	32,0	,640
W_D - f_ámb_G	-0,1	1,0	0,2	-0,5	0,2	-0,7	32,0	,501
W_D - f_amar_H	0,0	1,2	0,2	-0,4	0,4	0,0	31,0	1,000
W_D - Mich_I	-0,7	0,9	0,2	-1,0	-0,4	-4,3	32,0	,000
W_D - i_rojo_J	0,3	1,2	0,2	-0,1	0,7	1,5	32,0	,152
i_amar_E - f_rojo_F	0,0	1,5	0,3	-0,6	0,5	-0,1	32,0	,909
i_amar_E - f_ámb_G	-0,3	1,0	0,2	-0,6	0,1	-1,6	32,0	,130
i_amar_E - f_amar_H	-0,1	1,2	0,2	-0,6	0,3	-0,6	31,0	,572
i_amar_E - Mich_I	-0,8	1,4	0,2	-1,3	-0,3	-3,3	32,0	,002
i_amar_E - i_rojo_J	0,2	1,1	0,2	-0,2	0,5	0,8	32,0	,419
f_rojo_F - f_ámb_G	-0,2	1,1	0,2	-0,6	0,2	-1,2	32,0	,233
f_rojo_F - f_amar_H	0,0	1,4	0,2	-0,5	0,5	0,0	31,0	1,000
f_rojo_F - Mich_I	-0,8	1,5	0,3	-1,3	-0,3	-3,0	32,0	,005
f_rojo_F - i_rojo_J	0,2	1,3	0,2	-0,3	0,6	0,8	32,0	,414
f_ámb_G - f_amar_H	0,2	0,8	0,1	-0,1	0,5	1,3	31,0	,206
f_ámb_G - Mich_I	-0,5	1,1	0,2	-0,9	-0,2	-2,9	32,0	,006
f_ámb_G - i_rojo_J	0,4	1,3	0,2	0,0	0,9	1,9	32,0	,065
f_amar_H - Mich_I	-0,7	1,3	0,2	-1,2	-0,3	-3,2	31,0	,003
f_amar_H - i_rojo_J	0,3	1,6	0,3	-0,3	0,9	1,0	31,0	,325
Mich_I - i_rojo_J	1,0	1,5	0,3	0,4	1,5	3,7	32,0	,001

Table B11: Paired sample T-test for the variable "assistance"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	0,4	1,0	0,2	0,0	0,8	2,2	32,0	,035
i_bla_A - f_bla_C	0,1	1,2	0,2	-0,3	0,5	0,6	32,0	,555
i_bla_A - W_D	-0,5	1,4	0,2	-0,9	0,0	-1,9	32,0	,066
i_bla_A - i_amar_E	0,1	1,0	0,2	-0,3	0,5	0,5	32,0	,620
i_bla_A - f_rojo_F	0,1	0,9	0,2	-0,2	0,5	0,8	32,0	,458
i_bla_A - f_ámb_G	0,1	1,2	0,2	-0,4	0,5	0,3	32,0	,778
i_bla_A - f_amar_H	0,1	1,2	0,2	-0,3	0,5	0,5	32,0	,654
i_bla_A - Mich_I	0,1	1,7	0,3	-0,5	0,7	0,4	32,0	,677
i_bla_A - i_rojo_J	0,2	0,8	0,1	-0,1	0,5	1,7	32,0	,103
i_ámb_B - f_bla_C	-0,3	1,0	0,2	-0,6	0,1	-1,5	32,0	,141
i_ámb_B - W_D	-0,8	1,3	0,2	-1,3	-0,4	-3,6	32,0	,001
i_ámb_B - i_amar_E	-0,3	1,0	0,2	-0,7	0,0	-1,8	32,0	,086
i_ámb_B - f_rojo_F	-0,3	0,9	0,2	-0,6	0,1	-1,7	32,0	,095
i_ámb_B - f_ámb_G	-0,3	1,0	0,2	-0,7	0,0	-2,0	32,0	,054
i_ámb_B - f_amar_H	-0,3	1,0	0,2	-0,7	0,1	-1,7	32,0	,106
i_ámb_B - Mich_I	-0,3	1,4	0,2	-0,8	0,2	-1,1	32,0	,271
i_ámb_B - i_rojo_J	-0,2	0,9	0,2	-0,5	0,2	-1,0	32,0	,344
f_bla_C - W_D	-0,6	1,6	0,3	-1,1	0,0	-2,1	32,0	,042
f_bla_C - i_amar_E	0,0	1,0	0,2	-0,4	0,3	-0,2	32,0	,865
f_bla_C - f_rojo_F	0,0	1,0	0,2	-0,4	0,4	0,0	32,0	1,000
f_bla_C - f_ámb_G	-0,1	0,7	0,1	-0,3	0,2	-0,5	32,0	,601
f_bla_C - f_amar_H	0,0	0,9	0,2	-0,4	0,3	-0,2	32,0	,851
f_bla_C - Mich_I	0,0	1,3	0,2	-0,5	0,5	0,0	32,0	1,000
f_bla_C - i_rojo_J	0,1	1,1	0,2	-0,3	0,5	0,6	32,0	,545
W_D - i_amar_E	0,5	1,3	0,2	0,1	1,0	2,3	32,0	,027
W_D - f_rojo_F	0,6	1,4	0,2	0,1	1,1	2,4	32,0	,024
W_D - f_ámb_G	0,5	1,5	0,3	0,0	1,0	2,0	32,0	,058
W_D - f_amar_H	0,5	1,6	0,3	0,0	1,1	1,9	32,0	,062
W_D - Mich_I	0,6	1,4	0,2	0,1	1,1	2,3	32,0	,026
W_D - i_rojo_J	0,7	1,2	0,2	0,3	1,1	3,4	32,0	,002
i_amar_E - f_rojo_F	0,0	1,1	0,2	-0,4	0,4	0,2	32,0	,876
i_amar_E - f_ámb_G	0,0	1,0	0,2	-0,4	0,3	-0,2	32,0	,861
i_amar_E - f_amar_H	0,0	0,9	0,2	-0,3	0,3	0,0	32,0	1,000
i_amar_E - Mich_I	0,0	1,5	0,3	-0,5	0,6	0,1	32,0	,910
i_amar_E - i_rojo_J	0,2	0,8	0,1	-0,1	0,4	1,0	32,0	,304
f_rojo_F - f_ámb_G	-0,1	1,0	0,2	-0,4	0,3	-0,4	32,0	,721
f_rojo_F - f_amar_H	0,0	1,2	0,2	-0,5	0,4	-0,1	32,0	,887
f_rojo_F - Mich_I	0,0	1,3	0,2	-0,5	0,5	0,0	32,0	1,000
f_rojo_F - i_rojo_J	0,1	1,0	0,2	-0,2	0,5	0,7	32,0	,488
f_ámb_G - f_amar_H	0,0	0,8	0,1	-0,3	0,3	0,2	32,0	,839
f_ámb_G - Mich_I	0,1	1,3	0,2	-0,4	0,5	0,3	32,0	,797
f_ámb_G - i_rojo_J	0,2	1,1	0,2	-0,2	0,6	0,9	32,0	,351
f_amar_H - Mich_I	0,0	1,3	0,2	-0,4	0,5	0,1	32,0	,893
f_amar_H - i_rojo_J	0,2	1,1	0,2	-0,2	0,5	0,8	32,0	,432
Mich_I - i_rojo_J	0,1	1,6	0,3	-0,4	0,7	0,4	32,0	,662

Table B12: Paired sample T-test for the variable "desirability"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	0,0	1,1	0,2	-0,4	0,4	0,0	32,0	1,000
i_bla_A - f_bla_C	-0,1	1,2	0,2	-0,6	0,3	-0,6	32,0	,580
i_bla_A - W_D	0,3	1,4	0,2	-0,2	0,8	1,2	32,0	,231
i_bla_A - i_amar_E	0,1	1,2	0,2	-0,3	0,5	0,5	32,0	,654
i_bla_A - f_rojo_F	0,4	1,3	0,2	-0,1	0,8	1,6	32,0	,123
i_bla_A - f_ámb_G	0,0	1,2	0,2	-0,4	0,4	0,0	32,0	1,000
i_bla_A - f_amar_H	-0,2	1,3	0,2	-0,6	0,3	-0,7	32,0	,492
i_bla_A - Mich_I	-0,2	1,4	0,2	-0,7	0,3	-0,9	32,0	,394
i_bla_A - i_rojo_J	0,5	1,1	0,2	0,1	0,9	2,5	31,0	,020
i_ámb_B - f_bla_C	-0,1	1,0	0,2	-0,5	0,2	-0,7	32,0	,488
i_ámb_B - W_D	0,3	1,5	0,3	-0,2	0,8	1,2	32,0	,251
i_ámb_B - i_amar_E	0,1	1,0	0,2	-0,3	0,4	0,5	32,0	,598
i_ámb_B - f_rojo_F	0,4	1,3	0,2	-0,1	0,8	1,6	32,0	,129
i_ámb_B - f_ámb_G	0,0	0,9	0,2	-0,3	0,3	0,0	32,0	1,000
i_ámb_B - f_amar_H	-0,2	0,8	0,1	-0,4	0,1	-1,0	32,0	,304
i_ámb_B - Mich_I	-0,2	1,3	0,2	-0,7	0,2	-0,9	32,0	,353
i_ámb_B - i_rojo_J	0,5	1,1	0,2	0,1	0,9	2,4	31,0	,023
f_bla_C - W_D	0,4	1,3	0,2	0,0	0,9	1,9	32,0	,060
f_bla_C - i_amar_E	0,2	0,7	0,1	-0,1	0,5	1,6	32,0	,109
f_bla_C - f_rojo_F	0,5	1,3	0,2	0,0	1,0	2,1	32,0	,047
f_bla_C - f_ámb_G	0,1	0,7	0,1	-0,1	0,4	0,9	32,0	,354
f_bla_C - f_amar_H	0,0	1,0	0,2	-0,4	0,3	-0,2	32,0	,856
f_bla_C - Mich_I	-0,1	1,3	0,2	-0,5	0,4	-0,4	32,0	,687
f_bla_C - i_rojo_J	0,6	1,2	0,2	0,2	1,0	2,9	31,0	,007
W_D - i_amar_E	-0,2	1,2	0,2	-0,6	0,2	-1,0	32,0	,304
W_D - f_rojo_F	0,1	1,1	0,2	-0,3	0,5	0,3	32,0	,757
W_D - f_ámb_G	-0,3	1,2	0,2	-0,7	0,1	-1,5	32,0	,143
W_D - f_amar_H	-0,5	1,3	0,2	-0,9	0,0	-2,0	32,0	,057
W_D - Mich_I	-0,5	1,0	0,2	-0,9	-0,2	-2,9	32,0	,006
W_D - i_rojo_J	0,3	1,0	0,2	-0,1	0,6	1,7	31,0	,107
i_amar_E - f_rojo_F	0,3	1,2	0,2	-0,2	0,7	1,3	32,0	,203
i_amar_E - f_ámb_G	-0,1	0,8	0,1	-0,4	0,2	-0,7	32,0	,500
i_amar_E - f_amar_H	-0,2	1,1	0,2	-0,6	0,2	-1,2	32,0	,222
i_amar_E - Mich_I	-0,3	1,4	0,2	-0,8	0,2	-1,3	32,0	,216
i_amar_E - i_rojo_J	0,4	0,9	0,2	0,0	0,7	2,3	31,0	,026
f_rojo_F - f_ámb_G	-0,4	1,2	0,2	-0,8	0,1	-1,7	32,0	,090
f_rojo_F - f_amar_H	-0,5	1,4	0,2	-1,0	0,0	-2,2	32,0	,039
f_rojo_F - Mich_I	-0,6	1,3	0,2	-1,0	-0,1	-2,6	32,0	,014
f_rojo_F - i_rojo_J	0,2	1,0	0,2	-0,2	0,5	1,1	31,0	,296
f_ámb_G - f_amar_H	-0,2	0,8	0,1	-0,4	0,1	-1,2	32,0	,258
f_ámb_G - Mich_I	-0,2	1,1	0,2	-0,6	0,2	-1,1	32,0	,293
f_ámb_G - i_rojo_J	0,5	1,1	0,2	0,1	0,9	2,3	31,0	,026
f_amar_H - Mich_I	-0,1	1,1	0,2	-0,5	0,3	-0,3	32,0	,757
f_amar_H - i_rojo_J	0,6	1,4	0,2	0,1	1,1	2,6	31,0	,016
Mich_I - i_rojo_J	0,8	1,4	0,2	0,3	1,3	3,4	31,0	,002

Table B13: Paired sample T-test for the variable "raising alertness"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	0,3	0,8	0,1	0,1	0,6	2,5	32,0	,019
i_bla_A - f_bla_C	-0,1	0,8	0,1	-0,4	0,2	-0,9	32,0	,379
i_bla_A - W_D	-0,3	1,3	0,2	-0,8	0,2	-1,3	32,0	,194
i_bla_A - i_amar_E	0,2	1,1	0,2	-0,2	0,6	1,2	32,0	,256
i_bla_A - f_rojo_F	0,1	0,9	0,2	-0,3	0,4	0,4	32,0	,712
i_bla_A - f_ámb_G	-0,1	0,9	0,2	-0,4	0,2	-0,6	32,0	,585
i_bla_A - f_amar_H	-0,2	1,0	0,2	-0,5	0,2	-0,9	32,0	,377
i_bla_A - Mich_I	0,1	1,0	0,2	-0,2	0,5	0,7	32,0	,474
i_bla_A - i_rojo_J	0,2	1,1	0,2	-0,2	0,6	1,0	32,0	,338
i_ámb_B - f_bla_C	-0,5	1,0	0,2	-0,8	-0,1	-2,7	32,0	,011
i_ámb_B - W_D	-0,6	1,4	0,2	-1,1	-0,2	-2,7	32,0	,012
i_ámb_B - i_amar_E	-0,1	0,9	0,2	-0,5	0,2	-0,8	32,0	,458
i_ámb_B - f_rojo_F	-0,3	0,8	0,1	-0,5	0,0	-2,1	32,0	,048
i_ámb_B - f_ámb_G	-0,4	1,0	0,2	-0,8	-0,1	-2,4	32,0	,021
i_ámb_B - f_amar_H	-0,5	0,8	0,1	-0,8	-0,2	-3,3	32,0	,002
i_ámb_B - Mich_I	-0,2	1,1	0,2	-0,6	0,2	-1,2	32,0	,256
i_ámb_B - i_rojo_J	-0,2	0,9	0,2	-0,5	0,2	-0,9	32,0	,361
f_bla_C - W_D	-0,2	1,2	0,2	-0,6	0,2	-0,9	32,0	,374
f_bla_C - i_amar_E	0,3	0,8	0,1	0,0	0,6	2,3	32,0	,025
f_bla_C - f_rojo_F	0,2	1,0	0,2	-0,2	0,5	1,1	32,0	,296
f_bla_C - f_ámb_G	0,0	1,0	0,2	-0,3	0,4	0,2	32,0	,861
f_bla_C - f_amar_H	0,0	1,1	0,2	-0,4	0,4	-0,2	32,0	,876
f_bla_C - Mich_I	0,2	0,9	0,2	-0,1	0,5	1,6	32,0	,118
f_bla_C - i_rojo_J	0,3	1,0	0,2	-0,1	0,7	1,7	32,0	,096
W_D - i_amar_E	0,5	1,3	0,2	0,1	1,0	2,3	32,0	,027
W_D - f_rojo_F	0,4	1,4	0,2	-0,1	0,8	1,5	32,0	,136
W_D - f_ámb_G	0,2	1,2	0,2	-0,2	0,6	1,0	32,0	,304
W_D - f_amar_H	0,2	1,3	0,2	-0,3	0,6	0,7	32,0	,492
W_D - Mich_I	0,4	1,3	0,2	0,0	0,9	1,9	32,0	,065
W_D - i_rojo_J	0,5	1,3	0,2	0,0	1,0	2,1	32,0	,047
i_amar_E - f_rojo_F	-0,2	0,9	0,2	-0,5	0,2	-0,9	32,0	,361
i_amar_E - f_ámb_G	-0,3	1,1	0,2	-0,7	0,1	-1,6	32,0	,115
i_amar_E - f_amar_H	-0,4	0,8	0,1	-0,7	-0,1	-2,5	32,0	,016
i_amar_E - Mich_I	-0,1	1,1	0,2	-0,5	0,3	-0,5	32,0	,629
i_amar_E - i_rojo_J	0,0	1,0	0,2	-0,4	0,3	-0,2	32,0	,856
f_rojo_F - f_ámb_G	-0,2	1,0	0,2	-0,5	0,2	-0,9	32,0	,377
f_rojo_F - f_amar_H	-0,2	1,1	0,2	-0,6	0,2	-1,2	32,0	,256
f_rojo_F - Mich_I	0,1	1,1	0,2	-0,3	0,4	0,3	32,0	,751
f_rojo_F - i_rojo_J	0,1	0,6	0,1	-0,1	0,4	1,1	32,0	,292
f_ámb_G - f_amar_H	-0,1	0,9	0,2	-0,4	0,3	-0,4	32,0	,712
f_ámb_G - Mich_I	0,2	1,3	0,2	-0,2	0,7	1,0	32,0	,344
f_ámb_G - i_rojo_J	0,3	1,1	0,2	-0,1	0,7	1,5	32,0	,152
f_amar_H - Mich_I	0,3	1,2	0,2	-0,2	0,7	1,3	32,0	,213
f_amar_H - i_rojo_J	0,3	1,1	0,2	0,0	0,7	1,8	32,0	,078
Mich_I - i_rojo_J	0,1	1,3	0,2	-0,4	0,5	0,3	32,0	,786

Table B14: Paired sample T-test for the variable "goodness"

	Paired Differences					t	df	Sig. (2-tailed)
				Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
i_bla_A - i_ámb_B	0,0	1,1	0,2	-0,4	0,4	0,2	32	,872
i_bla_A - f_bla_C	0,0	0,8	0,1	-0,3	0,3	0,0	32	1,000
i_bla_A - W_D	0,3	1,3	0,2	-0,2	0,8	1,3	32	,201
i_bla_A - i_amar_E	0,2	0,9	0,2	-0,2	0,5	1,0	32	,344
i_bla_A - f_rojo_F	0,2	1,2	0,2	-0,2	0,7	1,0	32	,335
i_bla_A - f_ámb_G	0,2	0,8	0,1	-0,1	0,5	1,3	32	,206
i_bla_A - f_amar_H	0,3	1,2	0,2	-0,1	0,7	1,5	32	,152
i_bla_A - Mich_I	-0,1	1,3	0,2	-0,5	0,4	-0,3	32	,797
i_bla_A - i_rojo_J	0,2	1,2	0,2	-0,2	0,6	0,9	32	,374
i_ámb_B - f_bla_C	0,0	1,2	0,2	-0,4	0,4	-0,2	32	,882
i_ámb_B - W_D	0,3	1,5	0,3	-0,3	0,8	1,0	32	,306
i_ámb_B - i_amar_E	0,1	0,6	0,1	-0,1	0,4	1,1	32	,292
i_ámb_B - f_rojo_F	0,2	1,1	0,2	-0,2	0,6	1,0	32	,338
i_ámb_B - f_ámb_G	0,2	1,1	0,2	-0,2	0,5	0,8	32	,432
i_ámb_B - f_amar_H	0,3	0,9	0,2	-0,1	0,6	1,7	32	,107
i_ámb_B - Mich_I	-0,1	1,3	0,2	-0,5	0,4	-0,4	32	,681
i_ámb_B - i_rojo_J	0,2	0,9	0,2	-0,2	0,5	1,0	32	,325
f_bla_C - W_D	0,3	1,4	0,2	-0,2	0,8	1,3	32	,216
f_bla_C - i_amar_E	0,2	1,0	0,2	-0,2	0,5	0,9	32	,377
f_bla_C - f_rojo_F	0,2	1,2	0,2	-0,2	0,6	1,0	32	,325
f_bla_C - f_ámb_G	0,2	0,6	0,1	0,0	0,4	1,8	32	,083
f_bla_C - f_amar_H	0,3	1,0	0,2	-0,1	0,7	1,7	32	,106
f_bla_C - Mich_I	-0,1	1,4	0,2	-0,6	0,4	-0,2	32	,810
f_bla_C - i_rojo_J	0,2	1,3	0,2	-0,3	0,6	0,8	32	,423
W_D - i_amar_E	-0,2	1,5	0,3	-0,7	0,4	-0,6	32	,561
W_D - f_rojo_F	-0,1	1,4	0,2	-0,6	0,4	-0,4	32	,702
W_D - f_ámb_G	-0,1	1,4	0,2	-0,6	0,4	-0,5	32	,619
W_D - f_amar_H	0,0	1,6	0,3	-0,6	0,6	0,0	32	1,000
W_D - Mich_I	-0,4	1,7	0,3	-1,0	0,2	-1,2	32	,221
W_D - i_rojo_J	-0,1	1,4	0,2	-0,6	0,4	-0,5	32	,630
i_amar_E - f_rojo_F	0,1	1,0	0,2	-0,3	0,4	0,3	32	,737
i_amar_E - f_ámb_G	0,0	0,9	0,2	-0,3	0,4	0,2	32	,851
i_amar_E - f_amar_H	0,2	1,0	0,2	-0,2	0,5	0,9	32	,377
i_amar_E - Mich_I	-0,2	1,4	0,2	-0,7	0,3	-0,9	32	,386
i_amar_E - i_rojo_J	0,0	0,9	0,2	-0,3	0,3	0,2	32	,845
f_rojo_F - f_ámb_G	0,0	1,1	0,2	-0,4	0,4	-0,2	32	,876
f_rojo_F - f_amar_H	0,1	1,1	0,2	-0,3	0,5	0,5	32	,638
f_rojo_F - Mich_I	-0,3	1,2	0,2	-0,7	0,2	-1,3	32	,213
f_rojo_F - i_rojo_J	0,0	1,0	0,2	-0,4	0,3	-0,2	32	,856
f_ámb_G - f_amar_H	0,1	1,2	0,2	-0,3	0,5	0,6	32	,555
f_ámb_G - Mich_I	-0,2	1,4	0,2	-0,7	0,3	-1,0	32	,325
f_ámb_G - i_rojo_J	0,0	1,1	0,2	-0,4	0,4	0,0	32	1,000
f_amar_H - Mich_I	-0,4	1,4	0,2	-0,9	0,1	-1,5	32	,142
f_amar_H - i_rojo_J	-0,1	1,3	0,2	-0,6	0,3	-0,5	32	,594
Mich_I - i_rojo_J	0,2	1,4	0,3	-0,3	0,8	1,0	32	,340