Affective evaluation of the luminous environment in university classrooms

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Highlights

- Analysis of the luminous environment appropriate to different classroom tasks.
- 854 university students assess the lighting in situ in 29 university classrooms.
- Identification of students' affective response to the luminous environment.
- Luminous environment has to generate different sensations to adapt to new tasks.

Abstract

Universities worldwide are adopting new teaching methods and using new educational technologies. This progress requires changes in their physical environment, especially in the case of lighting, which is regarded as fundamental because of its recognised effect on the learning process. Different light levels are needed for new classroom tasks.
The aim of the present paper is to analyse the affective impressions of university students with regard to the luminous environment in their classroom, in relation to the different tasks they carry out there. This analysis is conducted in the frame of Kansei Engineering. A sample of 854 students assessed in situ the luminous environment of 29 classrooms. In the first stage, subjective evaluation scales adapted to the students were defined and then related to the classroom tasks.

The results show that students' affective responses in the assessment of the luminous environment in their classroom can be explained through the following dimensions: *Clear-efficient, Uniform, Cheerful-colourful, Warm-cosy, Surprising-amazing* and *Intense-brilliant*. The relation of these dimensions to the tasks shows that the luminous environments in the classrooms need to be changed in accordance with the nature of the tasks. The environment should be different for the tasks groups of *Writing-reading*, *Reflecting-discussing* (for collaborative work) and *Paying attention*. It seems, therefore, that new classroom lighting guidelines, tailored to the new methodologies and technologies, are needed.

Keywords

Luminous environment; classroom tasks; affective response; university classroom, Kansei engineering; student perception.

1. INTRODUCTION

Even in the earliest school buildings it was recognised that light, or its absence, has a fundamental effect in learning environments (Wu & Ng, 2003), as it can influence student performance (Samani & Samani, 2012) and academic achievement (Barkmann, Wessolowski, & Schulte-Markwort, 2012). The importance of light stems from its effects on humans (Boyce, 2010): visual (Korsavi, Zomorodian, & Tahsildoost, 2016), psychological (Veitch, 2001), biological (van Bommel & van den Beld, 2004) and physiological (Wilkins, 2016).

However, despite the many contributions on the impact of light on human beings, it is recognised that ensuring good light quality in an educational environment is a complex task (Bellia, Spada, Pedace, & Fragliasso, 2015). One of the most significant difficulties is in conducting these type of studies in real environments. Most experiments have been carried out in laboratory environments, controlling the effect of each variable (Yan, Lee, Guan, & Liu, 2012), generally using only electric lighting, because that can be easily manipulated. Thus, these studies have examined isolated effects of lighting, such as illuminance (Durak, Camgöz Olguntürk, Yener, Güvenç, & Gürçınar, 2007), colour temperature (Park, Chang, Kim, Jeong, & Choi, 2010) or uniformity (Chraibi, Crommentuijn, Loenen, & Rosemann, 2017), providing interesting specific contributions. It is not known, however, whether these results would be different if the experiments were reproduced in real environments, in which several specific light attributes would simultaneously be interacting (Bellia, Pedace, & Barbato, 2013). Furthermore, the classroom environment requires consideration of another issue; students spend many hours in an environment where daylight conditions can fluctuate greatly and very quickly. Most of that time, daylight interacts with artificial lighting and few studies have examined this interaction (Bellia et al., 2013). In fact, the need for integrated systems of daylight and electric light is broadly accepted (Ricciardi & Buratti, 2018).

An additional issue is the use and development of the new educational methods and technologies that are changing higher education. New ways of learning are expected to require changes in the physical environment (Beckers, van der Voordt, & Dewulf, 2015), which means that the educational community has become increasingly interested in adapting its spaces to these changes (Brooks, 2012). As much effective learning takes place as a result of interactions between students, designs need to provide a variety of spaces where students can together work and socialise (Kuh, Kinzie, Schuh, Whitt, & Associates, 2010). Learning is becoming more interactive and modern classrooms are expected to be more student-centric (Uzelac, Gligoric, & Krco, 2015). New technologies and new teaching methods mean that very different visual tasks are performed in the classroom, considerably complicating the analysis of the researcher.

A further problem is the identification of users' impressions. Most works evaluate this subjective component through questionnaires, tests or rating scales. Among the most important studies regarding these lighting aspects are the works of Flynn, Hendrick, Spencer and Martyniuk (1979), Mehrabian and Russel (1974), Hawkes, Loe and Rowlands (1994), Boyce and Cuttle (1990), Tiller and Veitch (1995), Manav and Yener (1999), Durak (2007), Newsham, Richardson, Blanchet and Veitch (2005) and Houser, Tiller, Bernecker and Mistrick (2002). In these studies, the evaluators are mostly non-experts in lighting, but all the concepts and evaluation attributes were always set out in advance by researchers or experts. This approach means that the questionnaires do not take into account the mental scheme of the non-experts or users, which is a significant limitation. Non-experts, such as the students in this case, may not perfectly understand the concepts put to them by the lighting experts, which can lead to erroneous results or increased response variance due to uncertainty over the meaning of the magnitude descriptors, as Fotios (2015) points out. Furthermore, as experts filter the information to assess, some of the parameters appreciated by non-experts may never be evaluated.

The technique used in this study is based on the Semantic Differential method (SD). The SD, developed by Osgood, Suci and Tannenbaum (1957), is a useful tool for measuring subjective responses to concepts (Ishihara, Ishihara, Nagamachi, & Matsubara, 1997). The technique studies product semantics by measuring the use of expressions and adjectives which reflect the user's affective impressions and perceptions, using a Likert scale. This technique is one of the most commonly used methods for assessing product perception in Kansei Engineering.

The Kansei/Affective Engineering (KE) technique, derived from the user-friendly product design area, is able to identify and quantify users' perceptions of a product in their own language and to find quantitative relationships between these subjective responses and design features (Nagamachi, 1995). The advantage of KE over other similar techniques, such as Quality Function Development (Cohen, 1995) or Conjoint analysis (Green & Srinivasan, 1978), is that it enables the establishment of a suitable framework to work with symbolic attributes and user perceptions not defined by experts, but expressed through the user's own words. KE is based on the principle that an individual's judgement is not only influenced by stimuli (a combination of objective and subjective parameters) but also by the conceptual scheme of a concrete group of users (semantic space). In essence, to achieve an accurate evaluation, the assessment variables must be adapted to the users' mental scheme. This conceptual scheme is represented by a set of independent concepts (semantic axes), employed by users to describe their sensations in relation to a product. Many works have used SD in the framework of KE to analyse users' perceptions of a multitude of products (Nagamachi, 1995), including in the analysis of lighting equipment (Xiaoyun, Xiaoj, & Yan, 2009). In the field of environmental appraisal, there have been contributions in acoustic and sound perception (Galiana, Llinares, & Page, 2012), thermal environments (Nishikawa, Hirasawa, & Nagamachi, 1997) and classroom environments (Castilla, Llinares, Bravo, & Blanca, 2017). Nevertheless, to our knowledge, there are no examples of the application of KE to classroom lighting with the aim of measuring students' responses.

The aim of the present paper is to analyse the affective impressions of university students with regard to the luminous environment in their classroom, taking into account the different tasks performed there. The study is conducted using KE methodology.

2. MATERIAL AND METHODS

The methodological development used a field study to collect students' evaluations of their classroom.

2.1. Subjects

The participants were 854 students, habitual users of the classrooms under evaluation. Their mean age was 22.3 years, with a standard deviation of 4.72. In the sample, 73.37% were between 19 and 24 years of age (Table 1).

Table 1. Data of the subjects participating in the field study

Gender	Male	414	48%
	Female	440	52%
Age	<20	201	24%
	20-25	539	63%
	26-30	77	9%
	31-40	20	2%
	>40	17	2%

2.2. Research settings

The research settings used in the field study were 29 classrooms in two universities (Figure 1). The extraction of affective impressions, or semantic axes, involves establishing relationships between many variables, and so responses in a broad range of judgements are needed. It is therefore advisable that the users be asked to give their opinions on a sample of classrooms with a variety of characteristics. The classrooms were selected, first, on the basis that their luminous environments were sufficiently representative and differentiated to form part of the sample. As regards daylight, the type of openings, window size and protection from direct sunlight were considered. Artificial lighting was distinguished by types of lamp, luminaires, average luminance, colour temperature, chromatic reproduction index and other light variables. As university classrooms are mostly used when natural light and artificial light are available, we ensured that both were present during the sessions. The experiment was conducted between mid-February and May, to ensure that the climatic conditions were as similar as possible and would not affect the students' responses as much as they might during a cold or hot season. Finally, the study attempted to cover a wide range of types of classrooms, with different ceiling heights, surface areas, finishes and types of teaching (theory, practical, laboratory and project work, etc.). This variety of characteristics or design attributes may seem to be confounding factors, not fully under control, and capable of creating bias in the results. However, the solution described was adopted to reduce bias by introducing the set of characteristics or attributes in a fully random fashion (Kish, 1995).

Figure 1. Classrooms in the stimuli sample

2.3. Questionnaire

The questionnaire had two clearly differentiated blocks. The first block collected information on the individual, i.e. age, gender and vision problems. The second block collected the following subjective information:

a. 37 expressions describing students' affective impressions of the luminous environment in the classroom.

The first step was to collect as many words and expressions as possible (from interviews with the students, scientific documentation, specialized bibliographies, the Internet, journals and professional lighting magazines) that are used to describe the attributes of the luminous environment in classrooms. The underlying objective was to collect a set of words capable of describing any possible perception about a specific attribute of the luminous environment. A total of 178 expressions were compiled in this phase. However, we decided that this number of adjectives was too great to be included in a questionnaire. To reduce this number the affinity diagram technique (Terninko, 1997) was applied. This technique consists of forming groups of similar words, according to their affinity, and assigning one significant word to embrace all the expressions in the group. The grouping was made in sessions with 10 participants (2 professors, 6 students and 2 Kansei experts). The sessions proceeded as follows: (a) the Kansei words were transferred onto post-it notes, so that each note contained only one expression. There was no questionnaire; participants simply wrote their impressions of classroom lighting on post-it notes. (b) the notes were grouped by similarity or affinity. This process ended when all the ideas or words were grouped and (c) each group was given a title or heading that represented all the Kansei words in the group. The set of expressions finally obtained formed the reduced semantic universe, in this case, 37 expressions. This set of affective impressions was included in the questionnaire with the expression, “In my opinion, the luminous environment of the classroom is ….”.

b. 12 types of tasks representative of the main activities performed in the classroom. These tasks were identified following the same process used to obtain the affective impressions. First, a total of 34 tasks were identified by reading teaching texts and manuals and consulting students and professors. These tasks were grouped into a total of 12, using the affinity diagram technique (Terninko, 1997), with the participation of the same 10 individuals. This set of tasks was included in the questionnaire with the expression: “In my opinion, the luminous environment of the classroom is suitable for ….”.

c. In addition to these expressions, one variable was included in the questionnaire to reflect the students’ overall evaluation of the luminous environment, with the expression: “In general terms, I think the classroom is well lit”.

The adjectives were evaluated using a 5-point-Likert scale, ranging through totally disagree, disagree, neutral, agree and totally agree. To ensure that the questionnaire could be completed in a reasonable amount of time and that the wording and the sequencing of the questions were appropriate, the questionnaire was pre-tested. This pre-testing process was carried out with 20 students.

2.4. Development of the field study

The field study collected the interviewees’ evaluations of the luminous environment of the classroom where they were, at that moment, physically located. As the subjects had to evaluate the luminous environment in situ, they were “immersed” in the stimulus. It was decided to undertake the field study in the classroom because laboratory conditions cannot represent real settings with 100% reliability.

Participants were asked to complete the questionnaires immediately after their classes had finished; thus, they had been in situ long enough to evaluate the luminous environment. Students were individually informed of the study objectives. The questionnaire included instructions on how to fill it in correctly. The average time taken to complete the questionnaire was 10 minutes. Five different versions of the questionnaire were created; and the order of the questions was randomized in order to avoid any bias in the subjects’ responses.

2.5. Data processing

The data were processed statistically using SPSS software. The analysis was divided into two phases. In the first phase, the objective was to identify the set of significant affective impressions of the overall assessment of the luminous environment. First, the set of affective impressions, or semantic axes, was identified, using Factor Analysis (Basilevsky, 1994). This technique is able to identify uncorrelated variables that characterize the perception of a concrete product, in this case, the classroom's luminous environment. Each axis, or factor, is made up of a combination of concepts from the original set, so it shows significant correlations in users’ responses. Thus, concepts that usually have similar evaluations are grouped and they represent common concepts that users implicitly employ to assess properties. After that, the impact of each of the axes on the global assessment was identified, using linear regression analysis. The second phase focused on obtaining the relationship between the affective impressions and the different tasks performed in the classrooms. Factor Analysis was run to identify the set of classroom tasks undertaken, grouped according to the luminous environment assessment. Then the relationship between these tasks and the affective impressions obtained in Phase I was analysed using Spearman's correlation coefficient.

3. RESULTS

3.1. Phase I: Identification of significant affective impressions in the overall assessment of the luminous environment of the classroom

3.1.1. Obtaining affective impressions or semantic axes

Factor analysis grouped the 37 expressions in the questionnaire into six axes or factors. These semantic axes represent the set of subjective evaluation scales adapted to the language of the students to assess the luminous environment; they explain 61.17% of the variance (Table 2). Factor analysis allows us to group the adjectives based on the users' assessments, so that the adjectives that make up a group show significant correlations to the users' responses. The contribution of the original variables to the axis was analysed to determine the concept associated with each of them; the following six axes were obtained:

Table 2. Factor analysis of affective impressions

Factor analysis

	1	2	3	4	5	6
Surprising	,853					
Amazing	,826					
Awesome	,727		,337			
Original	,718					
Interesting	,717					
Stimulating	,709					
Suggestive	,589		,446			
Efficient		,698				
Clear		,683				
Sharp (defined)		,649			,329	
With quality (rich)		,645				,360
Bright		,613			,357	
Functional		,568		,431		
Convenient		,555			-,328	,310
Comfortable		,501	,465			
Cheerful	,379		,667			
Colourful	,361		,636			
Friendly	,323		,633			
Lively	,430		,609			
Dynamic	,441		,532			
Beautiful	,471		,477			
Enabling	,386	,390	,454			
Uniform				,778		
Homogeneous				,741		
Balanced		,349		,671		
Orderly		,368		,671		
Glaring (dazzling)					,739	
Intense			,360		,634	
Brilliant					,600	
Calm				,314	-,441	,347
Quiet				,358	-,437	
Soft			,306	,355	-,422	,402
Warm						,712
Cosy						,599
Pleasant		,525				,531
Natural		,335				,517
Dim (subtle)					-,379	,487
% Variance explained	15.16	12.15	10.29	8.52	7.57	7.48
Cronbach's Alpha	0.91	0.87	0.88	0.80	0.66	0.70

- 1st axis: this axis describes the perceptions of the luminous environment of the classroom as *Surprising-amazing*. The kansei words that contribute most to this factor are “surprising”, “amazing”, “awesome”, “original”, “interesting”, “stimulating” and “suggestive”. This factor explains 15.16% of the variance.
- 2nd axis: this axis represents the sensations of *Clear-efficient* evoked by the luminous environment. The adjectives in this axis refer to the perception as “efficient”, “clear”, “sharp”, “with quality”, “bright”, “functional”, “convenient” and “comfortable”. It explains 12.15% of the variance.
- 3rd axis: this axis represents the impressions of *Cheerful-colourful* of the luminous environment. Adjectives such as “cheerful”, “colourful”, “friendly”, “lively”, “dynamic”, “beautiful” and “enabling” are very significant on this factor. It explains 10.29% of the variance.
- 4th axis: this axis reflects the perception *Uniform* of the luminous environment with adjectives such as “uniform”, “homogeneous”, “balanced” and “orderly”. It explains 8.52% of sample variability.
- 5th axis: this axis describes the impressions of the luminous environment as *Intense-brilliant*. The kansei words that contribute most to this axis are “glaring-dazzling”, “intense”, “brilliant” and have opposite meanings (negative correlation) to the adjectives “calm”, “quiet” and “soft”. This factor explains 7.57% of the variance.
- 6th axis: This axis represents the impressions of *Warm-cosy* of the luminous environment with “warm”, “cosy”, “pleasant”, “natural” and “dim, subtle” as main concepts. It explains 7.48% of the variance.

The consistency of the perceptual space was verified with Cronbach's alpha. The values for this reliability coefficient for the first six dimensions ranged from 0.66 to 0.91, showing that these scales have considerable reliability (Streiner, 2003).

It is worth emphasising that the ranking of the extracted factors is related to their eigenvalues and therefore to the amount of explained variance. A high eigenvalue for an axis implies that participants' answers display more variability along that axis than along others. For example, in this case, students find greater differences in the luminous environment of some classrooms compared to others with Surprising-amazing, Clear-efficient or Cheerful-colourful environments. In addition, they are uncorrelated factors, which means that conceptually the students are very clear that they are dealing with different attributes.

3.1.2. Analysis of the relationship between affective impressions and global assessment of the luminous environment of the classroom

Perception axes were ordered, using linear regression analysis, according to their relationship with the variable 'global assessment of the luminous environment of the classroom'. The model (Table 3) includes 5 significant axes. The R coefficient is 0.720, so the model has good predictive ability. The axis with the greatest influence on the global evaluation of the luminous environment is the perception "*Clear-efficient*", with a positive correlation over 0.57. This axis is followed by perceptions that it is "*Uniform*", "*Cheerful-colourful*", "Warm-cosy" and "*Surprising-amazing*". The axis "*Brilliant-intense*" is not significant in the model.

Table 3. Linear regression model of the global assessment variable of the classroom's luminous environment

Model	B	Standard dev.	β	t	Sig
(Constant)	0,438	0,024		18,085	0,000
Clear-efficient	0,573	0,024	0,595	23,658	0,000
Uniform	0,276	0,024	0,286	11,395	0,000
Cheerful-colourful	0,195	0,024	0,203	8,065	0,000
Warm-cosy	0,156	0,024	0,162	6,449	0,000
Surprising-amazing	0,122	0,024	0,127	5,047	0,000
Intense-brilliant	0,017	0,024	0,018	0,714	0,475
R = 0.72					

3.2. Phase II: Analysis of the relationship between affective impressions and the different tasks performed in the classroom

3.2.1. Obtaining groups of tasks

The factor analysis grouped the 12 types of principal tasks that students carry out in classroom into three factors, or axes, according to the assessment of the luminous environment. These axes explain 64.87% of the variance (Table 4).

Table 4. Factor analysis of groups of tasks

	1	2	3
Writing	,894		
Reading	,873		
Reviewing notes	,758	,314	
Drawing	.757		
Correcting	.583	.461	
Reflecting		.743	
Discussing	.312	.723	
Working on the computer		.658	
Paying attention to the board			.866
Paying attention	.323		.785
Asking the teacher		.383	.594
Looking at the projector		.401	.438
% Variance explained	28.42	18.29	18.16
Cronbach's Alpha	0.88	0.70	0.73

The contribution of the original variables to the factors was analysed to determine the concept associated with each of them, thereby obtaining the following three factors:

- 1st factor: This factor groups the tasks related to *Reading-writing* performed by students in the classroom. This factor is associated, with positive correlation, with the tasks "writing", "reading", "reviewing notes", "drawing" and "correcting". This factor explains 28.42% of the variance in the original variables.
- 2nd factor: This factor represents the tasks of *Reflecting-discussing*. It is associated, with positive correlation, to the tasks of "reflecting", "discussing" and "working on the computer". It explains 18.29% of the variance.
- 3rd factor: The third factor represents the tasks of *Paying attention*. It is associated, with positive correlation, to the tasks "paying attention to the board", "paying attention", "asking the teacher" and "looking at the projector". It explains 18.16% of the sample variance.

Consistency of perceptual space was verified with Cronbach's Alpha. The values for this reliability coefficient for the first three dimensions ranged from 0.70 to 0.88, showing that these scales have considerable reliability (Streiner, 2003).

3.2.2. Analysis of the relationship between groups of tasks and affective impressions

The relationship between the affective impressions of the classroom and the groups of tasks was established with a nonparametric Spearman correlation coefficient (Figure 2).

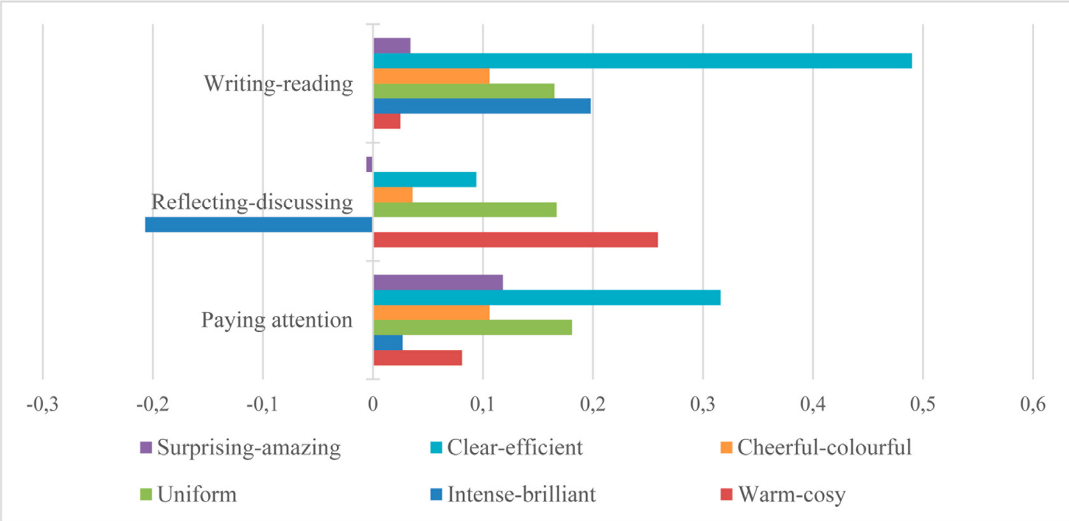

Figure 2. Relationship affective impressions and groups of tasks

The results clearly show that the different tasks to be carried out in the classroom require different luminous environments.

Thus, the tasks factor *Writing-reading* mainly requires the luminous environment to generate the sensation *Clear-efficient*. To a lesser extent, but also with a significant correlation, the luminous environment should generate the sensations *Intense-brilliant, Uniform* and *Cheerful-colourful.* The sensations *Surprising-amazing* and *Warm-cosy* have no significant correlation with the tasks factor *Reading-writing*.

The tasks factor *Reflecting-discussing* is mainly related to the luminous environment generating the sensation of *Warm-cosy* and not generating the sensation of *Intense-brilliant.* To a lesser extent it relates to the sensation of being *Uniform*. The other impressions, *Cheerful-colourful* and *Surprising-amazing*, show no significant correlation with this factor.

Finally, the tasks factor *Paying attention* shows significant correlations with the set of affective impressions, except for *Intense-brilliant*. Of the set of significant impressions, the sensation that the luminous environment is *Clear-efficient* stands out the most. With lower correlations, and by order of importance, are the sensations *Uniform, Surprising-amazing, Cheerful-colourful* and *Warm-cosy.*

4. DISCUSSION

This paper aims to analyse students' affective responses to the luminous environment in university teaching classrooms according to the tasks or activities they perform. For that purpose, in the frame of KE, evaluation criteria were determined that related to the overall assessment of the luminous environment in classrooms and its relationship to the tasks performed. The results show significant methodological and practical contributions.

From the methodological point of view, the most outstanding contribution is the application of SD, in the framework of KE, to evaluate students' affective responses to the luminous environment in their classrooms. Thus, the attributes used to find relations between the luminous environment and the tasks that students perform in the classroom are defined not by experts but by the students themselves. The studies about the subjective evaluation of lighting in classrooms are based on concepts or attributes defined by experts (Veitch & Newsham, 1997). In this approach, the evaluation process may be conditioned because users may not understand the concepts, which might lead to erroneous results being obtained (Fotios & Atli, 2012). In fact, Fotios and Atli (2012) suggest that judgements made about luminous parameters by naïve test participants can lead to different outcomes depending on whether the terms used in the assessment have been previously defined. In this work, the use of SD provides subjective evaluation scales adapted to the language of the students, without intervention from experts. This initial phase is fundamental in the Kansei process because, if the evaluation scales are based on attributes that are not understood by the students, or concepts that provide overlapping information, it is very difficult to find statistical evidence of the relationship between the affective response and the global assessment of the luminous environment.

As regards the practical contribution, the findings of this study provide important outcomes:

In the first place, the study has obtained the affective structure of students in relation to the luminous environment in their classrooms. Six axes, which explain 61.17% of the variance, were identified: *Surprising-amazing*; *Clear-efficient*; *Cheerful-colourful*; *Uniform*; *Intense-brilliant* and *Warm-cosy.* These more precisely describe the conceptual structure students use to differentiate between the luminous environments of university classrooms.

The results of this paper are difficult to compare with other works because of the few studies into the luminous environment in classrooms in the framework of KE (Hemphälä & Eklund, 2012). In general, most works assess a specific variable of light, quite often in controlled conditions, and not the sensation it generates overall where all the intervening variables are acting simultaneously. However, some of the results obtained are in line with results reported in previous studies.

In this study, the axis *Surprising-amazing,* understood as the ability of the luminous environment to generate surprise or interest, can be related to works that have used this dimension in a similar way, using expressions like "stimulating" (Boyce & Cuttle, 1990) or "interesting" (Veitch & Newsham, 1998).

The axis *Clear-efficient* unites the concepts of light and comfort which other studies have analysed separately (Boyce & Cuttle, 1990). In fact, these concepts appear to be linked to the concept of visibility or visual comfort, two important topics in lighting research (D. Loe, Watson, Rowlands, Mansfield, & Baker, 1999). This axis also appears to be related to the sensation of “bright”, a widely used adjective (Izsó, Láng, Laufer, Suplicz, & Horváth, 2009), “clear” (Küller & Wetterberg, 1993), “clarity” (Durak et al., 2007) or “brightness” (Newsham et al., 2005). In this case, the students’ responses have grouped the terms “clear” and “bright”. Fotios and Atli (2012) noted that, among non-experts, these attributes were similarly judged, although experts clearly differentiate between them. Moreover, Flynn et al. (1979) found that the adjectives clear-hazy, bright-dim and other rating scales were used in similar ways and grouped them under the label “visual clarity”.

The axis *Cheerful-colourful* reflects the union of the adjectives “friendly” and “beautiful”. These concepts were also grouped by Flynn et al. (1979), under the factor they denominated “evaluative”. The adjectives “colourful” and “friendly” have also been used separately in other studies (Boyce & Cuttle, 1990). The adjective “colourful” has also been used as “coloured” (Harfitt, 2012).

The axis *Uniform* can be related to the expression “complexity” used in the results reported by Veitch and Newsham (1998) and to other works that also used the adjective “uniform” (Boyce & Cuttle, 1990) or “uniformity” (Pellegrino, 1999).

The axis *Intense-brilliant* describes adjectives studied in other works, such as “brilliant” (Johansson, Rosen, & Küller, 2010) and their opposites, “relaxation” (Durak et al., 2007), “relaxing” (Izsó et al., 2009) and “soft” (Boyce & Cuttle, 1990). We highlight in this axis the concept "glaring-dazzling", previously used as "glaring" (Küller & Wetterberg, 1993). This inclusion reflects the affinity that the participants perceive between the concept "glaring-dazzling" and the other expressions that make up this axis. This relationship is important for lighting researchers if they include the concept "glaring" in their questionnaires, since, as can be seen, it seems to have different connotations for the user and the expert.

The axis *Warm-cosy* seems to be an important dimension in works on the evaluation of lighting as "warm" light (Küller & Wetterberg, 1993) and its opposite, the adjective "cold" (Harfitt, 2012). This axis unites the adjectives "warm" and "natural", which have been studied separately in other works (Boyce & Cuttle, 1990). It also includes the adjective "pleasant", which has been widely used (Arsenault, Hébert, & Dubois, 2012). The adjectives in this axis can be related to the "cosiness" dimension described by Vogels (2008) as a dimension to quantify the perceived atmosphere of an environment.

In second place, the regression analysis results are significant as they indicate that, although the set of axes are important for the global assessment of the classroom's luminous environment, efforts to improve the luminous environment should mainly be directed towards two aspects: the perceptions of the environments as *Clear-efficient* and *Uniform.* The axis *Clear-efficient* is an important dimension since it includes the adjectives "Clear" and "bright" together. Boyce and Cuttle (1990) asked test participants to describe the lighting in a room in their own words and found that they mainly used the terms brightness and clarity. In the case of the axis *Uniform*, the work of Slater & Boyce (1990) indicates that uniformity plays an important role in work efficiency and comfort. In addition, a comparison of these results with existing evidence from the literature shows that they are in line with other studies where these two dimensions are considered the most meaningful way of appreciating a space (Stokkermans, Vogels, de Kort, & Heynderickx, 2017). Hawkes, Loe and Rowlands (1979) suggest that people describe their perception of light in a space using two dimensions: brightness and interest (or non-uniform), where brightness is related to the perceived intensity of the light and interest to the perception of uniformity. They showed that spaces rated high on brightness and interest were often judged as more attractive.

Third, this study shows the relationship between the tasks that students perform and their affective impressions. The groups of classroom tasks linked according to the luminous environment assessments are *Writing-reading*, *Reflecting-discussing* and *Paying attention*. These three independent factors explain 64.87% of the variance. This relationship provides a significant contribution (Figure 2), the luminous environment must generate different types of sensations to adapt to the different types of tasks performed in a classroom. These findings are in line with the results obtained using variable lighting in teaching environments (Wessolowski, Koenig, Schulte-Markwort, & Barkmann, 2014). The tasks of *Writing-reading* mainly require a luminous environment that generates the sensations *Clear-efficient, Intense-brilliant* and *Uniform.* This result seems logical because, with an increase in illuminance, vision improves and, therefore, the ability to perceive optical information (van Bommel & van den Beld, 2004) increases, facilitating reading and writing (Govén, Laike, Raynham, & Sansal, 2009). In this regard, the results are in line with the governing standards, such as UNE-EN 12464-1(2012), which regulates the parameters of uniformity, illuminance and glare in teaching spaces. Note that the procedure used to develop this standard is based on reading and writing tasks.

The tasks of *Reflecting-discussing* mainly require a luminous environment that generates the sensation *Warm-cosy* and not the sensation *Intense-brilliant*. Some studies indicate that, to facilitate learning, students must feel comfortable enough to take the individual and collective risks necessary for significant interaction and learning (Uline & Tschannen-Moran, 2008). It has been found that an *Intense-brilliant* luminous environment is not suitable for these tasks. Schreiber (1996) suggested that, when brightness is reduced, children become more relaxed and interested in classroom activities.

Finally, the tasks related to *Paying attention* mainly require a luminous environment that generates the sensations *Clear-efficient, Uniform* and *Surprising-amazing.* Although the attribute *Clear-efficient* coincides with the tasks factor *Reading-writing*, its combination with the other attributes generates a totally different luminous environment. The task of *Reading-writing* requires a *Clear-efficient* and *Intense-brilliant* environment, which can be understood to mean a strongly lit environment. Whereas *Paying attention* requires an environment that is *Clear-efficient*, *Uniform* and S*urprising-amazing,* which seems to correspond to an environment suitable for paying attention to a board or a projection screen, that is, an environment with homogenous lighting but with sufficient contrast in the aspects that are the focus of attention, generating the sensation *Surprising-amazing*. Previous studies have shown that stronger lighting impacts on students' attention (Veitch, 2001) and concentration (Sleegers et al., 2012). These results suggest that further studies are required to propose new luminous environments in teaching spaces adapted to the new methodologies and technologies.

It is interesting to highlight the results obtained for the *Intense-brilliant* axis, which, despite explaining part of the variance in students' perceptions regarding lighting and having a strong influence on two of the main classroom tasks, does not seem to be significant in the overall evaluation of the luminous environment. It is possible that a compensatory effect is produced, that is, the positive and significant influence on the *Writing-reading* task compensates for the negative and significant influence on the task *Reflecting-discussing*. With the third task there is no significant relationship. Hence the importance of separating, in an evaluation analysis of the lighting environment, the different tasks to be developed in the classroom.

The limitations of the study include the fact that the experiments took place in real university classrooms. This has the disadvantage that the various elements that may influence perception were combined in the actual classrooms. However, this aspect is not so important in the phase where we obtained the semantic axes, where variety is of more interest than uniformity. The objective of SD is to obtain independent semantic axes based on the assessment of a sample of stimuli. For results to be representative there must be a sufficient sample of individuals, but also a sample of stimuli that provides a broad range of different assessments for each adjective and the relationships between them. In any case, the solution adopted here is the one described by Kish (1995) as a way of controlling an experiment, by including variables randomly, on the basis that chance will generate equivalent distributions of the units in all the variables under study. Thus, the bias produced is smaller.

5. CONCLUSIONS

This paper analyses the affective impressions of university students in relation to the luminous environment in their classrooms, taking into account the different tasks they perform there. The study defines subjective evaluation scales adapted to the users, by applying a model where the student is placed at the centre of the lighting design process in a classroom environment. This approach is based on KE as a methodology capable of connecting the luminous design elements of the classroom with students' affective responses, thereby obtaining improved student satisfaction with, and experience of, the luminous environment. The results show that the luminous environment must generate different types of sensations to adapt to the different teaching tasks. It seems, therefore, that new lighting guidelines for teaching spaces, tailored to the new methodologies and technologies used in the classroom, are needed. These results can be of interest for lighting designers, engineers and architects to develop new classroom lighting which attempts to satisfy students' specific expectations.

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