Empirical Evaluation of Optimal User-Centered LED Lighting Environments in Residential Bathrooms

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Abstract

This user-centered research aims to empirically evaluate color temperature (K) and illuminance (lx) of residential bathroom lightings to determine the most optimal lighting conditions for productive task performance as well as for satisfying users’ emotional needs. Using 3 LED lighting fixtures, 4 types of lighting contexts were investigated; main lighting, task lighting, shower lighting, and bath lighting. Two lightings were installed parallel to the vertical edges of the main bathroom mirror to be used as main and task lighting, while another fixture was installed above the bathtub to be used for shower and bathing. For each lighting context, subjects (N = 54) were instructed to perform a few tasks during which time the users were exposed to different lighting conditions with color temperature ranging from 2700 K ~ 6500 K and illuminance ranging from 100 lx ~ 700 lx. Upon completing the given tasks, subjects were asked to evaluate the lighting conditions and their applicability for performing the given tasks. Based on the user evaluations, the most optimal lighting conditions for the different lighting scenarios are as follow: 1) 3500 K ~ 4300 K and 150 lx for main lighting, 2) 3500 K ~ 4300 K and 500 lx ~ 700 lx for task lighting, and 3) 2700 K ~ 3500 K and 100 lx ~ 150 lx for shower/bath lighting. These results can be used to adjust the lighting standards suggested by KS, as well as be utilized by both engineers and designers in designing new types of user-centered bathroom lightings.

Key words: Emotional Design, Lighting Design, User-Centered Lighting, LED

1. Introduction

As society experiences economic and social development, living standards improve and people demand a higher quality of life. With this progression, the concept of bathrooms is also gradually transforming into a space full of vitality. In this regard, many researches have been conducted to explore and fulfill the new consumer needs with emphasis on bathroom architecture and interior design. In one study, the Korean people’s bathroom activities as well as thoughts and emotional responses to current bathroom situations were surveyed (Lee and Kim, 2010). Based on the findings, a basic design guideline for creating a healthy bathroom

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space that incorporates modern lifestyles was proposed. Another study investigates the importance and benefits of color in bathrooms, particularly for the elderly (Kang and Lee, 2009). The use of different colors can stimulate different feelings of temperature, and therefore produce various physiological and psychological reactions.

Together with social development, there have also been tremendous scientific advancements in LED lighting technology. A popular trend observed today is the replacement of traditional fluorescent with LEDs. The easy controllability to alter color temperature and illuminance of LEDs gives users the creative freedom to illuminate a room to best suit their needs. Hence, lighting design can be used as one of the main elements that contribute to inaugurating a user-centered bathroom environment for high quality living.

For the concern of safety, the lighting association of Korea (KS) offers standards for illuminance (lx) in bathrooms. However, actual bathroom lighting measurements in Korean homes indicated that illuminance levels are typically below their suggested values (Lee and Choi, 2005). Moreover, the KS does not provide any color temperature suggestions for bathroom lighting, nor has there been any empirical research regarding LEDs in relation to user-centered bathroom environments. Hence, this study aims to conduct a user-centered evaluation on color temperature and illuminance of residential bathroom lightings using LEDs to derive best lighting conditions for different bathroom scenarios.

3. Experiment 1: Psychological Evaluation of Bathroom Tasks

3.1. Objective of Experiment

Prior to conducting the main experiment on determining the most optimal lightings for different bathroom activities, it was first necessary to conduct a preliminary study to derive various bathroom scenarios in which the different lighting conditions could be evaluated. The purpose of Experiment 1 was to group bathroom activities based on their arousal level and to derive specific bathroom scenarios that need different lighting conditions from those groupings.

3.2. Participants

24 subjects (12 males and 12 females) were recruited to participate in Experiment I. The average age of subjects was 22.8 with a standard deviation of ±3.05. To concentration on activities and user behaviors of conventional Korean residential (apartment) bathrooms, all the subjects were Korean.

3.3. Method

In order to achieve the two objectives, Experiment I investigated the arousal levels of different activities in a bathroom. During the experiment, users were given a list of 12 common bathroom activities, which were carefully selected from previous research that examines daily actions in residential spaces (Lee and Hong, 2010). The list of the activities is provided in Table 1.

<table>
<thead>
<tr>
<th>Urination</th>
<th>Bowel movement</th>
<th>Bathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message</td>
<td>Reading</td>
<td>Hand washing</td>
</tr>
<tr>
<td>Shower</td>
<td>Use of Bidet</td>
<td>Laundry</td>
</tr>
<tr>
<td>Sink Activities</td>
<td>Styling hair</td>
<td>Applying makeup</td>
</tr>
<tr>
<td>(washing face, hands, brushing teeth, etc.)</td>
<td></td>
<td>and/or shaving</td>
</tr>
</tbody>
</table>

Table 1. 12 bathroom activities selected for arousal level evaluation.