Design features supporting optimal use of electric lighting: Testing a conceptual framework for human interaction with lighting control devices in hospital environments

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Abstract

Healthcare facilities consume a considerable amount of electricity due to their 24-hours services. In Swedish facilities, artificial lighting is one of the main consumers and accounts for 26% of electricity use. A better understanding of users' behavior in terms of maneuvering the lighting in this type of facilities could contribute to minimize energy use. The individual's visual perception of environments or objects may guide or obstruct his or her behavior. Consequently, the perception of lighting objects, including lighting control devices may therefore influence behaviors concerning energy saving.

This paper presents an empirical study that aims to develop a conceptual framework for human interaction with lighting control device in shared spaces in health care environment. The framework is based on the Theory of Affordances (Gibson, 1979) and the Theory of Planned Behavior (TPB) (Ajzen, 1991), which have been used for identifying possible factors influencing optimal use of electric lighting. The study was carried out in a dining room and two dayrooms in two Swedish hospitals where the buildings were designed and built under the 1960s. The data collection included users' experiences and behaviors in relation to the use of lighting control devices. It also included users' perceptions of environments and situations, perceived behavioral control to adjust electric lighting as well as levels of environmental concern.

The framework shapes better understanding of users' experience and interaction with lighting control devices in shared spaces in hospital environments. People generally have intention to

adjust electric lighting when they are dissatisfied with lighting condition. Therefore, they are likely to perform this behavior through interacting with lighting control devices. The feeling of how important to adjust the lighting also relate to the intention whereas relationships between subjective norm, and perceived behavioral control and the intention in this context are questioned. Besides the levels of environmental concern, the study found that the device characteristics which are easy to see and able to elicit people motivation and awareness to save energy related to optimal use of electric lighting in this kind of environments. These two characteristics also related to perceived affordances of lighting control devices which may contribute to the optimal use through individuals' perceived behavioral control. The location and suitability of lighting control devices in relation to the originality of physical environment may also support perceived affordances and visibility of the devices.

Keywords: *visual perception, lighting control device, affordances, perceived behavioral control, lighting, hospital environment*

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Introduction

The quality of the physical environment has received considerable attention in health care studies. There are several studies regarding the impact of physical environment as well as design features on well-being (Cohen-Mansfield & Werner, 1998) and mental health (Evans, 2003). However, it is also important to explore how specific features of physical environments in health care settings are used and the related impact on the environment.

During the use phase of health care facilities, a considerable amount of energy is consumed due to a 24-hours service. In Sweden, artificial lighting is considered one of the main consumers and account for 26% of electricity use in such facilities (Energimyndigheten, 2012). Generally, ineffective energy use of electric lighting could be found in shared spaces where the occupants do not feel as responsible to turn off the light manually when leaving as they would when leaving private spaces (Figueiro, 2004 cited in Galasiu, et al., 2007). Though modern lighting controls could reduce energy use in buildings, most occupants prefer to have the opportunity to control electric lighting (Moore, et al., 2002; Moore, et al., 2004; Doulos, et al., 2007). Since light has direct effects on mental health and people feel better when they can control their surroundings (Evans, 2003), it is likely that a possibility to control lighting manually would support human well being. Given this, lighting control devices may play an important role in effective energy use for lighting. The devices directly communicate and interact with users to control electric lighting.

Users' behavioral response to lighting control devices can possibly contribute to effective energy use by optimal use of electric lighting. In this paper, the optimal use refers to when a person i) turn on electric lighting only when he/she need it, ii) turn off when he/she does not need it, and iii) adjusts the lighting level to meet his/her preference; that meet both user satisfaction and energy effectiveness. Because these behaviors are meant to reduce a negative environmental impact, they can be referred to as pro-environmental behavior (Steg & Vlek, 2009).

Steg and Vlek (2009) pointed out that product characteristic and the availability of the product are contextual factors which may facilitate or constrain the behavior. Regarding this, visual perception of these contextual factors could influence people's behavior. In reference to Dijksterhuis and Bargh (2001), perception is humans' best action guidance and control device. Through the perception, the characteristic as well as availability of lighting control devices in a room may lead to or hamper behavioral response in relation to the use of electrical lighting and therefore affect energy use.

It is a challenge to find how a design of lighting control device can support optimal use of electrical lighting. This paper is part of a larger field study conducted in hospital environments with the aim to identify basic design features of lighting control devices that support the optimal use of electrical lighting in health care facilities such properties. Different lighting control devices are studied regarding how they visually communicate with users. Regarding this, it is important to understand people's experience and interaction with the devices. The specific objective of this paper is to develop a framework for human interaction with lighting control devices that can be applied to shared spaces in hospital environments. The focus is on psychological and physical factors which could influence human pro-environmental behavior and how they are related. The framework helps to explain why an individual perform a certain behavior in relation to optimal use of electric lighting in hospital environments.

Theoretical framework

The theoretical framework consists of two aspects relating to users' experience and interaction with objects: i) visual perception of object and ii) perceived behavioral control.

Visual perception of object

Theory of affordances

An impact of visual perception on performing a certain behavior can be described by the theory of affordances (Gibson, 1979): "*The affordances of the environment are what it offers to the animal, what it provides or furnishes, either good or ill*"(Gibson, 1979, p.127). Considering lighting control devices as objects, Gibson described that the objects afford possible behaviors through visual perception. When looking at the objects, individuals know what can be done with them and what they can be used for.

Considering lighting control devices as products in the field of industrial design, the term of affordances refers to the function or usefulness of an object (Chen & Lee, 2008) which provides strong clues that help to operate things (Norman, 1990). Properties or characteristic of an object offer potential uses to the user (Maier & Fadel, 2009). Furthermore, affordances of products can support user action without requiring his/her memory, inference, and further interpretation (You & Chen, 2006). Gibson (1982) mentioned that products are the possibilities of actions and individuals achieve their goal by interacting with the products. Generally, users interact with products through an interface and the controls are part of the user interface (Chen & Lee, 2008). Regarding this, individuals might perform behaviors due to perceived affordances of products, especially the control features. In case of perceived affordances of lighting control devices, individuals who would like to adjust lighting conditions know that they can push or turn control features of the devices to fulfill their demand.

However, affordances of the objects are, in some cases related to physical parameters of the individual (Gibson, 1979). To support the objects' function or usefulness, we have also considered "*Universal design*" which Story (1997) described as *"design for people of all ages and abilities''*. We employed the principles of universal design (The Center for Universal Design, 1997) that are considered to be related to design and use of lighting control devices to achieve better understanding of people's experience and interaction with the devices.

Experience in human-product interaction

It can be said that perceived affordances of objects or products is for physical interaction, mainly about how the objects/products are used by people. However, interaction with the objects/products is not only referred to physical interaction. According to Desmet and Hekkert (2008), it is also referred to non-physical interaction which refers to fantasizing about, remembering, or anticipating usage of the objects. An individual can anticipate interaction and also anticipate possible consequences of interaction, and therefore affective responses from the individual can be elicited.

Perceiving is one of the processes that involve the interaction (Desmet & Hekkert, 2007). Therefore, it can contribute to affective responses. It can be assumed that through perceiving, an individual can anticipate the interaction and also the consequences which contribute to affective responses before physical interaction occurs. These may both lead to and hamper behavioral responses. Regarding the use of lighting control device in hospital environments, for instance, by just looking at it, an individual may feel uncomfortable toward the use because he/she anticipates that using the device can cause infection. Thus, the use of the device may be hampered. It can be said that the device as well as its features communicate to the user only through visual perception that will influence physical interaction between those two.

Based on a framework of product experience in user-product interaction (Desmet & Hekkert, 2007), there are a number of factors that are involved in perception: i) the individual's characteristic such as background, cultural values, and motives and ii) the product's characteristic such as shape, texture, color and function which is referred to as affordances. In addition, the perception always occurs under a context which involves physical environment as well as social situation.

Visual perception of a product of lighting control device influencing the behaviors in relation to the optimal use of electric lighting and the related factors are proposed and illustrated in Figure 1.

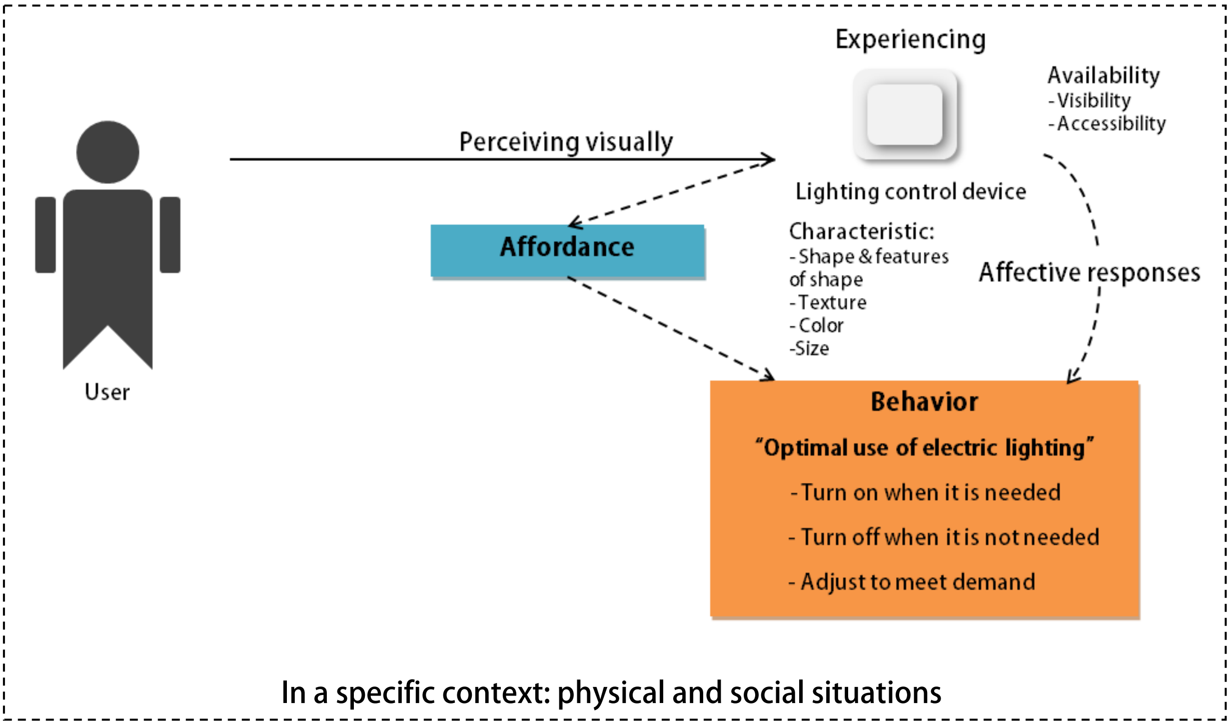

Figure 1 Visual perception of lighting control device influencing optimal use of electric lighting

Perceived behavioral control

Theory of Planned Behavior

The theory of planned behavior (Ajzen, 1991) described factors influencing the individual to perform a certain behavior. Degrees of perceived control of the behavior together with intention to perform the behavior can be used to predict whether the individual will perform the behavior or not. The intention is influenced by: i) attitudes towards the behavior which refer to the degree that an individual has a favorable or unfavorable evaluation or appraisal of the behavior, ii) subjective norm which refers to the perceived social pressure to perform or not perform the behavior, and iii) perceived behavioral control which refers to the perceived ease or difficulty to perform the behavior. The theory described that perceived control will influence the behavior directly and also indirectly, via the intention. However, it also described that a person may not perceive behavioral control when s/he has little information about the behavior, and/or when unfamiliar elements have entered into the situation.

According to Steg and Vlek (2009), perceived behavioral control expresses individuals' perceptions of contextual factors. Given this, it is assumed that perceived affordance of an accessible lighting control device may contribute to perceived behavioral control by providing information about behaviors that the device affords to an individual.

Moreover, design features may influence social interaction and therefore are associated with perceived control (Evans, 2003). We have considered that characteristics of the physical environment and social situation that an individual perceived will describe the context where he/she interacts with lighting control device(s). They may also influence perceived behavioral control as well as the behavior.

Based on the theoretical framework, Figure 2 illustrates a conceptual framework that establishes possible factors influencing lighting use in human-lighting control device interaction, and their relationships.

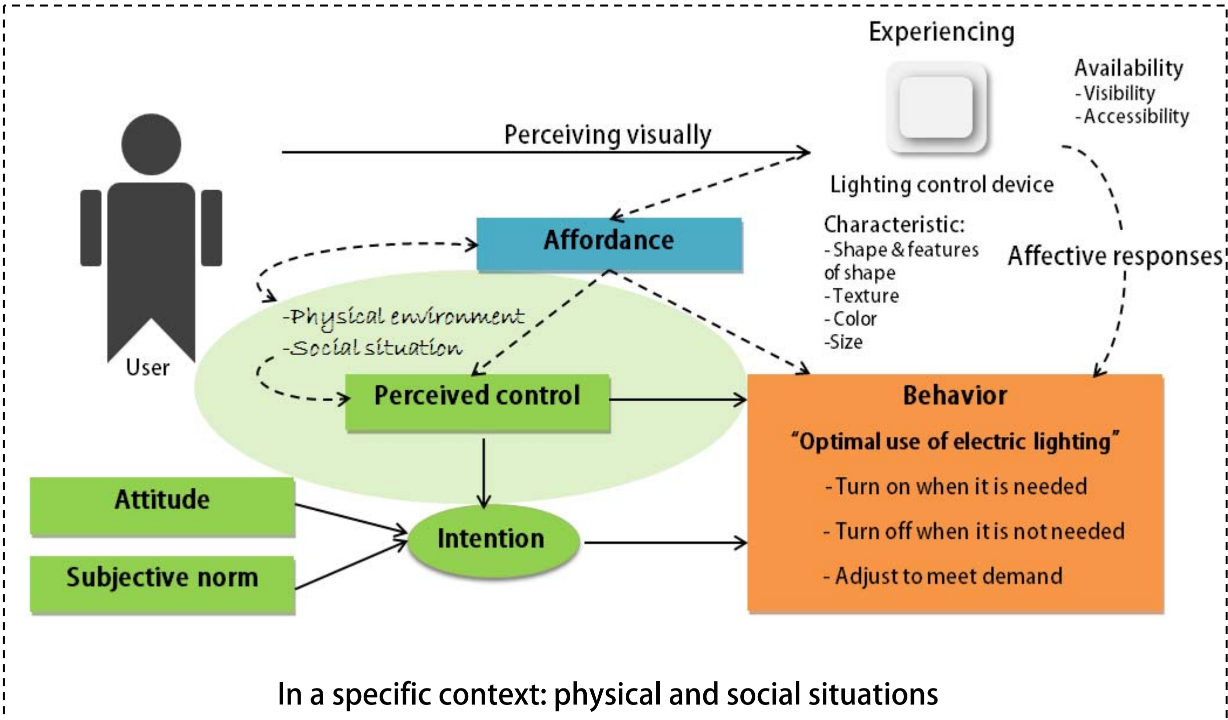

Figure 2 Conceptual framework for human interaction with lighting control device

Methods

The study was carried out in three patient wards at two hospitals in Sweden. A dining room and two day rooms where all users had possibility to manually control electric lighting were selected for this empirical study. The dining room and dayroom were located in two patient wards at a hospital in the south eastern coast, whereas another dayroom was located in a hospital in the southernmost of the country. The buildings were designed and built under the 1960s.

Environment

The rooms were selected due to their character of a shared space in hospital environments. The rooms provided sets of furniture for sitting and having meals, television, a refrigerator for storing patients' food, and a pantry for self-service coffee, tea and snack. The set of furniture was dining tables both round and rectangle shapes, and dining chairs. In addition, living chairs as well as bookshelves with some books and magazines were also provided in the day rooms.

All rooms had access to natural light. The main electric lighting in the rooms was from ceiling luminaires which could be controlled by using the lighting control devices. The devices in all rooms were wall-mounted push button switches situated close to the entrances. Their appearances were slightly different however, all of them were white push-button with white frames (Figure 3).

Dining room   Dayroom 1   Dayroom 2

Figure 3 Lighting control devices in the rooms

Direct observations in the dining room and dayroom covering: i) non-visiting hours between 9.00 and 12.00, ii) visiting hours between 14.00-15.00 and 19.00 of a weekday, and iii) visiting hours between 14.00 and 19.00 of a holiday were conducted to understand how the rooms were used. The observations were conducted in May 2012. Based on the observations as well as gathering available information on site, the purposes of using dining room and day room were considered similarly to some extent. They were used as an alternative place for patients to have their meals, and a place for patients to socialize with their visitors or other patients, for visitors to have coffee, tea and some snacks. The rooms were sometimes used as a waiting place for newly admitted patients and a staff member's visitor, and a place for conversation between staff-patient(s), staff-patient's visitor(s) and the visitor(s)-visitor(s). It seemed that the use of the rooms slightly differed between a weekday and a holiday. From the observations during weekdays, the rooms were mostly used by patients during lunch and dinner, by visitors at coffee time in the afternoon between 14.30 and 15.30 and evening between 17.30 and 19.00. Similar to holidays, the rooms were mostly used by patients for lunch and dinner. However, the rooms were more crowded and were used by both patients and visitors during the coffee time in the afternoon. The rooms were not often used by visitors in the evening.

Participants

People who use the three rooms: staff, patients and visitors aged over 15 years were approached to participate. They were asked to report their behaviors and their experiences of using electric lighting in the rooms in a questionnaire. The participation was voluntary.

A total of 46 people who were 31 staff or 15 patients (10 male, 36 female between 20 and 69 years old, *M*age = 42, *SD* = 14.49) participated in the study.

Instrument

The questionnaire consisted of the following measures:

Context of the room was assessed by questions regarding time and duration when the room was used together with 12 semantic scales. 4 scales from the Semantic Environmental Description (SED) (Küller, 1991) were used to measure perceived *originality* which concerns person's perception of unusual or surprising in an environment (e.g. ordinary, special). 8 scales from the Social Situation developed by Miljöpsykologi, LTH were used to measure perceived *familiarity* which concerns how common and well known a social atmosphere is perceived (e.g. different, everyday) and *friendliness* which concerns the perception of a positive or negative psycho-social atmosphere (e.g. friendly, respectable) in the room when the participants responded to the questionnaire. Perceptions regarding these scales was given on a seven-point rating scale ranging from *slightly* (1) to *very* (7).

Satisfaction of lighting in the room was measured by the question: Are you satisfied with the lighting here?, the response scale was a seven-point rating scale ranging from *unsatisfied* (1) to *very satisfied* (7).

Intention to adjust electric lighting was measured by the question: If you are not satisfied with the lighting here, what would you like to do with these ceiling lamps?, the response alternatives were *turn on*, *turn off, dim up, dim down* and *do nothing.*

Behavior was self-reported by answering the question: Have you done anything with lighting from the ceiling lamps in this room?, the response alternatives were *turned on*, *turned off, dimmed up, dimmed down* and *did nothing.*

Attitudes towards behavior (behavioral belief and feeling) were measured by 4 items (e.g., It is important to me to adjust the lighting in this room, energy use can be reduced if I adjust the lighting in this room) The responses to these items were given on a five-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5).

Subjective norm was measured by 2 items (e.g., It is common that people adjust the light in this room when they need). The responses to these items were given on a five-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5).

Perceived control of the behavior was measured by 2 items (e.g., it is easy for me to adjust the lighting in this room). The responses to these items were given on a five-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5).

Experience from visual perception of lighting control device was assessed by 14 items. Some items were adapted from the study by Beecher and Paquet (2005). The items were developed by a pilot study resulting in 6 indices (Maleetipwan, 2010) which had a possibility to discriminate between different lighting control devices. The responses were given on a five-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5). 4 items (Cronbach's α =.89) measure perceived *affordances* (e.g., lighting control device(s) in this room is easy to identify). Other 8 items correspond to the 5 indices which measured perceived *visibility, physical safety, suitability, hygienic use, and motivation and awareness to save energy*. Cronbach's α of the indices were between .89 and .79 except hygienic use (.47) ,however this index is kept due to it is considered as an important aspect in health care environments.

Moreover, a general *attitude towards lighting control device* was measured by the question: What do you think about the lighting control device?, the response scale was a seven-point rating scale ranging from *very bad* (1) to *very good* (7).

Attitude towards energy use for lighting in general was measured by 8 items. 4 items measured self-reported behavior in relation to the use of lighting (e.g., I only turn on the light when I really need it). The responses were given on a five-point scale ranging from *never* (1) to *all the time* (5). The other 4 items measured belief and feelings about the energy use (e.g. It disturbs me if I see that the lamps are on in an empty room). The responses were given on a five-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5).

The questionnaire also included 4 background questions (i.e. age, gender, country of birth and role in a hospital: staff, patient or visitor). The first page of the questionnaire provided brief information about the background and aim of the study as well as instructions on how to respond to the questionnaire, and the confidential treatment of data provided through participation in the study.

Procedure

Meetings were arranged with heads of the patient wards as well as staff where the rooms were located respectively to inform about the study regarding background, aim and implementation. One contact person from each ward was appointed to distribute the questionnaires to all staff and patients within the ward.

Response rate

A total of 80 questionnaires were distributed and 52 of them were filled in and returned. 2 of the returned questionnaires were removed because most of the important items were unanswered.

Statistical analysis

Relationships between occupants' satisfaction with lighting condition and intention to adjust lighting, actual behavior, and optimal use of electric lighting were examined through nonparametric correlations; Spearman's rho with the exclude cases pairwise option.

Descriptive statistics were used to present scores of users' experience from visual perception of lighting control devices, description of context of the rooms, and psychological constructs based on the Theory of Planned Behavior.

A one-way between group analysis of variance (One-Way ANOVA) was used to explore differences of the rooms concerning context, affordances as well as other characteristics of lighting control devices perceived in the different rooms. Relationships between the context, and perceived affordances and perceived behavioral control were examined mainly through nonparametric correlations, Spearman's rho with the exclude cases pairwise option. In addition, relationships between the context, and the other characteristics and perceived affordances of lighting control devices were also examined.

An independent-samples t-test was used to compare the scores of psychological constructs based on the Theory of Planned Behavior between staff and patients who participated in the study. Relationships between the constructs and intention to adjust lighting, and the actual behavior were also examined through the nonparametric correlations.

Furthermore, relationships between environmental concern represented as general attitude toward energy use of lighting (general behavior and feelings in relation to the energy use) and behavior concerning optimal use of electric lighting were examined by the nonparametric correlations. All analyses were performed by using IBM SPSS Statistics 19.

Results

The results regarding possible factors influencing optimal use of electric lighting in shared spaces in hospital environments and their relationships are presented as follows:

Satisfaction of lighting condition, intention, and behavior

29 participants reported that they were satisfied with lighting conditions in the rooms (gave scores higher than 3) whereas 15 participants reported that they were not satisfied with the lighting conditions. Table 1 shows a strong, negative correlation between degrees of satisfaction with lighting conditions and intention to adjust electric lighting ($n = 44$) and a moderate, negative correlation between the degrees of satisfaction and the actual behavior ($n = 43$). The intention significantly correlated with actual behavior with moderate strength ($n = 43$). The correlations were statistically significant at 0.01 level. It can be said that the less

people are satisfied with lighting conditions, the more they intent to adjust electric lighting and therefore they are likely to perform this behavior.

Then, we classified the subjects who reported that they were satisfied with lighting condition and therefore did not adjust electric lighting, and who actually adjusted it because of their dissatisfaction as ‘optimal use of electric lighting’. The subjects who were satisfied with lighting condition but actually adjusted the lighting and who were dissatisfied but did nothing were classified as ‘non-optimal use’. Table 1 also shows a moderate correlation between satisfaction with lighting condition and optimal use of electric lighting (n = 43). The correlation was significant at the 0.05 level.

Table 1 Correlations among the degrees of satisfaction with lighting conditions, intention, and actual behavior and correlation between the degrees of satisfaction and optimal use of electric lighting

	Spearman’s rho value		
	Satisfaction with lighting	Intention to adjust lighting	Actual behavior
Satisfaction with lighting	1.0	-.76**	-.47**
Intention to adjust lighting		1.0	.47**
Actual behavior			1.0
Optimal use of electric lighting	.36*	-	-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Visual perception of lighting control devices in the rooms

Table 2 shows the results from one-way between groups ANOVA. There was no difference in scores of experience from visual perception of the three lighting control devices in accordance with the criteria except for the criterion hygienic use and no difference in scores of general attitude towards the devices.

Table 2 Results of visual perception of lighting control devices from one-way between groups ANOVA

	Dining room (*n* = 12)		**Dayroom1 (*n* = 7)**		**Dayroom2 (*n* = 25)**		*Post-hoc* differences (Tukey HSD, $p<.05$)
	M	***SD***	***M***	***SD***	***M***	***SD***	
Affordance	3.83	1.20	3.57	1.03	4.12	1.04	Not significant
Visibility	2.96	1.30	3.50	1.19	3.42	1.30	Not significant
Suitability	3.29	1.23	3.71	1.15	3.58	1.10	Not significant
Motivation	3.36	.92	2.90	.60	3.00	1.06	Not significant

Safety	4.63	.64	4.08	.80	4.52	.76	Not significant
Hygienic	2.96	1.03	2.36	.63	3.60	1.13	Dayroom1&Dayroom2*
General	3.72 (*n* =11)	1.20	3.86	1.57	4.16	1.43	Not significant

Overall, participants perceived slightly high affordances (*M* = 3.95, *SD* = 1.08, *n* = 44) and high safety of the three lighting control devices (*M* = 4.49, *SD* = 0.74, *n* = 44). The visibility and motivation toward energy saving of devices were perceived close to the neutral score (*M* = 3.31, *SD* = 1.27, *n* = 44 and *M* = 3.08, *SD* = 0.96, *n* = 44). The suitability of devices was perceived slightly higher than the neutral score (*M* = 3.52, *SD* = 1.13, *n* = 44). General attitude towards the devices were reported at the neutral score, ranging from 1-7 (*M* = 4.00, *SD* = 1.38, *n* = 43). The statistical significance revealed that the hygienic use of lighting control devices was perceived differently in dayroom 1 and dayroom 2. The device in dayroom 1 was perceived as the lowest score of hygienic use.

Table 3 shows correlations among the criteria. Correlations between affordances and visibility, and suitability were strong with statistical significance at the 0.01 level whereas correlations between affordances and motivation, and hygienic use were moderate with the significance at the 0.05 level. There was a strong correlation between visibility and suitability, and a moderate correlation between visibility and motivation. As shown in the table, correlations were statistically significant at the 0.01 level. Correlations between the general attitude and affordances, and visibility were moderate with the significance at the 0.01 level. There were moderate correlations between the general attitude and suitability, and motivation with the significance at the 0.05 level.

Table 3 Correlations among the criteria and general attitudes towards lighting control devices

	Spearman's rho value						
	Affordance	Visibility	Suitability	Motivation	Safety	Hygienic	General
Affordance	1.0	.73**	.62**	.32*	.19	.30*	.40**
Visibility		1.0	.74**	.40**	.10	.20	.46**
Suitability			1.0	.18	.13	.07	.38*
Motivation				1.0	-.03	.11	.19
Safety					1.0	.24	.05
Hygienic						1.0	.36*
General							1.0

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Correlation between perceived affordances and perceived behavioral control

The first-round analysis pointed out that a correlation between perceived affordance of lighting control devices and perceived behavioral control was small and not significant, *rho* = .22, *n* = 44. Then, a scatterplot illustrating the nature of the relationship of the two variables was generated. We found four subjects who reported perceived affordances at a high score (4 or 5) while perceived behavioral control were reported with the lowest score (1). To reexamine and affirm the relationship, we excluded these subjects. Through the second-round analysis, a correlation between perceived affordance and perceived behavioral control turned out to be moderate, *rho* = .44, *n* = 40 and statically significant at the 0.01 level.

Correlations with optimal use of electric lighting

The first-round analysis suggested weak relationships between all criteria, general attitude and optimal use of electric lighting (*rho* values were between -.23 and .22). Scatterplots were generated and then few subjects (between 1 and 4 subjects) who gave extremely different scores for two variables were excluded from the second-round analysis. The suggestion of weak relationships between affordance, suitability, safety, and hygienic use of lighting control devices, and the attitude towards the devices and the optimal use was affirmed. The analysis could point to a moderate correlation at the 0.01 level between motivation and the optimal use, *rho* = .42, *n* =39 and a moderate correlation at the 0.05 level between visibility and the optimal use, *rho* = .40, *n* =40.

Context of the rooms

The context of each room was described through participants' perceived originality of physical environment and familiarity and friendliness of the social atmosphere. The results from one-way between groups ANOVA indicated no difference in scores of the originality, familiarity and friendliness perceived in all rooms where the familiarity obtained the highest scores (Table 4).

Table 4 Results of the room's contexts from one-way between groups ANOVA

	Dining room		**Dayroom1**		**Dayroom2**		*Post-hoc* differences (Tukey HSD, $p<.05$)
	M	***SD***	***M***	***SD***	***M***	***SD***	
Originality	2.53 (*n* = 10)	0.98	3.42 (*n* = 6)	1.63	2.39 (*n* = 23)	1.05	Not significant

Familiarity	4.98 (n = 11)	1.24	3.92 (n = 6)	1.50	4.94 (n = 24)	1.30	Not significant
Friendliness	3.59 (n = 11)	1.60	3.71 (n = 6)	.72	3.73 (n = 24)	1.47	Not significant

Correlations with affordance and perceived behavioral control

The first-round analysis suggested weak relationships between the context and perceived affordances of lighting control devices, and perceived behavioral control (*rho* values were between -.23 and .26) except for the correlation between perceived familiarity of social atmosphere and affordances. The correlation was moderate, *rho* = .38, *n* = 41 and statistically significant at the 0.05 level.

We again reexamined the nature of the relationships by generating scatterplotts. Then, few subjects (between 1 and 4 subjects) who gave extremely different scores for two variables were excluded from the second-round analysis. The suggestion of weak relationships between perceived originality of the rooms and perceived affordances, and perceived familiarity of social atmosphere and perceived behavioral control was affirmed. The analysis could point to a moderate correlation at the 0.01 level between perceived originality of the room and perceived behavioral control, *rho* = .47, *n* =34 and a moderate correlation at the 0.05 level between perceived friendliness of social atmosphere and perceived behavioral control, *rho* = .32, *n* = 38. It could also point to a moderate correlation at the 0.01 level between perceived friendliness of social atmosphere and perceived affordances, *rho* = .42, *n* = 37.

Psychological constructs

The results regarding psychological constructs are presented as i) comparison of each psychological construct between staff and patients and ii) correlations of the constructs with intention and behavior.

Attitudes towards behavior

Overall, participants expressed their behavioral belief concerning energy use and cost by adjusting electric lighting in the rooms slightly higher than the neutral score (*M* = 3.43, *SD* = 1.22, *n* =43). The participants expressed their feeling of how important and meaning to adjust electric lighting rather neutral (*M* = 3.15, *SD* = 1.06, *n* = 44). The t-test analysis suggested no significant in scores of the belief for staff (*M* = 3.63, *SD* = 1.27) and patients (*M* = 2.96, *SD* = .99); *t* (41) = 1.70, *p* = .10 (2-tailed). Regarding the feeling, there was also no significant in scores for staff (*M* = 3.27, *SD* = 1.14) and patients (*M* = 2.85, *SD* = .80); *t* (42) = 1.23, *p* = .23 (2-tailed).

Subjective norm

Participants slightly perceived low social pressure to adjust electric lighting in the rooms (*M* = 2.70, *SD* = .94, *n* = 22). There was no significant difference in scores of perceived the social pressure for staff (*M* = 2.71, *SD* = 0.96) and patients (*M* = 2.69, *SD* = .93); *t* (42) = 0.06, *p* = .96 (2-tailed).

Perceived behavioral control

The behavioral control perceived by participants is rather neutral (*M* = 3.18, *SD* = 1.91, *n* = 44). There was no significant difference in scores of perceived behavioral control for staff (*M* = 3.23, *SD* = 1.34) and patients (*M* = 3.08, *SD* = .76); *t* (42) = 0.37, *p* = .71 (2-tailed).

Correlations with intention and actual behavior

Besides all participants, we also examined the participants who reported that they were dissatisfied with lighting condition. This was done because the previous analysis showed a strong, negative relationship between satisfaction with lighting condition and intention to adjust electric lighting. Therefore, we were particularly interested in relationships between psychological constructs and intention, and behavior of these participants.

Table 5 shows that correlations between psychological constructs and intention to adjust electric lighting were not statistically significant except for feeling (*n* = 44). For all participants, correlations between belief, and perceived behavioral control and the intention (*n* = 43) were negative however, these correlations were not strong. There was a moderate, negative correlation between perceived behavioral control and the actual behavior (*n* = 43) with statistical significant at the 0.05 level.

Considering the group of participants with dissatisfaction with lighting condition (*n* = 15), all correlations between psychological constructs and the intention, and actual behavior were not statistically significant. Similar to the findings from all participants, correlations between belief, and perceived behavioral control and the intention were negative and not significant. Though a correlation between perceived behavioral control and the actual behavior was moderate and negative, it was not significant.

Table 5 Correlations between psychological constructs and intention, and actual behavior

	Spearman's rho value	
	Intention to adjust lighting	Actual behavior
All Participants		
Behavioral belief	-.15	-
Feeling	.53**	-
Subjective norm	.11	-
Perceived behavioral control	-.25	-.32*
Participants with dissatisfaction with lighting condition		
Behavioral belief	-.19	-
Feeling	.32	-
Subjective norm	.13	-
Perceived behavioral control	-.31	-.42

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Environmental concern influencing optimal use of electric lighting

The first-round analysis suggested weak relationships between the general behaviors and feelings in relation to energy use for lighting (*rho* values were between .22 and .27, $n = 43$). After the generation of scatterplots and the exclusion of 3 subjects who gave extremely different scores for two variables from the second-round analysis, correlations between the general behavior, and the general feelings and optimal use of electric lighting were moderate (*rho* = .42, $n = 40$, and *rho* = .43, $n = 40$, respectively) and significant at the 0.01 level.

Conceptual framework

A conceptual framework was developed through examining relationships among the possible factors influencing optimal use of electric lighting in shared spaces in hospital environments. The relationships are summarized in Figure 4.

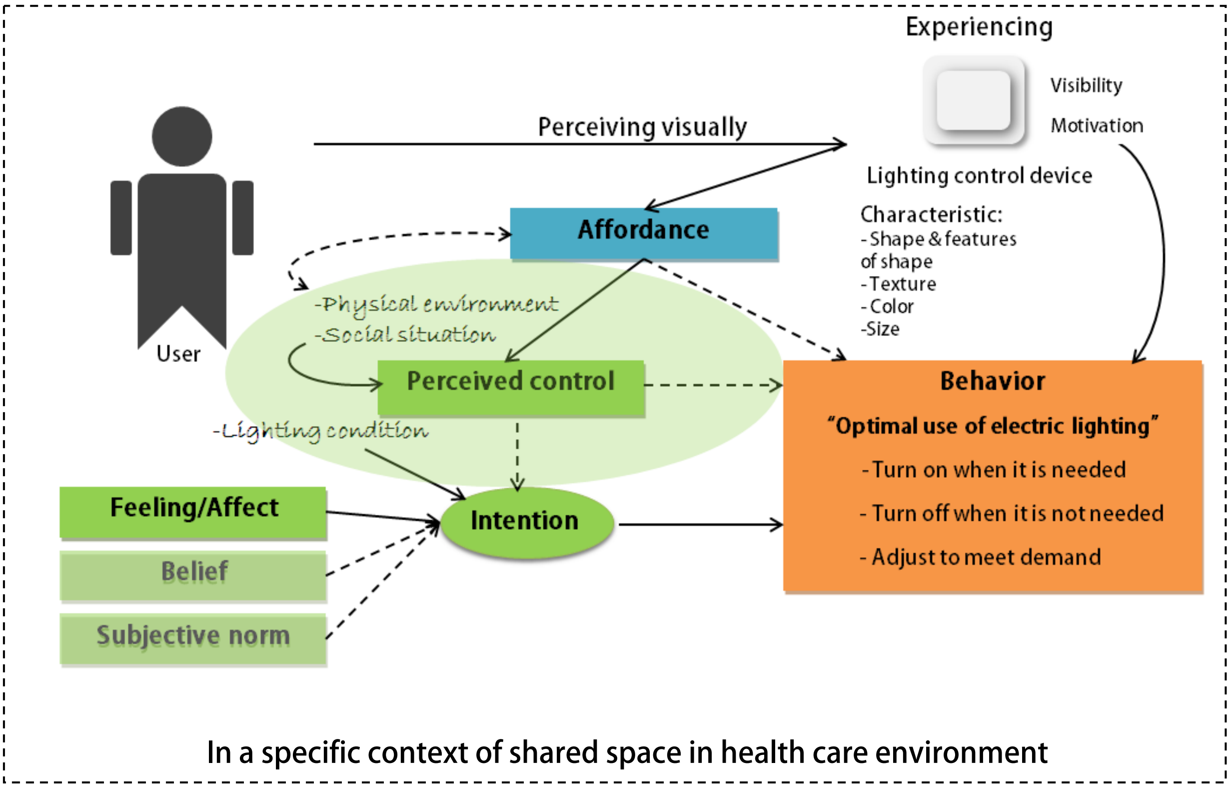

Figure 4 Conceptual framework and relationships among factors and optimal use of electric lighting

Discussion and conclusion

A conceptual framework was proposed to explain why an individual perform a certain behavior in relation to the optimal use of electric lighting in shared spaces in hospital environments. Considering the elements such as affordances of the devices, originality of physical environment, friendliness and familiarity of social atmosphere and perceived behavioral control, the framework may also be used to study impacts of built environment on perceived personal control supporting well-being of people.

It is clearly seen from the results that dissatisfaction with lighting condition could influence people to adjust electric lighting and therefore associate with optimal use of the lighting in shared spaces in hospitals. The moderate correlation between perceived affordances of lighting control devices and perceived behavioral control indicated that these two elements in the framework are related. The more degrees of perceived affordances of the devices could increase perceived ability as well as possibility to adjust electric lighting in shared spaces. However, relationships between perceived control and intention to adjust electric lighting, and the actual behavior are questioned. How perceived behavioral control relate to optimal use of electric lighting was also unclear and therefore studies with a larger sample size may be needed.

The moderate correlations between the characteristics of lighting control devices and optimal use of electric lighting indicated that the device characteristics can possibly influence people's use of electric lighting. We found that visibility of the devices and motivation and awareness to save energy perceived through the devices related to optimal use of electric lighting and also to perceived affordances. However, the study cannot establish a direct relationship between perceived affordances and optimal use of electric lighting.

Perceived affordances of lighting control devices may contribute to optimal use of electric lighting when people perceive behavioral control and then will adjust electric lighting. However, how affordances directly influence optimal use of the lighting is still in question. General attitude towards the devices did not seem to play a major role in optimal use of electric lighting due to the small correlation between them.

It was presupposed that perceived originality of physical environment will support perceived affordances of lighting control devices. However, the correlation indicated a weak relationship between them. Instead, perceived originality of physical environment seemed to relate to perceived behavioral control in the rooms. The originality may associate with locations and suitability of the devices as parts of the rooms and therefore may influence perceived behavioral control. Perceived familiarity and friendliness of social atmosphere in the rooms seemed to relate to perceived behavioral control. It could be said that people will perceive control in the rooms when they perceive familiarity and friendliness of the social atmosphere. It is quite unexpected that the results pointed to a relationship between perceived the familiarity and perceived affordances of lighting control devices. This may be because items used for measuring familiarity of social situation somehow could make respondents think about physical environment instead. The problem regarding communication of items used for measuring a social with respondents can further be mentioned due to an amount of missing data found in the returned questionnaires. Therefore, the reliability of these results is questioned.

The psychological constructs based on the Theory of Planned Behavior in the framework have been widely studied and resulted as relevant to behavior (Mannetti, et al., 2004; Kaiser & Gutscher, 2003; Kaiser, et al., 1999; Taylor & Todd, 1995). The theory has been successful in explaining various environmental behaviors. However, the studies seemed to focus on behaviors within a household context or social context. To the best of our knowledge, no study using the theory has been focused on behaviors in shared spaces in hospital environments. In this context, we found that the feeling of how important to adjust electric lighting significantly related to intention to perform this behavior. However, relationships between the other psychological constructs and the intention are questioned. Our empirical study affirms that intention can be used to predict behavior but cannot elucidate on perceived control influencing behavior. Characteristics of hospital or health care environments should be further studied regarding their impact on an individual to perform a certain behavior of interest. Though we found that levels of environmental concern related to optimal use of electric lighting in shared spaces in hospitals, a strong relationship between them could not be claimed.

There are features of this empirical study that may limit the ability to generalize the data and results. First, user characteristics such as skill and educational background that may affect visual perception and interaction with lighting control devices were not measured in this study. Second, using a survey approach with voluntary participation usually results in a low response rate. The small sample size may affect the reliability of the results. Third, using a self-reported measure could be questioned regarding its validity to obtain results of actual behaviors. However, we believe that these approaches are ethical to assess information of people's experiences and behaviors, especially in hospital environments.

The results are expected to facilitate in identifying basic design features of lighting control devices supporting optimal use of electric lighting in shared spaces in hospital environments. So far, it can be said that characteristics of the devices that are easy to see in the room and able to elicit people motivation and awareness to save energy could contribute to optimal use of electric lighting. They also appeared to associate with perceived affordances of lighting control devices. We have considered that affordances could contribute to the optimal use through individuals' perceived behavioral control. The location and suitability of lighting control devices in relation to originality of physical environment could support perceived affordances and associated with visibility of the devices.

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References

Ajzen, I., 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes,* Volume 50, pp. 179-211.

Beecher, V. & Paquet, V., 2005. Survey instrument for the universal design of consumer products. *Applied Ergonomics,* Volume 36, pp. 363-372.

Chen, L. & Lee, C., 2008. Perceptual information for user-product interaction: Using vacuum cleaner as example. *International Journal of Design,* 2(1), pp. 45-53.

Cohen-Mansfield, J. & Werner, P., 1998. The effects of an enhanced environment on nursing home residents who pace. *GERONTOLOGIST ,* 38(2), pp. 199-208.

Desmet, P. & Hekkert, P. M. A., 2007. Framework of product experience. *International Journal of Design,* 1(1), pp. 57-66.

Dijksterhuis, A. & Bargh, J. A., 2001. The perception-behavior expressway: Automatic effects of social perception on social behavior. *Advances in Experimental Social Psychology,* Volume 33, pp. 1-40.

Doulos, L., Tsangrassoulis, A. & Topalis, F. V., 2007. *Evaluation of lighting controls in office buildings.* Cairo, WSEAS Press, pp. 69-77.

Energimyndigheten, 2012. *Vårdlokaler.* [Online]
Available at: http://energimyndigheten.se/sv/Foretag/Energieffektivt-byggande/Belysning---ny/Inomhus/Vardlokaler/
[Accessed 31 05 2012].

Evans, G. W., 2003. The built environment and mental health. *Journal of Urban Health: Bulletin of the New York Academy of Medicine,* 80(4), pp. 536-555.

Figueiro, M. G., 2004. Occupancy sensors: Are there reliable estimates of the energy savings?. *Lighting Design + Application (LD+A)*, January.

Galasiu, A. D., Newsham, G. R., Suvagau, C. & Sander, D. M., 2007. Energy saving lighting control systems for open-plan offices: a field study. *Leukos,* 4(1), pp. 7-29.

Galvao, A. B. & Sato, K., 2005. *Affordance in product architecture: Linking technical functions and users' tasks.* Long Beach, ASME Press, pp. 1-11.

Gibson, J. J., 1979. *The ecological approach to visual perception.* Boston: Houghton Mifflin Company.

Gibson, J. J., 1982. The theory of affordances and the design of the environment, 1976. In: E. Reed & R. Jones, eds. *Reasons for realism: selected essays of James J. Gibson.* Hillsdale: Lawrence Erlbaum Associates, pp. 413-416.

Hackos, J. T. & C., R. J., 1998. *User and task analysis for interface design.* New York: John Wiley & Sons.

Hartson, H. R., 2003. Cognitive, physical, and perceptual affordances in interaction design. *Behavior and Information Technology,* 22(5), pp. 315-338.

Kaiser, F. G. & Gutscher, H., 2003. The proposition of a general version of the theory of planned behaviour (TPB): predicting ecological behaviour. *Journal of Applied Social Psychology,* Volume 33, pp. 586-603.

Kaiser, f. G., Wolfing, S. & Fuhrer, U., 1999. Environmental attitude and ecological behaviour. *Environmental Psychology,* Volume 1-19, pp. 1-19.

Küller, R., 1991. Environmental assessment from a neuropsychological perspective. In: *Environment, Cognition and Action. An Integrated Approach.* New York: Oxford University Press, pp. 111-147.

Maier, J. R. A. & Fadel, G. M., 2009. Affordance based design: a relation theory for design. *Res Eng Design,* Volume 20, pp. 13-27.

Maleetipwan, P., 2010. Design and validation of an instrument for measuring human perception of lighting control devices. In: S. Kabisch, A. Kunath & H. Feldmann, eds. *Abstracts of Presentations 21. IAPS Conference, 27 June-2 July 2010, Leipzig, Germany Vulnerability, Risk and Complexity: Impacts of Global Change on Human Habitats.* Leipzig: DDF Digitaldruckfrabrik GmbH, p. 426.

Mannetti, L., Pierro, A. & Livi, S., 2004. Recycling: planned and self-expressive behaviour. *Journal of Environmental Psychology,* Volume 24, pp. 227-236.

Moore, T., Carter, D. J. & Slater, A. I., 2002. User attitudes toward occupant controlled office lighting. *Lighting Research and Technology,* 34(3), pp. 207-219.

Moore, T., Carter, D. J. & Slater, A. I., 2004. A study of opinion in offices with and without user controlled lighting. *Lighting Research and Technology,* 36(2), pp. 131-146.

Norman, D. A., 1990. *The design of everyday things.* London: MIT Press.

Reed, E., 1988. *James J. Gibson and the psychology of perception.* New Haven: Yale University Press.

Shapiro, D. H. & Astin, J., 1998. *Control Therapy.* New York(NY): Wiley.

Steg, L. & Vlek, C., 2009. Encouraging pro-environmental behavior: An integrative review and reserach agenda. *Journal of Environmental Psychology,* Volume 29, pp. 309-317.

Story, M. F., 1997. Is it universal? 7 Defining criteria. *Innovation,* 16(1), pp. 29-32.

Taylor, S. E. & Brown, J. D., 1988. Illusion and well-being: A social psychological perspective on mental health. *Psychological Bulletin,* 103(2), pp. 193-210.

Taylor, S. & Todd, P., 1995. An integrated model of waste management behavior. A test of household recycling and composting intentions. *Environment and Behavior,* Volume 27, pp. 603-630.

The Center for Universal Design, 1997. *The Principles of Universal Design,* Raleigh: North Carolina State University.

Vihma, S., 1995. *Products as representations: A semiotic and aesthetic study of design products.* Helsinki: University of Art and Design.

You, H. & Chen, K., 2006. Applications of affordance and semantics in product design. *Design studies,* 28(1), pp. 23-38.