Project Report on Peripheral Interaction Design

"BUX" CONTROLLER FOR PHILIPS HUE LIGHT

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January, 2016

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Abstract

bux

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Bux is a controller for Philips Hue Light to interact with the lighting ambiance at home in an effortless way. Turning on or off the light is as simple as tapping the stick or the ball. The four corners represent four light modes and the center of the cross pattern is a default scene, which can be personalized by the user. You can choose light mode by simply moving the stick to that direction. The brightness can be adjusted by sliding the ball up and down. Bux also supports detailed control in the app, where the physical interface will automatically change with your adjustment.

Video can be watched from the link https://vimeo.com/151781870

The center and periphery of attention

The two most important functions of process of attention management is selective attention and divided attention (Bakker 2013). In our daily life, we are surrounded by a lot of stimuli and we can not attend to all the stimuli around us all the time, a process of selective attention is needed to make sense of the world. Selective attention is the process of filtering one's attention on one stimulus while intentionally ignoring others (Sternberg, 1999; Wickens and McCarley, 2008). However, selective attention usually only concerns sensorial attention (Bakker 2013). To explain how we can perform multiple attentional tasks at once we need to take a broader approach. A theory of divided attention proposed by Kahnemann (1973) is suggesting that we have limited amount of available mental resources and potential activities can only be carried out if there is mental resources allocated to them. The amount of mental effort needed for an activity decreases with practise and experience (Wickens and McCarley, 2008).

We can perform several tasks at once, such as Weiser (1997) described, we can drive a car, listen to the radio, chat with the passenger, change gears and scratching our hair all at the same time. During this multiple tasking we divide our mental resources. Our attention is centered on the road, the radio and our passenger but not on changing the gears (Figure 1a). Changing gears is something we do in our periphery of attention. "Periphery is what we are attuned to without attending to explicitly" (Weiser and Brown, 1997, p. 79). For instance, if there is an unusual noise coming from the gearbox, we immediately notice it. This shows that we are attuned to the noise in the periphery, and that's why we can attend to it quickly. When we center our attention on the gearbox to change the gears then in this case it is focused attention (Figure 1b). Our attention moves between periphery and center when they become relevant.

Bakker (2013) describe the center of attention as the one activity to which most mental resources are currently allocated, while the periphery consists of all other activities. An activity can therefore be performed in the periphery of attention when another activity is being performed simultaneously in the center of attention, which requires more mental resources. As explained before, the attentional process is very dynamic and the resource demand of an activity or the likelihood of being selected as center of attention or periphery of attention is subject to change all the time. Looking at example of talking on a

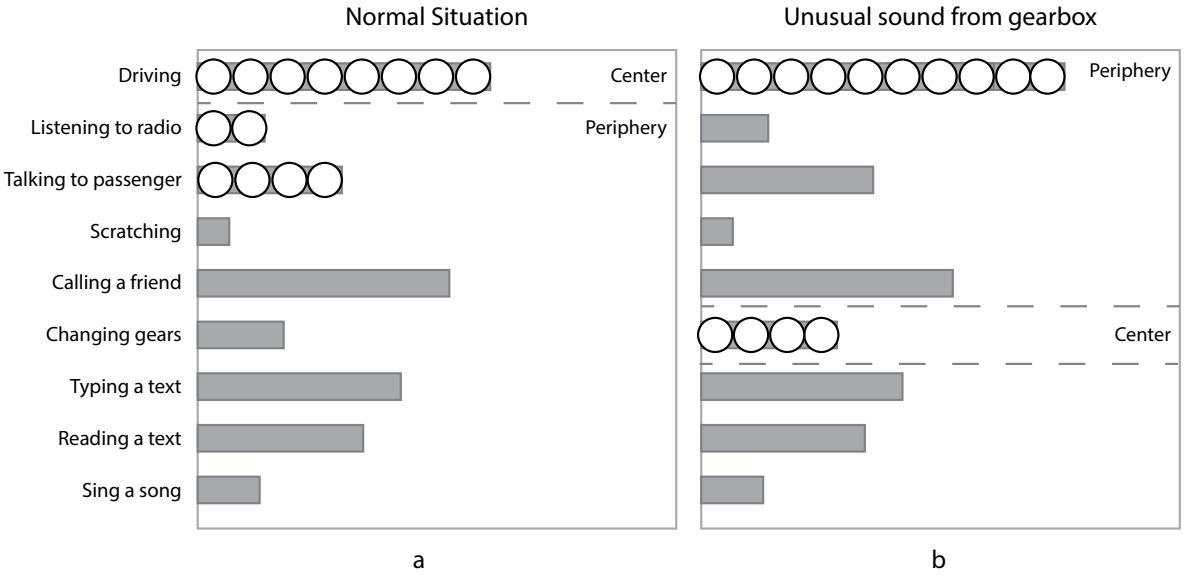


Figure 1 - Division or resources in different possible activities: normal (a) or unusual (b) driving situation.

phone while driving, if you have to dial by pushing the buttons, you will not be able to look at the road for short periods of time. Although we don't look, our information processing takes the advantage of peripheral cues from the road and our attention moves between center and periphery. However when driving the car is in the center of our attention, talking on the phone will be in our periphery of attention.

Video Analysis

To gain a better understanding of peripheral and focused interaction, we each filmed ourselves doing a daily task. Through video analysis, many unaware moments of multi-tasking and attention shifting were noticed. These key moments were classified into three categories: Focused activities, peripheral activities and shifting of attention (Figure 2).

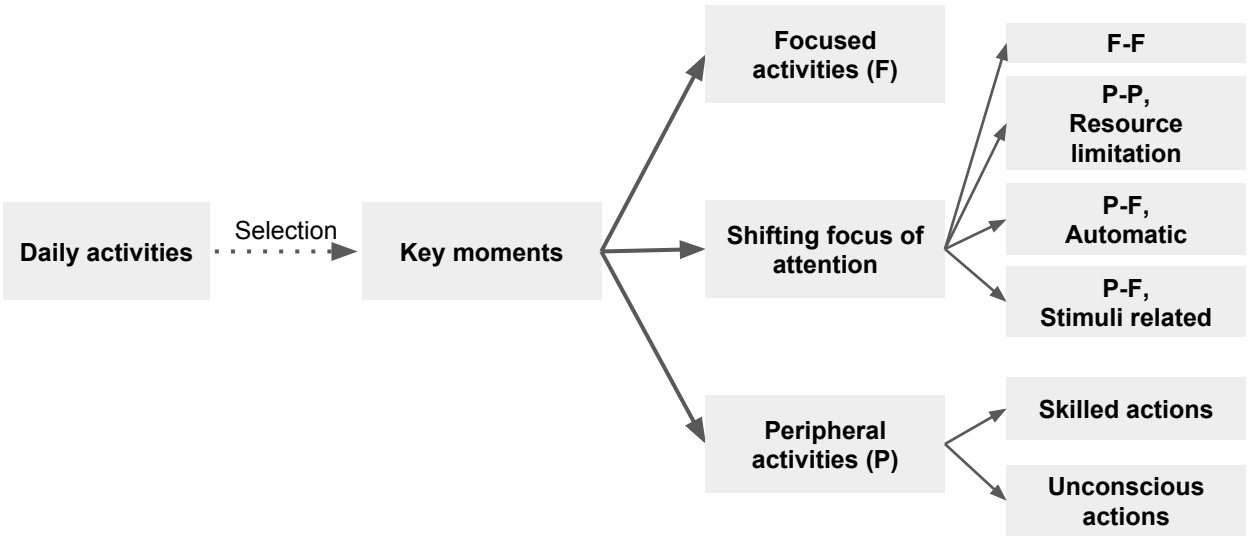


Figure 2 - Categories of video analysis

1. Focused activities

Within the focused activities, we found some examples that clearly showed moments where the person was focussed on one specific task. This is the moment where most of the resources were allocated in one main activity. From these examples, focused activities were found requiring a lot visual resource. However, during the discussion we came to the conclusion that looking attentively is not a requirement of focused activities. Focused actions can also happen without looking, such as listening to the radio carefully.

Figure 3 - Key moments within focused activity

2. Peripheral activities

Peripheral activities were regarded as actions that were subconscious, unconscious or not in the centre of our attention. One feature they had in common is the little mental resource demand. In general, we divided them into two categories: skilled actions and unconscious actions. Peripheral activity can be a skilled action, which has a specific goal like putting on the headphone; It requires learning before it becomes subconscious (Figure 4).

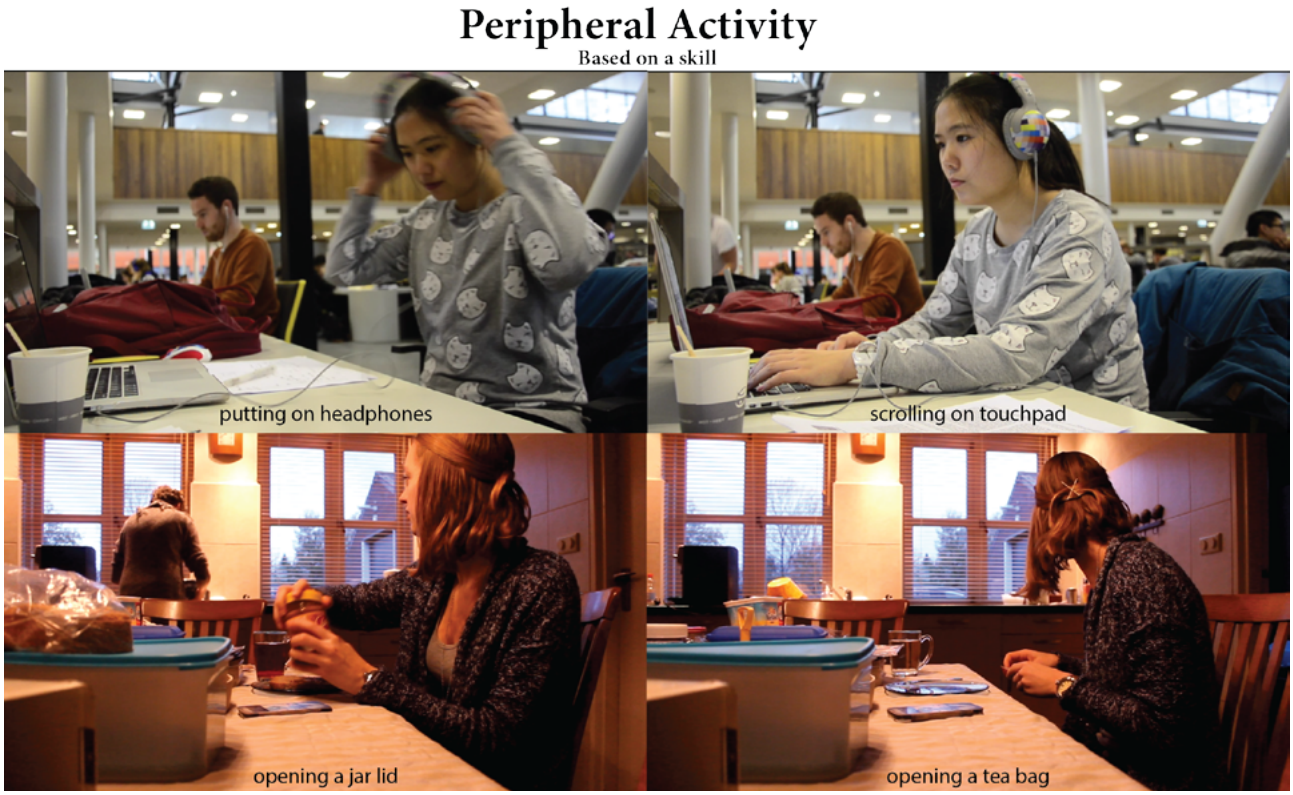


Figure 4 - Key moments within peripheral activity, based on a skill

On the other hand, many unconscious actions were found without clear purposes, such as playing with hair (Figure 5).

Figure 5 - Key moments within peripheral activity, based on unconscious behaviour

Figure 6 - Key moments within shifts of attention, from one focused activity to another focused activity

3. Shifting of attention

Shifting of attention happens when the attention shifts when relevant for or desired by the user. One of these shifts is in focus from one activity to another (Figure 6) where we see that either something you are primed for (such as your name) or a salience sound (such as loud footsteps) will shift your attention from one main activity to another.

Figure 7 - Key moments within shifting of attention, automatic shift from peripheral to focused

Figure 8 - Key moments within shifting activity, Stimuli related shift from peripheral to focus.

Another shift of attention is from the periphery to the focus. It can happen as an automatic response (Figure 7). For instance while pouring tea you focus on this because you know it is hot and needs visual feedback to avoid overflowing the cup. Furthermore, actions can shift from the periphery to the center of attention, when something unexpected happened, such as a lid that didn't closed as expected or music that stopped suddenly

(Figure 8). It shows that an unexpected or difficult event can become a stimuli of attention shift. In the case of listening to music, we can argue that it is more a peripheral perception than a peripheral activity that shift to your focus. However, it triggers you to focus your attention on why music stopped and perform the action of restarting it.

Figure 9 - Key moments within shifting of attention, resource limitation shift from peripheral to peripheral

Finally, we have an example of a shift of attention between peripheral activities. In Figure 9 we can see that the activities of drinking and scrolling are both in the periphery. Both of these activities are not performed at the same time. It shows a limitation in resources, with reading in the focussed activity the person can not drink and scroll at the same time.

Examples of existing interaction designs

1. Xiaoyu

EXAMPLE 1 - A LIGHT WITH A DISH (PERIPHERAL AND FOCUSED)

As described literally, ‘A Light with a dish’ is a light with a dish on the bottom. It narrates a universal routine: arriving home in the evening; setting down keys and spare change; and switching on a lamp. It encompasses this daily ritual in a small and simple package. When people walk into their place, they can intuitively turn on the light by leaving their keys and coins on the dish. As it is already their daily routine, people can do it without thinking. It only demands little mental resource and manages to happen in the peripheral of people’s attention (Bakker et al., 2015).

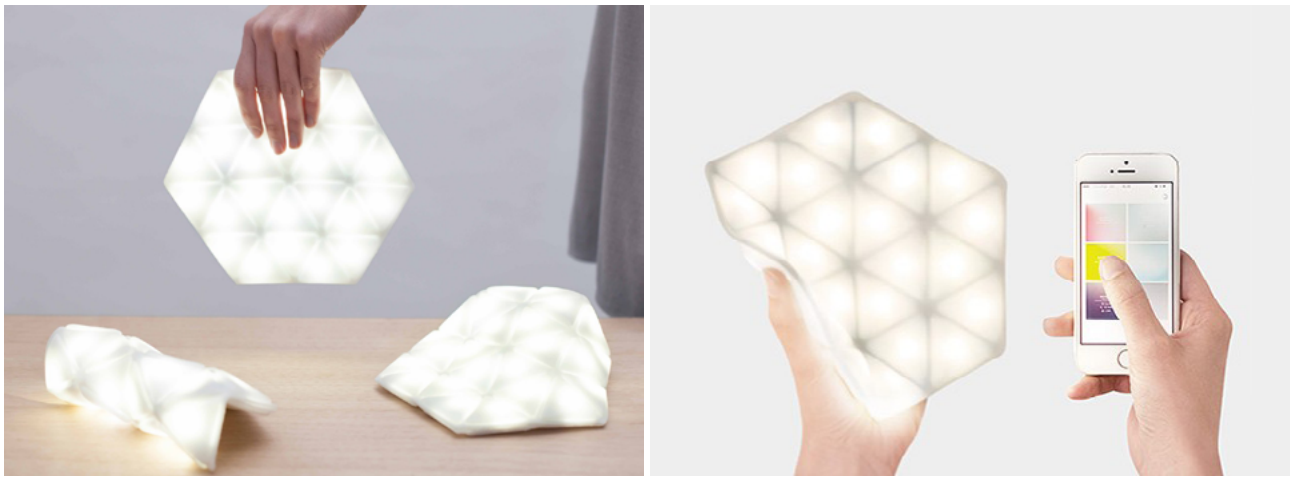
Picture 1 - A light with a dish

On the other hand, the lamp can also be controlled by the normal switch. Visual resource (find the switch) and manual control (switch it on or off) are required during this process. Generally, it demands more mental resources (Bakker et al., 2015) and usually happens in the focus of attention.

EXAMPLE 2 - KANGAROO INTERACTIVE LIGHT (PERIPHERAL- FOCUSED)

Kangaroo Interactive Light is a playful, portable, interactive light. It is touch sensitive, allowing users to to choose preferred lighting mood. And its special structure and material make it perfect for freely shape changing into a torch, reading light, or night light, etc. These tangible interactions (touch and shape changing) won't cost a lot of mental resource. Once being familiar with this product, people can shape and control the light in their peripheral attention (Bakker et al., 2015).

On the other hand, the accompanying app enables various types of interactions and illumination modes including light mood setting, sound triggers programming, alarm options control, intensity and pulse control. It requires users to look at the screen and make decisions among multiple choices. As a result, the process of multiple settings on the app demands a lot of mental resource and it will happen in the focus of attention (Bakker et al., 2015).



Picture 2 - Kangaroo Interactive Light

2. Thilly

EXAMPLE 1 - NEATO ROBOTICS VACUUM CLEANER

The first example we look at is an automatic vacuum cleaner (Picture 3), for instance from Neato Robotics. The vacuum cleaner can clean at set time slots or can be manually turned on to clean. When it bumps into an object it will change its direction to go around it. Focused interaction with the vacuum cleaner consists of setting the timeslots for when it should start cleaning and on which days. This interaction is focused because the screen will need your full attention in order to select the correct day and time. Followed from these settings will be the implicit interaction with the cleaner. It starts at a set day in the week and a set time, and when it bumps into you or your furniture it will automatically move around you or the object in order to continue. This is an interaction which you as a user don't have to pay attention to at all. When looking at users who are using this vacuum cleaner for a longer period of time, we can see that there is also a way of peripheral interaction with the machine. For example when you see that the house is dirty you can turn on the vacuum cleaner manually by pushing a button on the top; when you know where this button is situated, you can do this without having to look at it or pay attention to which button you need to press. While performing this interaction a user can focus on different tasks, which is a characteristic of peripheral interaction; Peripheral interaction takes place within a multitasking setting.

Picture 3 - Neato automatic vacuum cleaner

EXAMPLE 2 - SONY REMOTE CONTROLLER

Another example which includes focused and peripheral interaction is a remote control (Picture 4). Focused interaction with a remote control will take place for example when the user has find the button for a certain function, or when the user has to type in a channel number which is longer so they would have to watch where each number is situated. This interaction can for instance also be when the remote is new. Peripheral interaction with a remote will take place when for instance talking to a friend and

Picture 4 - Sony remote controller

wanting to turn down the volume. When the user is experience with using the remote he/she will be able to find the volume down or mute button without having to stop talking to their friend and focus on where the button can be found.

3. Damla

EXAMPLE 1 - IMPLICIT AND FOCUSED INTERACTION

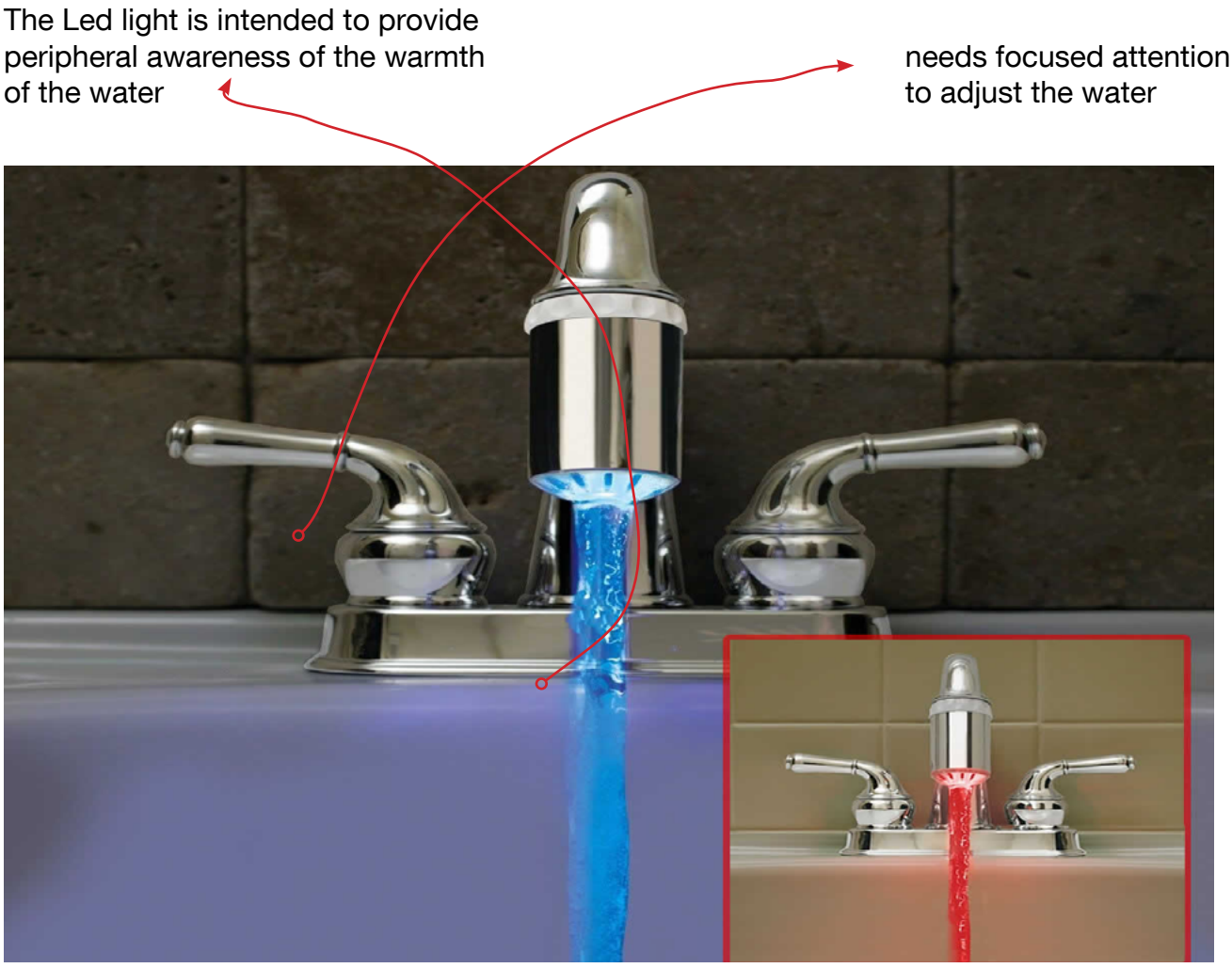
As my first example for implicit and focused interaction, I chose the automatic windshield wipers (Picture 5). The reason why I choose this is that, if we have a car equipped with an automatic windshield wipers, these wipers activate themselves when it rains. They can also adjust their speed depending on the rain. If the rain gets heavier, they flail back and forth faster and if it rains lighter, they work relatively slower. Till this point it is an implicit interaction (Ju & Leifer, 2008) because the interaction initiated by the system (our car's computer in this case). Although the ideal is the automatic wiper blades work flawlessly, it is not always the case. Sensors sometimes don't work accurately and the car still requires the driver's focused attention to activate or adjust the wiper mode. In this case, it becomes focused interaction with the system because user is actively engaged in diagnosing, deciding, and performing the task.

Picture 6 - Wiper manual controller

Picture 6 - Wipers

EXAMPLE 2 - FOCUSED & PERIPHERAL INTERACTION

As a second example for interaction (Picture 7), I chose LED faucet lights that we can use in our home. This lights enables us to understand the warmth of the water running from the tap. If the water is warm than the light turns red and if the water is cold than the light turns blue. After installing the attachment to our tap and getting used to using it (peripheral interactions usually needs some time for learning it to become peripheral) without actually putting our hand under the water, we know the warmth of the water which side of the tap we need to turn depending on the warmth of the water with our peripheral awareness (Bakker, Hoven & Eggen, 2015). So the interaction with the tap is an peripheral interaction. Let's take a case that the light is not working properly. It is showing the blue light while the water is hot. We put our hands under the water and sense that the water is actually very hot. In this case we take our hands away under the tap with an automatic reflex and we need to adjust the water by turning the tap with our focused attention. In this unexpected situation peripheral interaction turns to a focused interaction and we need our focused attention to adjust the warmth of the water.



Picture 7 - Wipers

Final Design

Design for peripheral interaction is a combination of perception and physical action that may take place in the periphery of attention. As Wickens and McCarley (2008) suggests, a physical action can become habituated and therefore be performed in the periphery of attention, when it is repeated and mastered enough.

After video analysis, we found out that we performed a lot of activities in our periphery of attention even without noticing it. Our design process (Figure 10) started with searching for simple interactions around us in our daily life. We chose a specific target group which is parents with children. The interactions were expected as simple and easy, so they can be performed while hands are full. After brainstorming and several tryouts we decided to use a ball with slider as a starting point for our design (Picture 8). A ball has an affordance of holding, grabbing and sliding up and down. Among them, sliding is not only a very inviting interaction but also provides a visual cue (the position of the ball) for adjustment levels. So we decided to use sliding the ball on a stick up and down for brightness control.

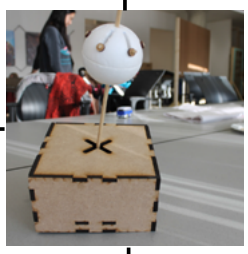
Picture 8 - Outcome of dirty prototyping

Based on the attention theory of Kahnemann (1973), we searched for everyday activities that require little or no attention and can therefore be performed in the periphery. In addition we wanted to find activities that may shift between center and periphery of attention. Although we focus on peripheral interaction, the user can use it in the center

Context
Family with kids

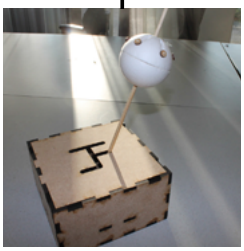
Dirty Prototyping
Sliding ball

Inspiration
Change gears while driving

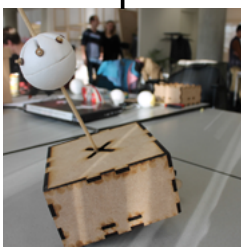


First Concept
1. Slide ball to adjust brightness
2. Move the stck to change scenes
3. Slide little blocks on the ball to adjust the brightness of a single light

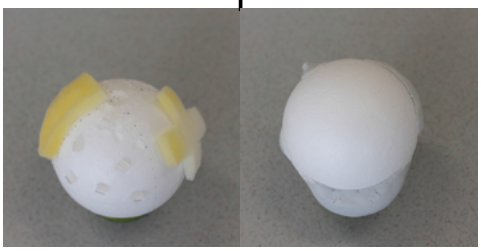
Feedback from client meeting
Difficulty on mapping the scenes to the controller



Iteration on patterns
Asymmetric pattern



Iteration on changing scene
Tilt controller



Iteration on changing scene
Different textures on ball

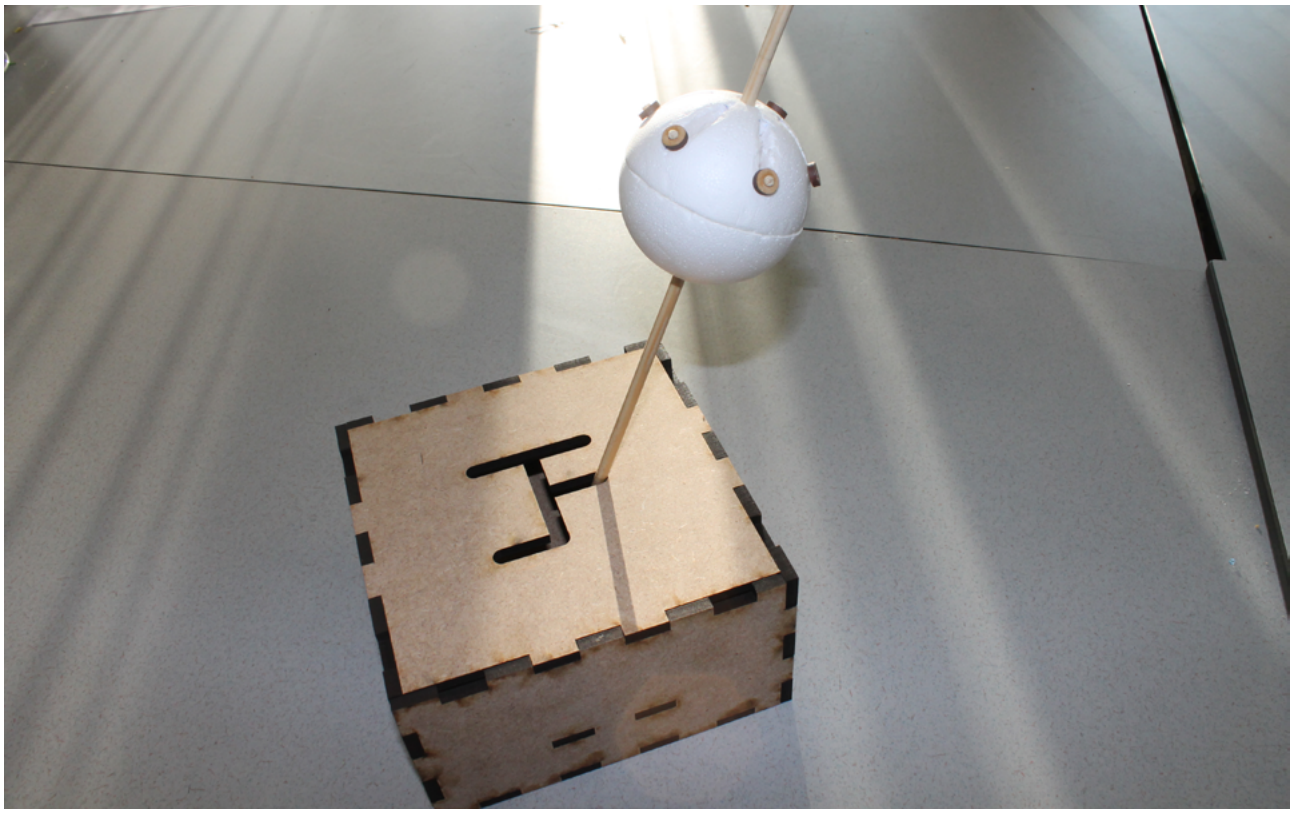
Feedbacks form User test
(appendix)

Final prototype

Figure 10 - Design process

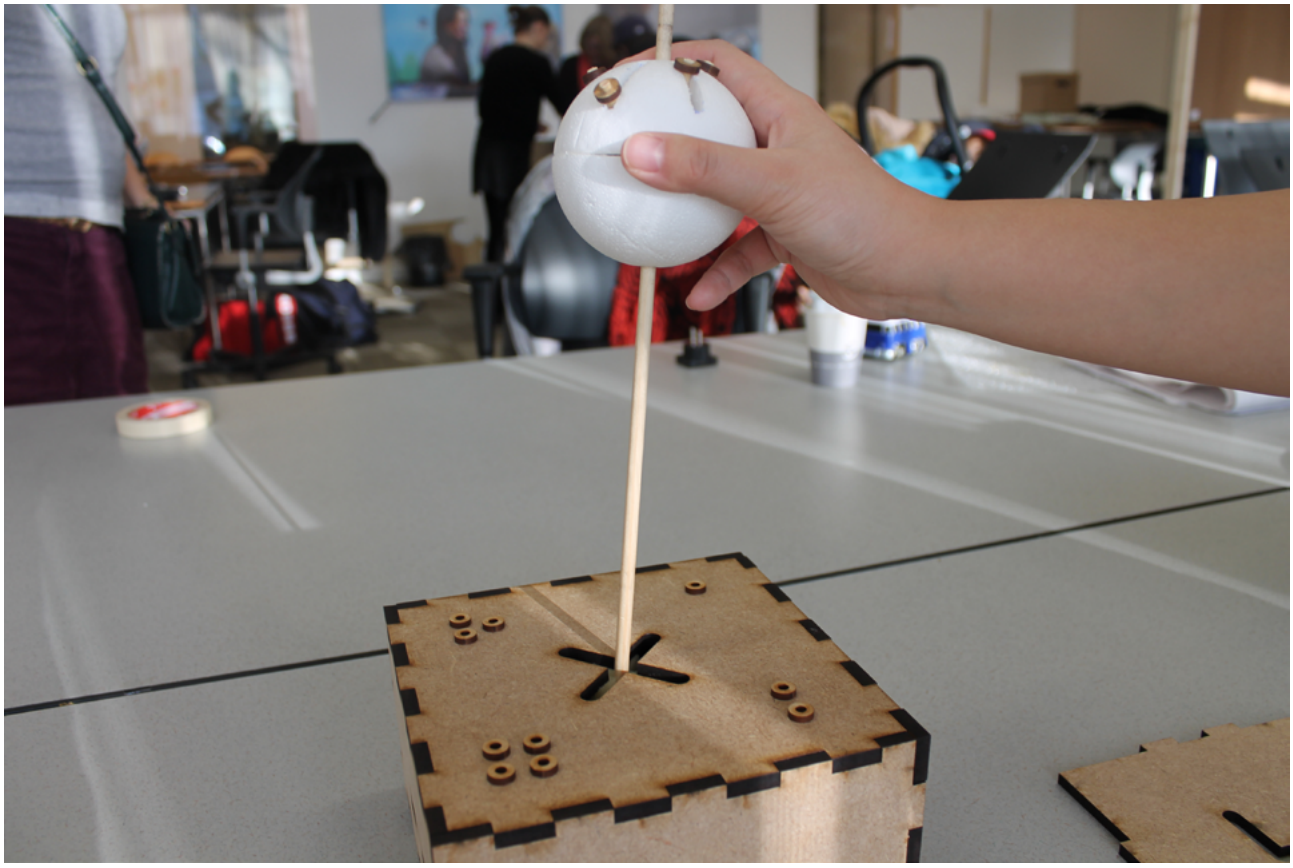
of attention as well, if needed. The shifts between center and periphery of attention are a very important part of the peripheral interaction (Bakker, 2013). If the user intended to perform the interaction in the center of attention, it is important to think about how these intended shifts may be performed. We decided to take a gearbox as a metaphor for our design. The reason why we chose a gearbox is: it is a controller with proximity of our hand reach and we can change at least 4 settings without even looking at it while driving a car, our attention moves between center and periphery of attention while using it and the system (e.g. sound of the engine) gives feedback to us in our periphery of attention as well. We thought it is a potential physical interface for peripheral interactions.

As a start, we wanted to control at least four modes of light settings, the brightness of the light and extra separate settings for specific lights. One of our prototype was shifting the stick like changing gears to change the main light modes (Picture 9). Unfortunately, although the pattern of gearbox works perfectly in the car situation because of the same angle and proximity in the car, it didn't work out for our controller which can be approached from any direction. In this case, the mapping of the light modes was very difficult to remember and operate from different angles.

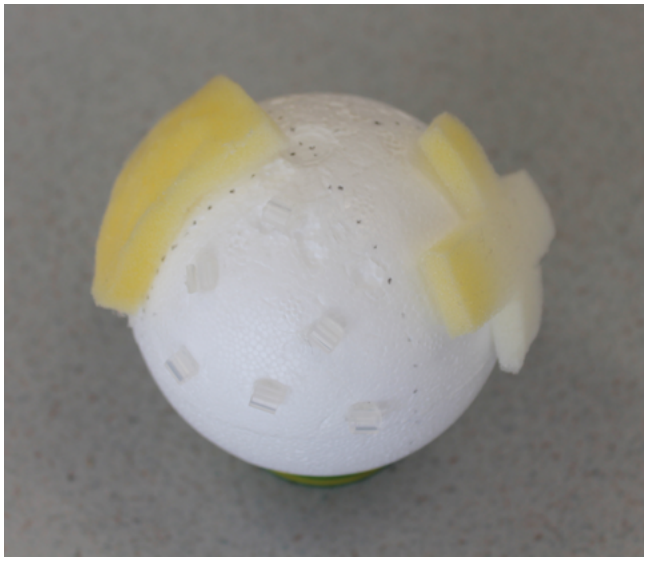


Picture 9 - Prototype with asymmetric pattern like gearbox

Another prototype was a more symmetric form as controller pattern so that it can be operated easily and smoothly from every angle without requiring a lot of mental resources (Picture 10).

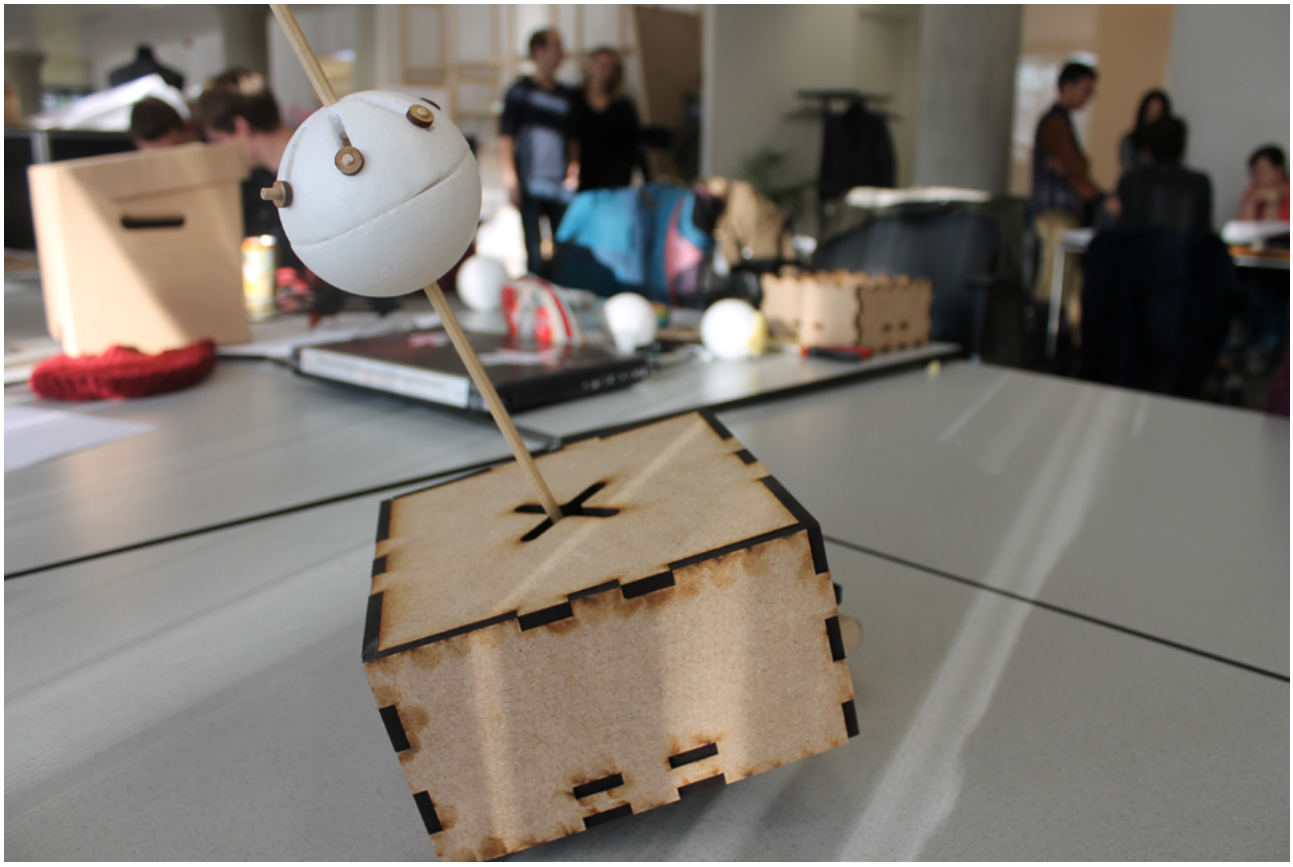


Picture 10 - Prototype with symmetric pattern



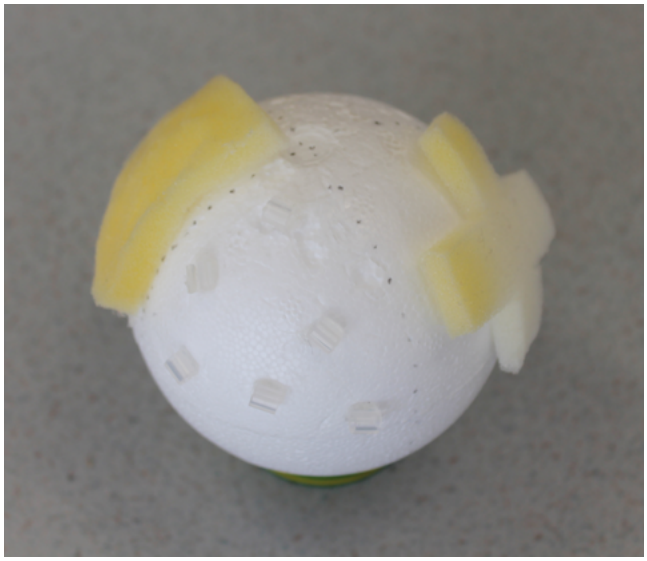
Picture 11 - Prototype with different textures on the ball

Although the action itself can be performed in the periphery of attention in a symmetric form and get a feedback from the system, change of light ambience is the feedback of this interaction, our next challenge was to know which mode is which direction before starting the interaction. We needed to give the user an anticipatory response (feedforward) before they chose the mode of the light. After trying out using different textures on the ball (Picture 11), tilting the box to give



Picture 12 - Prototype with a tilted base

a visual cue (Picture 12), or trying different reacting force while shifting the stick (Picture 13), we finally add colored lights and numbers at the corners of the box to give a visual feedforward.



After user evaluation, we saw that controlling one specific light was the most difficult to be mapped on the controller. It made the whole controller very complicated and could only be performed in the centre of attention, so we decided to leave this function in the app. Results of user evaluation can be found in appendix.

Picture 13 - Prototype with materials added under the surface to create different resistancy

Our light controller, Bux, works with the Hue app for smart phones. (Picture 14). The user can personalize their light settings, control separate lamps or moods via the app as usual, and this information can be synced to our controller via wifi. If the user changes a setting or mode, the controller changes implicitly to the new setting to give a visual feedback to the user.

Picture 14 - Final prototype

Personal discussion on final design

1. Xiaoyu

I am working on my PreFMP, which is about designing an active intervention for neck pain prevention in working context. Working is an activity requiring full attention. In order to make the intervention less distracting and more intuitive, how to design a peripheral display or interactive device becomes one of my concerns. Therefore, my learning objectives of this elective is to gain an overview of attention theories and learn practical guidelines of peripheral interactions design and evaluation.

The final design of our group is 'Bux', which is inspired by changing gears while driving. The design process gave me a new view towards the understanding of peripheral interactions.

Gearbox is fixed in one position, while the Hue controller can be approached in all directions. One of the challenges we met is how to make the interactions as easy as changing gears, even without looking (mentioned by clients). After trying asymmetric patterns, tilt controller base, textiles on ball and different reacting force while pushing the stick, finally we agreed on adding lights in different colors to indicate the lighting scene it represents, which provide a clear visual cue to its function.

When I reflect on this process, I found there are some confusion between feedforward and feedback. Inviting interactions and enabling users to know the result of a certain interaction is the function of feedforward. However, most of proposed solutions function as feedback. For example, the tilt controller base create the feeling of going up or down while moving the stick. However, it only happens when user is interacting with the controller. The 'trial and error' method can easily catch users' attention when it goes wrong. The same situation also happens to solution of asymmetric patterns and different reacting force. On the other hand, covering the ball with different textiles is a more suitable feedforward to indicate the directions of light scenes by different tactile impression. It wasn't adopted at last, because the participants of user tests found it more handy to move the stick directly, instead of grabbing the ball. But tactile impression is still

a nice feedforward for peripheral interactions design.

Another thing I learned from this elective is that whether an interaction is peripheral depends on the mental resource demand instead of senses that are used. Sight is a confused one among five senses. Looking at something doesn't mean it requires full attention. The question proposed by the clients (control without looking) is interpreted as pushing the usability and intuitiveness of the interaction to an extreme, rather than a necessary condition of peripheral interactions. Visual cues are able to stay in the periphery of attention if well designed. Therefore, we chose the visual cues as the main feedforward because of its intuitiveness, and different reacting forces as added feedback of this interaction.

To go a further step, what senses or what kind of mental resource should be chosen to mobilize while designing a peripheral interaction? I think it depends on the primary activity of users. During my project, I used Multiple Resource Theory (Wickens, C.D. and McCarley, J.S., 2008) to select appropriate design concept for working context. The resources occupied by work-related activities and the resource required by the design concepts was marked on the Four Dimension Multiple Resource Model (Wickens, C.D. and McCarley, J.S., 2008). At last, the concept smart headphone with audio feedback was selected, as it hardly shares any resource with work-related activities. However, another concept based on face-tracking technology requires visual resource, which is a big overlap with computing work. The users could be forced to shift focus to look at a specific window on the screen, which is a terrible interrupt.

In general, I find this elective an inspiring course. I learned a lot and I consciously applied these knowledge into practical design in my own design process. Besides the appliance of theory, I also used evaluation methods to design the user test of my project with the awareness of the importance of an experienceable demo. And I used dirty prototyping method in a co-creation session I organized at Hasselt University.

2. Thilly

The process towards our final design, bux, came with a lot of discussions around how to really make the interaction peripheral. One that regularly came back was the factor of having to look at the controller to use it. Since within our video analysis and discussion we came to the conclusion that you don't have to look at something for it to be in the center of your attention, which would also mean that if you look at something this doesn't have to be the center of attention. The discussion over this is that you can make a peripheral interaction which you need to look at to control. My personal opinion based on the applied attention theory (Wickens, C.D. and McCarley, J.S.2008) is that if your main task, in the center of your attention, is a visual task then you cannot use the focus of your sight for another task. So either the visual cues have to be so strong that you can notice and react upon them within your peripheral perception, or you have to shift your visual focus from your main task to the controller, which makes it a focused activity.

This point came back within the user evaluation, where we could see that a lot of the users needed to look at the controller in order to change a scene. Within this test we did have a really short learning phase, which also plays a factor in how well a user can perform a task in the periphery.

Within the user evaluation we also observed that changing the brightness could be something to perform in the periphery. The users did not have to focus on how to slide the ball and where to go, although their attention did shift from reading the article to looking at how the lights were changing.

When looking at the results of the user test we concluded that most of the interactions have a possibility to become a peripheral activity, except for adjusting the brightness of one light. This was done by means of little sliders that were placed on the ball. Within the final design, these sliders were excluded from the product. The reason for this was that these sliders would always be in the center of attention and we observed that users had trouble with mapping the sliders to the lights during the user evaluation. Even though the controller may be easier to use and to understand, I still feel that the control of a single light is an important functionality for the controller.

When looking at the context of the design, a parent with a child, I can imagine that you would want to turn on one specific light or control the brightness of one part of the room, for instance where a baby is sleeping. With the functionalities bux had now, the user

can only control all the lights in the room, or they have to use the app. Ideally changing the brightness of one light would be added to the final design, such as stroking the ball towards the area of the room where you want the lights to turn brighter or darker.

For the final design of bux, we took the results of the user evaluation and the feedback during presentations to adjust some things in the design. These were the height of the stick and box, adding different feedback in resistance in different directions and adding a visual cue on which scene is on which side.

As discussed earlier, I still have some doubts about the visual cues. My doubt is about if these lights could be seen and understood within your peripheral perception. If this is not the case, then the que's do not help the user when using the controller in the peripheral. For this the haptic feedback could be a solution. We were not able to test this feedback with users, therefore it is still the question if you would be able to perceive and react upon this, after a learning process, within your periphery.

When taking all these factors in mind we can look at where to place BUX on the interaction-attention continuum. Bux has interactions within all three of the fields, but the overall controller would be placed between focused and peripheral interaction, shifting more towards peripheral. In short I would conclude that the interactions will be placed as follows:

Focused/Peripheral interaction:	Changing the scene
Peripheral interaction:	Turning on/off (by sliding or tapping)
	Changing the brightness
Implicit interaction:	Changes with your changes on the app

3. Damla

In general, it was a very nice and hands on experience for me to design a physical controller for Philips Hue Light. Since I have a background of human technology interaction, I always had a tendency to combine the design with new technological developments such as embodied or tangible user interfaces (Ullmer and Ishii, 2000), voice recognition or smart technologies. Although I believe that combining new developments might help the design process for peripheral interaction, I am satisfied with our final product, which is physical peripheral interaction, as well.

From the beginning I had the idea that using tangible interaction with a wearable such as smart watch or smart phone may be suitable for peripheral interaction design. It would enable it to be at hand any time and it would fit in the daily routine of everyday life easily. In addition there are so many gestures that can be used on tangible user interfaces and I believe using the technology which is in hand would make our design more embodied with our daily life. Designing for peripheral interaction, especially without using any technological developments and creating a physical interface which can be controlled in the periphery of attention was a big challenge for me.

On the other hand, we observed from our video analysis that in everyday physical activities, we perform a lot of things in our periphery of attention and the attention shifts between centre and periphery very often. In this view we didn't expect our final design to perform only in the periphery of attention but also shift between centre and periphery of attention if needed. Main shift of attention from periphery to focus is the decision making of the mode of the light. Although we give visual cues to the user by color and numbers on the box to understand which mode is selected, to perception of the current light mode and making the decision of the next light mode is mainly done in the centre of attention.

One of our iterations of the prototype had the option of putting the box tilted so that the corners would be not in the same level but there will be a level difference between every corner. In my opinion it would be a good feedback for the user to understand the current light mode and feedforward to chose the next light mode. For instance the highest corner would represent the brightest setting such as the reading light mode and the lowest corner would represent the lowest setting such as the relax light mode. By this, in my opinion, the user could made the decision process also in the periphery of attention because there would be a visual cue for the choice itself.

Another critical point would be the place of the box. Unless it is in the proximity of hand reach or ready at hand, it is not easy to interact in the periphery of attention. The user always need to walk to the box to interact with it which may take place in the centre of attention most of the time, unless the user uses more resources for another main activity. It is possible that the user decides to change the mode of the light and walks to the box while sending a text message to her/his friend by her mobile phone. If the user succeeds with changing the light setting while she is busy with another main activity, than we can conclude if the interaction can take place in the periphery of attention or not.

Finally, as Wickens and McCarley (2008) suggests, a physical action can become habituated and therefore be performed in the periphery of attention, when it is repeated and mastered enough. As such, if the user practices the use of controller for enough period of time, I believe that he/she can learn to use our controller as peripheral interaction interface to control her/his light settings.

Bibliography

Bakker, S., van den Hoven, E., & Eggen, B. (2015). Peripheral interaction: characteristics and considerations. *Personal and Ubiquitous Computing,* 19(1), 239-254.

Bakker, S., van den Hoven, E., & Eggen, B. (2010). Exploring Interactive Systems Using Peripheral Sounds. *In Proceedings of the HAID'10 Workshop Haptic and Audio Interaction Design,* pp. 55–64.

Bakker, S. (2013). Design for peripheral interaction. Phd Thesis. Eindhoven University of Technology.

Ju, W., & Leifer, L. (2008). The design of implicit interactions: Making interactive systems less obnoxious. Design Issues, 24(3), 72-84.

Kahneman, D. (1973). Attention and effort (p. 246). Englewood Cliffs, NJ: Prentice-Hall.

Salvucci, D. D., & Taatgen, N. A. (2008). Threaded cognition: an integrated theory of concurrent multitasking. Psychological review, 115(1), 101.

Sternberg, R. J. (1999). Cognitive Psychology. *Harcourt College Publishers.*

Ullmer, B., and Ishii, H. (2000). Emerging frameworks for tangible user interfaces. *IBM Systems Journal, 39(3-4),* pp. 915–931.

Weiser, M., & Brown, J. S. (1997). The coming age of calm technology. In Beyond calculation (pp. 75-85). Springer New York.

Wickens, C. D., & Hollands, J. G. (2000). Engineering Psychology and Human PerformancePrentice-Hall. *Upper Saddle River, New Jersey.*

Wickens, C.D. & McCarley, J.S. (2008). Applied Attention Theory. CRC Press, Boca Raton, FL. (Chapter 8).

PICTURE SOURCES:

Picture 1
http://www.apartmenttherapy.com/light-dish-one-cool-landing-st-50555

Picture 2
http://eu.studiobananathings.com/products/kangaroo-light

Picture 3
http://www.hizook.com/blog/2009/12/20/ultra-low-cost-laser-rangefinders-actualized-neato-robotics

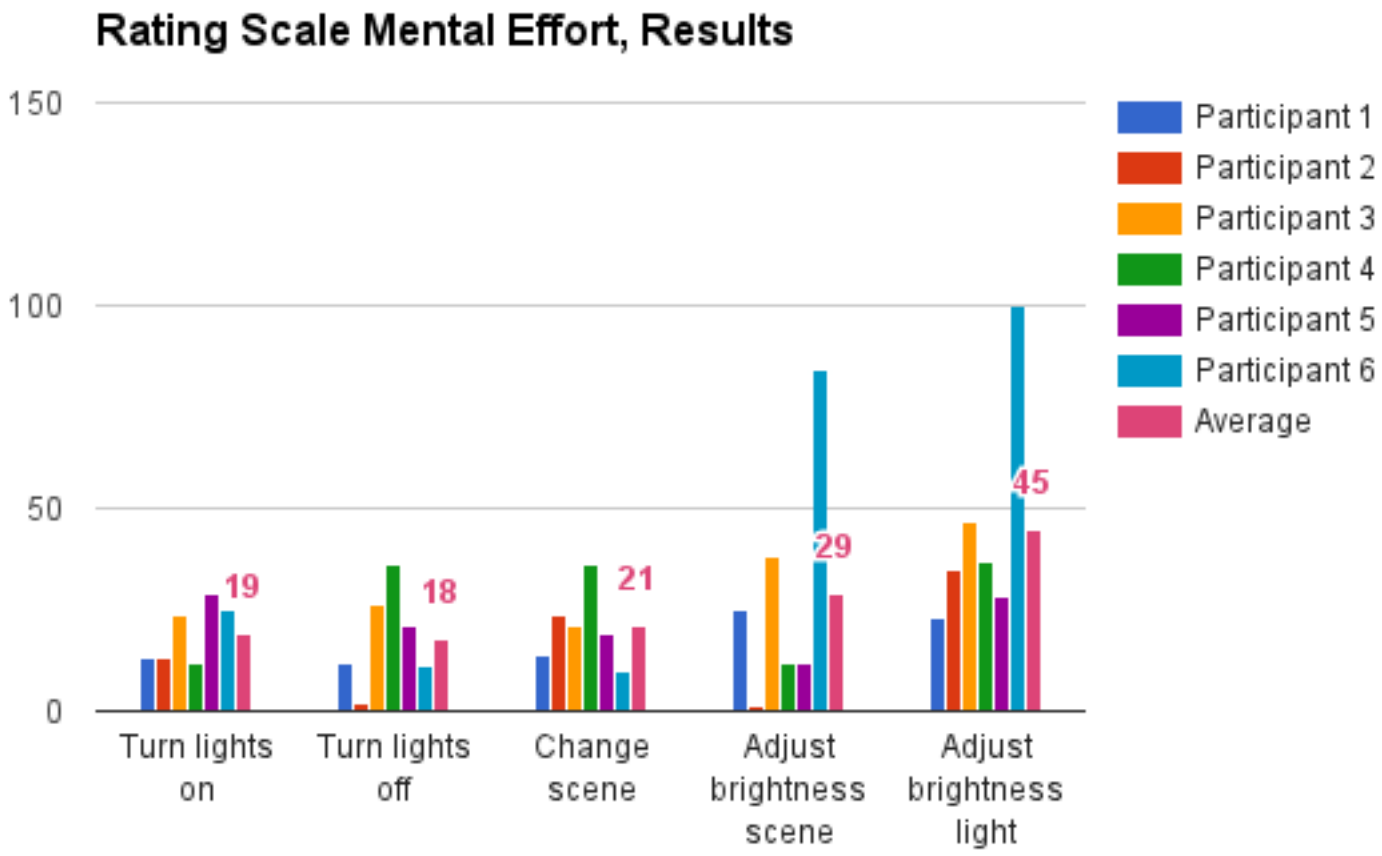
Picture 4
http://techoktech.blogspot.nl/2014/03/how-do-i-play-movie-with-subtitles-on.html

Picture 5
http://pressroom.subaru.pl/photo/2010m_obk/original/H28700230a%20Outback%20Automatic%20rain-sensing%20windshield%20wipers.jpg

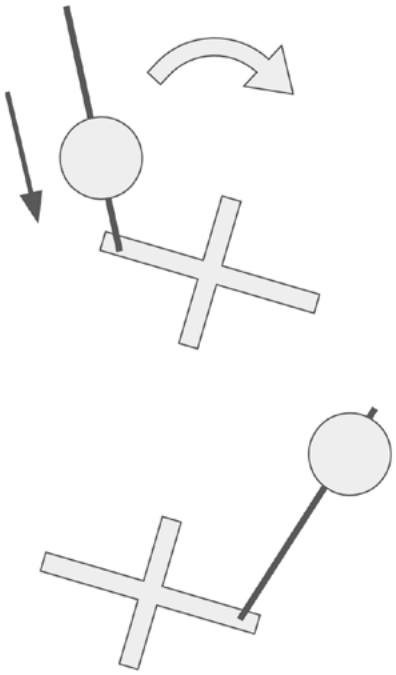
Picture 6
http://i.ytimg.com/vi/P1M-L36vCtU/maxresdefault.jpg

Picture 7
http://thelazylad.com/wp-content/uploads/2015/10/LED-Faucet-Lights.jpeg

Appendix


Rating Scale Mental Effort, Results
150
100
50
0
19
18
21
29
45
Turn lights on
Turn lights off
Change scene
Adjust brightness scene
Adjust brightness light
Participant 1
Participant 2
Participant 3
Participant 4
Participant 5
Participant 6
Average

2 (adjustments) in 1 (movement)



Participants did not notice this possibility

(Task settings: Assignments where 1 action at the same time.)

(They were not consciously aware of it.)

Potential to be learned

(Participants mentioned they did understand how this works and they are capable to do it as well)

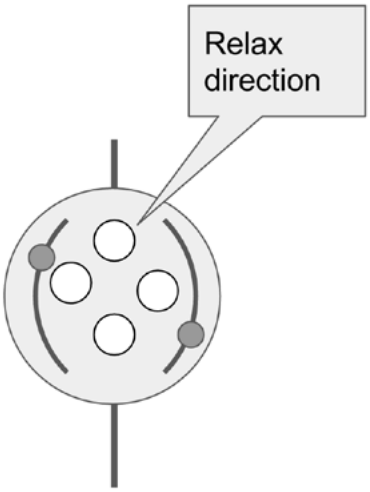
(More time needed)

Control without looking

Not really work in tests

Texture did not really help people to recognize the direction of scenes during the test.

(Ball controller could turn)



Potential to be learned

Participants mentioned they liked the texture and could maybe learn it.

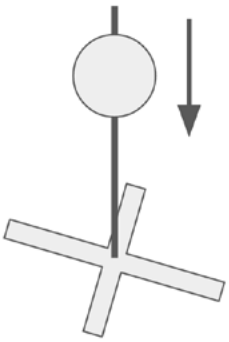
(More time needed)

Recognition confusion

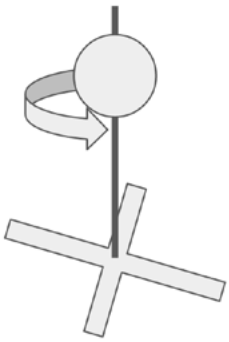
Trouble with knowing which scene is which side.

(The scenes are expected to be set by users)

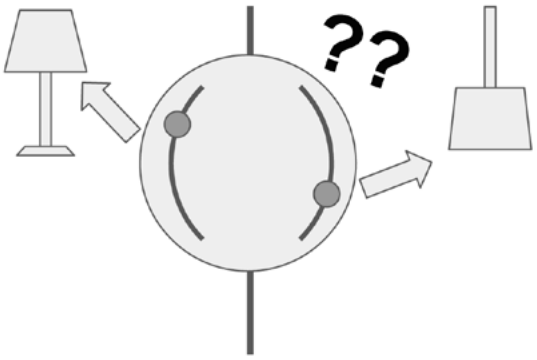
From mistakes to insights



Participants tried to adjust the brightness with the control stick in the center (this turns off all the lights)



Participants tried to turn the ball controller.



Trouble in mapping the sliding blocks to each specific lights in the room.

Insights

- **Suitable height and size** of the controller depends on where you place it
- The ball has an affordance of **turning it**
- The ball was expected to be more **stable** so the small sliding blocks can be controlled by a single hand
- Direction of small sliders can be **different** than the direction of brightness control to avoid confusion of the interaction
- Participants found the overall controller **easy** to use, and adjusting brightness is the most inviting interaction.