neru

M1 Design Report

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DIGSIM Squad, Getting Up Healthy context
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Abstract

Neru proposes a connected product-service ecosystem with the purpose of supporting the winding down process. This ecosystem features a physical hourglass, which is connected to operate under various contexts.

“Unwinding” is when tension and stress are reduced through relaxation or social or physical activities in order to prepare for bed. It is commonly associated with meditation practices. Neru is aimed at supporting this process by using an hourglass to guide users through their evening routine. Deliberately taking time for these activities aids in preparation for going to bed, both mentally and physically.

The effectiveness of *Neru* has been evaluated in a number of user studies and deployments with a fully functional prototype. The initial user feedback has shown a particular interest in bedtime triggers and winding down time. These results can be linked to an increase in perceived sleep quality, but this effect has not been effectively demonstrated. Further research is required in order to prove this link.

Neru has been conceptualised and developed in conjunction with Royal Auping BV.

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Introduction

Neru has been created as a M1 Design Project by Axel van Boxtel, Stijn Oude Lenferink and Lei Nelissen as a part of the DIGSIM Squad in the department of Industrial Design at Eindhoven University of Technology.

Neru has been an open exploration in the combination of IoT, sleep and health — particularly mental health. There is an increase in calls for our attention, particularly from internet-connected devices; mainly phones (Smith, 2018), but increasingly IoT as well. This is usually framed as being in the realm of convenience, but can rather be described as dark patterns, “where user value is supplanted in favor of shareholder value” (Grey et al, 2018).

A striking example of this is Netflix’ autoplay feature - though Netflix is far from the only offender, which many of us fall victim to. There comes a point in any Netflix-based evening where a decision is made whether to watch another episode or not. With Netflix usually making this decision for you, it has become exceedingly easy to go bed at a later time than you intended to.

A simple solution is to design to rid a user of these services. However, we see merit in an approach where we offer tools devices so that the user can make better and more informed choices. *Neru* couples this approach with insights, feedback and persuasion, so that we can create an experience that is entirely in the user’s interest.

The structure of the report reflects our way of working in this project. Since our early work and evaluations have been fed back into the design process, we felt it more natural to choose a chronological structure.

Axel, *Stijn* and *Lei*

Eindhoven, 14-06-2019

Project Context

DIGSIM

DIGSIM is a squad in the Industrial Design department currently headed by Joep Frens, Mathias Funk and Lenneke Kuijer. It intends to "*explore the next frontier of design: systems design. It aims to familiarize students with a new arena for design while engaging them in a designerly experiment that actively tries to explore new ground in systems design*" (Frens et al., 2019).

The squad is focused on designing Internet of Things solutions for the home, but in a broader, more complex context. While every student still designs their own concepts and prototypes in the general IoT context, the combined body of prototypes are subjected to a sensor- and actuator-equipped model home, where their functions have to be negotiated on both a conceptual and technical level. This is done to explore what can happen in real-life if the visions of wholly connected homes are to come true.

There is also a simultaneous aspect of user-centredness, through the "Donaldson-Dvorak" family, a hypothetical family that inhibits this home. They are mundane characters - as opposed to the "extreme characters" proposed by Djajadiningrat, Gaver and Frens (2000) - which lends the participating students a canvas to paint a picture of normal use of the home for their scenarios.

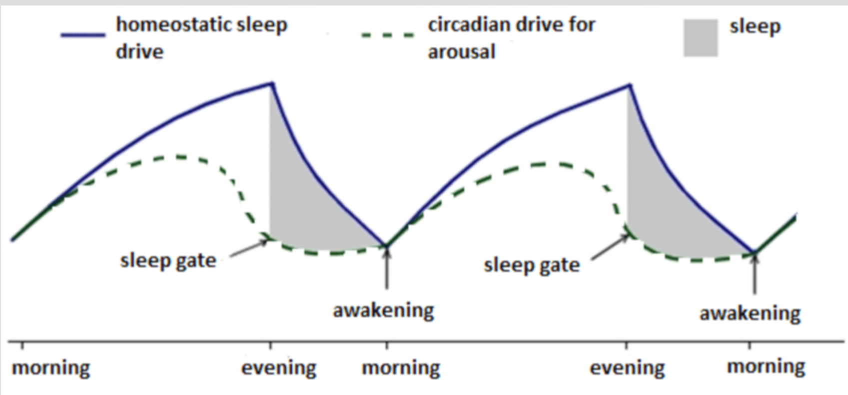
Getting Up Healthy

Getting Up Healthy is a specific context in the DIGSIM Squad. The design brief for this context is summarised as follows: *"Design for the getting up healthy experience in the home. Design for multiple characters and take a holistic perspective on the health of sleeping"* (Frens et al., 2019). This specific context also brought forth Auping as a client.

Theoretical Background

Sleep

According to the two-process model of sleep regulation, the timing and structure of sleep are determined by the interaction of a homeostatic and a circadian process. Homeostasis, in general, is any internal biochemical system that regulates the body's internal environment. Sleep-wake homeostasis, can be thought of as a kind of internal timer or counter that generates a homeostatic sleep drive or pressure for sleep as a function of the amount of time elapsed since the last adequate sleep episode (Thompson, 2019).



Two-process model for sleep (Angelhoff, C., 2017)

The circadian process is a 24-hour internal clock that is running in the background of your brain and cycles between sleepiness and alertness at regular intervals. It is regulated by outside factors like lightness and darkness, meals and social cues. Your circadian rhythm works best when you have regular sleep habits. (National Sleep Foundation, 2019). For the body to achieve sleep onset, the two process have to be synchronized. The circadian clock can be influenced through controlling exogenous zeitgebers (light, meals, etc.) but since the circadian clock is genetically determined this does not apply for all.

Morning chronotypes have earlier sleep-wake schedules, earlier diurnal peaks of alertness and performance and earlier sleep propensity rhythms than evening-type individuals (Lack, 2009). School, work schedules and social responsibilities interfere with the individual chronotypes with can lead to “social jetlag”

Social jetlag is the term used for late sleep onsets (controlled by the circadian clock) combined with early arousals (controlled by the external, social responsibilities) that lead late chronotypes to accumulate a substantial sleep debt during the work week, for which they compensate on weekends by extending sleep duration (Giannotti et al., 2002; Roenneberg et al., 2003b; Taillard et al., 2003).

Behavioral, environmental, and other sleep related cues that influence these processes are called “zeitgebers”. Peter Hauri took these zeitgebers and made “sleep hygiene” rules that can be used to treat patients with insomnia (Hauri, 1991).

Bedtime Routines and Unwinding

According to Hauri one should regularize the bedtime and follow a routine before going to bed. Regular bed- and arousal time seems to strengthen the circadian cycle and prevents the accumulation of a substantial sleep debt during the work week, which is compromised on weekends by extending sleep duration (Giannotti et al., 2002; Roenneberg et al., 2003b; Taillard et al., 2003). It is also associated with health benefits, such as reduced risk of obesity, diabetes and high cholesterol in both adults and children (Huang & Redline, 2019; Spruyt et al., 2011).

Patients with insomnia experience worry and rumination when in bed, prolonging the sleep onset. Lichstein indicated that individuals with insomnia were 10 times more likely to attribute their insomnia to cognitive complaints such as worrying and difficulty controlling thoughts (Lichstein & Rosenthal, 1980). Unwinding; i.e., when tension and stress are reduced through relaxation or social or physical activities (Rook & Zijlstra, 2006; Sonnentag & Kruel, 2006) can be achieved through mindful meditation techniques. Changing patients’ attitudes towards their thoughts to one of gentle acceptance, mindfulness helps cultivate a more holistic and enduring defense against the cycle of repetitive and automatic negative thinking (Teasdale et al., 2002).

Behaviour Change

“Design for behaviour change is an approach which seeks to change behaviour to encourage desirable human practices” (Niedderer, 2013). Fogg describes several methods of persuasion based on the role of computers, dividing them into Tools, Social Actor and Medium. In this case our solution can be considered a Tool for which applicable persuasion strategies are: “making target behavior easier to do”, “leading people through a process” and “performing calculations or measurements that motivate” (Fogg, 2003). Practically this is represented in the concept by making it easier to implement a healthy routine, guiding people through the process of designing a healthy routine/the routine itself, providing routine data to motivate the user.

Tromp, Hekkert and Verbeek describe a framework of influence from the point of the intended user experience based on the dimensions of force and salience. In contrast to decisive, coercive and persuasive, the seductive cluster can be considered an applicable approach for our concept (Tromp, Hekkert & Verbeek, 2011).

Mindful Design

In contrast to regular persuasive approaches, Niedderer proposes Mindful Design as an approach for sustainable behaviour change. “Mindful design is assumed to be able to operate without such a supportive context, and instead to work on the intersection of coercive and persuasive design, being strong and explicit, but giving the user the choice of how to act, thus requiring the user to take responsibility”, “Mindful design offers a specific conceptual approach which is based on attitude change through conscious reflection and commitment. The benefit of mindful design is its ability to shift the focus from an external locus of control associated with design for behaviour change to internal locus control, which enables conscious decision making and commitment as an essential basis for attitude change and subsequently for lasting behaviour change” Niedderer, 2013).

Slow Design

According to Alastair Fuad-Luke “Slow Design focuses on ideas of well-being. Wellbeing needs are indirect impacts on health though their relationship to personal fulfillment, quality of life and psychological health. Failure to meet well-being needs results in psycho-social maladjustment and stress-related illnesses. The guiding philosophical principle of Slow Design is to reposition the focus of design on the trinity of individual, socio-cultural and environmental well-being” (Fuad-Luke, 2005).

“The philosophy behind the Slow Movement originated from the observation that, in the current world, people live lifestyles that are too fast; a behavior that leads to work overload and stress. By slowing down, focusing, and thinking about what they are doing and why, people will be able to take control and begin to relax” (Grosse-Hering, Mason, Aliakseyeu, Bakker & Desmet, 2013).

Microboundaries

Cox, Gould, Cecchinato, Iacovides & Renfree, propose implementation of friction in interaction to evoke mindful reflection for sustainable behavior change. “Work from cognitive psychologists suggests that we have two modes of thought: System1 and System2. System1 is the fast, automatic system that guides most of our behaviours and is employed during the automatic, mindless interaction. System2 is the slower, more deliberate system that is employed when we are more mindful and conscious of what we are doing. We are arguing that System2 could and should be invoked through careful interaction design in a way that advantages users. Here we define mindful as deliberate and intentional rather than as an awareness and non-judgmental acceptance of the experience of the present moment. frictions that are designed with intention, and introduced with care, have the potential to elicit interactions that are reflective.”, “A microboundary is an intervention that provides a small obstacle prior to an interaction that prevents us rushing from one context to another. It does this by creating a brief moment in which we might reflect on what we're doing. This small barrier to interaction can be implemented via a short time cost and prompts a switch from System1 behaviour to that of System2. A microboundary provides a micropause in which the more mindful System2 is prompted to take over control of behaviour” (Cox, Gould, Cecchinato, Iacovides & Renfree, 2016).

Approach

Design Direction

After preliminary research into sleep and systemic design we elaborated on potential opportunity areas. We considered a different perspective on sleep quality and proposed a holistic approach by looking at factors that affect sleep quality outside the bed itself. Starting points are persuasion, rituals & routines to improve sleep quality. We defined three opportunity areas; Ritualizing an existing routine, Guiding routines, Shaping a new bedtime ritual.

We arranged a meeting with Geert Doorlag, the contact person at Auping. He shared that an important aspect of sleep is relaxing before bedtime and that many people have trouble relaxing in the evening which has serious impact on their sleep quality. Doorlag was enthusiastic about the approach to influence sleep outside of the bed and he sees value in a solution that helps people relax in the evening.

We visited the Centre of Sleep Medicine at Kempenhaeghe to learn about sleep and discuss our ideas with an expert. According to Somnologist Sebastiaan Overeem there is a lack of understanding on the importance of routines and their influence on sleep quality. Overeem points out the two-process model of sleep regulation and zeitgebers as a means to explain the role of routines in sleep. Overeem shares that he sees value in raising awareness and knowledge on these topics.

We learned there is opportunity for a solution that increases awareness and helps users to relax in the evening through a healthy evening routine. We frame our design scope as such: a solution that Improves sleep quality through evening rituals.

Exploratory Design Phase

Concept Development

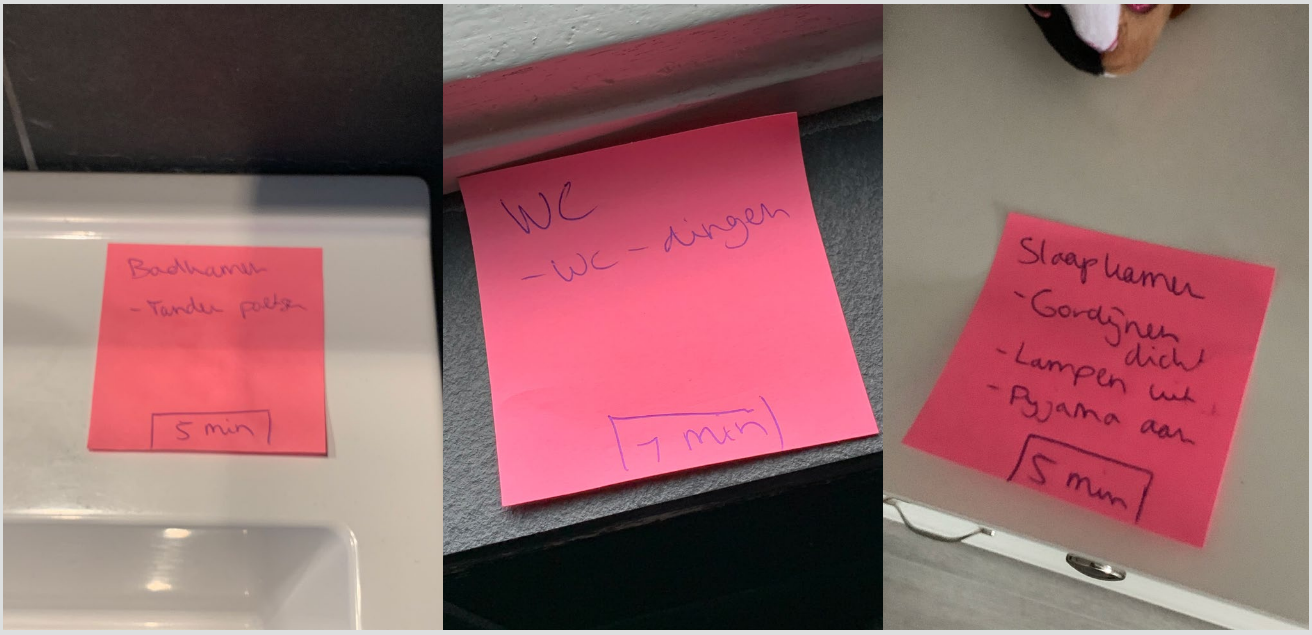
To get to know the subject of sleep and find interesting design opportunities. A series of brainstorm sessions was conducted. It ranged from an extreme characters brainstorm to paper prototyping. These creative tools where used to generate concepts and for the team members to get to know each other.

The concept that were generated had a commonality that was to provide guidance during the evening and morning routine. Ranging from a going offline routine for the smartphone, personalized slide over door handles to emphasize the transition between spaces, a slipper that will guide you through your routine with changes in texture and a handheld color changing artifact that represent the different spaces within the home. To take a step back and validate the commonality we made an MVP post-it demo.

Post-it Demo

One way of evaluating our design direction was through the use of small user-test conducted by ourselves (Axel and Lei). We designed a routine using post-its, which we would hang in the respective places for that part of our routine. We would then use our phone timer to experience what timing an evening routine could look like.

Our main finding is that designing a routine is a major driver for awareness in routine composi-



Examples of post-its as used in the post-it concept validation

tion and length. Additionally, the action of timing the steps helped prompt reflection about the design of the routine, which in turn helped link the activities to sleep. Insights were also gained for minimal timer length, friction in interaction and non-normative use (see Appendix E).

Routine Timer

With the booklet users can form their routine by timing and arranging activities. The activities are clustered and connected to QR location stickers. To set up, the user places the stickers at the corresponding locations. This process should make the users aware of their routines. Moreover, the booklet invites the users to give feedback and reflect on the effect of the solution with corresponding questions. In the booklet there is a QR code to set-up the phone application. The booklet also holds an informed consent form.

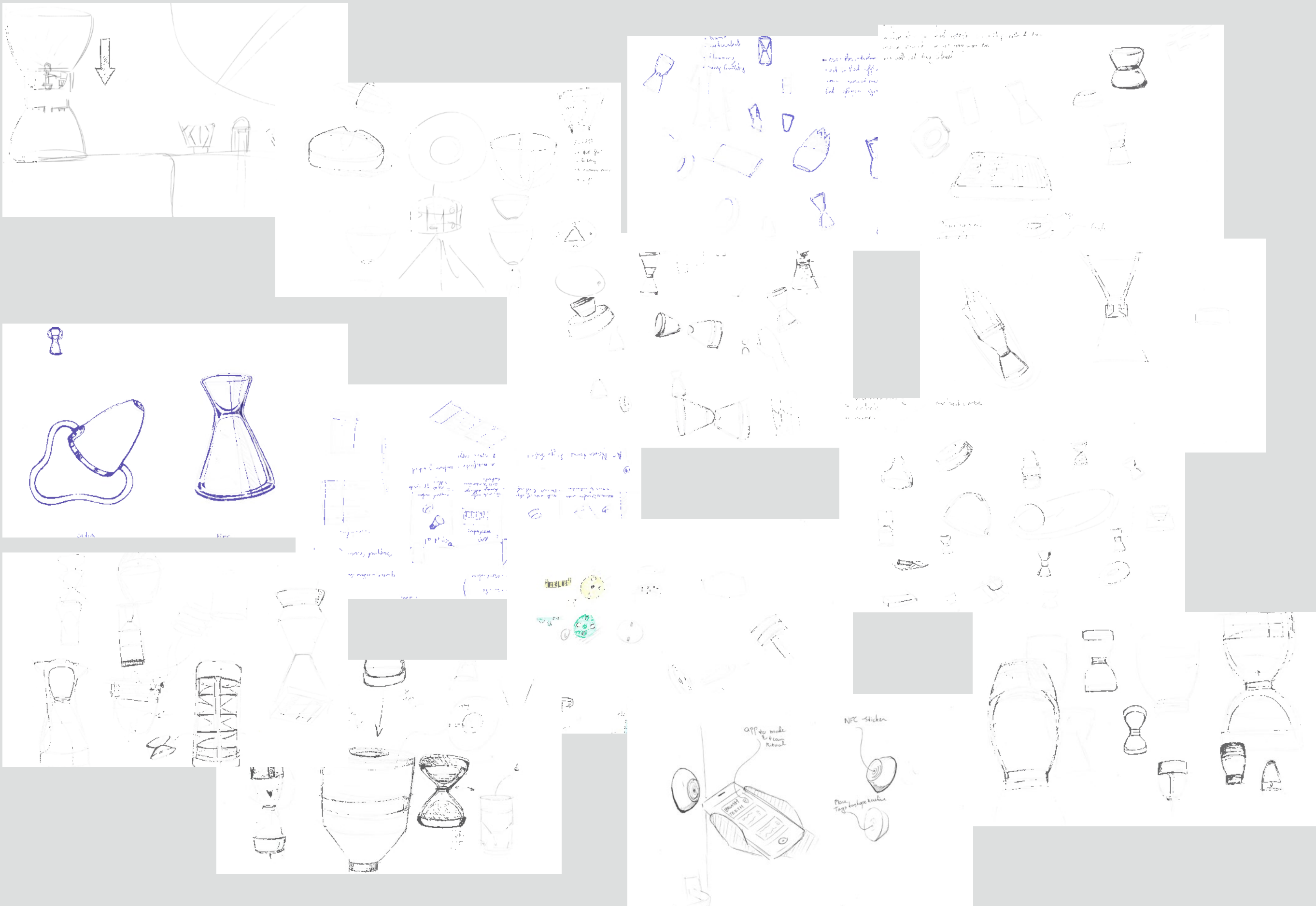
The QR stickers are pre programmed with specific timers (1min, 2min, 5min, 10min, 15min, 30min). The users place these stickers at the location corresponding to this activity.

The web-application is launched when scanning a QR it then visualizes the time spent on the activity. Data is gathered by the application to get insight on the use of the stickers throughout the test. (see Appendix H)

User Involvement

Photo of in-situ QR Code

In order to evaluate our concept on a basic level, we involved a number of users in a concept-validation user test. In the test users were asked to design their evening routine and cluster their activities by location. The users placed QR stickers at the corresponding location to time their evening activities. The QR stickers linked to a timer web-app (see https://github.com/leinelissen/sleep-routines). The users also set an alarm



A number of sketches exploring prototype forms

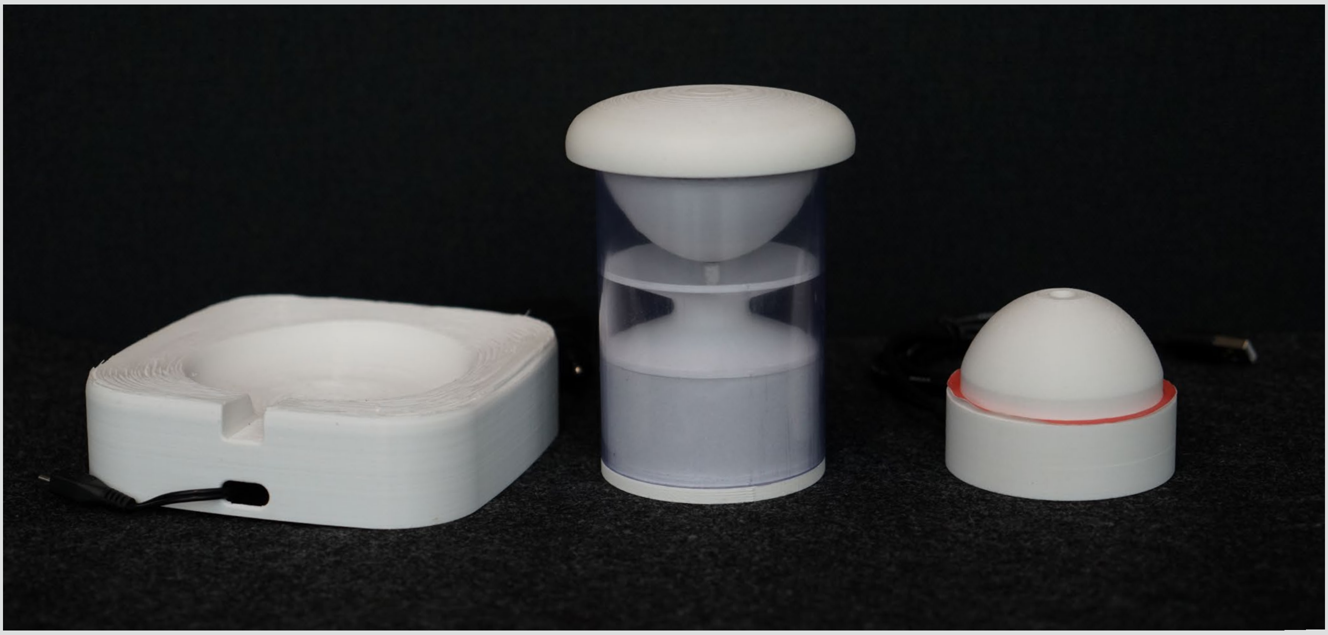
for the time that they should start their evening routine. The test was conducted for a week with 7 participants. After completion, semi-structured interview techniques where used to validate the hypotheses and gather new insight into the topic of sleep routines. (See Appendix A)

"...usually, I would focus on completing my routine as quickly as possible, ... but I realised I still had a lot of time left ... I immediately noticed the tranquility that it afforded me".

"I am usually quite easily distracted. I would be doing the dishes, and I would see something lying around, and I would think: "That's something I also still have to do [before going to bed]", although it could be done the day after just as well. So, my routine lasts a lot longer than it needs to, so I really appreciated the timer"

Most participants mentioned that the activity of designing their routine lead to new insights into and increased awareness of their evening routine. This resonated with our hypotheses (see Appendix A) that (H1) scheduling, (H2) timing and (H3) physicalising would increase awareness of the routine as a whole. Most of our hypotheses regarding strengthening the routine (H4), relaxation (H5) and sleep quality (H6) were more or less rejected by the user group at large, citing either the phone-centred interaction or competitive interaction with the system.

However, most of the participants who rejected the last three hypotheses also noted that they did appreciate a method of reminding them about their time of going to bed, coupled with their increased awareness about routine length.



The functional prototypes as they were deployed in the usertest

Informed Design Phase

In her book about self regulation, psychologist Georgia DeGangi shares 17 strategies for improving sleep. The three strategies that we aim to address in our solution are “Establish a bedtime routine that is predictable so that there is a winding down of your day”, “Institute a calm and organized bedtime ritual, the time between dinner and bedtime should be relaxing and enjoyable” and “Make a consistent plan for bedtime” (DeGangi, 2012).

Making the Functional Prototype

From the exploratory design phase an interesting design opportunity surfaced “Using persuasion frameworks to establish a lasting routine” and “Giving Insight, creating awareness and giving control over the “bedtime” activities to elevate uncertainty stress”. From this point we set out to realize and prototype that would focus on these aspects. Together with slow design, mindful design is taken forward in our process as an approach for behaviour change.

A participant has been selected from the initial user testing that will partake in the informed design phase. She had a routine that consisted of 5 cluster with a total duration of 30 min. Which was more or less average when looking at the data from the first user test. We took this as a starting point to develop the functional prototype.

A challenge with this prototype was the transparent housing. We made a shape exploration for a housing to be 3d printed but abandoned this train of thought because of its complexity. We opted to change the shape of the hourglass to accommodate a transparent PVC tube that encaptures the electronics, glass beads and waist.

The “waist” connecting the upper and lower compartments in combination with the volume and diameter of the filler material are the variables that influence the run time an hourglass when opened. A formula has been made to determine the right proportions (see Appendix B). Alongside empirical research had been done to validate the results.

To throttle the flow and make it possible for the hourglass to open and close. A rack and pinion mechanism houses within the electronics casing. With a servo controlled by an ESP32 a pin can be retracted and ejected so throttle the flow and lengthen the runtime.

The docks have an internet connected ESP32 and a Hall sensor to detect the hourglass when docked (see https://github.com/leinelissen/sleep-routines-wifi). The charger is shaped so the affordance communicates to charge the hourglass in an upside down position. Alongside the physical prototype an application was made to configure the evening routine with Setup and instruction manual video see (https://github.com/leinelissen/sleep-routines-app for the application, and https://www.youtube.com/watch?v=OtZH6B4wdGQ&t=29s for the video).

User Deployment

User deployment focussed on concept

From the exploratory design phase testing a participant was selected to partake in the informed design phase testing. Her sleeping routine is not structured and her perceived sleep quality is below average. She used the QR-code prototype and the deployment prototype for 14 days and these are some of her insights. The interview was conducted in Dutch but for the sake of the report the quotes have been translated to English.

"....With the clusters i because more efficient in my routine. I would do my routine in 20 min instead of 30 min. This is because normally I would get distracted but with the clusters i would be more focussed and leave the other things for the next day".

"...What is interesting is that I'm able to quickly pick up a routine and I link sleep and the use of the product, the mental preparation of going to bed starts earlier and makes me more relaxed during my routine".

"...The prototype that is used has some shortcomings, it was difficult to see the progress of the hourglass because there is a construction in the way .... the 3D printed housing is the same color as the sand, that's inconvenient".

From this exit interview we validated a lot of our assumptions and had a solid foundation to further develop the final prototype.

User deployment focussed on interaction

To explore the possibilities of emergent functions a week long deployment was arranged with 5 other projects from the DIGSIM squad. A multitude of IOT devices was installed within a 5 family member home *(see Appendix F)*. Mother, father and three children with ages 3, 6 and 18 years old. The general conclusion that can be drawn is that the experience for the participants was a bit overwhelming and our prototype was only interacted with for 3 days. These are some of the insights. The interview was conducted in Dutch but for the sake of the report the quotes have been translated to English.

"...It is difficult to see the sand level during the routine, one of the first activities is to turn of the lights and the feedback was minimal so we did not get a lot out of the concept".

"... for me it was stressful to interact with the prototype, it felt like I needed to hurry my routine. My partner on the other hand was not stressed at all".

An overview of the 3D-printed form explorations

"... because of the children we had a fairly standardized evening routine, we are structured people so the guidance through the routine feels a bit arbitrary".

"...what is was looking forward to was the notification to start with the evening routine but unfortunately i never received such a notification". (this is a technical failure because the intent was to send such a notification).

To conclude the participant used the product for a short amount of time and due to technical failure the added value for not evident.

Glass Prototype

The Equipment Prototype Centre (EPC) located on the TU/e campus has the facilities to fabricate the glass volume by hand. This opened up the possibility to produce a prototype that catered to mindful interaction with attention. The deployment prototype focused on the building and design of routines and proved to be working in this regard.

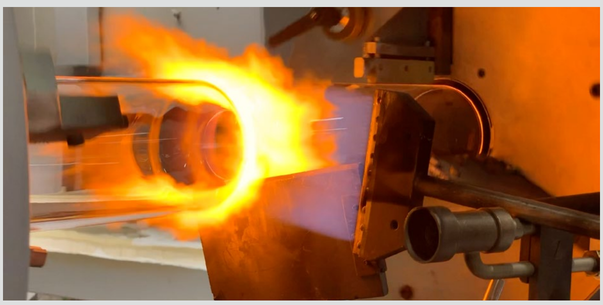
To establish a lasting routine in which the user is able to unwind and induce a tranquility vibe, a high quality experience prototype from glass and small metal balls was created. This prototype an exploration into interaction with attention. The use of seemingly fragile materials makes the prototype so that it has to be handled with care and attention.

The decision was made to use bearing balls as filler material. When comparing this to glass beads there are a couple of benefits. Steel balls have the tendency to bounce when they come in contact with the glass this results in a more prominent visual feedback when the hourglass is opened, the whole lower compartment radiates movement. The steel balls provide auditory feedback so the user can visually focus on the task at hand. Lastly the spherical shape of the balls makes it possible to form grid like patterns when they are stacked, this gives the feeling of structure within complexity.

Through the user test we found that there is a divide between people who would like a general overview of their bedtime routine progress and people who like a precise progress indication of the individual clusters. To cater to these needs a modular system has been designed, the docks have a central column that represent the total duration of the routine with disks that represent the duration of the activity. When the metal balls starting flowing the level starts rising when this level is in line with the height of the disk the user should continue to the next activity.

Integration

One of the facets of the DIGSIM project, is its inclusion of a physical, connected model home, that acts as a sandbox for exploring the concept of growth and emergence in systems (see Project Context). Prior to deployment, we had already organised some workshops and meetings discussing how to design for emergence. These gradually led to a design and setup for the home that was constructed for Demo Day, which has been a cooperation with all Final Bachelor students in the squad.



The glassblowing process

Designing for Emergence and Growth

On the 15th of May, we organised an integration design workshop with the FBP students. We

Experience prototype within the home context

asked the participating students to reduce their concepts to simplistic sensor-, actuator or mediator-based products. We then presented a number of scenarios (see Appendix C) as input for a group-brainstorm session. The brainstorm then ended with pitches from the participating groups on how their connected ecosystem of products could handle the needs of the situation at hand.

If anything, the results from designing for integration, from this effort, as well as another session planned for the 12th of April, and the construction of the home - have shown that designing for integration and/or complexity is an incredibly hard problem.

Research from the field has shown that this is not a solved problem either. Wilson and Hauxwell-Baldwin note that “an integrative approach to smart home user research is neither desirable nor practical” (2015). Their established “need to develop a better picture of who users are and how they might use smart homes“ is probably the inspiration for how the DIGSIM squad is setup, with the scenarios and sandbox as extra grounding in reality, es

Multi-user, Multi-activity Scenarios

This was a major topic for discussion when discussing the function of the home when presenting on Demo Day, and it brought on the realisation of the home as an interaction object, which would have two-way communication with all of our prototypes.

The “Donaldson-Dvorak” family consists of grandpa, mother, father and 2 childern. Our focus with Neru is on the evening activities of the adults. Their cluster routines could take place at the same location e.g. the same docks. To take this into account we made a way for multiple users to use the same docking station. With the use of colored markers one could identify to what level the filler material should rise before one should move on to the next activity. Further research is required to conceptualize a mechanism that takes multi user same activity into account.

The DIGSIM Home

The home was a collaborative effort between the M1 and Final Bachelor students.

The home itself is designed by Joep Frens, and we recycled the home that was left over from the previous semester. In order to recycle the bottom plate, we decided to mirror the home, so we

The finished DIGSIM Home

could use the clean underside. The walls were remade through use of the laser-cutter, and painted white to match the aesthetic we were aiming for. We also 3D-printed new furniture and prototypes for the home.

We settled on a list of inputs and outputs for the home through discussion. The home would have general lighting for every room, as well as LEDs indicating usage/activity for either rooms or specific prototypes. Additionally, there would be a number of buttons and toggle switches indicating activities, as well as hinge switches for every room, indicating whether someone was present in the room.

The elecontrics were constructed by all students in close cooperation with Huub Smeitink, who designed the input and output boards for the ESP, for which he also wrote the software. We (the M1 students) then selected the specific components and electronics design so that they could be mass manufactured.

The home was finally constructed by drilling holes in the MDF walls and floors, so that the sensors could be placed in the actual home. The home is accessible through OOCSI, to which it connects over WiFi. The home Data Canvas (see Appendix D) was used to convey the inputs and outputs from the home, along with the inputs and outputs for the students' prototypes.

Emergence and the Home

Given the interactive home, we could get to work with actually implementing emergence. The emergence was implemented through the home (via OOCSI, Funk, n.d.), primarily using the Data Canvas, as well as discussions with the peers we were integrating. When designing for emergence, we focused on two particular angles: (a) ecosystem interaction, which meant gathering data from and outputting data to the home from our own ecosystem, and (b) using the basic function of the hourglass (timing) for emergence.

The scripts that have been written to enable the emergence using the DIGSIM home can be retrieved from https://github.com/leinelissen/sleep-routines-mqtt-scripts.

Final Design

Neru features an ecosystem of an hourglass, a number of docks, a charger and mobile applications. Before use, the application is used to precisely design an evening routine, featuring specific activities, clustered together around a number of locations. The user also determines the amount of time they want to spend on the location, as well as a sleeping time. The docks are then placed at the respective locations, and the hourglass in placed in the charger to await its first use.

Half an hour before the routine, the Hourglass will open up, indicating the routine start time is nearing. When it is full, it should be taken from the charger to the first location, where the Hourglass will open. The Hourglass is filled with small metal balls, providing a continuous, white noise-like sound that acts as direct auditory feedback. After the pre-designated time has run out, the Hourglass will close again, indicating that the user should move to the next activity.

This process is repeated until the last dock is reached in the bedroom. The Hourglass is similarly docked, after which the user undertakes their last activities. When the Hourglass runs out, the time for sleep has come. The next morning, the Hourglass is fetched from the dock and returned to the charger for use later that day.

The interactions with the docks, charger and hourglass are designed to elicit care and attention from the user, which act as hooks for ritualisation. This helps a user to learn to associate their evening route with sleep, allowing for preparing for sleep mentally before getting to bed.

A render of the proposed ecosystem

The Hourglass


A side view of all elements

The Neru Hourglass is the physicalization of the routine progress and the primary means of guiding a user through their evening routine. It consists of a handmade, double-walled glass hourglass, with two concave surfaces: one for the dock, and one for a 3D-printed case housing the electronics. From this housing protrudes a retractable pin that precisely fits the neck of the hourglass. This provides a novel way of precisely controlling the flow of the hourglass mechanically.

The Hourglass is filled with roughly 1 million chrome-plated steel bearing balls, 0.5mm in diameter.

In terms of electronics, the Hourglass features a custom-made PCB containing chips for both Bluetooth and Wi-Fi in order to facilitate connection to the home. Furthermore, there is a servo that controls the retractable pin, as well as a battery and inductive charging coil.

The Docks

We made a customizable dock where the user can choose to include progress markers. These markers are color coded for the individual family members so the docks can accommodate multiple users.

There is a further engineering challenge in regards to docking detection. Ideally, the docks contain only passive electrical components - for the sake of simplicity in manufacturing and costs, but given the distance between the dock and the Hourglass, the steel bearing balls and the limited power, wireless direct connections are simply infeasible. Another option could be a physical connection with wires running through the glass, but this poses problems with manufacturing these wires into the glass.

If the previously mentioned problems turn out to be irresolvable, there is always the option of communication over WiFi or Bluetooth, with a simple sensor (ie. a hinge switch or hall sensor) in the dock, at the expense of increased cost, manufacturing complexity and minor user inconvenience.

The Charger

The charger serves primarily as a device that recharges the hourglass after use. Since the hourglass battery is limited, it will need to be charged, ideally daily. It also functions as a means for the hourglass to fill back up, as it is hung upside down in the charger. Lastly, the charger functions as a hub for the ecosystem in the home. The inclusion of a low-power chip allows for it to store data and connect the ecosystem locally, instead of in the cloud.

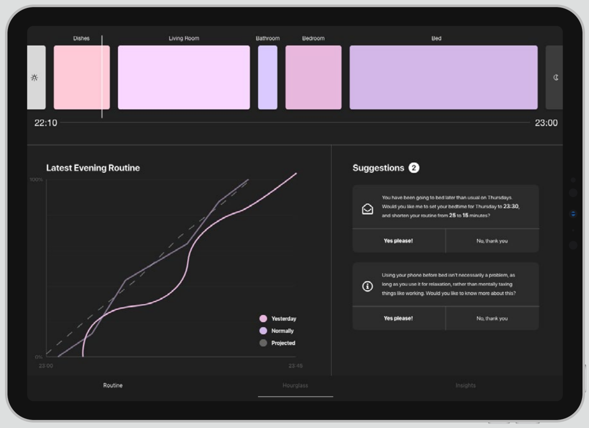
The charger features an inductive charging coil for the hourglass, as well as a microprocessor on a custom-made PCB, capable of running multiple services - MQTT, the machine learning algorithm, data storage and application back-end - as well as communicate via WiFi and Bluetooth.

Interaction with the charger invites for mindful interaction through its use of a platform with arms in which the hourglass is hung. Microboundaries in the interactions evoke a mindful start of the evening routine. A microboundary is an intervention that provides a small obstacle prior to an interaction that prevents us rushing from one context to another. In the context of behaviour change, microboundaries have been used to make people more mindful of their behaviours. (Cox, Gould, Cecchinato, Iacovides & Renfree, 2016) The design of the charger invites to interact with attention through the fragility of glass floating above the surface in combination with the delicate closing mechanism. The start of the routine become a delicate action where users switch to a calm and reflective state that allows for relaxation throughout the routine.

Ecosystem

The hardware devices are supported by a service ecosystem that provides for a software infrastructure, as well as additional user benefits in the form of suggestions. These suggestions are provided via a machine learning algorithm that runs off of the charger.

The ecosystem is made interactable through the use of mobile applications. These allow for higher-level settings, and are also the interface through with detailed insights can be gained, either on the user's data particularly, or sleep in general. By being combined with the systems' suggestions, it provides a rich feedback and feedforward system for the user. Additionally, the system can send out a prompt to a personal user's device to let them know to relax. This is a key part in the start of the evening routine.



A view for the iPad App

Discussion

Our attempts at facilitating integration show two important learning points for the DIGSIM squad. Firstly, the quality of integration is highly dependent on its integrated parts. Simple sensors can feed into more complex ecosystems, but the reverse is not true. When most students opt for complex ecosystems in their designs, integration becomes a problem of systems looking for input. If designing for growth is the project goal, then a balanced composition of (a) open-ended sensorial/actuatorial products and (b) systems integrating those is required. If designing for emergent phenomena, it might even be beneficial to split a design process in two phases, where the former are conceptualised and made first, and the latter are constructed subsequently.

We have learned from our user deployments that emergence needs to be designed for, and our additional constraint of designing a “product family” shows that the project requires careful navigation of designing for a system and its constituent parts. If this balancing act is to succeed, students need a way of determining how the home fits together. The data canvas is a solid starting point for this, but since it mostly features the data aspect of the IoT home, we think there is a more holistic approach in documenting the complexity under which the home operates. It could, for example, be interesting to have a data canvas-like layer in OOCSI that acts as the connecting fabric for our prototypes, so that the data canvas is no longer hypothetical and that it provides an opinionated approach on how integration could work, instead of every student figuring it out for themselves.

Retrospectively, the Data-Enabled Design methodology (Van Kollenburg & Bogers, 2019) could have been a very interesting way of developing a product of this kind in the project. Especially the digital aspects of our deployments lend themselves really well to this, and it would have been very interesting to have a feedback loop with our participants, and also presenting them with the data they generated, rather than the more linear approach we have followed currently. It would also have been beneficial in interpreting our data better. It is however up for debate how well this would mesh with designing for emergence and growth, particularly given the house as a design object and its relation to the demo day.

Conclusion

The designed ecosystem shows great promise in positively influencing individual agency in evening routines as well as improving sleep quality. However, there is room for improvement in narrowing design interactions as well as more definitively researching the impact. Also, while the glass prototype is a great benchmark for the intended interaction, there is still a lot of work left in terms of electronics and software.

The design has been submitted for the Mind the Step Exhibition at the 2019 Dutch Design Week. A review of the design conducted with Auping has revealed their intention of collaborating on a functional prototype for either their own Dutch Design Week exhibition and/or the Mind the Step Exhibition.

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Appendices

Appendix A: User-test Approach

Appendix B: Physics Model Hourglass

Appendix C: Scenarios for the DIGSIM home

Appendix D: Data canvas

Appendix E: Post-it Demo Setup and Reflections

Appendix F: Deployment Booklets

Appendix G: Persuasion Framework

Appendix H: User-test Booklets