Frontiers of Architectural Research (2018) 7, 600–609

Available online at www.sciencedirect.com

Frontiers of Architectural Research

www.keaipublishing.com/foar

RESEARCH ARTICLE

Emotional evaluation of lighting in university classrooms: A preliminary study

Nuria Castilla[a,*], Carmen Llinares[b], Fabio Bisegna[c], Vicente Blanca-Giménez[a]

[a]*Dpto. Construcciones Arquitectónicas, Universitat Politècnica de València, Camino de Vera, s/n, Valencia 46022, Spain*
[b]*Instituto de Investigación e Innovación en Bioingeniería, i3B, Universitat Politècnica de València, Camino de Vera, s/n, Valencia 46022, Spain*
[c]*Dept. of Astronautical, Electrical and Energetic Engineering (DIAEE), SAPIENZA University of Rome, Via Eudossiana 18, Rome 00184, Italy*

Received 24 July 2017; received in revised form 3 July 2018; accepted 15 July 2018

KEYWORDS
Kansei engineering;
Lighting;
Fluorescent;
LED;
Subjective assessment;
University classroom

Abstract
In educational environments an improvement in the quality of interior lighting has a direct benefit in increasing productivity and alertness of students and teachers, as well as very important implications for the energy efficiency of the education facilities but when a replacement with different lighting is analyzed, research may be tarnished by users' pre-formed opinions, influenced by manufacturers and advertising. Consequently, it is necessary to understand the users' point of view, even before of being subjected to any change in the lighting stimulus.
Based on the Kansei Engineering framework, the general objective of this paper is to evaluate and compare the subjective evaluation of students' pre-formed opinions to lighting provided by two types of lamps (fluorescent and LED). The subjective assessment of 427 university students has been compared over four years. The results show significant differences in students' subjective evaluation. This finding highlights the existence of symbolic or functional attributes of the usefulness perceived by the student that could influence on investigations in which different types of lighting are compared.

*Corresponding author.
E-mail address: ncastilla@csa.upv.es (N. Castilla).
Peer review under responsibility of Southeast University.

https://doi.org/10.1016/j.foar.2018.07.002

1. Introduction

When planning new lighting, architects, engineers, and lighting designers tend to assume that their individual experience reflects the requirements and wishes of most of the public; thus, they base their projects and designs on incorrect assumptions about human perception. Further research is required for architects, engineers, and lighting designers to combine design criteria and human emotional preferences when planning lighting in buildings. This requirement is especially important in educational spaces for which research has shown that school facility design affects student learning, attendance, and teacher turnover rates (O'Neill and Oates, 2001). In addition, students consider lighting an important design factor in classroom environment (Castilla et al., 2017). Lighting conditions have been shown to have an influence on the fundamentals of human life, that is, health, wealth, and safety (Boyce, 2003). Therefore, learning spaces, where the quantity and quality of light is controlled, should be created. Many studies have analyzed the subjective component of user response to specific lighting arrangements but ignored users' involuntary or unconscious reactions.

Light-emitting diodes (LEDs) are the next-generation energy efficient illumination. They offer long lifetimes, dynamic light effects, and great design flexibility (Caicedo et al., 2011). These characteristics make LEDs an attractive light source. LED downlights surpass traditional compact fluorescent (FL) lamps in terms of lighting efficiency and quality (Hoelen et al., 2008). However, the use of LED tubes as replacements for FL lamps is controversial. Several distributors recommend their products as superior replacements for conventional T8 FL lamps because of potential energy savings and the long life of LEDs (Ryckaert et al., 2012); however, they do not consider other implications, especially in learning environments where improvements in the quality of indoor lighting increase productivity and alertness in students and teachers (Hughes, 1981). Improved lighting also has important implications for energy efficiency in education centers.

Numerous factors are linked to people's intrinsic attributes, which condition the perception of luminous stimuli. One of these is the prior opinion individuals already hold regarding the stimulus under study. Further research should be conducted to clarify the relationship between lighting quality parameters and aesthetic and emotional judgements (Manav, 2007). Physiological and psychological factors affect the perception of light and space. Light induces visual and non-visual responses; light affects performance, mood, and attention and influences the synchronization of the biological clock (Mills et al., 2007). A luminous stimulus is a multisensory concept; thus, the perception of a specific stimulus is conditioned by an array of senses.

Interior design uses the manipulation of many interrelated elements, including space, form, structure, lighting, texture, and color. Of these elements, lighting often receives the least attention (Durak et al., 2007). In this regard and in view of the psychological principles of emotions, the contribution of emotional design and subjective elements may provide a useful tool for professionals who can incorporate these concepts into their projects. Knowledge of users' points of view can help researchers and manufacturers when making assessments to offer products that are closely tailored to user requirements.

Several researchers have investigated the psychological aspects of space lighting. The attributes employed in this research are based on those used by Flynn et al. (1979), the pioneer in this field, and other important related studies (Mehrabian and Russell, 1974; Gurbindo and Ortega, 1989; Boyce and Cuttle, 1990; Loe et al., 1994; Veitch and Newsham, 1998; Manav and Yener, 1999; Houser et al., 2002; Newsham et al., 2004, 2005; Boyce et al., 2006; Hidayetoglu et al., 2012).

When a lighting replacement is being analyzed, the research may be influenced by the users' pre-formed opinions, manufacturers, and advertising. Therefore, the users' points of view should be understood before they are subjected to any change in lighting stimulus. Thus, analytical methodologies that can rigorously analyze these aspects and has user-centered processes should be utilized. Within the scope of user-centered design, a series of techniques or methods, have been developed to identify users' expectations and wishes (Dahan and Hauser, 2001). Among them, the most used are the Kano model, conjoint analysis, the Pugh method, quality function deployment, and Kansei engineering (Agost and Vergara, 2010). The advantage of Kansei engineering over other similar techniques is that it enables the establishment of a suitable framework to work with symbolic attributes and user perceptions. This subjective or perceptual aspect is important in the field of architecture because architectural assessment is a mental construct. Thus, spatial cognition creates a mental representation of space that links our perception of the environment with decision making (Kaplan, 1973).

Many studies have used Kansei engineering to analyze users' perceptions of a multitude of products in automotive industry (Zhang and Wang, 2013), housing design (Matsubara and Nagamachi, 1997; Nagasawa, 1995), office furniture (Jindo et al., 1995), and acoustics and sound perception (Galiana et al., 2012). Nevertheless, to our knowledge, this technique has not been applied to date in the field of lighting with the aim of comparing different types of lighting.

The use of the Kansei engineering methodology for the emotional evaluation of lighting in classrooms provides a framework for quantifying the relationship between the design characteristics of an educational space and students' emotional responses. Results are applicable to architectural design and can affect students' comfort levels. The design of educational buildings that improve learning is critical; an improvement in the quality of interior lighting is directly beneficial to increasing productivity and alertness in students and teachers in addition to having considerable implications for the energy efficiency of educational buildings.

On the basis of the Kansei engineering framework, the present study aims to evaluate and compare the subjective evaluation of students' pre-formed opinions of the lighting provided by two types of lamps, namely, FL and LED. Specifically, the following questions are set. (1) How do students in general evaluate FL lighting in comparison with

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

				Year 1	Year 2	Year 3	Year 4
Gender	Male	214	50.12%	79	65	25	45
	Female	213	49.88%	67	62	32	52
Age	19-20	52	12.18%	5	8	12	27
	21-22	271	63.47%	103	87	27	54
	23-24	41	9.60%	10	18	7	6
	25-26	33	7.73%	12	10	6	5
	$>$ 26	30	7.03%	16	4	5	5
		427		**146**	**127**	**57**	**97**

LED, particularly in terms of its adequacy in the classroom? (2) Is there any difference between the users' assessments over time? (3) Given that LED lighting is common, is it valued positively?

2. Material and methods

The methodological development was focused on a field study that collected student assessments to examine the subjective previous opinions on FL and LED lighting. Data were collected and analyzed over a four-year period.

2.1. Subjects

A total of 427 students of the School of Architecture at the Universitat Politècnica de València (UPV), Spain volunteered to participate in the study. The average age of the students was 22.36, with a standard deviation of 3.28. Table 1 shows the principal characteristics of the sample, which was structured on an annual basis.

The participants had no previous knowledge of or teaching in lighting or lamps. Therefore, they were average users of university classrooms.

2.2. Questionnaire

A questionnaire was prepared for the field study. The questions were drafted to show the evolution of differences of opinion. It comprised of two blocks. The first block gathered objective information on an individual, that is, age and sex. The second contained subjective information about a set of evaluation variables for each type of lighting. Subjective opinions on FL and LED lighting were collected with six adjectives, which were adapted from previous research and made appropriate for this study (Flynn et al., 1979; Loe et al., 1994; Veitch and Newsham, 1998; Houser et al., 2002; Boyce et al., 2006). The six expressions were as follows: "The lighting is attractive"; "The lighting is efficient"; "The lighting is cutting-edge technology"; "The lighting is stimulating"; "The lighting is comfortable"; and "The lighting is cozy." The following global assessment variable for each lamp was also included: "In general terms, I think it is adequate lighting for a classroom." The questionnaire items were assessed using a 5-point Likert scale with the following outcomes: strongly disagree, disagree, neutral, agree, and strongly agree. The questionnaire was validated following many pilot tests to ensure it that could be completed in a reasonable amount of time and that the wording and sequencing of the questions were appropriate. This pre-testing process was conducted with 23 students.

2.3. Settings

The questionnaires were completed in 20 classrooms of UPV (Spain). Table 2 shows the most significant design characteristics of these classrooms. No changes were made to the classroom lighting during the field study because the aim of this study was to obtain the students' opinions of the two types of light source (i.e., FL and LED) before the lighting stimuli were changed.

A possible bias in using actual classrooms is the presence of confounding factors; that is, the results might be conditioned by the design variables of the space itself rather than the lighting. This problem is difficult to eliminate when working with actual classrooms where the design characteristics may be changed. However, we consider this type of in situ experiment important, that is, working in actual classrooms and situations where users are immersed 100% in real experience. The assessment of the real space contributes certain nuances to the subjects' responses, which cannot be obtained in a laboratory. To reduce the influence of this bias, the solution proposed by Kish (1995) was adopted, that is, the inclusion of these variables in a random manner, assuming that chance would generate equivalent distributions of the units in all the variables under study. Thus, the bias was still present in a reduced degree. In selecting the classrooms, we attempted to ensure that the sample was sufficiently representative and differentiated.

2.4. Development of the field study

The field study was conducted over four years. Participants were asked to express their views spontaneously to capture their first true impressions. To avoid any bias in the subjects' responses, the order of the questions in the survey was randomized and five versions of the questionnaire were created. The field study was conducted under these conditions rather than in a laboratory, because laboratory conditions cannot represent actual settings with 100% reliability. The students were personally informed of the study

Table 2 Characteristics of the 20 classrooms.

Class-room	Dimension (width*-length* height) [m]	No of sitting places	Type of light	No of windows	No skylights	Total windows surface [m^2]	Type of lamp	No of lighting sources	No of tubes	Power of the fluorescent tubes [W]	Shading system
1	5,42*11,92*2,97	76	Artificial and daylight	5	0	18,57	LED	12	24	23 W	Blinds
2	8.92*17.97*2.90	136	Artificial and daylight	8	0	17,97	Fluorescent	33	33	36 W	Metal slats
3	8.88*35.75*4.75	80	Artificial and daylight	6	6	107,06	HQI-T	22	-	150 W	-
4	6.00*12.00*4.75	60	Artificial and daylight	0	2	4,00	HQI-T	6	22	150 W	-
5	5.35*8.48*3.00	30	Artificial and daylight	3	0	9,12	Fluorescent	6	24	14 W	Blinds
6	9.60*12.70*3.40	34	Artificial and daylight	2	0	6,00	Fluorescent	18	36	36 W	Blinds
7	7.17*16.68*3.85	72	Artificial and daylight	4	0	35,36	Fluorescent	24	48	36 W	Blinds
8	11.95*17.95*3.98	79	Artificial and daylight	6	0	57,80	Fluorescent	18	54	36 W	Curtains
9	11.90*10.58*3.55	96	Artificial and daylight	6	4	29,40	Fluorescent	16	48	36 W	-
10	15.00*7.00*2.80	26	Artificial	0	0	0	Fluorescent	12	36	14 W	-
11	11.55*14.14*2.80	73	Artificial and daylight	5	0	48,44	Fluorescent	30	90	14 W	Blinds + aluminium slats
12	5.90*10.07*3.01	26	Artificial and daylight	3	0	6,35	Fluorescent	12	2	36 W	Blinds
13	5.50*14.80*3.55	43	Artificial and daylight	4	0	66,04	Fluorescent	20	40	36 W	Blinds
14	7.50*14.96*2.99	31	Artificial and daylight	20	0	44,13	Fluorescent	8	24	36 W	-
15	8.87*11.68*3.00	84	Artificial and daylight	4	0	7,50	Fluorescent	8	16	58 W	Blinds
16	8.78*12.73*3.23	96	Artificial and daylight	3	0	6,45	Fluorescent	21	42	36 W	Blinds
17	6.45*10.24*3.30	40	Artificial and daylight	4	0	28,26	Fluorescent	15	30	36 W	Blinds
18	11.88*6.75*2.75	60	Artificial and daylight	3	0	37,48	Fluorescent	16	32	36 W	Aluminium slats
19	7.64*8.75*3.26	50	Artificial and daylight	1	0	4,58	Fluorescent	14	28	36 W	-
20	9.42*14.12*2.75	38	Artificial and daylight	3	0	16,58	Fluorescent	24	48	36 W	Aluminium slats

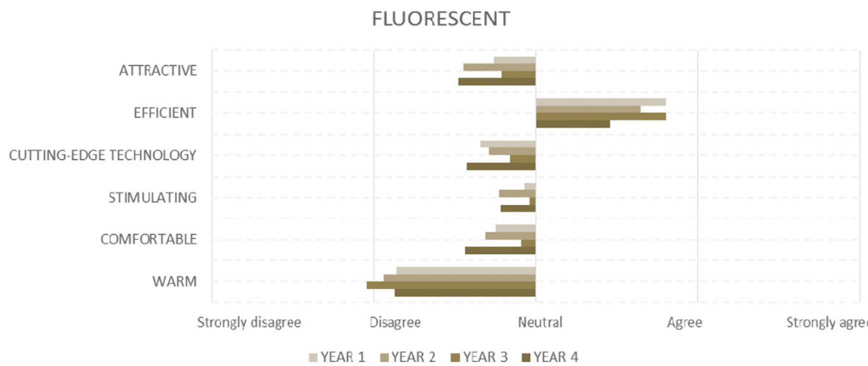

Figure 1 Comparison of FL opinion over the four years.

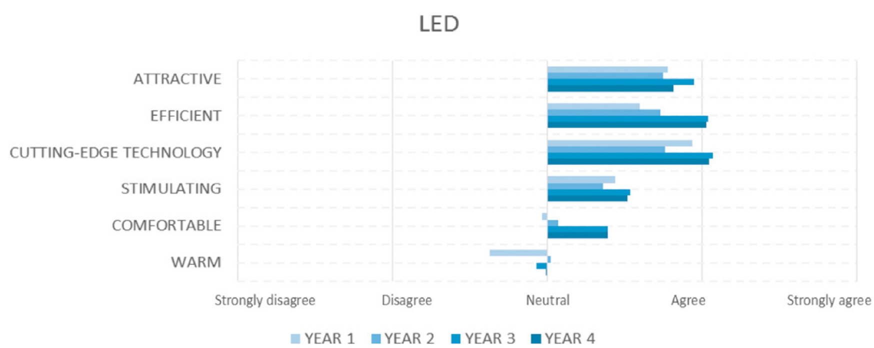

Figure 2 Comparison of LED opinion over the four years.

objectives, and the questionnaire included instructions on how to fill it in correctly.

2.5. Data processing

The data were processed statistically using the SPSS software. For exploratory data analysis, we used descriptive techniques to calculate the central values, dispersions, and distribution histograms of the variables. ANOVA was subsequently applied to verify the existence of significant differences (sig $<$ 0.05) between the means of the groups. We annually checked for significant differences between the subjects' opinions about FL and LED.

3. Results and discussion

The present work aims to obtain students' emotional responses to two types of lighting.

3.1. Assessment of FL and LED lighting over the four years

Students assessed FL lighting as significantly more efficient than LED. The other scores for FL were negative over the four years in all aspects. Thus, FL lighting was not perceived as cozy, attractive, comfortable, cutting-edge technology, or stimulating (Figure 1). By contrast, LED lighting obtained better assessments from students in all variables. Students perceived LED as cutting-edge technology, attractive, efficient, and stimulating. The comfortable variable obtained more neutral evaluations. LED lighting was most poorly assessed in the variable cozy (Figure 2).

3.2. Comparison of the assessments of both types of lighting over the four years

To verify the existence of significant differences between the subjective impressions of FL and LED lighting over the four years, ANOVA was applied on each variable to determine which showed significant differences (sig $<$ 0.05).

3.2.1. Attractive

Significant differences were found between FL and LED lighting throughout the entire study period. The students all assessed LED lighting as attractive but not FL lighting. Figure 3 shows the means of this variable for each type of lighting and the ANOVA values for each of the four years.

3.2.2. Efficient

Both types of lighting were assessed as efficient (Figure 4). The analysis of the evolution of the assessments showed that the evaluations of FL and LED lighting changed as years went by. In the first year, FL was labelled as more efficient. Through gradual changes, LED was assessed as more efficient by the time of the final year of the evaluation. We found the most significant differences between FL and LED in the fourth year.

3.2.3. Cutting-edge technology

The findings showed that the students considered LED to be cutting-edge but not FL. This assessment remained stable

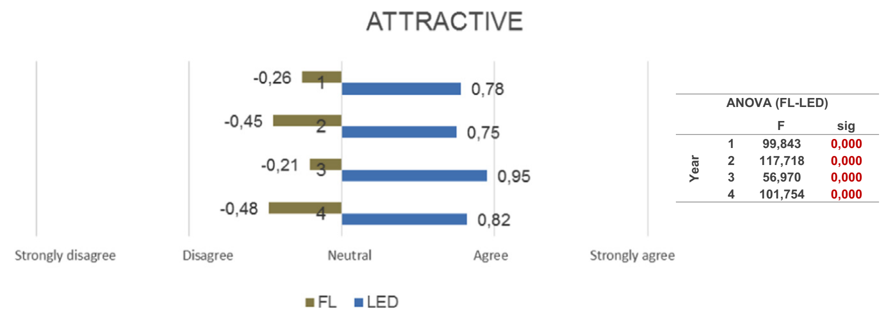

Figure 3 Evaluation of FL and LED as an attractive lighting over the four years.

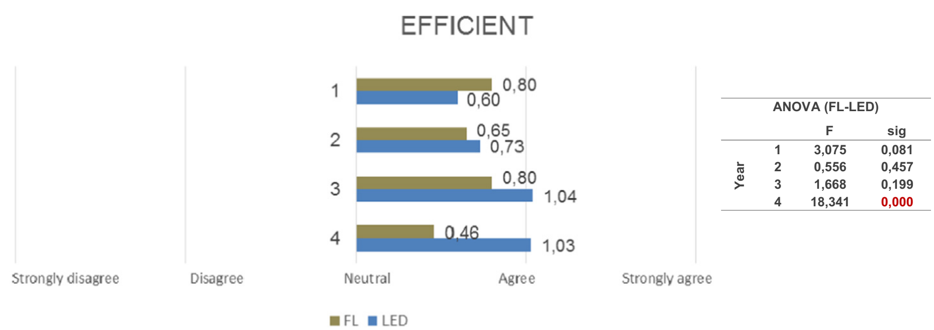

Figure 4 Evaluation of FL and LED as an efficient lighting over the four years.

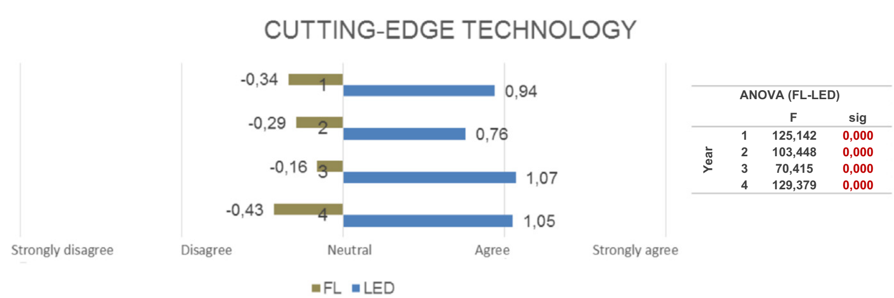

Figure 5 Evaluation of FL and LED as a cutting-edge technology lighting over the four years.

over the years (Figure 5). These differences between FL and LED were significant over the four years of the survey.

3.2.4. Stimulating

The results shown in Figure 6 indicated that the differences between FL and LED over the four years were significant because the students agreed every year that LED lighting was stimulating, which is in complete contrast to their assessment of FL lighting.

3.2.5. Comfortable

Figure 7 shows that in the first year, the evaluations of both lamps were negative. In the second year, FL remained negatively evaluated but LED had a slightly positive evaluation. In the third year, FL had a slightly negative evaluation, whereas LED received an increase in positive evaluation. Finally, FL obtained a more negative evaluation in the fourth year than in the previous years. Meanwhile, LED received the same evaluation as the previous year. The differences between the lamps remained significant over the four years. An analysis of the evaluation of FL over the four years showed that the differences were insignificant. However, the LED evaluations showed significant differences (F: 7.602; sig: 0.00). The Bonferroni test showed significant differences between the first and third years, the first and fourth years, and the second and fourth years, thereby confirming that the assessment of FL remained constant and negative, whereas that of LED evolved over the years from a slightly negative evaluation in the first year to a positive evaluation in the fourth. This evolution might be caused by the increasing presence of LED in educational facilities and users' greater acquaintance with it.

3.2.6. Cozy

The results shown in Figure 8 indicated that the differences were significant between FL and LED in all years analyzed. The assessments were negative for FL every year. However, LED assessments were negative in the first year and then subsequently showed a neutral evaluation. A time-based analysis showed significant differences (F: 6.23; sig: 0.00) between the first and second years and between the first and fourth years. A positive evolution of the LED assessment could also be observed over the years.

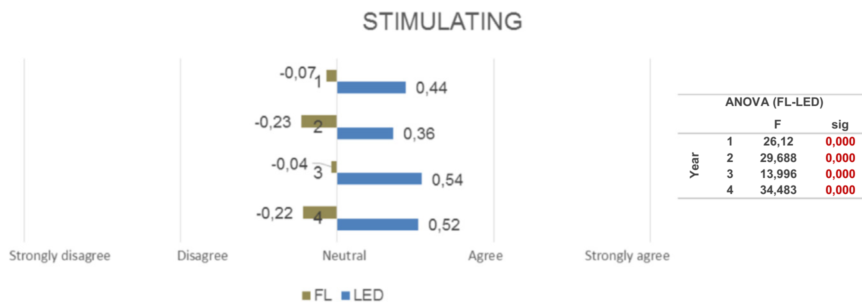

Figure 6 Evaluation of FL and LED as a stimulating lighting over the four years.

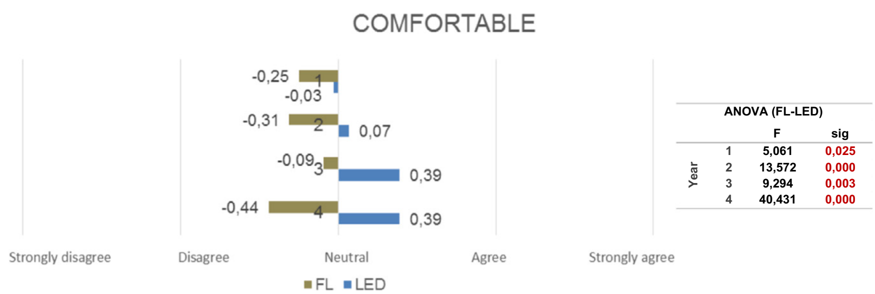

Figure 7 Evaluation of FL and LED as a comfortable lighting over the four years.

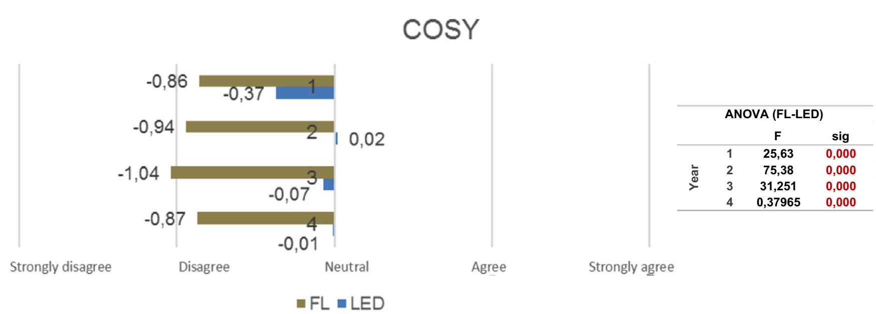

Figure 8 Evaluation of FL and LED as a cozy lighting over the four years.

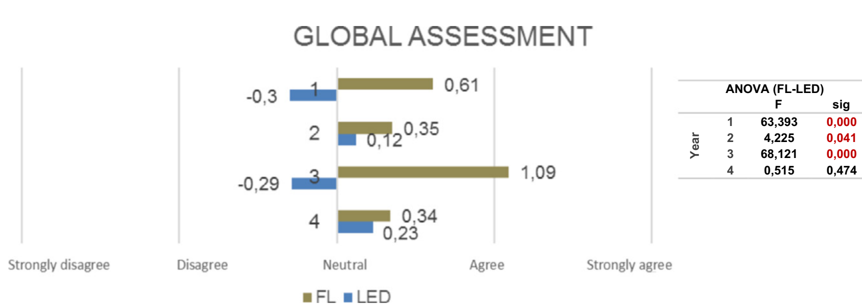

Figure 9 Global assessment of FL and LED over the four years.

3.2.7. Global assessment

Despite the aforementioned results, the global assessment of the two types of lighting as being adequate for university classrooms (Figure 9) interestingly showed that FL obtained a positive average score over all the years. Meanwhile, the score for LED implied relatively neutral evaluations because the scores varied from strongly disagree to strongly agree, depending on the year. The first and third years showed negative evaluations, which turned positive in the second and fourth years. From these results, the differences between FL and LED were large and significant in the first and second years and particularly significant in the third year. A time series analysis of FL assessments showed significant differences (F: 9.81; sig: 0.00) between the second and third years and between the third and fourth years. The LED assessments showed significant differences

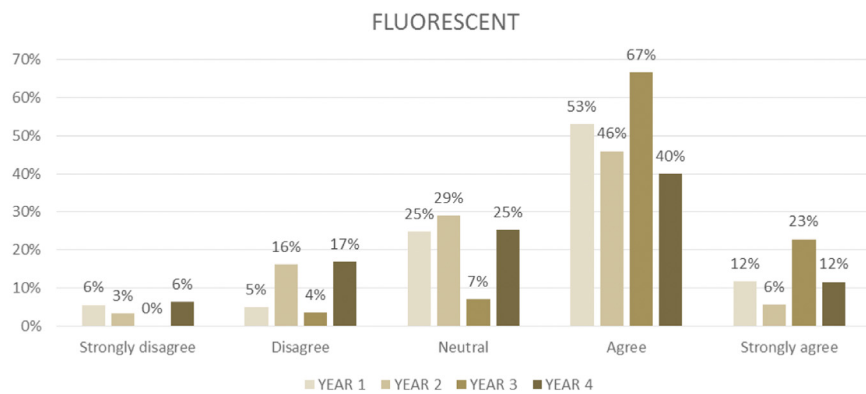

Figure 10 Evaluation percentages of FL lamps over the four years.

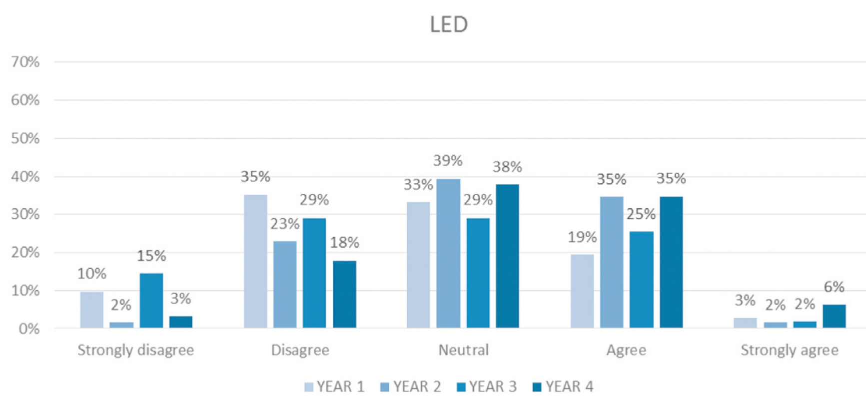

Figure 11 Evaluation percentages of LED lamps over the four years.

(F: 8.762; sig: 0.000) between the evaluations in the first and third years and in the second and fourth years.

Figs. 10 and 11 show the distribution of frequencies of the global assessment in relation to suitability for classroom use for both types of lighting over the four years. In general, the global assessment of FL lighting was slightly higher than that of LED lighting. This finding could be possibly due to the fact that students normally have FL lamps in their classrooms and are thus more accustomed to them and considered them more suitable for classroom use. Meanwhile, Figure 11 shows that LED lighting obtained better evaluation scores in the fourth year. Thus, the impression caused by LED exhibited a positive trend, which was probably due to the influence of advertising and a better understanding of it among users.

At the time of the study, LED lamps were rarely seen in university classrooms, and FL were the lamps generally used in educational environments. LED lighting was used only in homes, which might explain the lower evaluation of its suitability for classrooms.

The results showed that significant differences existed in students' subjective evaluations of the two types of lighting (i.e., FL and LED), even when they were not subjected to different stimulus. This finding showed the influence of the symbolic or functional attributes of the usefulness perceived by the students when assessing each lamp. These data are consistent with the ideas and concepts drawn by Flynn et al. (1979) who suggested that human responses to spatial lighting patterns are, to some extent, shared experiences; they concluded that some perceptions of spatial light might be communicative in the sense that these patterns suggest or reinforce ideas that are shared (to some degree) by people with the same cultural background. The results are also in line with the ideas proposed by Veitch (2001) that aesthetic judgements, which are slightly different from emotional reactions, affect the interpretation and categorization of what people see.

This study has significant limitations. The field study was conducted in actual classrooms, which is a disadvantage because actual classrooms combine elements that may influence perceptions. Nevertheless, we consider working in actual classrooms interesting because users are 100% immersed in real experience. However, to reduce the influence of this bias, the solution proposed by Kish (1995) was adopted, that is, the inclusion of variables in a random manner, assuming that chance will generate equivalent distributions of the units in all the variables under study. Thus, bias remains in a reduced degree.

4. Conclusions

The present work aims to compare and evaluate the subjective evaluations of students of the lighting provided by two types of lamps, namely, FL and LED.

The proposal makes two relevant contributions: one at the methodological level and one at the practical level.

From a methodological point of view, the interest lies in the analysis of the evolution of the users' responses. Our proposal allows us to measure the subjective impressions of lighting in educational spaces to provide information from the student's point of view rather than just the experts' perspective, as has been the case to date. This methodology opens an interesting technological route for manufacturers to create products that are suited to users' emotional, cognitive, and efficiency needs.

In reference to the practical application of our proposal or the concrete results obtained, the conclusions can be summarized as follows.

- The results show significant differences among students' subjective assessments of FL and LED lighting. This result demonstrates the presence of general trends and lines of influence derived from the different symbolic or functional attributes related to the perceived utility of each of these lamps when assessing them as light sources.
- The analysis indicates that the students negatively valued the perception of the lighting from FL in the variables cozy, attractive, comfortable, cutting-edge technology, and stimulating over the four years. However, LED was perceived positively in nearly all variables, except for cozy.
- No significant differences were found in the evaluation of FL and LED in terms of efficiency. Both types scored positively in this aspect in all the study years. However, in the first years FL obtained a more positive evaluation for efficiency, whereas LED obtained the best scores as the years went by.
- The evaluation of FL lighting remained stable over the years, whereas the evaluation of LED evolved. Specifically, the evaluation of this lighting as comfortable changed from negative in the first year to slightly positive in the final year. The same evolution, although to a lesser extent, was observed in the cozy variable, which became nearly neutral after showing a slightly negative score.
- In terms of the global score for FL and LED on their suitability for classroom use, FL obtained a slightly higher average score than LED throughout the years of study. This result may be because FL lamps were the most usual source of light employed in these classrooms. This finding suggests that students gave the highest global scores to the type of lighting they were more familiar with and considered appropriate. This aspect should be considered when conducting surveys in which specific users are asked about their subjective impression of any lighting change.

The results of this study are applicable to architectural design and can have an immediate effect on students' comfort levels. Educational buildings should be designed to improve learning; an improvement in the quality of interior lighting has a direct benefit to increasing productivity and alertness in students and teachers in addition to having significant implications in the energy efficiency of educational buildings.

In future works, the psychophysiological responses of students as a measure of their emotional unconscious or unintentional responses to actual and virtual lighting in the classroom would be interesting to evaluate.

Acknowledgments

This research was supported by the Ministerio de Economía, Industria y Competitividad, Spain (Project BIA2017-86157-R).

References

Agost, M.J., Vergara, M., 2010. Taking the customer into account in collaborative design. Springer, Berlin, Heidelberg, 174-177.
Boyce, P.R., 2003. Human Factors in Lighting. London, Taylor & Francis doi: ⟨http://dx.doi.org/10.1201/9780203426340⟩.
Boyce, P.R., Cuttle, C., 1990. Effect of correlated colour temperature on the perception of interiors and colour discrimination performance. Light. Res. Technol. 22, 19-36.
Boyce, P.R., Veitch, J.A., Newsham, G.R., Jones, C.C., Heerwagen, J., Myer, M., Hunter, C.M., 2006. Lighting quality and office work: two field simulation experiments. Light. Res. Technol. 38, 191-223.
Caicedo, D., Pandharipande, A., Leus, G., 2011. Occupancy-based illumination control of LED lighting systems. Light. Res. Technol. 43, 217-234.
Castilla, N., Llinares, C., Bravo, J.M., Blanca, V., 2017. Subjective assessment of university classroom environment. Build. Environ. 122, 72-81.
Dahan, E., Hauser, J.R., 2001. Product development - managing a dispersed process. In: Weitz, B.A., Wensley, R. (Eds.), Aplicaciones de La Ingeniería Kansei Al Análisis de Productos Inmobiliarios. SAGE, London, pp. 179-222.
Durak, A., Camgöz-Olguntürk, N., Cengiz, Y., Güvenç, D., Gürçinar, Y., 2007. Impact of lighting arrangements and illuminances on different impressions of a room. Build. Environ. 42, 3476-3482.
Flynn, J.E., Hendrick, C., Spencer, T., Martyniuk, O., 1979. A guide to methodology procedures for measuring subjective impressions in lighting. J. Illum. Eng. Soc. 8, 95-110.
Galiana, M., Llinares, C., Page, Á., 2012. Subjective evaluation of music hall acoustics: response of expert and non-expert users. Build. Environ. 58, 1-13.
Gurbindo, N., Ortega, J.E., 1989. Adaptación de las escalas de placer, activación y dominancia de Mehrabian y Russell en sujetos hispanoparlantes. Rev. Psicol. Soc. 4, 179-183.
Hidayetoglu, M.L., Yildirim, K., Akalin, A., 2012. The effects of color and light on indoor wayfinding and the evaluation of the perceived environment. J. Environ. Psychol. 32, 50-58.
Hoelen, C., Borel, H., de Graaf, J., Keuper, M., Lankhorst, M., Mutter, C., Waumans, L., Wegh, R., 2008. Remote phosphor LED modules for general illumination: toward 200 lm/W general lighting LED light sources. Proc. SPIE.
Houser, K.W., Tiller, D.K., Bernecker, C.A., Mistrick, R.G., 2002. The subjective response to linear fluorescent direct/indirect lighting systems. Light. Res. Technol. 34, 243-264.
Hughes, P.C., 1981. School lighting for the total persom a psychobiological approach. Cefp journal, 19:4-7.
Jindo, T., Hirasago, K., Nagamachi, M., 1995. Development of a design support system for office chairs using 3-D graphics. Int. J. Ind. Ergon. 15, 49-62.
Kaplan, S., 1973. Cognitive maps in perception and thought. In: Downs, R., Stea, D. (Eds.), Image and Environment: Cognitive Mapping and Spatial Behavior. Transaction Publishers, Chicago, USA, pp. 63-78.
Kish, L., 1995. Survey Sampling. John Wiley and Sons, New York, USA.

Loe, L., Mansfield, K.P., Rowlands, E., 1994. Appearance of lit environment and its relevance in lighting design: experimental study. Light. Res. Technol. 26, 119–133.

Manav, B., 2007. An experimental study on the appraisal of the visual environment at offices in relation to colour temperature and illuminance. Build. Environ. 42, 979–983.

Manav, B., Yener, C., 1999. Effects of different lighting arrangements on space perception. Archit. Sci. Rev. 42, 43–47.

Matsubara, Y., Nagamachi, M., 1997. Hybrid Kansei engineering system and design support. Int. J. Ind. Ergon. 19, 81–92.

Mehrabian, A., Russell, J.A., 1974. An Approach to Environmental Psychology. M.I.T. Press, Cambridge.

Mills, P.R., Tomkins, S.C., Schlangen, L.J.M., 2007. The effect of high correlated colour temperature office lighting on employee wellbeing and work performance. J. Circadian Rhythms 5, 1-9.

Nagasawa, S., 1995. Fuzzy sensory evaluation of condominia's facade, In: Proceedings of the International Joint Conference of the Fourth IEEE International Conference on Fuzzy Systems and The Second International Fuzzy Engineering Symposium. IEEE, pp. 503–508.

Newsham, G.R., Marchand, R.G., Veitch, J.A., 2004. Preferred surface luminances in offices, by evolution. J. Illum. Eng. Soc. 33, 14–29.

Newsham, G.R., Richardson, C., Blanchet, C., Veitch, J.A., 2005. Lighting quality research using rendered images of offices. Light. Res. Technol. 37, 93–115.

O'Neill, D.J., Oates, A.D., 2001. The impact of school facilities on student achievement, behavior, attendance, and teacher turnover rate in central Texas middle schools. Educ. Facil. Plan 36, 14–22.

Ryckaert, W.R., Smet, K.A.G., Roelandts, I.A.A., Van Gils, M., Hanselaer, P., 2012. Linear LED tubes versus fluorescent lamps: an evaluation. Energy Build. 49, 429–436.

Veitch, J.A., 2001. Psychological processes influencing lighting quality. J. Illum. Eng. Soc. 4480, 124–140.

Veitch, J.A., Newsham, G.R., 1998. Lighting quality and energy-efficiency effects on task performance, mood, health, satisfaction and comfort. J. Illum. Eng. Soc. 27, 107–129.

Zhang, F., Wang, J., 2013. Application of kansei engineering in electric car design. Appl. Mech. Mater. 437, 985–989.