Emotional Lighting Design of Indoor Spaces by Kansei Engineering

Sotirios PAPANTONOPOULOS *, Theano XANTHOPPOULIDOU **
and Margarita KARASAVOVA

* Democritus University of Thrace, 12 Vassilissis Sofias, Xanthi 67100, Greece
spapant@pme.duth.gr
** Democritus University of Thrace, 12 Vassilissis Sofias, Xanthi 67100, Greece
theanoxanthopoulidou@hotmail.com

Abstract: New lighting applications aspire to provide more benefits –than simply allowing vision– such as improving mood, sleep quality, and daily performance. 3D printing and laser cutting technologies found an application in the design of luminaries with very complicated artificial structures where the creation of unique light patterns is achieved. Computer-based, lighting simulation and assessment tools can assist in the creation and analysis of the lighting quality of space. However, these outcomes depend on the lighting designer’s knowledge and experience. It is necessary to develop methods to quantitatively evaluate people’s feelings and preferences toward such stimuli and to implement those emotional qualities into the lighting of space. This introductory study proposes a lighting design approach where the elements of light patterns, such as the direction of light, the beam pattern, the color temperature of light and the symmetry of light distribution, are assumed as design elements. The second assumption was that the lit lamp has a different appearance than the non-lit lamp, thus these can be understood as two different products requiring two different Kansei scales in order to evaluate the emotional impressions they give to the perceiver. In this context, the study had two goals: (a) to apply Kansei Engineering for the classification of lit and non-lit wall sconces based on the people's emotional perceptions; (b) to implement the people's emotional preferences of wall sconce's lighting into the selection of a wall sconce that creates an intended space mood in the dark and an invisible effect in daylight.

Keywords: Kansei Engineering, Lighting Design, Indoor Space, Emotional Design, Kansei Words

1. INTRODUCTION

New lighting applications have appeared in home environments, aspiring to provide more benefits than simply allowing vision, such as improving mood, sleep quality, and daily performance. On the other side, the development of 3D printing and laser cutting technologies found an application in the design of luminaries with very complicated artificial structures emerging from beautiful concepts where by the use of light and shadows the creation of unique light patterns is achieved. An intended mood of the space can be created by the use of soft shadow-light patterns of wall lamps with less material and spectacular lighting effects. Lighting simulation and assessment tools are very helpful in assisting the creation and analysis of lighting quality of space. However, the outcome depends on the lighting designer’s knowledge and experience. It is necessary to develop methods to quantitatively evaluate people’s feelings, impressions, sensitivity, and preferences toward such stimuli and to implement these emotional qualities into the lighting of the space. Kansei Engineering (KE) is applied, widening its application well beyond the physical form of the product.

One type of indoor wall sconces is made from plaster (ceramic), with minimalistic style and small-to-medium size, which all make them eco-friendly. They are sold in white color. The design of this type of sconces has achieved a level of personalization by allowing the user to use them as they are or being painted in the customer’s most preferable color, usually contrasting, complementing, or totally matching the color of the wall.

The presented introductory study has two goals: (a) to apply KE for the evaluation of wall sconces based on the people's emotional perceptions either when lit, using the design elements of the emitted light patterns, or unlit, based on their appearance; (b) to select a wall sconce that creates an intended space mood in the dark and an invisible effect in daylight. The identification of the relationship between the total appeal of non-physical (emitted light pattern) and physical (shape) design attributes of the lit sconces and just the physical design attributes of the non-lit sconces, on the one hand, and the people's emotional perceptions, on the other, contributes to the novelty of the study.
2. METHODOLOGY

A product is conventionally described by its size, color, shape, weight, and quality. An emitted light pattern has all those characteristics without the weight. It has its own size: the lit surface area; color: the color temperature of light; shape: the shape created by different directions of light and the beam angle; structure, created by the composition of light and shadow; and quality, which depends on how well it serves its purpose.

2.1 Procedure

A total of 24 Greek people (9 females and 15 males), 23 to 32 years old, with normal vision and color acuity participated in the survey. All had wall sconces in their homes. The assumption that the evaluators will develop a good imagination of the light pattern emitted from wall sconces when shown an image was supported by the following: (a) the participants have seen many wall sconces because this type of wall lighting is very common in the Greek home lighting culture and (b) large online sales for this type of product show that people trust the mental images of their space lit by a specific lamp that they create based on its online image.

2.2 Product space

To better define the space of properties for the Kansei analysis, the product domain was narrowed to the light patterns emitted from wall sconces displayed on typical online retailing sites with the following characteristics: Application: indoor; Type of bulb: LED; External and internal color: white; Material: plaster; Style: minimalistic; Size: small-to-medium; Non-movable; Architectural type. Images of 60 switched-on wall lamps that are sold online were analyzed and classified based on dissimilarities in their emitted light patterns by the use of the affinity diagram method. In analyzing many light patterns emitted from wall sconces, the main items and categories were extracted. The final set of 16 wall sconces used for the evaluation is shown in Figure 1. They represent 5 design items and 26 design categories shown in Table 1.

2.3 Semantic space

The appeal of any lamp, when switched on in the dark, is very different from its impression when switched off in daylight. Therefore, two evaluations need to be performed for each lamp for these two appearances separately because the same semantic differential scale (SD scale) cannot be applied. In this context, the Kansei words (KW) for the evaluation of the lit lamp were determined through a procedure according to Nagamachi [3] with the initial set of words collected from customer reviews related to wall sconces. Cluster analysis was applied based on the data collected from a special questionnaire for evaluating the most appropriate KW for the expression of a space illuminated with wall sconces on a 5-point SD scale and mid-level of 26 KWs. 8 KWs were selected to create the emotional SD scale for the lit sconce: Relaxing, Attractive, Harmonious, Warm, Natural, Pleasant, Opens the space, Romantic.

| Direction of light (6 categories) | Upward, Downward, Upward/downward, Horizontal, Backward (toward the wall), Backward-all directions |
|----------------------------------|--------------------------------------------------------------------------------------------------|
| Beam pattern (7 categories)      | Flood (90°-120°), Very narrow spot (<15°), Narrow flood (60°-90°), Spot (30°-60°), Flood (90°-120°)/Spot (30°-60°), Narrow spot (15°-30°), Narrow flood (60°-90°)/spot (30°-60°) |
| Color temperature of light (3 categories) | Extra warm white (= 2700K), Warm white (= 3000K), Cool white (= 4000K) |
| Symmetry (side view) of light distribution (2 categories) | Symmetrical, Asymmetrical |
| Shape of the sconces (8 categories) | Spherical, Round, Shell, Rectangular, Slim, Cubical, Multilayered, Curved rectangular |

Figure 1. The 16 wall sconces selected for the study

Table 1: Design items and categories of wall sconces

Next, a different emotional SD scale was created for the
evaluation of non-lit wall sconces by the use of 4 adjectives: simple, invisible, practical, and pleasant. The KWs for this second scale were “must-have” emotional expressions of non-lit sconces and were used to identify which products express such needed emotional appeal in daylight, according to the evaluators. The experiment was based on an online-distributed questionnaire that included: (a) a short description of the survey and the guidelines, requesting participants to perform the evaluation in the evening at a dark room and with full screen; (b) demographic information; and (c) the evaluation part. The evaluation part consisted of a plain page that set the scene for a follow-up page with the lit sconce. This plain page was in full size and had the color number of the background (the wall) extracted by the use of color analysis of the follow-up image of the lit sconce (12cmx12cm). The evaluator was asked to count up to 15 while observing the plain page, before continuing to the next page and to see the image with the lit sconce on the same background. In this way, the effect of a switched-on luminary on the previously observed plain wall (page) with some background was intended as well as to erase their main image from the previous sample. Participants were then asked to rate the lit luminary on a 5-point SD scale with the 8 KWs for lit sconces. Then the evaluator was asked to imagine the sconce switched off and to rate his/her impression on a 5-point SD scale with the 4 KWs for non-lit sconces. Factor analysis was performed by the use of the average values of the Kansai ratings. The results were analyzed by the use of Minitab.

3. RESULTS

The internal consistency of the scales used in the survey for lit and non-lit sconces was acceptable, with Cronbach’s alpha values of 0.894 and 0.890, respectively. The results from one-way ANOVA with Tukey Post-hoc indicated a statistically significant difference in the emotional responses toward the KWs for the evaluation of the lit sconces: values of $F(7,120)= 3.76$; $p=0.001$; mean differences from 0.612 for “romantic-pleasant” to 0.015 for “pleasant-attractive” and the smallest mean difference of 0.008 for “opens the space-warm”. The same analysis for the KWs for the evaluation of the non-lit sconces revealed the following results: values of $F(3,60)= 4.38$; $p=0.007$ and mean differences from 0.054 for the pair “practical-invisible” to 0.621 for “simple-pleasant”, indicating a statistically significant difference of the KWs for the evaluation of the non-lit sconces.

3.1 Factor analysis of the lit wall sconces

Component loadings showed that the X-axis has the semantics of “relaxing”, “attractive”, “harmonious”, “pleasant” and “opens the space” and this was named “Harmonious relaxation”, while the Y-axis has the “warm”, “romantic” and “natural” and this was named “Natural warmth” (Table 2). The positions of the 16 lit wall sconces with different light patterns are shown on the Kansai map (Figure 2).

The experiment showed that the emotional appeal of different light patterns emitted by the particular set of wall sconces can be distinguished and evaluated on the selected SD scale according to people’s visual perceptions. For example, P1, classified close to the “attractive” and “pleasant” vectors, has an asymmetrical and upward/downward direction of light, flood 90°-120°, a warm white color temperature of light, and a semicircular shape. Close to the “romantic” vector is P7 which has an asymmetrical, upward/downward direction of light, flood 90°-120°/spot (30°/60°), a warm white color temperature of light, and a soft round shape.

Table 2: Rotated Factor Loadings of lit sconces

| Variable          | Factor 1 | Factor 2 |
|-------------------|----------|----------|
| Relaxing          | 0.595    | 0.567    |
| Attractive        | 0.807    | 0.341    |
| Harmonious        | 0.892    | 0.274    |
| Warm              | -0.061   | 0.899    |
| Natural           | 0.555    | 0.639    |
| Pleasant          | 0.841    | 0.449    |
| Opens the space   | 0.718    | -0.099   |
| Romantic          | 0.377    | 0.854    |
| Variance          | 3.479    | 2.668    |
| % Variance        | 0.435    | 0.334    |

Figure 2: Kansai map of factor loadings of the lit sconces

The product classified close to the “natural” vector was P16 which has an asymmetrical, upward/downward direction of light, flood 90°-120°, a warm white color temperature of light, and a rectangular shape. Although
P8 imitates the candlelight pattern, it was not within the positive Kansei space. Close to the “relaxing” vector was located the P3 wall sconce which has an asymmetrical upward direction of light, flood 90°-120°, daylight color temperature of light, and rectangular curved shape. The product classified close to the “warm” vector was P6 which has an asymmetrical upward/downward direction of light, flood 30°-60°, a warm white color temperature of light, and a semispherical shape. None of the emitted light patterns from the selected products were perceived to have the quality to make space feel bigger – to “open the space”. Close to the negative side of the vector “opens the space” were products P8 and P2 with a very narrow spot type lit area. The location of all products can be analyzed in detail in a similar way.

3.2 Factor analysis of non-lit wall sconces

Factor analysis was performed by the use of the average ratings from the emotional scales for non-lit sconces. Two factors were determined (Table 3). The first factor showed that the X-axis has the semantics of “invisible” and “simple” and was named “Invisible simplicity”. The second factor showed that Y-axis has the “practical” and “pleasant” and was named “Pleasant practicality”. Not big diversification towards “simple” was expected since the selected products do not have decorative value. The purpose was to identify the simplest non-lit sconce which, when painted with the color of the wall, will be invisible. As the Kansei map shows the non-lit P3 stands out from the other sconces on the Y-axis dimension and P16 stands out on the X-axis dimension.

Table 3. Rotated factor loadings of non-lit sconces

| Variable   | Factor 1 | Factor 2 |
|------------|----------|----------|
| Invisible  | 0.584    | 0.741    |
| Practical  | 0.772    | 0.545    |
| Pleasant   | 0.916    | 0.294    |
| Simple     | 0.302    | 0.920    |
| Variance   | 1.867    | 1.779    |
| % Variance | 0.467    | 0.445    |

The comparison of the location of each product on the Kansei map of the lit (Figure 2) and non-lit (Figure 3) sconces based on participant ratings can give information about which product combines the intended emotional expression in the dark and in daylight. For example, if a sconce is needed for creating a relaxing space in the dark and has to be invisible in the daylight, then P3 can be selected for the lighting of the bedroom (Figure 4).

Figure 3: Kansei map of factor loadings of the non-lit sconces

Figure 4: Upper image: Relaxing lighting of bedroom according to people's perceptions. Lower image: Invisible simplicity of the sconces in daylight.

4. CONCLUSIONS

The study found that the created emotional scales were sensitive towards a set of lit and non-lit wall sconces and that people's impressions can be evaluated. These emotional preferences can be implemented in the lighting design of indoor space with intended mood in the dark and be invisible in daylight. This knowledge will be applied for further exploration of the relationship between the design elements of light patterns and the morphological elements of sconces, on one hand, and the people’s emotional perceptions, on the other.

REFERENCES

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