Embedding Social Translucence in Modern, Connected Lighting Systems in a Home Environment

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ABSTRACT
Lighting technology has come a long way from the incandescent light bulb. In addition to altering the brightness, colour and the level of saturation, this current technology allows individual lamps to be linked to form a connected system that can be controlled digitally. This brings a lot of positives: it mainly is substantially easier to fine-tune the settings to your personal preferences, although not everything is improved. By making the interaction digital, it no longer is possible to see the intentions of others in a shared environment, known as social situational awareness. In this paper, we investigate how to account for the loss of information because of the more complex controls by designing a physical controller for a multi-user lighting system. This design will be used to gain a better understanding on how to reintroduce situational awareness in controllers for connected lighting systems.

Author Keywords
Social translucence; Multi-user; Lighting; Design; Home environment; Philips hue

INTRODUCTION
The on-going development in the field of Light-Emitting Diode (LED) technology is pushing lighting as a whole towards new heights: light can now be produced brighter and more energy-efficient (Makdessian 2015),while also allowing adjustments to many more properties, such as colour, saturation and brightness. To some extent, many of these new technologies can be relatively easily controlled. However, since these three parameters offer such a large variety of settings, the traditional way of controlling them with physical light switches and faders is no longer sufficient. Instead, the interaction is made digital to allow more advanced changes. Although this seems to be a suitable solution, some problems arise when multiple people would like to adjust the settings simultaneously.

The market leader in the field of new home lighting is Philips (Detwiler 2015) with their Hue product (iTunes). Philips Hue is a series of advanced, Wi-Fi connected lights that can be controlled with a mobile phone application (Phillips). This allows for an easy, on-the-go interaction where colour, saturation, brightness and even placement of the lighting can be adjusted. When this is compared to the classical methods of operating light through physical switches, some benefits become apparent. In general, digital interfaces offer a faster interaction (Terrenghi, Kirk et al. 2007) as more settings can be controlled at the same time. However, digital interfaces have their disadvantages as well. A significant drawback is the fact that an interaction is no longer easily visible to others. Nearly all-current systems are not prepared for multiple-user inputs (Offermans, Essen et al. 2014), which produce unpredictable results when users have conflicting lighting desires. With traditional lighting controls, people make use of social, situational awareness that gives them the relevant information needed to make decisions.

This situational information is known in literature as social translucence (Erickson and Kellogg 2002) , which consists of three main components: visibility, awareness and accountability. In an environment where the lighting is controlled by physical controls, it is easy for people to see what other users do, which enables them to assess and predict their intentions. If someone is walking in the direction of a light switch, it is clear to the others that person would like to see changes made to the current lighting situation. Users are able to see who is making changes, which gives them the ability to hold them accountable for their actions.

This is different in a situation where the controls are no longer tangible. The Hue application has a fully digital interaction, which makes it increasingly difficult for others to employ social translucence to acquire information about the setting. Designing multi-user systems is proven to be a troublesome task (Niemantsverdriet, Broekhuijsen et al. 2016), and multi-user lighting systems are no exception (R. Magielse 2013). In order to restore the social translucence in lighting control, we aim to find ways to allow people to share

their lighting wants and needs with a tangible controller interface.

In this paper we will try to find an answer to our research question, which is:

"How does embedding situational information in a tangible lighting controller affect the user experience in a multi-user home environment?"

The aforementioned 'situational information' can be seen as a part of Erickson and Kellogg's social translucence. We define situational information as information about other people's wants and needs in a multi-user situation. This information can be used for the people using the room as a way to assess the overall atmosphere in the room, and draw conclusions on what others would want in terms of light settings. Therefore, providing sufficient situational information can be a useful asset in creating a fulfilling multi-user experience.

RELATED WORK AND THEORY

Social translucence is often assumed in regular human to human interaction, however as communication is increasingly done through technology, deliberate measures have to be taken to increase the situational awareness of multiple users. This raises the difficult task of transmitting social cues through electronic devices and screens. Many mobile applications have already incorporated social translucence in various ways. The WhatsApp (www.whatsapp.com 2016) and Facebook messenger (Facebook 2016) applications visualise who has seen what and at what time, allowing the sender to know if their message has been received and more importantly if it has been read. Another on screen example is Spotify (Kosoff 2014), by following and seeing what your friends are listening to allows you to gain some situational awareness on that person. Depending on how well you know the person their music preference can be an indication of whether or not they can be disturbed, e.g.; ambient music may mean they are studying, upbeat music may mean they are socialising and open for conversations with others.

The case of Spotify relates to social translucence in the way that when you are in the presence of someone, body language and facial cues give you situational awareness, which become more obvious the more time you spend with that person. An example of a tangible system is Uber's colour coded 'SPOT' (Constine 2015). This allows users to match the colour displayed on their mobile device to the colour emitted from a LED light in the Uber car. Not only is this a very practical solution to finding your ordered car in a busy place but it incorporates social translucence in a number of ways. Visibility is clear to the user, multiple users are aware if they make a mistake (getting into the wrong Uber), and both user and driver can be held accountable for taking the wrong passenger.

By looking at designs that already have aspects of social translucence embedded in them we are able to see what has been successful and what has not. These products may also have been designed without the awareness and influence of social translucence literature, in which case we are able to connect ideas between real world applications and literature to gain new conclusions.

METHOD

In order to gain more insight in people's needs and thoughts on the emerging lighting technologies we have conducted a series of user studies. The initial phase involved Context Mapping (Stappers 2003), where four participants were asked to perform some basic tasks with the Philips Hue system, after which they were invited to join a discussion and brainstorming session on this system. Common criticisms and ideas were then formulated into a matrix, of which the highlights can be seen in figure 1. After using the current Philips Hue application, the participants indicated that they would want to have a 'simple interaction' where they would be able to make 'limited and/or simple adjustments', rather than the complex interaction that the application currently offers. From an interaction standpoint simplicity was considered the most important factor, while from a social translucence standpoint the new interface should complement habits, hierarchies and communication within

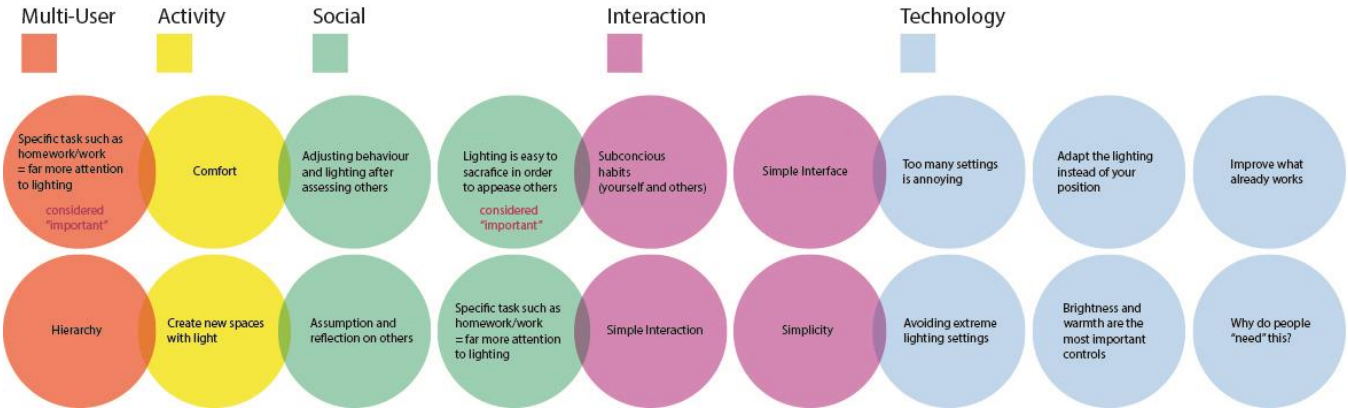

Figure 1: The highlights of the overview matrix of the criticisms.

the home. The general consensus was that current application did not facilitate simultaneous inputs from multiple users, as the system produced unwanted results, and failed to show the lighting wants and needs of those in the room.

Huenite: a new interface for the Philips Hue

With the results of the context mapping in mind, a new interface was designed to control the Philips Hue system. The interface will be referred to as *Huenite*, and can be seen in figure 2. The main vision for this interface was to offer a simple, user-friendly interaction that allows users to control the lighting in their living areas as well as display situational information to support social translucence. This interface has the ability to change the lights to three pre-sets in colour schemes, adjust the amount of saturation these colours have, and finally, it can also be used to regulate the brightness of the lights.

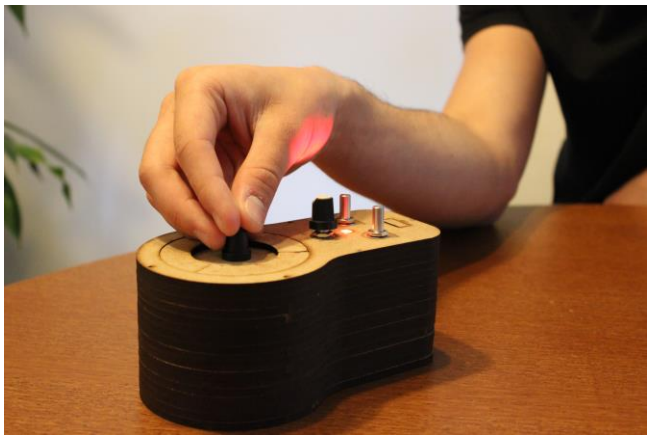

Figure 2: The Huenite in use: an interface that reintroduces an advanced physical interaction with lighting systems in a home environment.

An important addition we have made to the controller is the introduction of an urgency selector, which can be seen in figure 3. When asked, the participants stated that they were unaware of the needs of other people in the room, which brought the need for it to be visualised. The urgency selector has three states: low, medium and high urgency. The level of urgency is clearly visible on the Huenite, as it is being broadcasted into the room through a small light source changing in colour. If the urgency is set to low, this light is green. If it is set to medium, it has got an orange colour, and if it is set to high, the Huenite will start emitting a clear, red light.

The urgency selector does not only provide situational information about the needs of others in the room, it also has an effect on the interaction people have with the lighting environment. If the urgency is set to high, all other functions on the controller will be disabled, meaning that the lighting settings cannot be overruled unless the high urgency setting is dismissed. If the urgency is set to medium, the brightness and saturation of the lamps can be adjusted, although the base colour can no longer be changed. With this urgency selector, the users have obtained a way to indicate their needs, and also have a way to ensure their preferred setting is preserved.

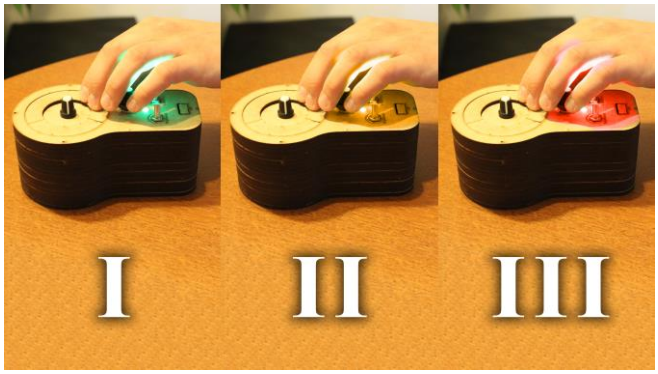

Figure 3: The three states of urgency of the Huenite. I is low urgency, II is medium urgency, III is high urgency.

Pilot test (Test I)

This lighting interface was used to study the behaviour of people in a multi-user, home lighting environment, with the main goal of observing if the influence of the urgency selector affected the user's lighting habits and social behaviour. During a pilot study the lighting interface functionally replaced the traditional light controls of three separate lights, which forced the participants to use the Huenite. The interface was placed in a four-person (family) living situation, for a period of six days. The participants, aged 54, 53 and 18, were asked for their opinion before and after the test through relevant questions (qualitative and quantitative) and interviews.

Short-term user test (Test II)

A second iteration of this study was conducted based on the pilot test: the interface was placed within a shared room in a student house consisting of four inhabitants, aged from 22 to 26, for a period of fourteen days. Just like in the pilot test, the interface effectively replaced the traditional ways of controlling all the lights. This means that they could only use the Huenite to interact with the lights. The purpose of this test was to analyse the effect of visualising the urgency or importance of a task and how it affected others behaviour, as well as to see if they consider such a function is useful for a light controller. Just like the pilot test, the participants were handed pre-study and post-study questionnaires, and invited for a group interview to discuss the results.

Long-term user test (Test III)

Finally, a third iteration of the study was conducted. In this short user test, three participants aged 18, 19 and 20 were invited to experience interacting with the Huenite for roughly an hour. After this period of time they were asked to compare this tangible interface with the traditional Philips Hue application. We asked them to reflect on their experiences and tried to figure out how the Huenite would change the behaviour in their current home environment, related to discussion, indicating important tasks and we discussed if the Huenite could prevent or solve problems they would encounter with a modern lighting system.

Afterwards, all participants of the user tests were invited to discuss their experiences in their respective groups. For the statistical part of the research we conducted several scaled questionnaires based on the Likert scale method (McLeod 2008), where a score of 1 meant they strongly disagreed, and a score of 5 meant they strongly agreed with the question asked. We asked our respondents to fill in a pre-research questionnaire and a post-research questionnaire. We conducted three different tests and there will be three different conclusions, which will be compared in order to gain an overall view on how the Huenite is perceived.

RESULTS AND FINDINGS

Pilot test (Test I)

From the data of the pilot test (Figure 4) we can make several observations. We assume that the lower the standard deviation is, the more significant the mean can be perceived. Significance in this paper will not be used as "statistical significance" but as an indication on how big the deviation from the mean is. In the pre-questionnaire a significant high mean (4,33) can be seen on the question *"whether you won't change the lighting environment if a person indicates it as being important for him/her."* Also a tangible control next to the app seems to be important for the respondents. Respondents indicate that the importance of seeing how important a light setting is for someone is just above the middle of the Likert scale (3,67) and also has a large standard deviation (1,528). The user-friendliness of the app scores just above the middle (3) with a high standard deviation. For this we can conclude the app is not perceived as very user-friendly, which corresponds with our findings in the context-mapping.

The open questions of the pre-questionnaire confirm this data with the following analysis:

- 2/3 participants: said current light settings causes discussion, because people are changing the lights and it is not known who is changing it and for what task.
- 3/3 participants: said they would not change the light environment if they knew that it was used for an important task (but only if this importance was indicated in a way that they could see or know it).

For the post-questionnaire, all respondents agreed with a 4 that the Huenite is easy to make small changes regarding the lighting environment. *"The Huenite helped with getting a better knowledge about the importance of the activities that others are performing in the room", "The tangible device made it easier to see when and by whom the lighting settings were adjusted"* and *"The shared interface supports the discussion about the lighting environment"* were all graded with the same significant mean of 4,33. Also the Huenite helps to set the lighting in a multi-user environment with a significant mean of 3,67. Moreover the respondents agree that people can be held more accountable for changing the lighting if they are aware of the importance (mean 3,67), but this has a lower significance than other questions (1,528). The significance of whether the Huenite is a good extension of the app is also lower (standard deviation 1), but still is graded with a mean of 4.

The open questions gave us a deeper insight on how the people thought of this:

- 2/3 participants: think that the Huenite adds value to a multi user environment, because it added the extra function that is both useful and important to them.
- 2/3 participants: agree that "seeing if a light setting is important for someone is important to me because I will adapt my own light preferences to this".
- 2/3 participants: would use the Huenite to indicate if a light setting is important to them because they don't want people to change the lights when they are doing a high priority task.

*Note: the one person that did not agree with this declared this during the interview: *"the living room is a room that is for everyone and if you want to do something important, you should do it in your own room. I should be able to change the light whenever I want because of this."*

This data is supported with quotes from the open questions: *"It would be helpful to see that your light setting is constant while doing study activities", "relevant to function to see in a multi-user environment with priority tasks", "helps to see when people are doing high priority tasks" and "a valuable addition to the HUE system".*

From the pilot test we can observe that there is a desire for a more socially translucent device in conjunction with or to replace the Philips Hue App when the system is used in a multi-user home environment. This result confirms our research set-up and reaches towards an answer on the research question. Therefore we can decide that this research-setup is sufficient to continue with and conduct the official research.

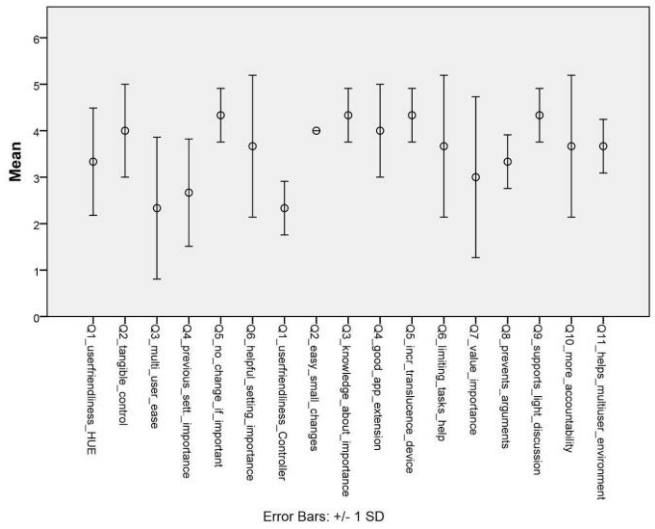

Figure 4: Processed data of the pilot user test (I).

Short-term user test (Test II)

In the pre-questionnaire the question: "*I would not change the setting of a lamp if I knew that someone was using the light for an important activity"* had a significant high mean (4,67). This corresponds to the findings in the pilot test. Also the respondents of the short-term test indicate that it would be helpful for them to see how important a light setting is (mean 4,67). Also from the short-term tests the average user-friendliness of the app in a multi-user environment appears to be high (mean 4) but has a higher standard deviation (1). These outcomes are contradicting with the pilot test respondents.

The open question gave us a better insight to how people thought of the initial problem:

- 3/3 participants: did not really have much discussion on the current lighting environment, but saw the problems that the Hue-system could cause.
- 3/3 participants: would not change the light environment if they knew that it was for an important task and think that it's important to see if people are doing an important task or not.

The post-questionnaire results (Figure 5) nearly all have a higher significance. Only the user-friendliness of the Huenite and the improvement of seeing when and by whom the lighting was adjusted have lower significance (both 1,155), but are both graded with relatively high means of respectively 4,33 and 3,33. For the rest all respondents agree that the Huenite is easy to use for small changes (mean 4,67), that it would help in a multi-user environment (mean 4,33), that it is valuable to see the importance of others (4,33) and that the Huenite helps you to clearly see this importance (4,33). Respondents indicated they think a device like this would prevent arguments when used in combination with the Philips Hue system in their own home environment (4,33).

The open question helped with confirming this:

- 3/3 participants: think that the Huenite adds value to a multi user environment because it add an extra function that if both use useful and important for them.
- 3/3 participants: seeing if a light setting is important for someone is important to me because I will adapt my own light preferences to this.
- 3/3 participants: would use the Huenite to indicate if a light setting is important for them because they don't want people to change the lights when they are doing a high priority task.

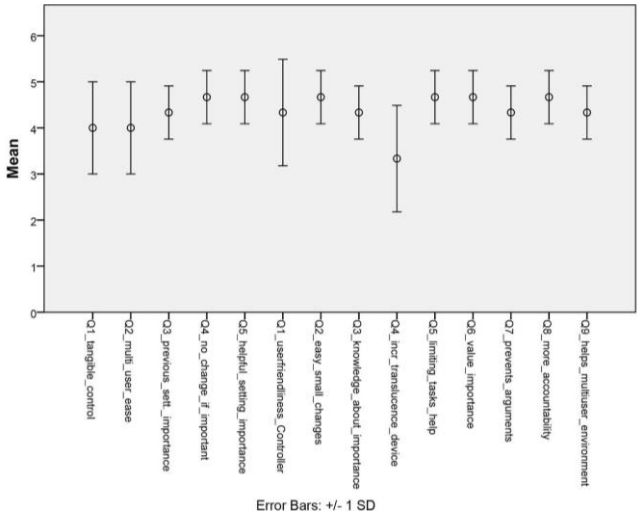

Figure 5: Processed data of the short-term user test (II).

The quotes resulting from the interview also helped confirm this: *"really helps in a multi user environment", "in a large household many activities happen, even simultaneously [...] this light would be a good and easy way to show this without being disrupted" and "it could help me focus".*

In the short-term user-test no means below level 3 can be seen, which indicates the device is perceived as an addition to the Philips Hue system in multi-user home environments. The theory of social translucence that we applied to our design seems to work in the use of the prototype on a short term. To verify the value of social translucence on a longer term another test will be conducted over a sufficient period of time.

Long-term user test (Test III)

The test conducted over a longer period of time allows for a more realistic measurement because after a while any device will show signs of habituation. Prior to the test all respondents indicated they would prefer a tangible controller for the Hue system (mean 4, standard deviation 0). The user-friendliness of the app is perceived as low (mean 2,33, standard deviation 0,577) and as well as the other tests they would significantly not change the light settings if they knew that the setting was important for someone else (mean 4,33).

The open question gave us more insight on this:

- 2/2 participants: saw the importance of knowing if a light setting is important for someone, because they will adapt to this, or start a discussion, instead of changing it without asking the one that is using it.
- 2/2 participants: think that a light setting for work and/or schoolwork is more important and therefore be less likely to change it.

*Note: Only two of the participants filled in the open questions of the pre-questionnaire.

After the test period there are two remarkable points indicating the respondents fully agreed on: the Huenite is a good extension of the app and that it helps in a multi-user environment (both mean 4). Also it supports the lighting discussion and the value of seeing the importance, yet the significance in these points is lower (both mean 4, standard deviation 1). They agreed that while using the Huenite you are more accountable for changing the lights and that it is easy to use for small changes in lighting environment.

On the other side the respondents agreed that the Huenite's user-friendliness doesn't differ from the app (mean 2,33, standard deviation 0,577). *"The Huenite helped with getting a better knowledge about the importance of the activities that others are performing in the room"* was also graded relatively low (mean 2,67), but seeing the standard deviation of 1,155 this is not a very significant outcome. (Figure 6).

The data of the open questions gave us a better insight and helped to confirm this:

- 3/3 participants: think that it is important to see if someone is using the lighting setting for something important
- 3/3 participants: would not change a light setting when they knew someone was using it for something important.
- 2/3 participants: think that it would be helpful to see the importance of a lighting setting, on your lighting device, and 2/3 participants think that this would be helpful but that this also can be accomplished in a different way.
- 3/3 participants: think that you should indicate in some way if you are using the light for an important activity, especially in a multi user environment.

As did the following quotes: *"it would be relevant, especially in case of the lights are not in the same room", "you can change the light and don't have to break someone's concentration " and "it would be an addition to the Hue-lamp (if it was a bit more user-friendly)".*

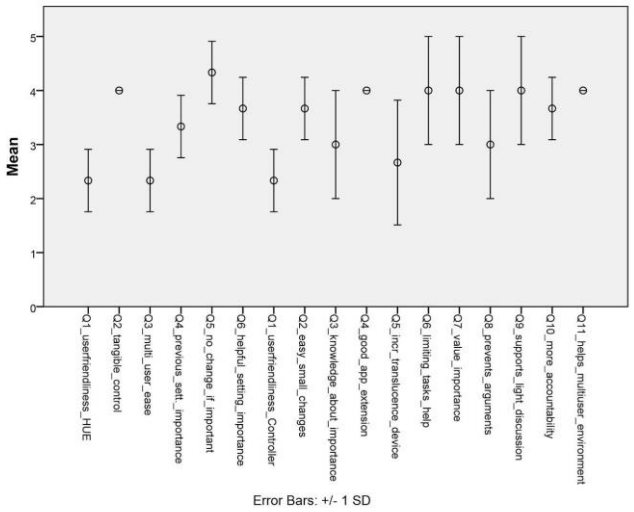

Figure 6: Processed data of the long-term user test (III).

Summarized results:

To summarize we can say that in the pre-questionnaires the opinions about the multi-user experience of the Hue app seem to differ between the short- and long-term tests; resp. mean 4; standard deviation 1 for the short-term test and mean 2,33; standard deviation 0,577 for the long-term test. However the respondents of both the short- and long-term tests agreed on the fact that they would not change the light settings if they knew someone indicated the setting as being important. (resp. mean 4,67; standard deviation 0,577 for the short-term test and mean 4,33; standard deviation 0,577 for the long-term test).

Both results for the post-questionnaires indicate this interface supports the use of the Hue-system in a multi-user environment, (resp. mean 4,33; standard deviation 0,577 for the short-term test and mean 4; standard deviation 0 for the long-term test). Also both tests show respondents think a person can be held more accountable of his actions regarding the lighting using this interface (resp. mean 4,67; standard deviation 0,577 for the short-term test and mean 3,67; standard deviation 0,577 for the long-term test). Finally all respondents agree that the interface helped them to gain understanding about the importance of the activities of others in the room (resp. mean 4,33; standard deviation 0,577 for the short-term test and mean 3; standard deviation 1 for the long-term test).

Something that is also significant is the fact that both tests indicate that the user didn't feel that the interface indicated clearly when and by whom the lighting environment was changed. This is especially the case in the long-term research (resp. mean 3,33; standard deviation 1,155 for the short-term test and mean 2,67; standard deviation 1,155 for the long-term test).

CONCLUSION

This research was started with the following research question:

"How does embedding situational information in a tangible lighting controller affect the user experience in a multi-user home environment?"

In conclusion we can say that our tangible controller for the Philips Hue lighting system is seen as a valuable addition to the existing app. This is mainly because of the provided situational information. In the user tests, the app scored below average in the context of suitability for a multi-user experience. The participants perceived the Huenite as a support for the use in a multi-user environment. With the data they provided we can say that their ability to assess the wants and needs of others regarding the lighting has increased.

The Huenite helps to raise awareness and with this accountability within a multi-user home environment. Interacting with light therefore has an increased social value and through the modern lighting systems the users will be united.

We can state that according to our data the predicted added value of a socially translucent, tangible control interface for the Philips Hue lighting system is sufficient for users, yet not unconditionally needed. Although the Huenite is a good starting point on tangibilizing modern lighting interaction, respondents indicated that visualizing when and who changed the lights would be an important feature that is missing from the Huenite. Similar to the results of other work we can also conclude that the interface was able to enhance feelings of connectedness within the home and was able to encourage rather than replace direct communication between users in a shared environment (Metaxas, Markopoulos et al. 2012).

DISCUSSION

We conducted user tests over a period of four weeks. We did three different user tests which all lasted a certain time (14 days, 6 days and 1 day). The data - and with this also the analysis - of our user-tests were based on these three tests and had some restrictions that could have influenced our data.

One of these restrictions could have been the time frame. The test that covered the largest period lasted fourteen days. We believe that during this part of the research habituation to the Huenite occurred after a certain time. However we cannot really be sure about this. A longer user test, which lasts for more than fourteen days, should prove if people are really becoming used to the Huenite. This will give us a better pattern on how the Huenite is used, and if it is used regularly. It would also give us more reliable data, because the Huenite will be better integrated within a household.

Our long-term user test was done in a student home. This gave us an abundance of information on how people control the light in a multi-user environment. A household with only 'students' may have a different social hierarchy to others and with this also a different hierarchy towards the light control. This will be different within a family household (which we had for the pilot test). A longer user test in a family home should be done in a follow-up research. This follow-up research will give you a better knowledge on how families will behave towards the Huenite in a multi-user environment with possibly a different hierarchy.

The data of our research was based on the nine participants that volunteered in our user-tests. A better conclusion could be drawn with more data from more participants. Which would also give us a better overview on how people are using the Huenite and if they think that it is valuable to see the importance users light settings. Although we could still see usable patterns in the data, more tests should be conducted in different contexts in order to gain a better insight on how the Huenite will be perceived on a broader societal level.

In the future we would do a follow-up study to gain a better knowledge about the social significance of seeing the importance of the light. To achieve this a couple of changes could be made. One of these changes would be to limit the number of controls on the Huenite. This will emphasize the function on the urgency selector and its influence. This will give the researcher a better knowledge on the use and practicality of such a selector.

A second change is to add an extra function. This function is an option where the user has the possibility to see who made the last change on the current lighting setting. This is something that we found as a result from this research. The participants thought that the Huenite could be more translucent if people knew who made the last change. A function that would make a controller more socially translucent would help both the future user and improve the research approach towards answering the research question.

A third approach could be an attempt to create an interface that doesn't replace the Hue app but works in conjunction with it. This could be in the form of an external tangible control or an add-on to the existing app that compliments people's existing knowledge of the system.

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