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ANALYSIS OF THE FUNCTIONAL MODEL - LED LUMINAIRE: HEURISTIC EVALUATION AND FOCUS GROUP

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Abstract: The present work aims at the application of a formative evaluation in a functional model of LED luminaire, centered on the concepts of User-Centered Design (DCU) according to Maguire (2001). The evaluation process was applied in the Laboratory of Ergonomics and Usability from UFPR (LabErg) and was divided in 3 phases: the first phase consists of an evaluation with 5 experts referring to the model; evaluating the heuristics and ergonomic criteria infringed. In the second phase the focus group is applied with 12 low-income users, divided into two groups. A pilot with 4 users (female) and a final group with 8 users (male). This phase aims to evaluate the perception of the use of the luminaire before the experiences of users in the environment. The third and final phase is related to the evaluation of illuminance in the simulation environment (living room). The analysis of the procedure allowed to identify and describe the negative and positive characteristics of the evaluation of the model with the

users in relation to the ergonomic and usability aspects, as well as recommendations to qualify the product in development. The information obtained from the study points to two main difficulties in the process: the first consists in the difficulty of conducting research with a public of low schooling; the second refers to the choice of the technique for evaluation of a product, with emphasis on the user, in which an arrangement of methods is necessary that allows a closer assessment of the real context due to the use of the functional model.

1. INTRODUCTION

The model is the result of larger research entitled LED luminaire platform for social housing at master's level and developed by the Federal University of Paraná – UFPR in partnership between the Design and Sustainability Center and experts
(SERBENA, 2013).

The product to be evaluated is a modular luminaire with LED technology oriented towards an eco-efficient system concept. The model has 1 hexagonal base, 3 square modules and a switch as shown in images 1 and 2. Its concept is to save energy through conscious use by the user and the lighting comfort in homes

Image 1. LED luminaire installed.

As Serbena (2013) discusses, saving energy allows families to spend less on their lighting bill, being able to allocate this resource to meet other needs. Lighting comfort is related to the user's well-being and the correct level of light present in the environment in order to avoid visual fatigue or even health problems due to poor lighting during various tasks throughout the day.

Imagem 2. Interruptor avaliado.

The power LEDs selected for building the model were from the company Seoul Semicom Acriche, model AN4214 of 8 watts, AN3211 of 4 watts in 3300K and 5500K. The material of the functional model is steel sheets, surrounding the

cutting and bending process and finishing in

epoxy paint. The luminaire uses the output from the ABNT NBR 14136 standard socket, to ensure safety for the user of the electrical connection.
The lighting system is based on a central hexagonal platform with three supports for adding LED modules (consisting of heatsink and chipled). They can also be turned on separately, creating a scale of brightness in the environment using the switch as desired by the user (image 3): Image 3. Module evaluated.

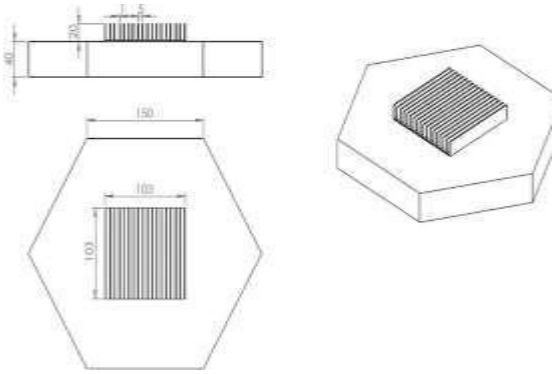
Fonte: Fotos tiradas pelos autores em laboratório. 2015.

The platform's main objective is to provide general lighting for the environment and the mobile modules have the function of directing the light to the region where more lighting is needed. The LED modules present in this component are the same ones

used on the central platform (SERBENA, 2013).

Below are the schematic drawings of the model (LED luminaire), with their respective measurements, as shown in image 4:

Imagem 4. Dimensões do módulo hexagonal (sem o plug de encaixe).



Fonte: Elaborado pelos autores. 2015.

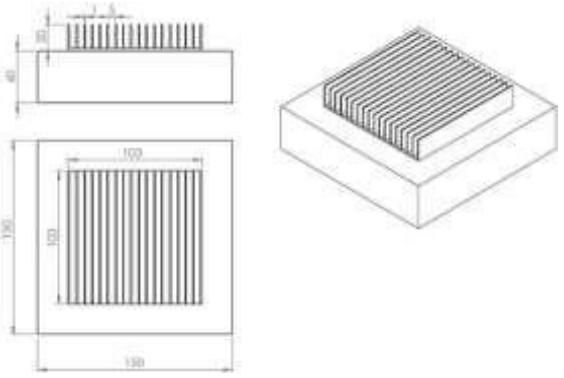
The hexagonal fixing base measuring 150mm on each side, the loose module (all 3 have the same measurements) 150mmx150mmx40mm, the image shows the angle at which the modules fit into the base (10°).

As shown in image 5, the details of the heatsink are also demonstrated, as LED technology produces less heat than a conventional lamp; however, according to the project, dissipation behind the modules is necessary, avoiding an increase in internal temperature which could lead to accidents:

Imagem 5. Dimensões do módulo quadrado (sem o plug de encaixe).

Fonte: Elaborado pelos autores. 2015.

Thus, the main idea of the project is versatility in needs.



As it has a good rate of illuminance variation, the luminaire can be used for different purposes in different domestic rooms. There is also the advantage of selectively lighting the modules, in order to receive the necessary amount of ambient light and also avoid excess energy expenditure.

2. METHODOLOGY

development

(MAGUIRE, 2001). A

To carry out the evaluation of the functional model, planning was necessary, which covers the classification in relation to the content to be analyzed;, the place of performance; the dimension of the evaluation; the emphasis on collecting or controlling variables and, also, user involvement. Thus, as it is a functional model in the research phase, the evaluation is considered formative, referring to the identification and correction of problems, with a view to improving the product in the research process.

user-centered (DCU), that is, thaT

considers user participation in one or more stages throughout the design process, in product improvement. For research organization purposes, the method was divided into 3 phases, as shown in table 1. The first phase consists of a heuristic evaluation with 5 experts applying the analysis of the heuristics infringed by Nielsen and Molich (1990), and also the ergonomic criteria violated according to Bastien and
Scapin (1993) on the functional model.
In the second stage, a focus group is applied, according to Morgan (1997), with participants who have the same profile as the product's target audience - the aim of which is to evaluate the perception of use of the luminaire. Therefore, a pilot evaluation was carried out with 4 users and, after refining the process, a focus group validation was carried out with 8 end users. This type of method offers more detailed information about the values and opinions of the selected participants than individual interviews, due to the fact that the interaction provides immersion in the discussion of the topic.
The third and final phase is more related to the characteristics of the product in relation to illuminance in the environment, comparing them with Brazilian domestic lighting standards. After applying the applied methods, we obtained a conclusion about the process as well as guidelines for improving the model in its final phase.

Chart 1. Research evaluation phases

Assessment phases
PHASE 1 - Heuristic Evaluation Round with professionals Sign and usability (5 experts) – structured online questionnaire.
PHASE 2 - Final focus group (8 users). Round with users-structured interviews.
PHASE 2 – Illuminance assessment product/environment.

Source: prepared by the authors. 2015.

At each stage, experts and users should, before answering the questionnaire or interview, go through the following process to explore the product and the environment:

1. Sign the free and informed consent form (attached).
2. Handle the functional model without being installed (base, modules and switch).
3. Turn the installed luminaire on and off using the switch

(connect the base and each module) and observe each type of lighting.

4. Use better lighting to watch TV and read a book with the ceiling lamp installed.
5. Use better lighting to watch TV and read a book with just one module connected.

Therefore, participants were asked in each task about the use of the lamp, which was carried out in a space more similar to the real one (simulated in the laboratory).

The analysis of the procedure adopted allows us to identify and describe the negative and positive characteristics of the evaluation of the functional model with users in relation to ergonomic and usability aspects, as well as recommendations to qualify the product through the users' experience. Furthermore, the choice of methods is related to the time of the research, as this way it is possible to collect a large amount of quantitative and qualitative information in a short period or session. The information obtained through this research procedure highlights two main difficulties. The first of these is the difficulty in carrying out research with people with low education; the second difficulty refers to the choice of technique for evaluating a product, with emphasis on the user, in which it is necessary to have an arrangement of methods that enable an evaluation closer to the real context, due to the medium fidelity model that would bias the performance of a usability test - that is, some properties are different from the final version, such as material, texture and weight.

2. RESULTS

2.1. HEURISTIC EVALUATION

To carry out the heuristic evaluation phase, 5 subjects were invited, students of the postgraduate course in design (02 master's students, 2 masters, and 1 doctoral student), who had already taken the usability discipline of the Postgraduate Program in Design and who work in research within the area of usability. The 5 individuals were invited to voluntarily participate in the test, on a pre-determined day and time. Each test was performed individually, without contact with the other subjects.

After the results obtained from the heuristic evaluation carried out by experts, all points about the product were added together to better visualize the questions applied, as well as better understand the variables. In this way, the product was evaluated as a whole, and not specifically for each item (switch, base and modules).

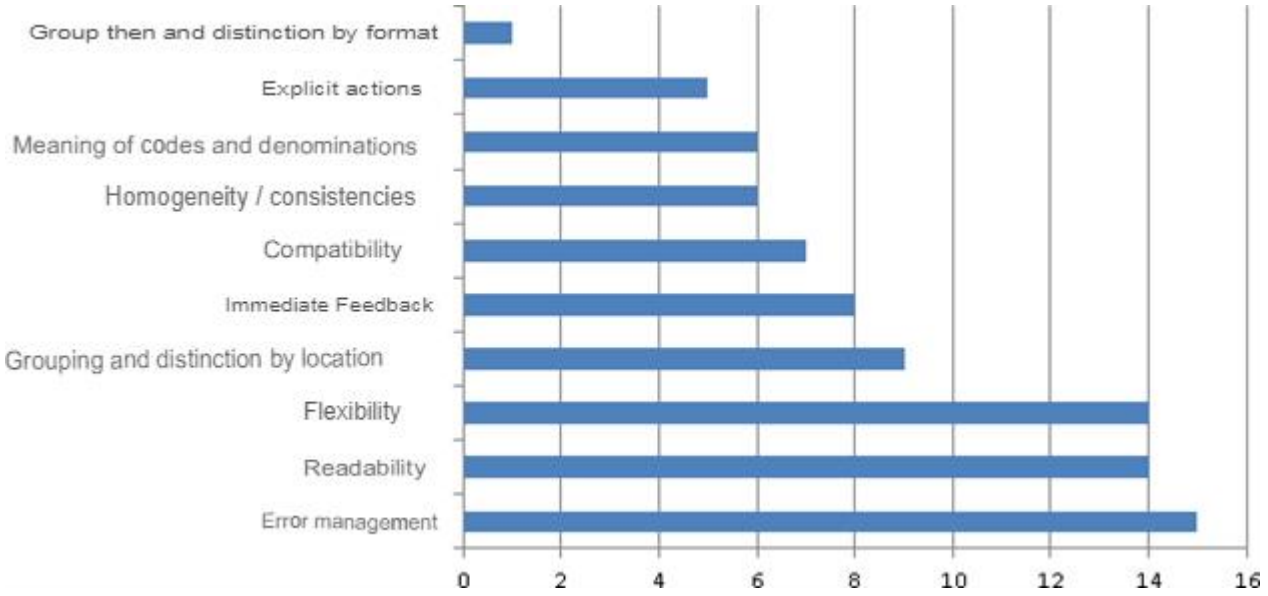
The results obtained seek to understand the source of usability problems

related to the luminaire. Regarding the infringed heuristics as shown in graph 1, all heuristics were infringed more than 4 times, which shows a general problem in the luminaire

- the one that represents the greatest concentration was flexibility and efficiency in use, being cited 19 times, around 17% of the total. Thus, a problem can be seen in the product's lack of flexibility: despite being a multifunctional luminaire (which reduces energy with conscious use), it does not efficiently facilitate use, which leads the user to spend a lot of time in simple tasks or even giving up on them.

The second most cited was error prevention, with 17 citations (15%), which demonstrates a lack of warnings or product safety, without immediate feedback from the system, linking user-system-activity in a better communication relationship. The third is system visibility, noted 15 times with around 13% of the total. This data demonstrates problems related to product communication, in the difficulty of the physical interface in showing options, form or solution for the task to be carried out successfully. Furthermore, as there is no digital interaction, it may be more difficult to communicate and visualize more possibilities for use, such as the interaction of modifying intensity, color, projection:

Graph 1. Sum of infringed heuristics.

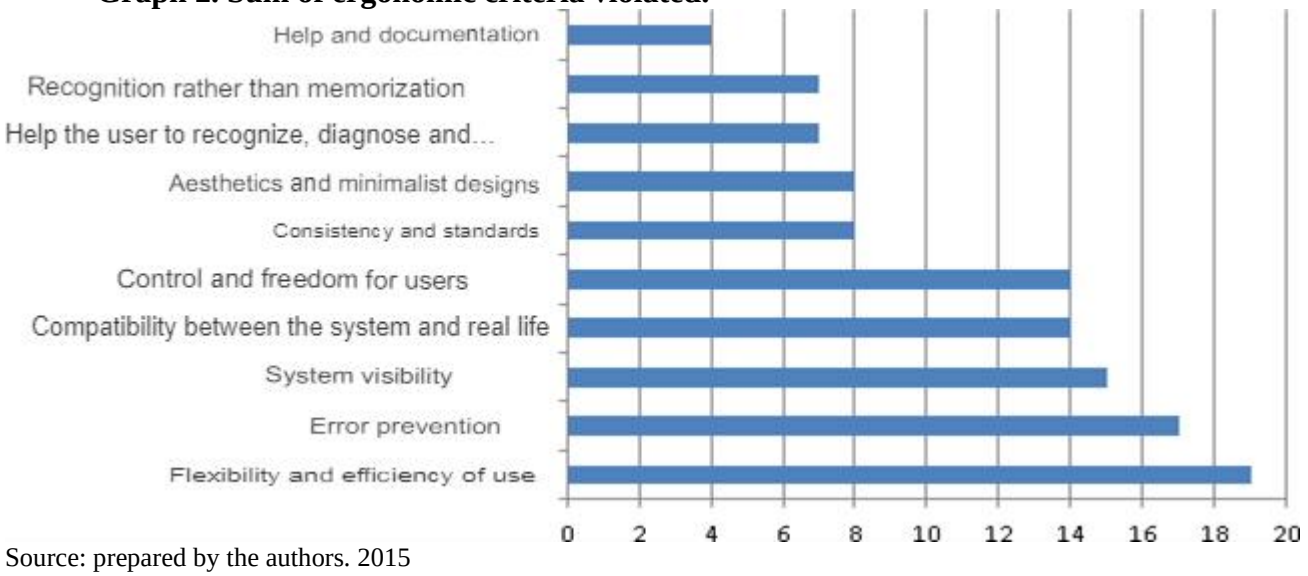


Source: prepared by the authors. 2015.

Regarding the total violated ergonomic criteria of the luminaire, as shown in graph 2, all were violated at least once, with a predominance in error management (15 citations with 17.6%), which is related to the error prevention heuristic . In that order, the readability and flexibility of the product are tied for second with 16.4% (14 citations), a result very close to error management. Thus, in the same way, this is correlated with the general result of the heuristics (system visibility and flexibility), which emphasizes the origin of the 3 most cited problems.

Regarding the general severity level of the luminaire, there is weighting on the average severity, as shown in graph 3 (largest graphs concentrated in the middle). The results are related to the development phase of the functional model, which is in the formative process. Probably with a lighter prototype or model or without its final phase, there would be a change in severity from the midpoint to ‘’very little’’ (item 1):

Graph 2. Sum of ergonomic criteria violated.



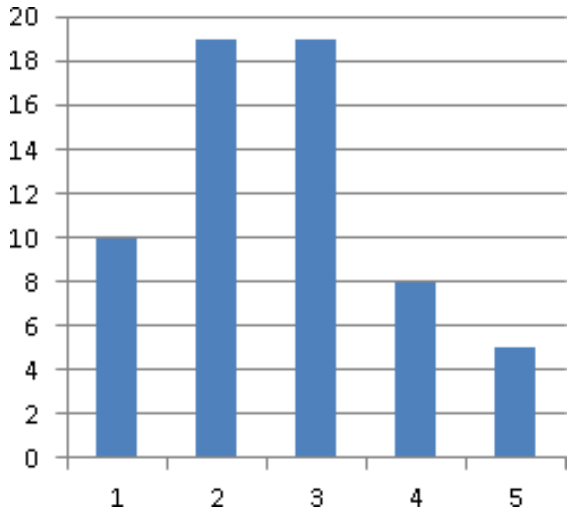
Source: prepared by the authors. 2015

Thus, there is a concentration on items 2 and 3 (31.14%), in which a medium concern prevails (between little and very severe) of the problems identified in the product, which should not be disregarded, as combined they exceed half of the total (62.28%).

Regarding where there will be negative implications on the usability of the product, in general, user satisfaction when using the luminaire was identified as the main point with

42.85% (30 occurrences), in second place the effectiveness (34.28% - 24 occurrences) and finally efficiency with 24.28% (17 occurrences).

Graph 3. Sum of the severity level of the observed problems.



Source: prepared by the authors. 2015

Thus, the origin is more directed towards satisfaction, that is, the user's reaction to the product, likes and dislikes when using it. Efficacy prevails over efficiency, showing that the user will make more mistakes related to doing the wrong tasks than spending more time on tasks, that is, they have more of a tendency to trial and error than spending more time on a given task:

Graph 4. Sum of dimensions where there will be negative implications.

Source: prepared by the authors. 2015

2.2. Focus group evaluation

Image 6. Focus group evaluation of 8 users in the laboratory.

Source: Photos taken in the laboratory by the authors.

better data analysis; the application took place in the same location at LabErg on 08/01/2014.

User profile: total of 8 individuals, male, average age 43.5 years. The level of education was 05 individuals with primary education, 02 with secondary education and 01 without literacy. The individuals' homes had the following number of rooms: 08 rooms (01 individual); 04 rooms (06 individuals) and 04 rooms (3 individuals). 07 subjects said they use ceiling lamps in the kitchen and 01 subject uses them in the living room. Mobile type luminaire is used by 5 individuals in the bedroom, by 2 individuals in the living room and by 1 individual in the hallway. Below is the transcript of the evaluation team's assessment.

The characteristics most highlighted by individuals were:

- Durability (mentioned twice);
- Beautiful (mentioned 2 times);
- Soft;
- Of glass;
- Good lighting;
- Attractive and Round.

The application of the focused group resulted from the observations of 4 evaluators present. Initially, in order for the group to feel more comfortable, individuals were asked to sit down, observe the space and check if the room was the same size as their home. Everyone if they felt at ease and found that the space felt like home.

I. What tasks do you normally do in the room?

- The comments were unanimous: watching television, eating, talking and watching cell phones.

II. Do you know how to see the energy savings on the packaging when purchasing?

- The comments were unanimous: The subjects demonstrated that they are more accustomed to buying fluorescent lamps, as they are more economical and safer.

III. What characteristics do you consider/notice of this lamp in general? (heavy, light, strong, complex, beautiful, pointed, qualities).

- There is a consensus that the luminaire is more practical, however, heavier, they also realized that it poses less risk, providing greater safety.
- Specifically, it was observed by 01 subject that it was difficult to handle and the structure could be smaller to reduce discomfort.

2.3. Product-specific questions (each task)

IV. Do you find the switch comfortable to press?

- By consensus, the lamp is comfortable.
- And specifically, there would be no need for color, the position of the buttons is enough for the user.

V. Is the switch defective?

VI. The switch is comfortable and the shapes are more interesting than the colors. It is more intuitive to follow the geometry, by trial and error and only then identify by colors.

VII. Did you have difficulty understanding the modules/parts, no ON/OFF response, identification of colors with the base (shape, patterns)?

- The subjects unanimously felt that the colors did not help in understanding the product on a day-to-day basis, but the design pattern of the switch helped a little more.
- Some specific comments: a) changing the colors would be interesting depending on the height of the switch, as it would help children understand how to turn on the lamps; and b) a sticker next to the switch or a user instruction manual was suggested.

VIII. Would you like to understand how much energy the switch uses? (perception of the economy).

- Yes, it would be interesting, but it would require a manual. On the switch would be the best place to see this information.

IX. Would you like to regulate the light strength for each type of task using the switch? (reading, watching TV, other). Is it useful? Do you realize that you save energy by doing this?

- Unanimously, the subjects would like to have just one adjustment on the base, it would not be necessary on the modules.

X. Would you like to change the colors using the switch? What colors?

- Unanimously, the subjects did not want to change the color, claiming it was not functional, as it is already possible to change luminosity according to the number of connected modules.

XI. Is the light pleasant for watching TV?

- The light is unanimously pleasant for watching television depending on each user's preference (half-light or completely off).

XII. And to read?

- For reading, users felt comfortable in this activity and the luminance was unanimously good (all modules accessed or with one module turned off).

XIII. Did you have any difficulty fitting it in? Why?

- They unanimously found the fitting easy, but in the dark it is very difficult to find the fitting.

XIV. Do you think this base fit is safe? What if there was a docking warning?

Unanimously they did not consider it safe, they considered that it needs to have a fitting warning, to avoid bending the plug. However, they considered that it is difficult to get a shock, as the fitting works differently than screwing in a traditional lamp, as the base housing protects it.

XV. Did you have any difficulty fitting it in? Why?

- They unanimously consider fitting the socket to be easy, with no difficulty in fitting.

XVI. o you think this module fit is safe? What if there was a docking warning?

- Unanimously it would be better to have a safety warning. As approached for the base.

XVII. Is the light comfortable? For what situation?

- The majority of the group reported that they felt comfortable with the module's lighting, few said otherwise, as the module is close to the face, providing a strong light.

XVIII. Did you find a product difficult, moderate or easy? Why?

- In general, participants considered the product to be easy to use, as the fittings are easy, it saves energy when used, it has colors that can be viewed, the switch layout, and there is no risk of shocks. Finally, they considered it easy to use and versatile.

XIX. Regarding the product, what are your suggestions for improvement?

- As a suggestion for improvement, users unanimously addressed an improvement in the fit, providing more security, the possibility of purchasing just the base (without the modules), changing the format (very ‘’square’’).

IX. Would you buy this lamp “in this form” (model)?

- Unanimously, yes. Mainly because of energy savings, but it would also depend on the value of the product.

2.3. Illuminance assessment

The illuminance assessment in lux was carried out in the same simulated environment in which the other assessments were applied (images 7). Thus, the living room has an area of 3.6m x 3.9m with the lamp positioned at a height of 2.25m. The study area was sealed with paper and black plastic film to prevent interference from external lux.

Image 7. Dimensions of the living room.

Source: prepared by the authors. 2015

Lux meter was recorded using a Luxmeter (Digital Lux Meter – MLM1010 – Brand Minipa), on July 2, 2014, at 12 noon on a partially cloudy day with few clouds as shown in image 8. The meter was positioned on the surface of a wooden table centered exactly under the center of the lamp (h= 0.75m), as shown in image 12 and also at eye level while seated (50% percentile male, with eye height of 1.22m).

Table 2. Average lux at coffee table level.

Situation	Average Lux recorded at the table level center (0.75m)	Lux indication for living room - NBR 5413
Neutral environment with the lamp turned off	1	-
The assembled module with all its LED lamps on.	268	General Activities **150**
Only the Central Module	117	
Red module only	48	Local activities
Orange Module Only	55	(reading)
Green Module Only	48	**500**

Source: prepared by the authors. 2015

Table 3. Average lux at eye level when sitting.Source: prepared by the authors. 2015

Situação	Average Lux recorded at eye level (1.22m)	Lux indication for living room - NBR 5413
Neutral environment with the lamp turned off	1	-
The assembled module with all its LED lamps on.	163	General Activities **150**
Only the Central Module	84	
Red module only	26	Local activities
Orange Module Only	17	(reading)
Green Module Only	36	**500**

From tables 2 and 3, it can be seen that the lux produced by the model under the incidence of natural light on the environment, without any other source of artificial light, was 1 Lux in both situations. The lux produced in the table position was greater than in the sitting position, due to the fact that the incidence of light was greater under the lamp, thus showing the difficulty of distributing light equally throughout the environment (more than double the lux in the table position). table than sitting).

Following the standards of NBR 5413 for Illuminance in lux, by type of activity, in the sitting position the luminaire proved to be effective with all modules accessed for general activities (13 lux beyond the ideal). However, for localized activities, whether for a situation with all accesses or for each module, it was identified as ineffective for both activities, not reaching the necessary lux according to the standard.

For general lighting in the rooms listed above, there is a divergence from the norm on occasions noticed in the focus group, in which there is no need to light more than the central module, as they felt comfortable, thus allowing the user to remove the side and side modules. Use them in other areas of the home.

Similarly, the side modules can be used in different positions due to the fact that they are removable, however, as already discussed, they may not perform a good function as a type of lampshade, due to the light being very harsh and not reaching the recommended level. On the other hand, they provide good general ambient lighting when connected together.

3. DISCUSSION

In the evaluation with the experts, the main sources of problems were identified due to the heuristics and ergonomic criteria violated, these showed concerns mainly related to the flexibility of use, error management and readability of the system; being identified in a natural way, putting themselves in the user's shoes.

Thus, they are linked to the intuitive use of the switch and modules, which they pointed out as not efficient, requiring more time from the user in a normally simple task; in fact, this was also proven in the application of the two focus groups. Therefore, there was a great relationship between the two evaluation phases, as what was collected in the first phase was validated in the second phase, in the actual use.

The first phase showed that the luminaire needs changes in terms of flexibility of use and that this will drastically affect user satisfaction, changes in relation to the interface recognition time, which needs to be reduced, facilitating easily memorized operations with the switch, with buttons more intuitive or digital. One option would also be to adopt designs from the luminaire itself and maintain the already proposed layout with more contrasting colors. Regarding the modules and the base, changing the material to a polymer will directly affect the weight of the final product,

facilitating unstable fittings. It would also be interesting to make the light softer for the light to exit.

In short, the 1st phase highlights the high cognitive load to understand the procedure, as well as the system being excessively bureaucratized to carry out a simple action (turning on a light bulb). Furthermore, the format does not communicate energy savings. The color code and positioning system is not effective. Another aspect identified is the inconsistency between the location of switches and modules. They are presented with different spatial orientations and, therefore, the user's perception may change between a horizontal and vertical reading. Therefore, reviewing the graphical presentation of the button panel allows greater fidelity in the relationship with the user's vision of the product.

However, regarding the application of the focus group in the second phase, in general, users found the product to be easy to use, with simple fitting, as, compared to conventional lamps, which are "screw-in", the product appears as innovative, as it is easy to use. But it was suggested that there be a change in the identification colors and that more contrasting colors be used, as seen in phase 1, due to the fact that there are users with low vision.

There were similar and distinct opinions regarding the pilot group (female) and the second group (male). In the two focus group applications there was a consensus that it could be lighter to handle and that they would buy the model with the changes as long as it was not expensive. Furthermore, the pilot group was more concerned than the second group regarding issues related to children's safety, proposing fixed socket protectors in the modules' fitting, thus avoiding accidents and accumulation of dirt.

There were also differences in the groups when approached about colors, in the pilot they found it interesting and in the second unnecessary, since there is the positioning of the buttons, but both indicate that it should come with a manual or explanatory drawing.

The second group was able to identify more operational problems with the system, such as the lack of an ‘’ON/OFF’’ option for the user when connecting loose modules, so as not to be repeatedly plugging in and unplugging. However, the assessment sought to address the requirements for making lighting more flexible to the context of use and regulating light intensity, given that different activities are carried out in the house and require different intensities, but both groups pointed out how

unnecessary, as there is already some control over the activation of each module.

Regarding the illuminance assessment, it was observed that there were disagreements with the focus group related to the reading activity, as users felt comfortable, but the recommended lux of 500lux was not reached even with all modules accessed. Therefore, it is understood that the model worked better for more general activities, being more effective in use for the user than non-localized activities (such as writing).

Finally, the evaluation of the long-term use experience of the functional model based on the experience of users in homes was disregarded, as many problems had already been raised with the adopted procedure; Therefore, it is more relevant to have an in-home evaluation with a high-fidelity prototype after production.

4. CONCLUSION

According to the data obtained by the adopted procedure, we observed the effectiveness of the proposed methods, as the evaluation considered aspects related to user-centered design, as well as their experience in relation to use, in which general terms were better discussed and specified. Thus, the process and results were satisfactory.

5. ACKNOWLEDGMENTS

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