CHALMERS
UNIVERSITY OF TECHNOLOGY

Developing the interaction of a health monitoring wearable

A design in hardware and user interface, 2021

Bachelor's Thesis in Product Design Engineering

Edvin Nielsen Johansson

Department of Product Design Engineering
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021

Bachelor's thesis 2021

Developing the interaction of a health monitoring wearable

A design in hardware and user interface, 2021

Edvin Nielsen Johansson

Department of Product Design Engineering
Chalmers University of Technology
Gothenburg, Sweden 2021

Developing the interaction of a health monitoring wearable
A design in hardware and user interface, 2021
Edvin Nielsen Johansson

Supervisor: Olof Wranne and Thomas Waldner
Examiner: Olof Wranne, Department for Design & Human Factors at the Institution for Industry- and Material Science

Bachelor's Thesis 2021
Department of Product Design Engineering
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 70 772 9099

Cover image: The final hardware design, displaying the home page of the final user interface.

Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2021

A design in hardware and user interface, 2021
Edvin Nielsen Johansson
Department of Product Design Engineering
Chalmers University of Technology

Abstract

The existing wearable was developed at Sony and is part of a product system referred to as mSafety. With its built-in sensors and connectivity it is used to monitor and inform of the users' well-being. Fundamentally, the use cases are widespread and not limited, but those pre-defined are within the health-care domain, risky sport-activities, and hazardous work environments. For the second generation it was initially suggested the entire product system, including the service design, could be reconsidered. However, due to the time constraint, three major components stood in focus. The user interface, the layout of interactive mediums, and the hardware form. With the objective to develop an improved product in these three categories, the aim is to a greater extent meet the user and its expectations in functionality and accessibility.

In the pre-study, the system and its users were clearly mapped, while the user interface, physical hardware, and functions were thoroughly disintegrated and analyzed. Eventually, a *Specification of Product* with demands and requirements similar to those of the previous generation was established. Accompanying the hard requirements, visual material was produced to provide the soft values in terms of experience and expression.

Utilizing the knowledge collected throughout the bachelor study, complemented with literature studies, a range of methods were used to generate and evaluate new possible solutions. Throughout the generative phase, methods of divergence, in combination with feedback-sessions were iterated on. Possible users and experts were consulted, and theories were verified, while the usability of different concepts was determined.

A final concept was compiled with development in hardware form and layout, and user interface. It is heavily backed by design arguments from literature, users studies, expert opinions and ISO-standards. The result fulfils the goal of providing an improved, and realistic, solution in terms of interaction, experience, and usability.

Keywords: product development, wearable, IoT, hardware layout, hardware form, hardware design, ui design, user experience

Acknowledgements

This report is the result of a thesis project (15 HP) at *Product Design Engineering* (180 HP) at *Chalmers University of Technology*, Gothenburg. The project is a collaboration with Sony. It was carried out during SP 2021.

I want to express my deepest gratitude to my Thesis Sponsor, **Thomas Waldner**, *Director Design Centre Europe -Nordic, Sony* and my Supervisor at Chalmers University of Technology, **Olof Wranne**, *Lecturer, Industrial designer MFA, and Head of programme for the bachelor program Design Engineering, at the division of Design & Human Factors, Department of Industrial and Materials Science.* Their guidance and engagement made the project possible.

Further, I want to express very great appreciation to **Andreas Hallonsten**, *Senior Product Manager, Sony Network Communications Europe*, and his team, for sharing time and knowledge throughout the project.

My gratefulness also extends to **Anna Jakobsson**, *Senior Designer, Design Centre Europe -Nordic, Sony*, **Simon Henning**, *Senior Designer, Design Centre Europe -Nordic, Sony*, **Matthias Keirysch**, *Senior Designer, Design Centre Europe -Nordic, Sony*, and **Fredrik Johansson**, *Senior Design Manager, Design Centre Europe -Nordic, Sony.* Their time and feedback have been crucial to the success of the project.

My family, partner and friends should also be mentioned, for their patience and support.

Edvin Nielsen Johansson, Malmö, May 2021

Contents

List of Figures

Terminology

- **IoT**
  Internet of Things. A system of objects which over an internet connection communicate data amongst themselves to create a smart and seamless user experience.

- **Wearable**
  Technological device physically worn by the user.

- **UI**
  User Interface. The interface of communication between human and machine.

- **IxD**
  Interaction Design. The process of developing a user interface.

- **UX**
  User Experience. The experience the user encounters in interaction with an object, and/or interface.

- **ISO**
  International Organization for Standardization. Provides a database of research-based standards, including on ergonomics.

- **SIS**
  Swedish Institute for Standards. Validates, translates, and catalogues ISO-standards on a national level.

1

Introduction

This chapter intends to describe the background of the project, and its purpose. Included are descriptions of the company's current situation, the desired result, and the author's role. Furthermore, the limitations of the project, and the issue at hand, are specified.

1.1 Background

In the physical format of a smartwatch the mSafety, developed by Sony, can monitor, and inform about the user's well-being. The wearable with its sensors, display, and connectivity, can assist both users and service providers with valuable, and possibly vital, insights. This type of near-body IoT device finds several uses, such as within the healthcare domain, during conduction of risky sports activities, as well as in hazardous work environments. However, being a first-generation product, the previous version of mSafety does have aspects in need of optimization. The next generation will now be developed, mSafety II.

In new product development, it is of high importance to fully explore and define the issue to be solved. The overarching issue at hand must be fully understood, so that it can be resolved effectively. However, in a generational upgrade the process revolves around a previous product. It means the major issue is already solved, that being *monitoring well-being, remotely and continuously.* The solution is the current IoT wearable with health and wellness tracking. The generational upgrade should instead provide optimization and improved performance compared to the previous product, within the areas of focus. Those being the three main components of the user experience, (i) the user interface, (ii) the layout of interactive mediums, and (iii) the hardware form.

1.2 Aim and Objective

The aim consists of three chronological sections. (i) To fully analyze and understand the previous product solution, which in turn allows (ii) the formation of a *Specification of Product* which breaks down the product into its essential functions, where new ambitions of the client can be included. Following, (iii) a thorough design process rebuilding the product to at large fill a similar gap as the previous generation, but with improved performance in the three areas of focus, user interface, layout, and form.

In short, the **aim** is to understand the product and its context, identify areas of improvement, and thoroughly process a redesign within the areas of focus. Specifically, the product should to a greater extent meet the user and its expectations in functionality and accessibility.

The **objective** is to ultimately provide an improved product in interface, layout, and form, thus, an improved user experience. Included should be suggestions on the use and placement of the interactive mediums. They should be embodied in an appropriate form for context and brand. Additionally, a framework for an improved user interface adjusted to fit the hardware, should be included.

1.3 Limitations

It is initially suggested that the entire product system should be reconsidered. However, when the entirety of a *wearable device* is redesigned, there are several parallel focus areas to deal with. They can naturally be divided into *service*, *hardware* and *interface*. With a limit of 400 work hours available, limitations of expectations become necessary. It streamlines the work process and ensures that the result created has a certain deeper value. As a result, not all parts of the product can be handled to the same degree.

The dependency between *hardware* design and *interface* design is generally more profound, thus, the *service* design is more easily separated. As a result, the second generation service design will be based on the existing design. In turn, it allows for a more elaborate and complete product in terms of hardware and interface, together forming the user experience. As a result, expected deliveries within each aspect are set as follows:

A Service
Based on existing service design. Meaning, the new product solution will fill the same functional gap as its predecessor. However, the service and its function must be fully understood and mapped.

B Hardware
The physical form and functionality of the product must undergo iterations to reconsider the optimized solution. Deliverables include a complete product specification, as well as material for presentation in the form of renderings with a high level of detail.

C Interface
The design of the user interface undergoes iterations to reconsider the optimized solution, as well as ensure seamless unity with the redesigned

hardware. Deliverables include a limited selection of elements, as well as guidelines for continued design.

Furthermore, other limitations follow:

- The functionality of the product will not be reconsidered. It is assumed that the functionality of the previous product, its use cases and target market, are viable as defined by the client.
- As the development process concerns a generational update, the concept will, as the previous generation, be wrist-worn.
- No internal component selection will be included. If a feature is not explicitly changed, it will be assumed that components of similar dimensions are to be housed.
- The final concept for hardware will not undergo the final steps of preparations for mass production. Thus, no production documentation will be provided, such as drawings etc.

1.4 Specification of Issue Under Investigation

How should mSafety II be designed to meet the expectations of a generational upgrade, and to effectively meet the user and its needs?

- What is the previous solution, and what overarching problem does it solve?
    - How is the service designed?
    - How is the previous physical device designed?
    - How is the previous user interface designed?
- What is the optimal solution to the given problem?
    - How should the physical device be designed?
    - How should the user interface be designed?

2

Theoretical Background

This chapter will provide essential theories and principles, and present established research as a basis for decisions made throughout the project.

2.1 Design for All

The concept of *Design for All* has its roots in functionalism and ergonomics and aims to create a *society for all* in terms of accessibility and equality. (Johannesson, Persson, & Pettersson, 2013, p. 271-272). For the individual designer, in effort to harmonize with the concept, careful consideration of every individual who will be affected by the design is needed.

2.2 Design for Accessibility in Interaction

Accessible interaction design, which provides systems that can be used effectively regardless of impairments to cognition, senses and motor skills, are further defined by Cooper et al. (2014):

A Users can perceive and understand all instructions, information, and feedback

B Users can perceive, understand, and easily manipulate any controls and inputs

C Users can navigate easily, and always be aware of where they are in an interface and navigational structure

2.3 Usability

Usability consists of the two components (i) *functionality* and (ii) *user-friendliness* (Bohgard et al., 2015, p. 420). For the product of high usability, the *functionality* provides carefully integrated functions based on the user need, while the *user-friendliness* puts a demand on easy use of those functions.

Determining user needs, and in turn needed functionality, can be a lengthy and challenging process. However, the final result will be a concretely defined list of functions. Determining the user-friendliness of the product is far more abstract. Many of the concepts and theories in this chapter provides guidelines to which will compile a user-friendly product. Utilizing those guidelines through the development process means the final product should ultimately be usable, provided the integrated functions are appropriate.

2.4 Interface Posture

One fundamental concept applied in interaction design, *posture*, is used to categorize the interface depending on how, when and where it is used. In turn, it dictates the preferable approach on various aspects of its design. Cooper et al. (2014, p. 215-235) explains that there are several fluent categories of *postures* within interaction design, the three main categories will be presented following.

The application of a *Sovereign Posture* typically consumes the user's attention for lengthy periods, such as software used throughout a workday. It can therefore be allowed to be more complex, while providing more functionality. Thus, it should be optimized for the intermediate user, since this is where the majority of the use base will lie. It is also recommended to allow it to take up screen space while keeping visual elements at a minimum. Further, it can allow space for rich visual feedback while providing a variation of input.

In contrast, the *Transient Posture* categorizes the application that is brief, infrequent, and is called for a specific function. Such as the built-in calculator of a desktop computer. However, the transient character can also be derived from which context the users interact with it, as the static software on a device which is only glanced at from time to time. The infrequent use demands ease of use and clear navigation. Thus, if an application is determined to be transient, it is recommended to be simple, clear, to the point, and not spread out across different views. In turn this means the user profile with low experience should receive more focus, since the same user might never get well versed with the software.

Finally, the *Deamonic Posture* concerns invisible applications functioning in the background. Thus, guidelines on design are obviously sparse.

For the wearable device, two additional postures become relevant, which are closely related to the already mentioned main categories.

The *Standalone Posture* is assigned to the device which is functioning as its own device, like a modern smartwatch. Thus, it possesses many similarities to the sovereign posture. Meanwhile, due to typically being used in noisy environments, with a limited display, makes it in many ways similar to the transient posture.

The *Satellite Posture* concerns a device which is used in combination with other hardware. Such as a fitness-tracker, bound to a smartphone or computer, where the full functionality might be reached through the latter device. The use is typically limited to an information feed flowing to the user, with some low-level activities of navigation and input. In principals and use, it is similar to the interface of transient posture. Designed to be used briefly and infrequently, it should consider users with a low level of experience.

2.5 Mental Models

In contrast to mechanical machines and tools, the digital interface only presents the user with a representation of its inner workings and functions. Meanwhile, the user who approaches a digital interface will have a *mental model*, which represents the expectations on how various functions and structures might work (Cooper et al., 2014, p. 17-20).

The closer the interface designer gets in providing an interaction where the representation is based on the user *Mental Model*, rather than the technical *Implementation Model*, the friendlier the experience will be from the user's perspective (See Figure 2.1).

Figure 2.1: *Visualization of the gap between the user Mental Model and the technical Implementation Model. (Cooper et al., 2014)*

2.6 Navigational Excise

Excise is the price the user pays in terms of cognitive, memorial, visual and physical strain during an interaction (Cooper et al., 2014, p. 271-297). To allow a pleasant user experience, any excise should be minimized. Especially, the action of navigation can easily introduce futile excise to the user. Cooper et al. (2014) provides a list of guidelines, to minimize navigational excise:

A Reduce the number of places to go
Fewer views to navigate among increases the ability to stay oriented.

B Provide signposts / overviews
A persistent element regardless of view, a signpost, can both signal possible

actions at all times, and provide information on the current location in the structure. However, the current location and overview can be provided in alternative ways, such as a visual trial taken through a hierarchy.

C Properly map controls to functions
There should be a clear mapping of the physical elements with a *target* and a *result*. Meaning, the user can expect which element in the interface that will be affected when interacting with a control.

D Avoid hierarchies
Hierarchies are an intuitive way of organizing a large amount of data. However, the navigation through a hierarchy with limited controls might not be entirely intuitive to the user. Especially, when display size is limited and the hierarchy in question cannot be fully visible.

E Don't replicate mechanical models
A function should not necessarily use an interaction comparable to how the interaction would work with a physical counterpart (See Figure 2.1 Mental Model). It should always be reconsidered to best suit the digital context.

2.7 Idiomatic Interface

The idiomatic interface is recommended over the traditional *implementation-centric*, and later the *metaphoric* interface (Cooper et al., 2014, p. 300-310). The latter, with symbols, icons, and simplifications, is more intuitive compared to implementation-centric interface, which in contrast is used precisely how it is programmed and typically has a button assigned to every programmed function. However, the metaphoric interface can still be risky, relying on the individual's experience of association. Improving upon both is the idiomatic interface, which instead relies on the natural human process of learning. Thus, an idiom must only be learned once, while demanding a minimum from the user in terms of previous experience.

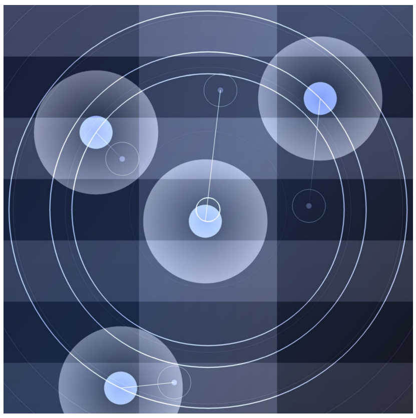


Figure 2.2: *The completely idiomatic interface of TC-11, a unique synthesizer. (Cooper et al., 2014, p. 307)*

The interface in Figure 2.2 shows an example of a unique, idiomatic synthesizer which must be learned, but in turn provides an optimized experience of creating sounds.

In conclusion, the recommendation is to aim to create an appropriate idiom, rather than relying on established metaphors as a quick solution. While the idiom will have to be learned, it can be precisely customized without demanding a specific experience.

2.8 Legibility

Based on the principles of accessible design, legibility as a function of font size, viewing conditions and age is determined by ISO 24509 (2019), *A method for estimating minimum legible font size for people at any age.* It can be used to determine the needed font size in the interface of portable display, such as a smartwatch (See Figure 2.3).

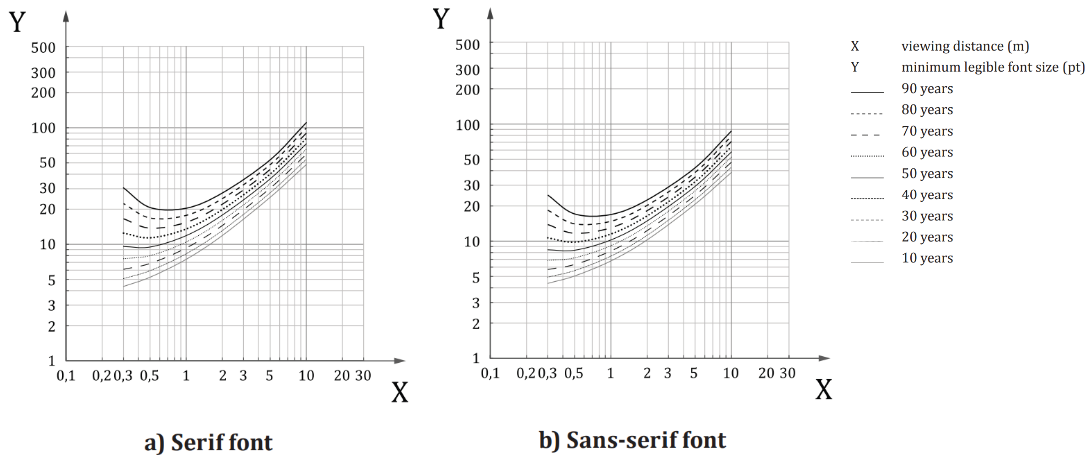


Figure 2.3: *Legible font size depending on viewing distance, age, and font type, at luminance* $100cd/m^2$*. Assumes the viewer does not have pathological disorders in their eyes, but neither wear assigned spectacles. (ISO 24509, 2019, p. 11)*

2.9 Visual Interface Design Principles

This section is based on a section by Cooper et al. (2014, p. 411-432) with the same title, *Visual Interface Design Principles.* The guidelines should be used as general rules in development of any visual interface.

A Convey a tone / Communicate the brand
The coherent visual tone should deliberately convey an identity and theme, associated with the brand but also suitable to the context. It provides sensations, which will affect the user experience.

B Lead users through the visual hierarchy
Establish visual hierarchical relationships suitable to the content, which help emphasize critical elements, using positioning, contrast, size and grouping by proximity.

C Provide visual structure and flow at each level of organization
A clear visual structure increases the usability due to increased continuity, the aesthetic appeal due to uniform balance, and the development efficiency due to a sound framework. A good way to ensure a sound structure is to establish a grid for the spacing of elements. It can then be used as a template. Consider,

asymmetrical balance allows logical entry points to the visual hierarchy, in contrast to a symmetrical interface.

D Signal what users can do on a given screen
Provide the user with indications of possible actions. Visually separate elements of different behavior, and clearly communicate their function.

E Respond to commands
Provide visual feedback to user actions, by signaling registration even if the result is not immediate.

F Draw attention to important events
Basic human perception is utilized when attention is needed. Using contrast, sound and motion will draw attention. However, make the signal appropriate to the message.

G Minimize the amount of visual work / Keep it simple
Remove as many elements as possible, without infringing on the function. Further, keep variation to a one or two typefaces, in a few sizes. Any variation in color, placement or sizing should be distinctly different, or the same.

2.10 Affordances and Signifiers

Some of today's most widely used principles in interaction design was first expanded on by Norman (2013, p. 10-22) in *The Design of Everyday Things*. The concept of affordances and signifiers strongly binds the physical form, and the perceivance of an object and its functions. Thus, it highly affects the usability.

The *affordance* is the action possible to the individual in the context of interaction. Meaning, regardless of the user being aware of a specific function, a possible interaction, or action, presents an affordance. Further, the affordance is specific to the particular individual. Thus, an affordance to the first user, might not be one to another user with a variation in ability. Thus, they are not properties, but relationships.

Meanwhile, the *signifier* allows the users to perceive the *affordance*. It is an indication of possible interaction and is important in a user-friendly product. While signifiers can signal in many ways, even as a sign with text, the most elegant solution *incorporates them into the design, providing a coherent expression.*

2.11 Design Language

A fundamental function of any physical product is what it conveys to the user, through its form, in character, identity and function (Österlin, 2016, p. 116-121). It is of high importance that the final expression of the physical product retains a powerful message while falling in accordance with the expectations of the user.

The *character* of the product indicates how it feels. It integrates carefully selected keywords, adjectives, which are deemed suitable for the specific context. Examples are simple/complex, dynamic/static, mechanic/organic, or precision/rough.

The product *identity* puts it in a context. Connections can be made to previous products of the specific brand, by selecting overarching themes and identifying the contributing details.

The *functions* should be expressed through form to accommodate use, without the need of abundant instructions. Here, the knowledge of affordances and signifiers is of value (See Theory 2.10). Elements of a design can indicate how the user can interact with them. *Grip* and *press* are a few actions that could be encouraged, if usable.

A method to encircle how a language should be conveyed is to collect visual material of contexts and products, to be referenced in the development process.

2.12 The Ergonomics of Physical Interactions

This section collects guidelines and theories within the ergonomics of physical buttons and controls, as well as haptic and tactile feedback. The material is not complete nor general for all types of interaction but picked in reference to a wearable device. For methodology, see Section 4.1.

Button guidelines (ISO 9241-410, 2008)

- **A** The button can be pressed without excessive deviation from natural hand position, causing muscular strain
- **B** The button can be pressed without loss of control
- **C** The design protects against accidental button activation
- **D** The design assists in finger positioning
- **E** Force requirement is minimized (0,5 N to 1,5 N)
- **F** Displacement is between 0,5 mm to 6 mm, to provide kinaesthetic feedback

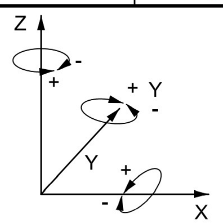
Control guidelines (ISO 21054, 2020)

- **A** Controls allow manipulation regardless of physical limitations, meaning the main control is located on an accessible surface
- **B** Controls can easily be separated with change in shape, color, tactile point or marking
- **C** Each control has only one function, to reduce cognitive burden
- **D** Controls of similar functions are logically arranged in proximity
- **E** Controls providing a reference point can easily be identified, with change in shape, color, tactile point or marking
- **F** Controls for a main function are easily separated from other controls

G Controls are clearly marked with visual symbols, text or tactile symbols facilitate use with limitations in vision

Force Demand (ISO 9241-920, 2016)
Different types of grips, including variations of force directions and used body parts results in specific maximum force requirements. It allows for a user-friendly and ergonomic experience for the widest of populations. Even without the possibility to measure forces applied, it gives an indication of the sensitivity of various positions and grips (See Figure 2.4). E.g. a *clench grip* allows more force applied while remaining ergonomic compared to a *pinch grip*.

Type of grip	Part of hand applying force	Other factors	Max. recommended linear actuating force N	Max. recommended linear actuating torque N·m
Contact grip	Finger	Any direction	10	0,5
	Thumb	Any direction	10	0,5
	Hand	Any direction	20	0,5
Pinch grip	Finger/one hand	Any direction	10	1
		X direction	10	2
		Y direction	20	2
		Z direction	10	2
Clench grip	One hand	X direction	35	—
		Y direction	55	—
		Z direction	35	—
		0,25 m radius	—	20
	Both hands	0,25 m radius	—	30



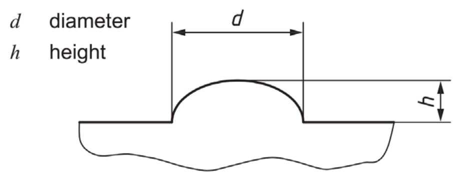
(Table and illustration taken from ISO 9355-3:2006, Table 4 and Figure 3.)

Figure 2.4: *Maximum recommended force or torque for manual controls. (ISO 9241-920, 2016, p. 13)*

Tactile Dots (ISO 24503, 2011)

The tactile dot should be placed on a button to either (i) separate arrayed controls, or (ii) identifying a function, generally a major function (See Figure 2.5).

It can be used to haptically reinforce a specific button even when visibility is low.



d mm	*h* mm
from 0,8 to 2,0	from 0,4 to 0,8

Figure 2.5: *Recommendation on tactile dot dimensions. (ISO 24503, 2011, p. 4)*

Non-interference (ISO 9241-410, 2008)

A physical device used for input cannot interfere with its own use. Meaning, all interactive elements can be operated without affecting the usability of the device.

Examples of this is a remote in which the hand must cover the IR-sensor when buttons are pressed, or more relevant, a wearable on which the display is visually covered when the user reaches for buttons.

2.13 Experimental User Research

According to Karlsson (2007, p. 29-30) experimental testing, usually in combination with either interviews or observations, is suitable when the effect of one, or a few, stimuli are compared. The method considers causality by providing a context where several (maximum seven) attributes are simultaneously tested. Meaning, it can be used to select the *best* of two moderately complex solutions, or when making decisions on a product layout where different versions can be compared.

2.13.1 Participant Selection

There are two dimensions in selecting participants for user testing, the qualitative, and the quantitative. (Karlsson, 2007, p. 30-36) In term of the qualitative dimension, referring to *who* participates, there are several different principles of making selections.

One principle is the **Theoretically Representative**, where participants are selected to represent a specific target audience. Meaning, the selected representative owns characteristics that can be assigned to that target segment as a whole and are relevant in the context of the product. The characteristics can be demographical, physical, cognitive, attitudinal, or based on experience. In comparison, the more dominant **Statistically Representative** principle relies on statically representing a section of a population by selecting a calculated segment. A third principle is selecting the **Theoretically Critical** which is based on the idea that if the *weakest* users' needs are fulfilled, then every user's needs are fulfilled. However, the latter method is generally only suitable when testing physically demanding solutions. The last principle is the one of **Expert Users**. The theory states it is not enough to own or use a product to know which attributes should be considered most beneficial. If the user instead is educated in the area, by knowing the product category in general, understanding the criteria to be fulfilled, and even have insights into how certain design decisions will affect the end result, they will be more appropriate to provide feedback. The expert might also in a higher regard see past stimulus noise introduced by mock-ups of a simple material, and non-functioning components (Karlsson, 2007, p. 30-34).

In the quantitative dimensions it is considered *how many* participants that are needed, where typically an increase in participants has an increase in the validity of the result. In the earlier phases of the project, when user research is used to identify user needs, Fig. 2.6 is typically referred to. It shows the increase of *percent of needs identified* in correlation to number of participants. In contrast, Karlsson (2007, p. 34-36) further states, when in later phases of a project and solutions are evaluated, 12-20 participants are considered an appropriate aim to provide an appropriate statistical foundation.

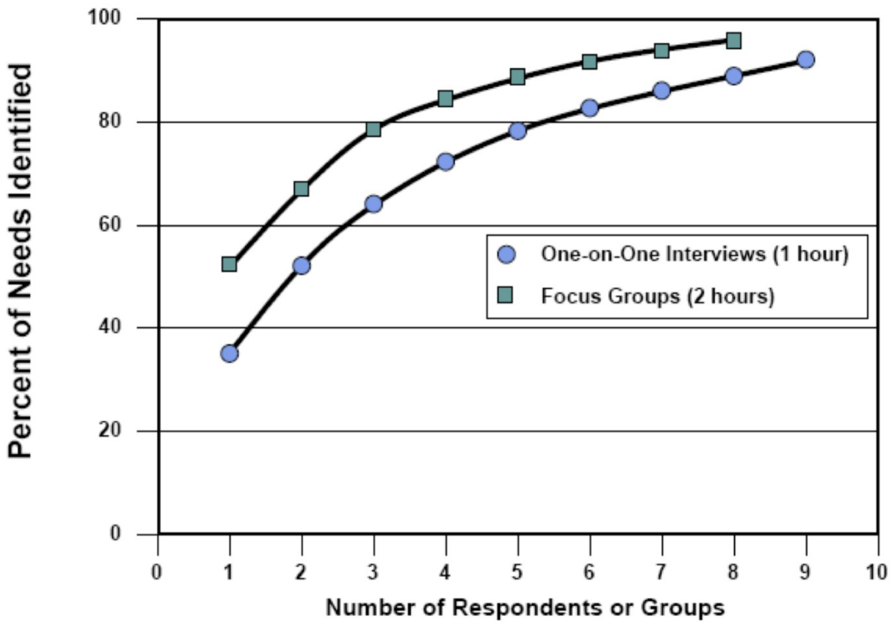


Figure 2.6: *The number of needs identified increases with the number of questioned users. (Griffin & Hauser, 1993)*

3 Methodology

This chapter contains an exhaustive list of the methods that are implemented throughout the project. However, the design process is highly iterative, and some methods will be implemented multiple times. Meaning, the chapter simply defines the toolbox. Instead, the practical implementation is specified in chapter **4 Results**, where a solid chronology is introduced. In addition to describing what each method entails, its usability and purpose is also given.

Through this chapter, individual methods are divided according to three overall phases, **Pre-Study**, **Concept Generation**, and **Concept Evaluation**.

3.1 Phase 1: Pre-Study

The pre-study includes analytic methods for functional demands of the *hardware* and the *interface*. It builds a framework, which functions as a starting point in the generative phase, as well as a basis of evaluation in the later stages.

The main output of the phase is the *3.1.4 Specification of Product* which summarizes the results into one document. Moreover, inspirational material is compiled in the form of a trend analysis, a form analysis and in turn a form-board.

3.1.1 Function Analysis

The function analysis maps the previous hardware design, by disintegrating all its functions into *sub-functions*, structured in a tree diagram (Österlin, 2016, p. 50-53). Thus, it is clarified precisely which concrete fundamental components are needed to compile into the, typically more abstract, main function. Additionally, non-essential, but generally beneficial *support-functions* are integrated into the diagram. Being a generational update, it is beneficial to thoroughly map out the existing wearable and its functions. It forms a basis for the *Specification of Product* (See Method 3.1.4), on which the aims of the updated version can build upon.

3.1.2 HTA

The HTA (Hierarchical Task Analysis) maps out the previous UX-design, by listing and disintegrating key tasks (Bohgard et al., 2015, p. 496). In the analysis a common task is declared. Moving vertically in the diagram, the task is divided into sub-tasks. At the lowest level, the result is a series of actions taken to reach the goal of the task. Additionally, a short description of how the user plans to move through the series of actions is included, indicating a flow. At each low-level action, a key interaction can be identified. The method is useful to understand the process of a user solving a specific task, in relation to a user interface. In turn, it can be used to identify needed functionality in the UI and the frequency of key interactions. Thus, forming a basis for needed criteria in the redesign of the UI.

3.1.3 IxD Framework

The IxD (interaction design) framework aims to help envision the ideal interaction (Kumar, 2018). It utilizes the HTA (See Method 3.1.2) to describe an ideal scenario, while pointing out potential issues. Additionally, it maps out the internal and external components of interaction in the previous device, the navigation map of the UI, and the physical buttons. The method provides useful additions to the HTA analysis, with a shifted focus to the user.

3.1.4 Specification of Product

All criteria identified in previous analyses are compiled into a list, where they are valued as necessary or desirable (Johannesson et al., 2013, p. 150-156). Further, if an aim is measurable, the target values are defined. Other notes, as well as a reference to which process the criteria is derived from, is included. Necessary functions are hard requirements, while desirable functions are given a value of importance in collaboration with the client. Values span between 1-5 with an increase in importance with a higher value. The specification provides a starting point for what is to be sought during concept generation, as well as a framework of evaluation. It collects all research on user needs and needed improvements and modifies the list of previous functions into a list of desirable functions. In short, the result is a written description of the ideal physical solution.

3.1.5 Trend Analysis

A trend analysis examines previous products on the market within the same category, and acts as a type of market research (Wikberg Nilsson, Ericson, & Tornlind, 2016, p. 51). The method entails a creation of a product catalogue, based on the current market and competitors. Following, the catalogue is analyzed, and patterns noted. The method helps in identifying trends and solutions, as well as provide inspiration for concept generation.

3.1.6 Form Analysis

The form analysis aims to identify types of form languages (See Theory 2.11) which can be utilized in the development of the physical form (Österlin, 2016, p. 117-121). A range of artefacts can be examined and categorized by similarities in expression. These categories are assigned with keywords, describing their respective assumed target expression, character, and its purpose. To the new context, suitable languages can be selected, and provides the foundation of the form-boarding (See Method 3.1.7). The method ensures the resulting product has a desirable and aesthetically pleasing expression.

3.1.7 Mood/Form-boarding

A board is a collage of visual material that is intended to have a similar expression as the product being developed, and should eventually be associated with (Wikberg Nilsson et al., 2016, p. 101). It can be divided into the *mood-board* which abstractly represents a sensation and an atmosphere, while the *form-board* provides inspiration on physical forms and styling. In the latter, the expression sought for, and in turn the selection of visual material, is based on the form analysis (See Method 3.1.6) which channels the design language. The material for the mood-board can be gathered more freely, meaning to represent a sensation. In the creative process, the boards act as inspiration and sounding boards. Additionally, they ensure that different parties are in consensus.

3.2 Phase 2: Concept Generation

The development phase includes a range of generative methods to help span the solution space.

3.2.1 Individual Brainwriting/Mindmapping

This is a method to quickly document and explore ideas and their associations (Wikberg Nilsson et al., 2016, p. 45). Words, thoughts, and descriptions are written without evaluation, and any connections between them are drawn. The method allows for an initial divergent phase in creation, which provides an outlet for a build-up of ideas.

3.2.2 Individual Brainstorming/Sketching

This is a method to quickly document and explore ideas and their associations (Wikberg Nilsson et al., 2016, p. 125). Sketches and descriptions are freely drawn. The method intends to further widen the space of possible solutions.

3.2.3 Osborn

Osborn includes a collection of sweeping statements, that will be put against already produced solutions, and follow: *Change of Purpose, Adaptation,* *Modification, Magnification, Reduction, Substitution, Inversion, Regrouping, Combination, and Transformation* (Johannesson et al., 2013, p. 166). It aims to regain forward momentum in the thought activity, by forcing distinction in thought process.

3.2.4 Morphological matrix

The morphological matrix is produced by arranging needed sub-functions into a matrix (Johannesson et al., 2013, p. 174-175). Following, already produced concepts are disintegrated and alternative sub-solutions are listed in the respective columns. These are then combined for new complete solutions. The method introduces a systematic generative workflow, to further increase the space of possible solutions.

3.2.5 Low Fidelity Wireframe

A wireframe of low fidelity consists of the basic layout of the user interface (Cooper et al., 2014, p. 119-143). Individual views are produced in the form of simple outlines, where text fields, navigational elements, status fields, etc., are visualized. Additionally, the relationship between different views is shown. The method allows early visualization of the interface, with a low level of detail and resolution to allow a high degree of modification.

3.2.6 PNI

In the PNI method (*Positive/Negative/Interesting*) the feature being investigated is quickly evaluated, and given short written descriptions in the aspects of *positive*, *negative* and *interesting* (Wikberg Nilsson et al., 2016, p. 217). The method allows for quick and simple comparison. The positives of different solutions can be evaluated, or weaknesses to eliminate identified.

3.3 Phase 3: Evaluation and Refinement

The phase includes methods to facilitate elimination, evaluation, and refinements in iterations.

3.3.1 Pugh Matrix

The Pugh matrix is a type of evaluation method that assigns a score to the concept in question and presents to which degree the *Product of Specification* has been met (Wikberg Nilsson et al., 2016, p. 219). The value of desirability for each criterion is referenced. Following, by determining a degree of fulfillment for the same criterion, *value of importance* and *degree of fulfillment* are multiplied together. A total score can be given by adding all sub-functions. In turn, the method provides a solid basis to determine the holistic value of each concept, which enables a choice of a final concept.

3.3.2 User Testing

User testing is based on the theory of *experimental testing* (See Theory 2.13) while applying the selection of *theoretically representative* participants. Meaning, several concepts can be evaluated and compared with the voice of potential users. Participants are selected as representatives from each of the target segments. Mock-ups of the concepts to be evaluated are provided, and interviews conducted. The testing both provide an opportunity to verify theories on intended usability, and further, allows determining *degree of fulfilment* for individual criteria in the *Specification of Product* (See Method 3.1.4). Additionally, open-end questions are used to collect inspirations for refinement.

3.3.3 Expert Testing

Expert testing is based on the theory of *experimental testing* (See Theory 2.13) while applying the selection of *expert* participants. Mock-ups are provided to participants, who are considered experts in the area. Meaning, original product developers, product representatives and designers of various expertise with background knowledge of the development objectives. Following, a feedback session can be held, where any opinions and recommendations are lifted. The testing is useful in a range of aspects, and provides input for a final concept selection. Further, any identified weaknesses can be pointed out, to be later modified. Additionally, it ensures that the concept is in line with the expectations.

4

Results

This chapter provides a narrative of the chronological development process of the project. While each individual method used during the **Pre-Study** typically is carried out once and provides a self-standing result, the phases of **Concept Generation**, **Evaluation and Refinement**, and **Visualization** all contain iterations and variation of method implementation. Thus, the documentation in the chapter will not only provide individual results but explain the specific implementation of the previously defined methodology.

4.1 Literature Review/Theory

The literature review compiles into Chapter 2, *Theoretical Background*, and is therefore given its own section. Thus, for the results of the literature review in whole, see Chapter 2. Further, it will be highly referenced in design decisions made during later stages of the project. Chronologically, this process is carried out throughout several phases of the project.

4.1.1 Review of ISO-standards

To provide support for design decisions in both hardware and interface, relevant ISO-standards are collected. Every article in the major category of ”ISC 13.180 Ergonomics” is processed. Further, articles within the subcategory of "ISO 9241 Ergonomics of Human-Computer Interaction" receives additional attention.

The processing of each article amounts to an initial title review. A relevant title leads to a review of the abstract. If it can be determined that any sections of the standard could cover relevant aspects, the standard is thoroughly studied, and usable findings collected.

Relevant aspects are within *physical input*, *tactility*, *haptics*, *information on display*, *legibility*, and general interactions between a human and a wearable device.

4.1.2 Review of About Face

To provide support within the development of the user interface, *About Face: The Essentials of Interaction Design* by Cooper et al. (2014) is thoroughly studied. The title is course literature at the Master's Programme *Interaction Design and Technologies* at Chalmers University of Technology, and is therefore selected.

The processing of the book is initiated with a chapter selection from the table of contents. A relevant chapter is studied, and usable findings are collected.

A chapter is considered relevant if it covers any aspects of interaction between a human and a wearable device.

4.2 Phase 1: Pre-Study

The results of the pre-study are divided into two major sections. In the *Analysis* all components contribute to the major output of the pre-study, the *Specification of Product*. It is the document which will form the basis for further work concerning concept generation and evaluation. However, the second section of the pre-study, the *Output*, additionally contains visual material as a complement to the text-based specification. These are the results of several self-standing processes, contributing with inspirational, visual material. It includes the trend analysis, the form analysis and inspirational boards.

4.2.1 Analysis

The section contains initial analytic methods, which aims to thoroughly map out the previous product solution and potential issues. This includes analyses of the system architecture, the users, the physical product, and the interaction.

4.2.1.1 Mapping of the System and Use Cases

Client provided material was studied and a flow chart was compiled and verified. It provides an overall picture of the system, including different types of use cases. The creation of the chart provided a broad understanding of the service design and the basic functions of the product.

mSafety currently provides a two-part solution to bridge the gap between the service-provider and end-user. The wearable, when used by the end-user, communicates and collects vital data through its internal, and externally connected sensors. The second part, the IoT connectivity enables continuous communication of mentioned data with the service-provider. The scope of the thesis is also shown, and includes the wearable, and its interaction with the end-user (See Figure 4.1).

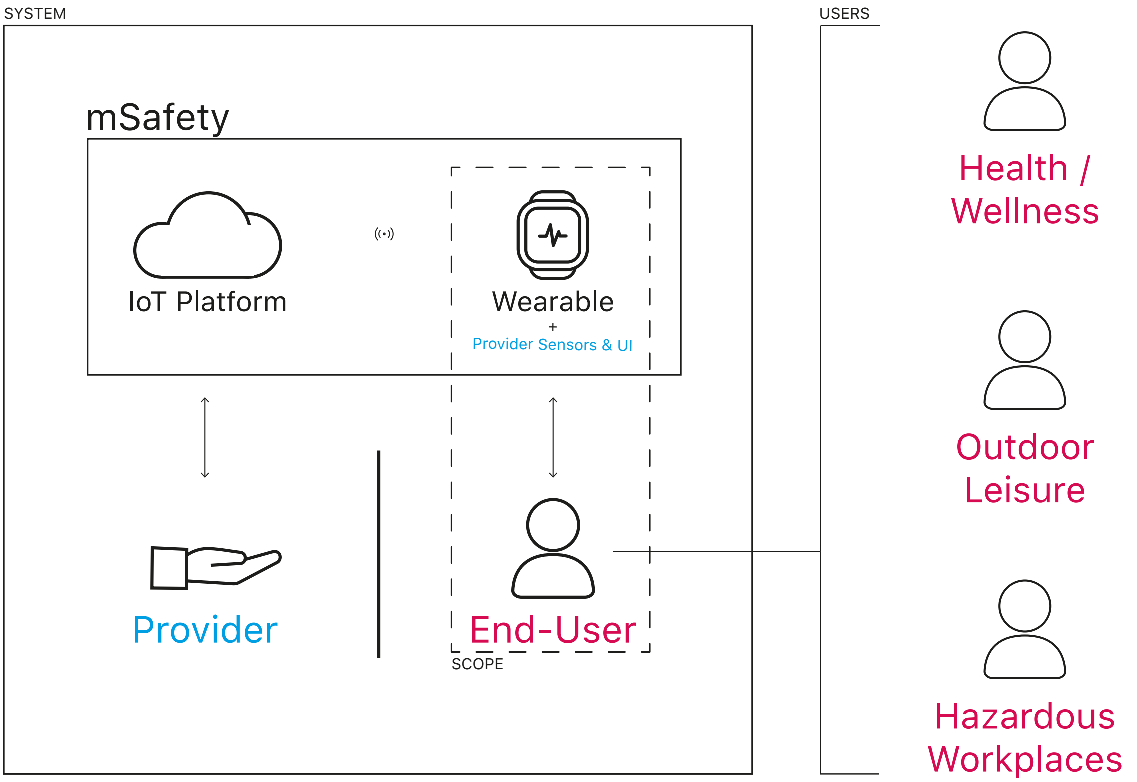


Figure 4.1: *The system architecture showing the two-part solution of mSafety. Further, the end-users, and the scope of the project are shown. Author's own illustration, 2021.*

There is a great variety in users and use cases. While there are three main targets listed today, the ultimate aim is to provide a solution which is as versatile as possible. Meaning, the hardware should not be designed to perfectly suit these specific three use cases, *healthcare*, *outdoor leisure* and *hazardous work environments*, but to suit as many as possible.

Within the *healthcare* domain we could find a person with diabetes which has to continuously track their blood sugar levels to avoid levels which would be harming. Meanwhile, an elder taking a fall could utilize the locational tracking, to call for help. Locational tracking is also beneficial within many *outdoor leisure* activities. The surfer who might be struck with cramps or caught in a storm can let emergency services see their exact location, and the hiker who gets lost in exposure can be found again. With a remote work force the OSH (Occupational Safety and Health) officer, at the *hazardous workplace*, can on large scale catch early warning signs and immediately locate an employee in danger. Meaning, the application is suitable in many industries, such as at industrial plants, in forestry and on oil rigs, for instance.

4.2.1.2 Function Analysis

The function analysis breaks down the main function, *Monitor Well-being, Continuously and Remotely*, into sub-functions and support functions in hierarchical tree structure (See Figure 4.2). Due to the full diagram being of substantial size, see Appendix A.1.

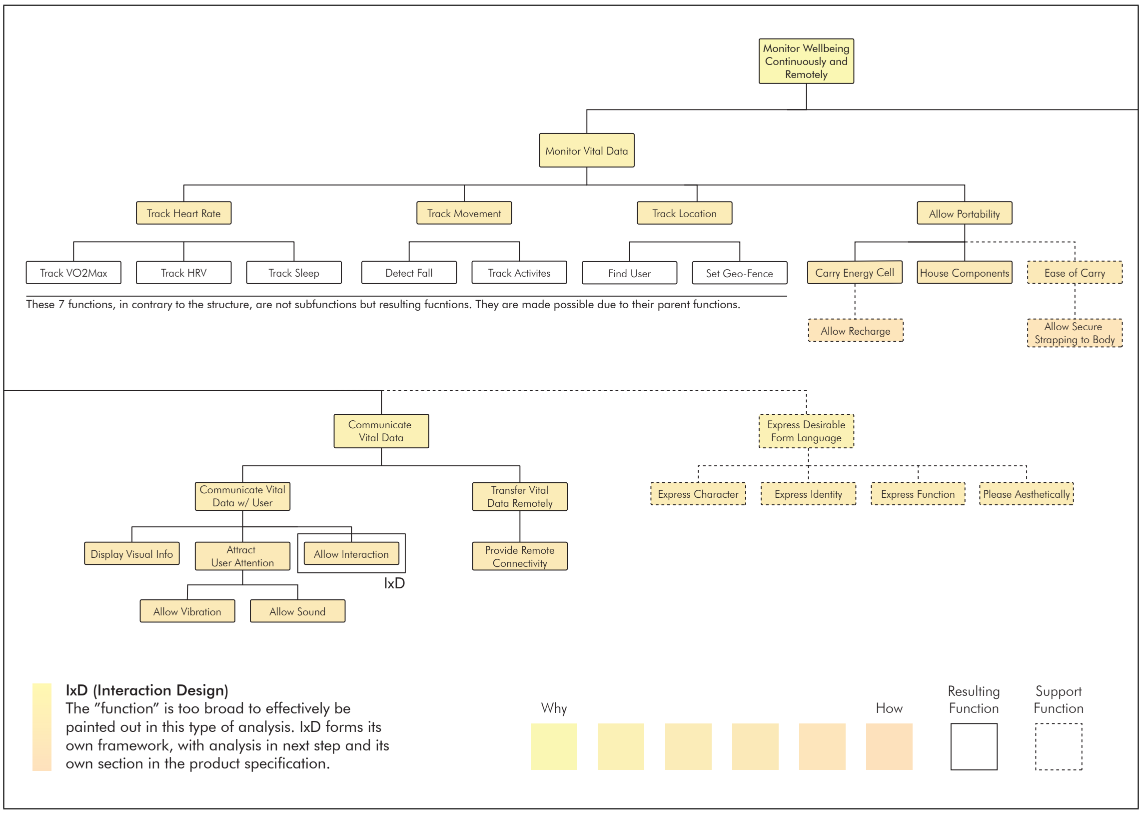


Figure 4.2: *The function analysis of the previous hardware device. It shows the main overarching function at top, disintegrated into sub-functions further down. Author's own illustration, 2021.*

Typically, the rather abstract and intangible main function can be divided into a few essential sub-functions, in this case being *Monitor Vital Data* and *Communicate Vital Data*. Notice, these fall in the definition of an IoT device. Further, the support function of *Express Desirable Form Language* was also placed at the same level.

By continuously dividing each sub-function into its components, the entire structure of functions needed to fulfil the main function is concretized. At the lowest level of each branch, fundamental functions can be collected, which will be implemented into the *Specification of Product* (See Section 4.2.2.1). These follows:

- House Internal Components
- House Sensor Eye
- Allow Strapping to Body
- Recharge Capability
- Communicate Vital Data with User
- Express Character
- Express Identity
- Express Functionality
- Please Aesthetically

Due to the limitation of *no internal component selection* (See Section 1.3), in combination with the assumption that the functions of *Track Heart Rate*, *Track Movement* and *Track Location* are a result of the internal sensors, these will not be further investigated. Meaning, it is assumed the product would be granted these functions by reusing the same sensors.

By reconstructing the disintegrated fundamental functions, in theory, the resulting product could have a distinct different form but should fulfil the same top-level, main function of **Monitor User Well-being, Continuously and Remotely**.

4.2.1.3 HTA

The *function analysis* (See Section 4.2.1.2) provides an exhaustive list of functions, to rebuild the physical device. However, to determine demands made by the intangible interaction and interface, a *Hierarchical Task Analysis* (HTA) analysis was applied (See Figure 4.3). For an enlarged diagram, see Appendix B.1.

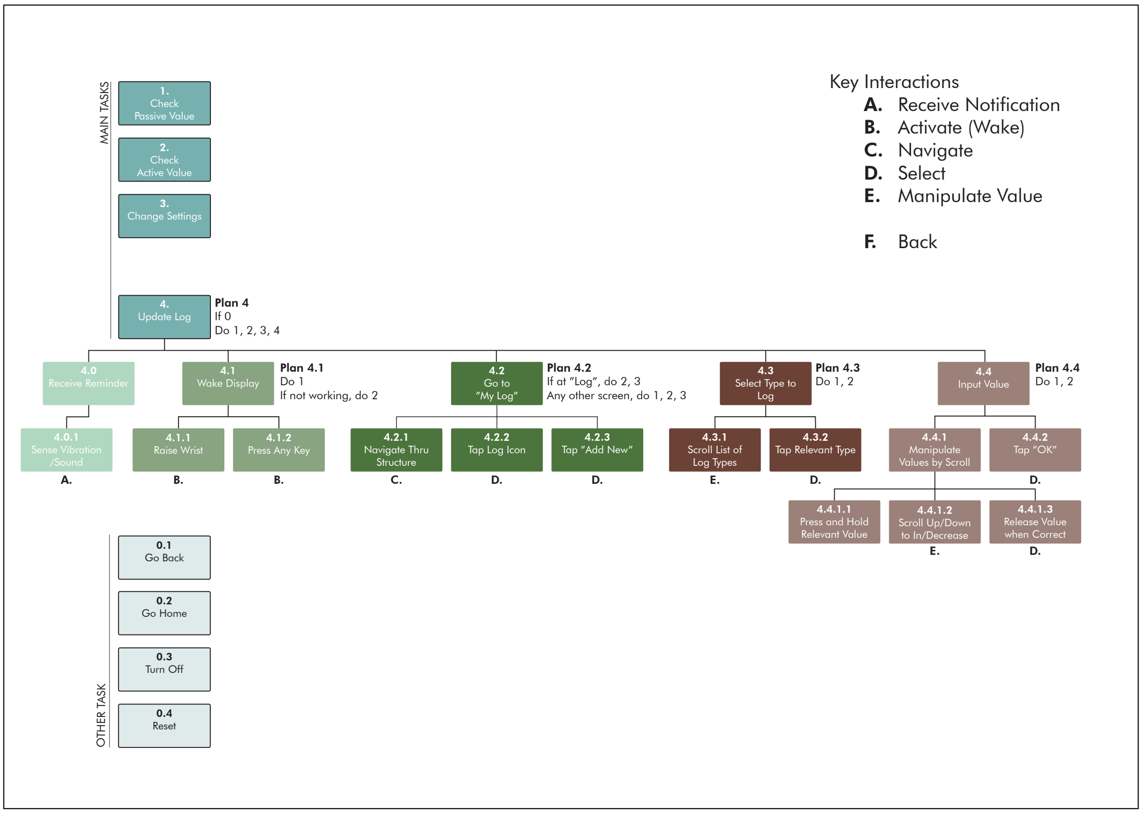


Figure 4.3: *HTA of one of the identified main tasks, to Update Log. It disintegrates the selected task into single actions. Author's own illustration, 2021.*

By disintegrating the main tasks carried out on the device, key interactions were encircled, and essential UI functionality determined. While the selected task, *Update Log*, necessarily is not the most frequent task, it does showcase each major type of interaction between user and wearable.

From the analysis, it was concluded that the following key interactions must be allowed to provide similar usability. In turn, they are listed as demands in the *Specification of Product* (See Section 4.2.2.1).

A Receive Notification
B Activate
C Navigate
D Select
E Manipulate Value
F Back

4.2.1.4 IxD Framework

The IxD framework consists of two components, which in complement to the HTA (See Section 4.2.1.3) provides a concise picture of the interaction from a user perspective. The maps in Figure 4.4 provide visual explanations of the physical and digital interaction, while the *Ideal Path* further explores the task from the HTA, *Update Log*, by pointing out desirable aspects, and possible downfalls.

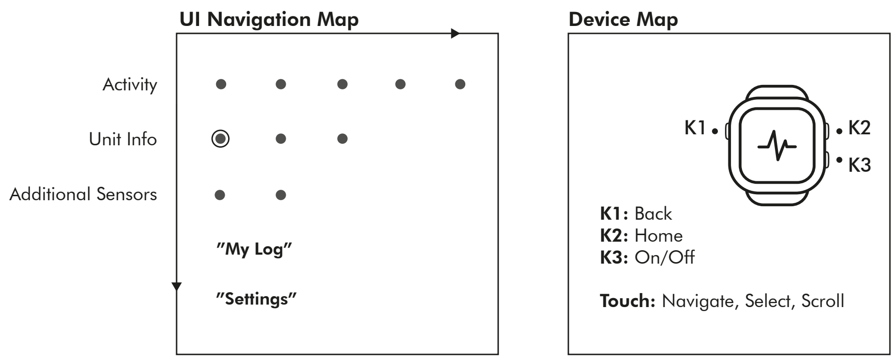


Figure 4.4: *Maps of the previous device and navigation. The left illustration shows the UI structure, and the views the user will navigate through. The right illustration shows the buttons and their use. Author's own illustration, 2021.*

Ideal Path of Activity 4: Update Log.

Background:
The logbook provides the functionality to save notes and values, for future reference. This could be medicine ingested, vitals, etc.
Task:
Input a numeric value in the log book, to save for future reference.
Ideal Path:

- The user receives a timely notification, which clearly states its purpose and how to proceed. Ideally with a shortcut to the relevant location, *the log*.
- In the log it is effortless to see the required type of information, and in which format.
- A dynamic and suitable input method simplifies inputting the correct value, quickly.
- A clear confirmation is provided, to ensure the user that everything is in order.
- At all times, a function helps the user correct any mistakes.

Edge Cases:

- User wears gloves: Key presses are accidental or missed
- User is inexperienced: The shortcut in the notification is missed. Instead, navigation through structure is needed
- User in water (or other condition which impairs touch functionality): Touch is not working, instead the task must be carried out using hardware only

4.2.1.5 Review of Internal Components

The previous hardware device was taken apart and examined. As stated in limitations (See Section 1.3) it is assumed that components that are not explicitly changed in the development should be allowed a similar volume of housing. By measuring height, width and depth of the emptied shell, an estimate on the requirement of needed internal volume can be calculated.

- **Height**: 31 mm
- **Width**: 31 mm
- **Depth**: 11 mm
- **Total Volume**: 11 cm^3

4.2.1.6 Previous Design Decisions

By analyzing which aspects were considered important in the development of the original wearable, a viewport into the previous design team's knowledge of the user and the market was obtained. The conclusions that were drawn to meet user- and market-demand were relevant to follow if aim was to fill the same functional gap. Furthermore, it provided an insight into the demands of realism. It takes into account the possibilities in terms of cost, size, power consumption, performance, component availability, production logistics and risk. Working within the limit of their decisions should be considered working within the limit of the realistic space of possible solutions and could provide a result of greater value.

The table compiles every major decision made in previous development (See Table 4.1). The information was obtained in correspondence with the previous design team and manager. It provides a description of each decision, its perceived benefit but also the trade-off effects. The table can be used as a starting point in setting requirements on the new development process. Meaning, a previous design decision will initially be included in the *Specification of Product*, except if the client in hindsight considers that decision as flawed.

Table 4.1: *Previous design decisions, with benefits and trade-offs.*

Decision	**Benefit**	**Trade-Off**
Monochromatic Display	Power Use, Cost	No Colors
Large Battery	Battery Life	Size of Device
IP68 Rating	Water/Dust-Tight	Voice Capabilities
Limited Amount of Sensors	Power and Size, Cost	Bio-Tracking
Few Buttons	Complexity, Reliability, Cost	Versatility
Device Color: Black	Safe Choice, Logistics, Cost	Decreased Expression
Over-the-Edge Front Glass	Aesthetics	Endurance
Limited Screen Size	Power Use, Availability, Cost	Aesthetics
One Version	Logistics, Cost	Decreased Expression
No Metal	Antenna Performance, Cost	Quality Feeling
Non-Integrated Wristband	Complexity, Cost	Interchangeable
One-Sized Wristband	Cost	Excludes Edge-Cases

4.2.2 Output

The section contains all the pre-study outputs, which will form the basis for the concept development phase.

4.2.2.1 Specification of Product

The specification is the main output of the pre-study (See Figure 4.5). It summarizes all criteria, which according to the analyses of the pre-study, were key in developing a product meeting the aims of the project. It should be noted that the document is open for revision even after the pre-study is concluded, as the knowledge on the subject typically increases during the development process.

Some criteria are considered hard requirements (noted with R), to provide fundamental functionality, while others are given a level of desirability (noted with D and a value between 1 to 5, from low to high important). The value is typically decided in consensus with the client. Furthermore, if any, calculated targets are listed.

Each criterion is also noted with a reference, indicating from which process of the pre-study they are derived from.

- **Gen.1 FA** - *Function Analysis* (See 4.2.1.2)
- **Gen.1 HTA** - *HTA & IxD Framework* (See 4.2.1.3 & 4.2.1.4)
- **Des. Resp.** - Designer Responsibility (See 2.1 & 2.2 & 2.3)
- **Client** - Criteria directly communicated by client or based on previous design decisions (See 4.2.1.6)

Specification of Product		*Project: mSafety II*			*Created: 2020-12-22*	
Criteria		**Target**		**R/D**	**Reference**	**Note**
1. Physical Functionality						
1.1	Allow Strapping to Body			R	Gen. 1 - FA	See further, "5. Body Attachment".
1.2	Recharge Capability			R	Gen. 1 - FA	
1.3	IP68 Rating			R	Client	Water/Dust resistance.
1.4	Monochromatic Display			D2	Client	
1.5	Low Mechanical Complexity			D1	Client	E.g. Minimal amount of buttons.
1.6	Dedicated Emergancy Buttom			R	Client	
2. Dimensions						
2.1	House Internal Components	10	cm³	R	Gen. 1 - FA	Volume to enclose, sensors, 1 d battery, haptic motor etc.
2.2	House Sensor Eye	1*0,7	cm	R	Gen. 1 - FA	The contact point between sensor and user.
2.3	Max. Body Connection Length	4,8	cm	R	Client	Max ergonomic length between strap attachment points.
3. Aesthetic						
3.1	Express Character			D2	Gen. 1 - FA	
3.2	Express Identity			D2	Gen. 1 - FA	The identity of the manufacturer and the service provider.
3.3	Express Functionality			D3	Gen. 1 - FA	E.g Distinguishable signifiers.
3.4	Please Aesthetically			D1	Gen. 1 - FA	
3.5	Premium Expression			D1	Client	CMF should give a premium feeling
3.6	Adaptable Expression			D3	Client	Implementation should as late as possible in production process.
4. IxD						
4.1	Communicate Vital Data w/ User			R	Gen. 1 - FA	
4.2	Output: Attract Attention			R	Gen. 1 - HTA	K.I. (Key Interaction) A
4.3	Input: Activate			R	Gen. 1 - HTA	K.I. B
4.4	Input: Navigate			R	Gen. 1 - HTA	K.I. C
4.5	Input: Select			R	Gen. 1 - HTA	K.I. D
4.6	Input: Back			R	Gen. 1 - HTA	K.I. F
4.7	Input: Manipulate Value			R	Gen. 1 - HTA	K.I. E
4.8	Fully Operable w/ HW Only			R	Client	Includes power on/off + reset.
4.9	Low Interface Complexity			D4	Client	E.g. Simple mental model.
5. Body Attachment						
5.1	Allow Adaption to Body			R	Gen. 1 - FA	Suitable for a variety of body types.
5.2	Secure Attachment			R	Gen. 1 - FA	W/ firm connection between sensor eye and body.
5.3	One-Sized Strap			R	Client	
5.4	Non-Integrated Strap			R	Client	Interchangeable.
5.5	Comfortable to Wear			D5	Client	Low weight, small, round edges.
6. Design for All + Usability						
6.1	Comfortable to Manipulate			D5	Des. Resp.	Easy to reach and interact with. (+ w/ Gloves)
6.2	Intuitive Interaction			D5	Des. Resp.	
6.3	Mistake Forgiveness			D4	Des. Resp.	Allow the user to correct mistakes.
6.4	High Readability			D3	Des. Resp.	Large Display, Readble Font

Figure 4.5: *The Specification of Product. It lists all criteria for the new product development. Author's own illustration, 2021.*

Each of the six sections represents a specific process of the pre-study, however, the last one *6. Design for All + Usability* refers to the initial sections of the *Theoretical*

Background (See 2.1 & 2.2 & 2.3). While approved by the client, the criteria were included on the author's initiative, to fulfill the responsibility of the designer, and carefully consider every user.

4.2.2.2 Trend Analysis

With the initial *Specification of Product* established, the *trend analysis* was used to evaluate the level of desirability of some criteria (such as *1.4 Monochromatic Display, 5.4 Non-Integrated Strap*), and to provide inspiration for possible solutions (such as *Interaction Types*). To create a product catalog which can be subjected to the trend analysis, the "Best Smartwatches" and "Best Fitness Trackers" from three major technology-oriented magazines were compiled (See Figure 4.6). For full catalogue and sources, see Appendix C.1. The following categories for each device in the catalogue will be determined:

- **Device**: Smartwatch(S)/Fitness Tracker(F)
- **Screen**: Color/Monochrome
- **Interaction**
- **Wristband**: Integrated(Int)/Non-integrated(Non)
- **Price**

The price was rounded to the closest 500 SEK, then divided by 500, which gives a value between 1 to 10 in price class.

Device	Type	Screen	Wrsitband	Interaction	Price
Amazfit Band 5	F.	Color	Int.	E.	1
Amazfit Bip S	F.	Color	Non.	B.	1
Fitbit Sense	F.	Color	Int.	D.	6
Fitbit Versa 3	F.	Color	Int.	D.	5
Garmin Vivofit 4	F.	Color	Int.	C.	1
Garmin Vivosport	F.	Color	Int.	E.	2
Honor Band 5	F.	Color	Int.	E.	1
Huawei Band 3 Pro	F.	Color	Int.	E.	1
Xiaomi Mi Band 4	F.	Color	Int.	E.	1
Apple Watch 6	S.	Color	Int.	B.	10
Fossil Gen 5	S.	Color	Non.	B.	4
Fossil Sport	S.	Color	Non.	B.	4
Garmin Forerunner 245	S.	Color	Non.	C.	6
Honor Magic Watch 2	S.	Color	Non.	E.	3
Samsung Galaxy Watch 3	S.	Color	Non.	A.	8
Samsung Galaxy Watch Active 2	S.	Color	Non.	E.	4
TicWatch Pro 3	S.	Color	Non.	E.	7
Garmin Venu Sq	S/F	Color	Non.	C.	4
Garmin Vivoactive 4	S/F	Color	Non.	C.	6
Fitbit Charge 4	F.	Mono	Int.	D.	3
Fitbit Inspire 2	F.	Mono	Int.	D.	2
Fitbit Inspire HR	F.	Mono	Int.	D.	2
Garmin Vivosmart 4	F.	Mono	Int.	E.	2
Garmin Forerunner 25	S.	Mono	Non.	C.	2

Figure 4.6: *Trend analysis catalogue, it shows analysed devices and values in the key aspects. For full catalogue and sources, see Appendix C.1.*

The major outtakes and patterns found:

- Color screens are found at both ends of the price category, in price class 1, and price class 10. Most monochromatic screens are associated with a specific brand (Fitbit), which lies in low/mid-range price class. All are classified as fitness trackers.
- Fitness trackers typically use integrated straps (91%). Smartwatches typically uses standardized wrist straps (90%). The integration of wristband seems to be mostly related to character of the device (See Figure 4.7).
- A majority of devices use either only touch interaction, or only keys. 54% are of a single interaction type.
- There are 5 types of interaction methods utilized (See Figure 4.8). In high regard, a specific interaction type is associated with a specific brand.

Figure 4.7: *Top: Fitbit Inspire 2, a fitness tracker with an integrated band. (Fitbit, 2021) Bottom: Samsung Galaxy Watch 3, a smartwatch with a traditional band. (Samsung, 2021)*

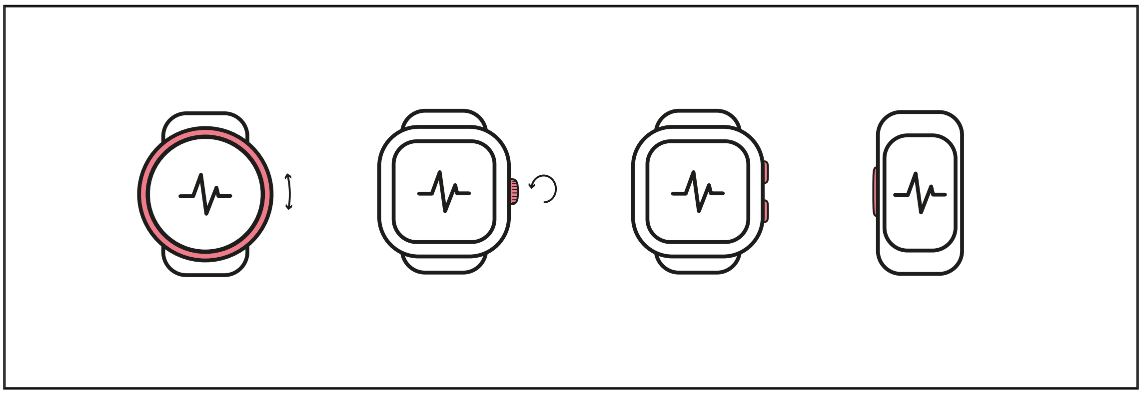


Figure 4.8: *Categories of found input methods / interaction types. From left to right: Dial, Crown, Buttons, Haptic. Author's own illustration, 2021.*

4.2.2.3 Form Analysis

A form analysis, using Sony products to maintain brand identity, results in a suggestion of two types of form languages, which were considered suitable inspirations (See Figure 4.9).

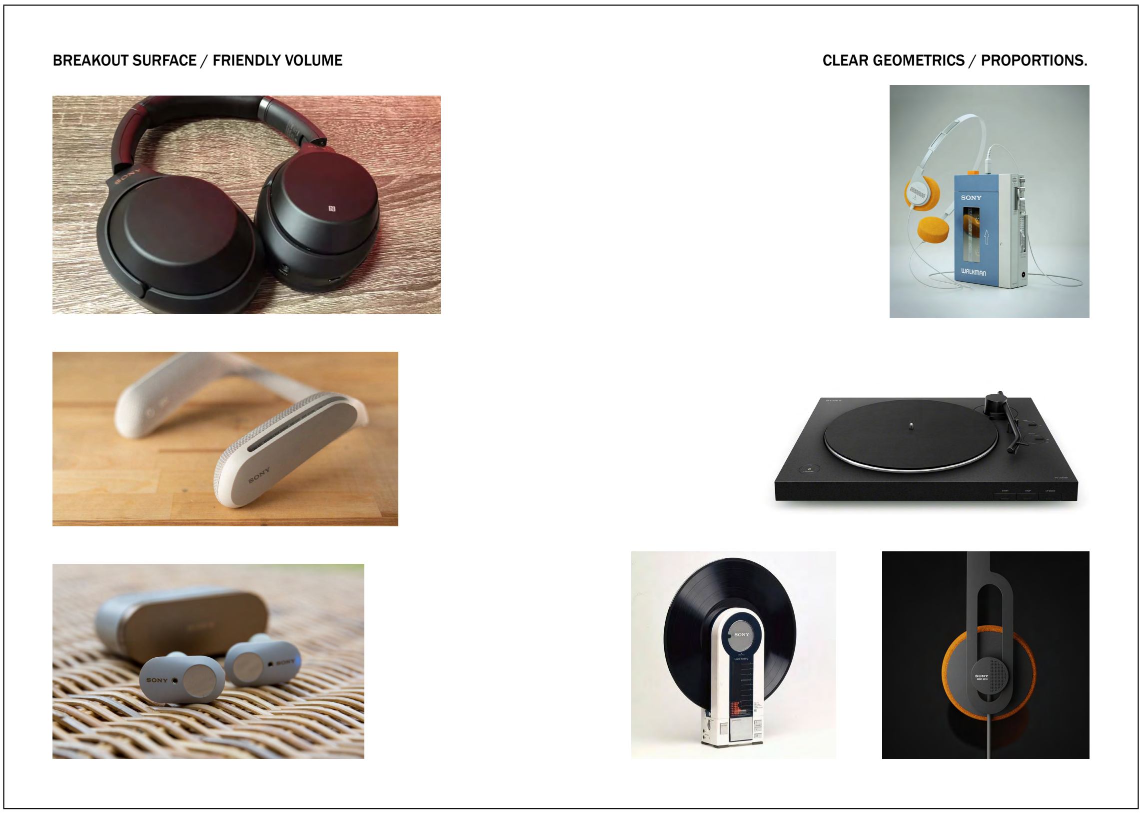


Figure 4.9: *Form analysis showing Sony products categorized according to form language. From left to right: (Carnoy, 2019) (Renner, 2016) (Druber, 2020) (What Hi-Fi?, 2020) (Henderson, 2019) (Sony PS-F9, n.d.) (Brown, 2019)*

The contemporary *Breakout Surface / Friendly Volume* uses organic shapes and clear surfaces to create a modern, *close-to-human* impression. It is highly utilized within the Sony wearables, and therefore was deemed suitable.

The traditional *Clear Geometrics / Proportions* gives a more utilitarian and functional impression, which could be suitable for the context of the target groups and the use of the product.

By combining these styles of forms and expressions, we can produce the basis for a new, strong and suitable form language. The *identity* is ensured by reference to brand products, the *character* is inspired by close to human expression, and the *functional* aspect is inspired by the utilitarian expression.

4.2.2.4 Boards

Based on the form analysis (See Figure 4.9) images were collected into a form-board (See Figure 4.10). It is bearing values in form similar to identified languages, but diversifying on product categories. The board should act as an inspiration.

Among the images, the typical hard geometric shapes provides the utilitarian expression *Clear Geometric / Proportions*. Meanwhile modern influences are found in some of the prominent surfaces and human friendly forms, as in *Breakout Surface / Friendly Volume.*

Figure 4.10: *Form-board of styling. It shows products from different categories with similar form-values as will be desired. From top to bottom, left to right: (Astell&Kern, 2019) (nopicnic, n.d.) (nopicnic, n.d.) (Samsung, n.d.) (PANTER&TOURRON, n.d.) (Heyninck, 2019) (Cheung, 2019) (Junyoung, 2016) (twelvemonthly, 2017) (Guttenberg, 2015) (Dang, 2016)*

A second board, a mood-board, was produced (See Figure 4.11). Similar to the board representing form, the second board should act as an inspiration, by providing a desirable atmosphere. It was based on the target segments, *Healthcare*, *Outdoor Leisure*, and *Hazardous Workplace.*

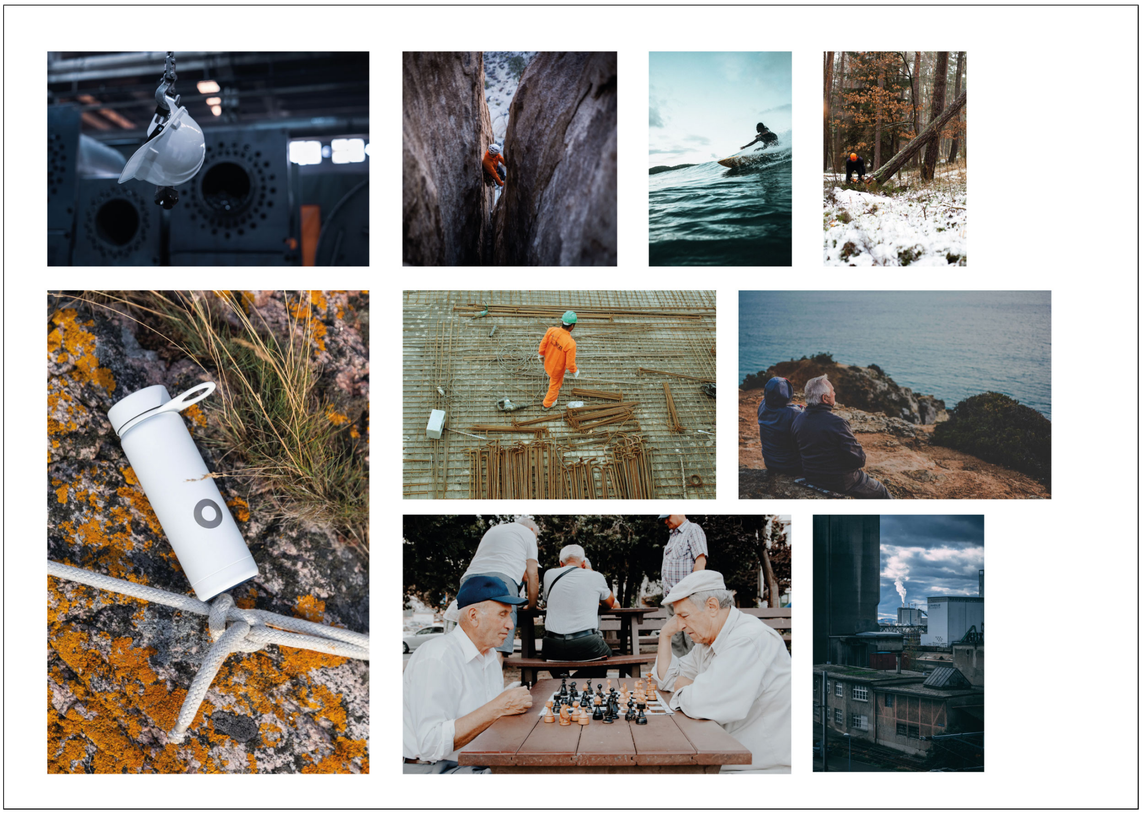


Figure 4.11: *Mood-board of context. It builds an atmosphere and context in which the new product should fit. From left to right: (Ümit Yıldırım, 2020) (Lisbin, 2019) (Sjöström, 2018) (Bluewater, 2020) (Cunha, 2017) (Grabowska, 2018) (Sargu, 2017) (Lade, 2018)*

4.3 Phase 2: Concept Generation

Three iterations of concept generation were conducted. Each including an introductory divergent phase, spanning out the space of solutions, followed by a convergent phase with feedback sessions and refinement. The feedback was given following a presentation at the end of each iteration and was provided by members of Studio Nordic and mSafety. Each iteration was allowed a week in duration.

4.3.1 Iteration I

The first iteration starts with a blank page and ends in an initial concept catalogue, or idea bank. Being the most tangible aspects of the product, the first iteration has a higher focus on *physical form and interaction methods.*

4.3.1.1 Methods Used I

The iteration was initiated with highly open and free sessions of *mind mapping* (See Method 3.2.1) and *individual brainstorming* (See Method 3.2.2) simultaneously, to allow an outlet for the build-up of ideas throughout the pre-study. Without any type of evaluation, the mind map was produced over the components of the watch (See Figure 4.12).

Figure 4.12: *Mind map. It shows free thoughts and ideas of the different components of the product to be developed. Author's own illustration, 2021.*

Further, *Osborn* (See Method 3.2.3) was used with the previous product as a basis, to ignite the flow of ideas.

Osborn

Adaptation
Similar to iPod, without the music. Navigate lists. Comparison to other smartwatches have been made.
Modification
Should resemble a watch, not to confuse user. Only fix is a display facing user, and a strap to secure on arm. Buttons, slides, scroll wheels, or other interaction methods.
Magnification
Ideally, what should be enlarged are interaction surfaces and display.
Reduction
All else should be made as small as possible. Thickness, bezel. All which is not in interaction with user. Still fix points for wrist strap.
Substitution
In comparison to previous device, the type of interaction can be replaced. Likely being the core for the rest of the design.
Inversion
The order of keys should be restructured. The placement is awkward as is, since reaching for left buttons results in the hand covering the display. And are they as efficient as possible?
Combination
Should try open testing of different combinations of interaction methods.

Each initial idea and sketch were disintegrated into sub-solutions that can be restructured in a *Morphological Matrix* (See Table 4.2). By selecting a combination of solutions, and imposing them into a new concept, the space of possible solutions was expanded (See Method 3.2.4).

Table 4.2: *The morphological matrix displays different sub-solutions for each major function (in physical form and interaction).*

Functions	**A**	**B**	**C**	**D**
1. Interaction - Main	Buttons	Surface	Crown	Dial
2. Interaction - Support	Buttons	Surface	Crown	Dial
3. Form	Circle	Squircle	Rounded	Square
4. Modularity	On/Top	Strap	Interaction	Frame

A goal of producing a total of ten concepts using the matrix was set, which in turn were directly integrated into the first catalogue (for full catalogue, see Appendix D). Moreover, each concept receives a quick evaluation using *PNI* (See Method 3.2.6).

4.3.1.2 Output: Catalogue I

The image in this section is a summary of the produced ideas. For all ten variations with PNI evaluations, as presented during the feedback session, see Appendix D.

The code given at the bottom left of each concept (See Figure 4.13) corresponds to the morphological matrix (See Table 4.2). Based on the four key words given by the matrix, an idea was thoughtfully but slightly arbitrarily developed.

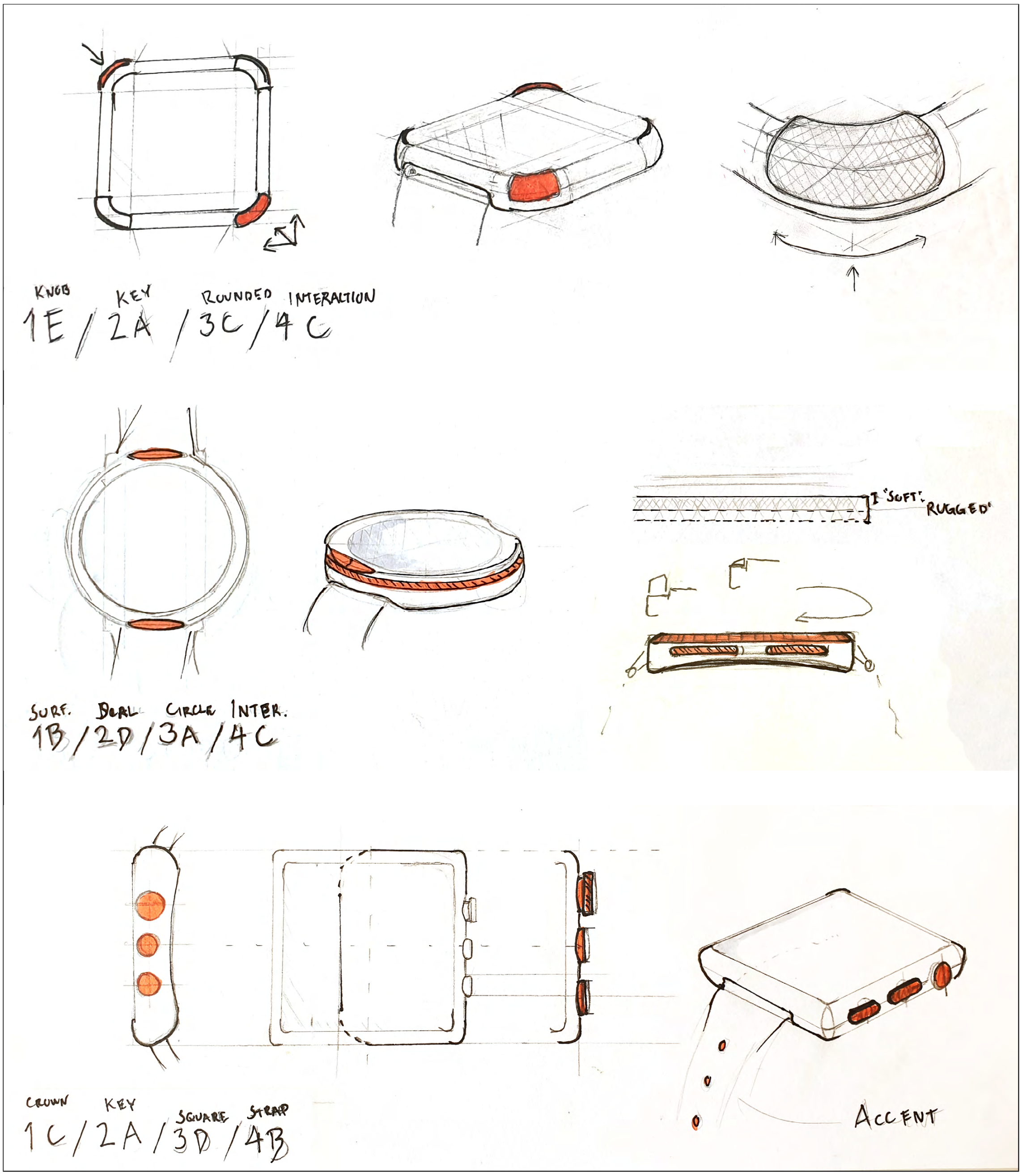


Figure 4.13: *Sketches of 3 initial concepts. The codes corresponds to the morphological matrix. Author's own illustration, 2021.*

4.3.1.3 Feedback Session I

The feedback session consisted of a digital meeting where the results shown in the previous section (See Section 4.3.1.2) were presented, and then discussed among a product manager and senior designers of Sony. Following is a summary of the feedback session.

The three concepts shown in Figure 4.13 were concluded as the most viable paths to follow, and while they can be vastly changed, they will lay the foundation to be iterated on. Suggestions and opinions given during the session are noted in this section. First listed are general input, followed by concept specific notes.

- A strap and a button in the same area need extra consideration.
- A free moving dial/wheel can be challenging for elder. A *jog dial* could be an alternative.
- Accidental input should be considered, especially when placing buttons on corners.
- Differentiate the shape of buttons on the same side. E. g. three buttons on the same side could use an elongated one in the middle, and two smaller ones on the sides. Texturing could also differentiate them.
- Each concept should have a special/emergency button.

Concept: Rounded

- Make corner buttons more protected
- Modularity is still a challenge

Concept: Round

- Test jog dial as top bezel. Bezel should be thicker
- Modular styling with different bezels
- Add a select button

Concept: Square

- 3 regular side buttons: up, down and select
- Modularity is still a challenge

4.3.2 Iteration II

Based on the first feedback session (See Section 4.3.1.3), three general ideas in terms of form and interaction elements were considered at the start of the second iteration. While development was needed in all aspects of the device, a different focus could be applied in the second iteration. Specifically, the *UI, its structure, and the combination* with different button layouts received attention.

4.3.2.1 Methods Used II

The second iteration, likewise the first, was initiated with a phase of open *individual brainstorming* of alternatives on buttons layouts and UI structures. Meanwhile, since only three concepts remained, the time investment of initiating *CAD-modeling* was acceptable, to further allow visualization and prototyping. CAD-modeling (Computer Aided Design) enables the digital creation and modification of 3D-objects. In turn, the tool allows testing of dimensions and measuring of volumes, prototyping and exchanging components, used as a basis for 3D-printing, or to be aesthetically studied. The method demands software, specifically Autodesk's *Fusion 360*. In parallel, to prototype UI structures, an early stage of *wireframing* (See Method 3.2.5) was utilized.

4.3.2.2 Output: Catalogue II

The summary of the concept catalogue after the second iteration consists of a rendering of each model produced, with an idea of how each UI navigational structure might look, and how interactive elements could map (See Figure 4.14).

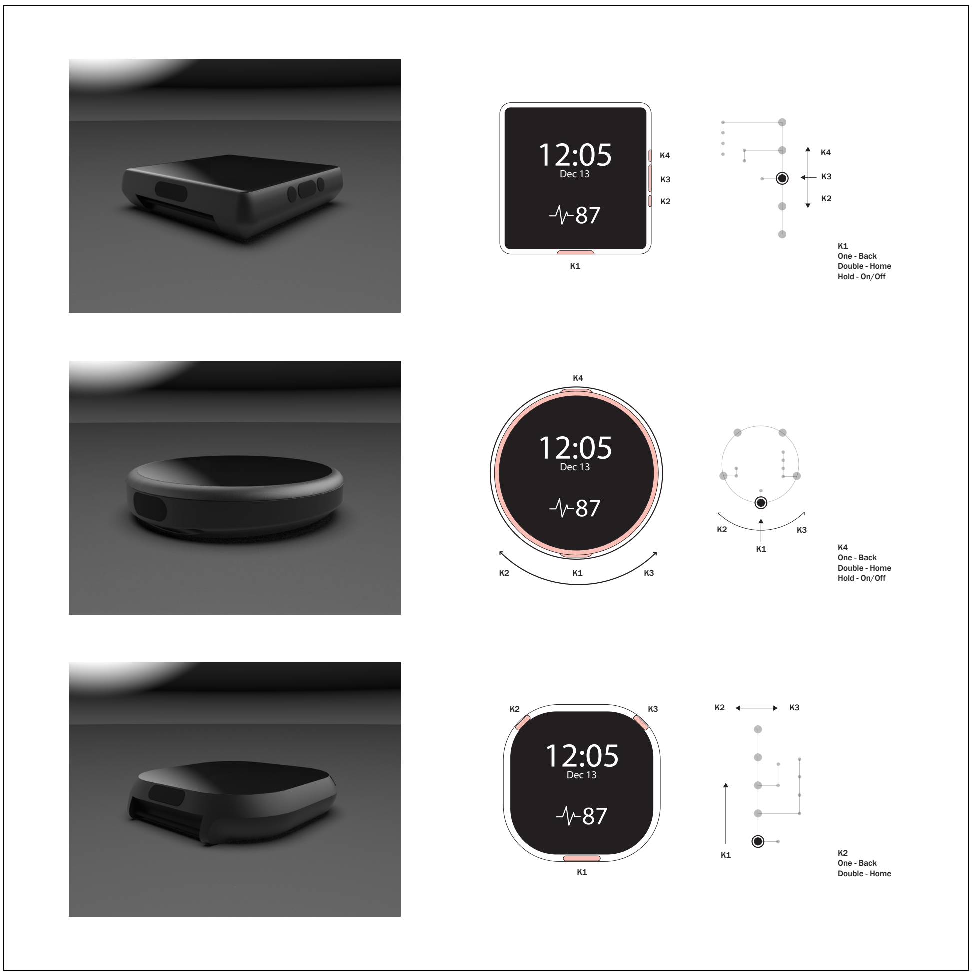


Figure 4.14: *Summary of the second concept catalogue. For each concept it includes a rendering of the model, a buttons layout, and a UI structure. Author's own illustration, 2021.*

In the illustrations, each interactive element is colored red and given an ID (K1, K2 etc.). In the structure the main views are represented by larger dots, with the home view encircled, and the sub views as smaller trails. The previous structure is found in Figure 4.4.

4.3.2.3 Feedback Session II

The second feedback session consisted of a digital meeting where the results shown in Section 4.3.2.2 are presented, and then discussed among a product manager and senior designers (in industrial- and UI-design) of Sony. Following is a summary of the feedback session with general opinions listed first, followed by concept specific notes.

- Power/Reset can be stored in menus
- Buttons need to be spaced so they can be differentiated with touch
- Contrasting textures is generally not enough to differentiate buttons
- UI structures should be moving left to right, and preferably linear, to be clear
- Movement through structure should be the same as the physical direction of a button press
- The device should primarily be optimized to be used only with hardware buttons (No touch)
- Each key should use a single press with a specific function
- Have a dedicated emergency button
- One button per axis, no opposing force

Optimization for use with hardware buttons only, plus the need for a dedicated emergency button could mean up to five buttons in total. Each suggested idea should have a button per following function: *Select, Back, Emergency, Up, Down.*

Concept: Rounded

- Make the major button function as *emergency* only

Concept: Round

- Could have indicator at 0 degrees
- Dial could be up/down, in contrast to left/right
- Select on right side, back on top right (One key per axis)

Concept: Square

- Buttons further apart
- Could have select on opposite side of up/down

4.3.3 Iteration III

While a major refinement process will proceed, this section represents what could be referred to as the last iteration. It will have a combined focus on *button layout and UI structure*, but also include some evaluation. In preparation of the third iteration, it has been determined there are five different buttons which need to be placed, while reusing buttons for multiple functions should be avoided. Further, it should be avoided to have several buttons on the same axis. Distinction should be made with each side of the watch body, while no axis should be reused to avoid accidental presses. This presents the major challenge of the last iteration.

4.3.3.1 Methods Used III

Again, *individual brainstorming* was used initially to give an outlet for ideas. Further, modeling was used to adjust 3D-models with new layouts. The iteration was also concluded with a first *Pugh evaluation* (See Method 3.3.1), as a basis to cut the number of alternative concepts.

4.3.3.2 Output: Catalogue III

To allow brainstorming of various button layout solutions, possible general locations were mapped out for each concept (See Figure 4.15).

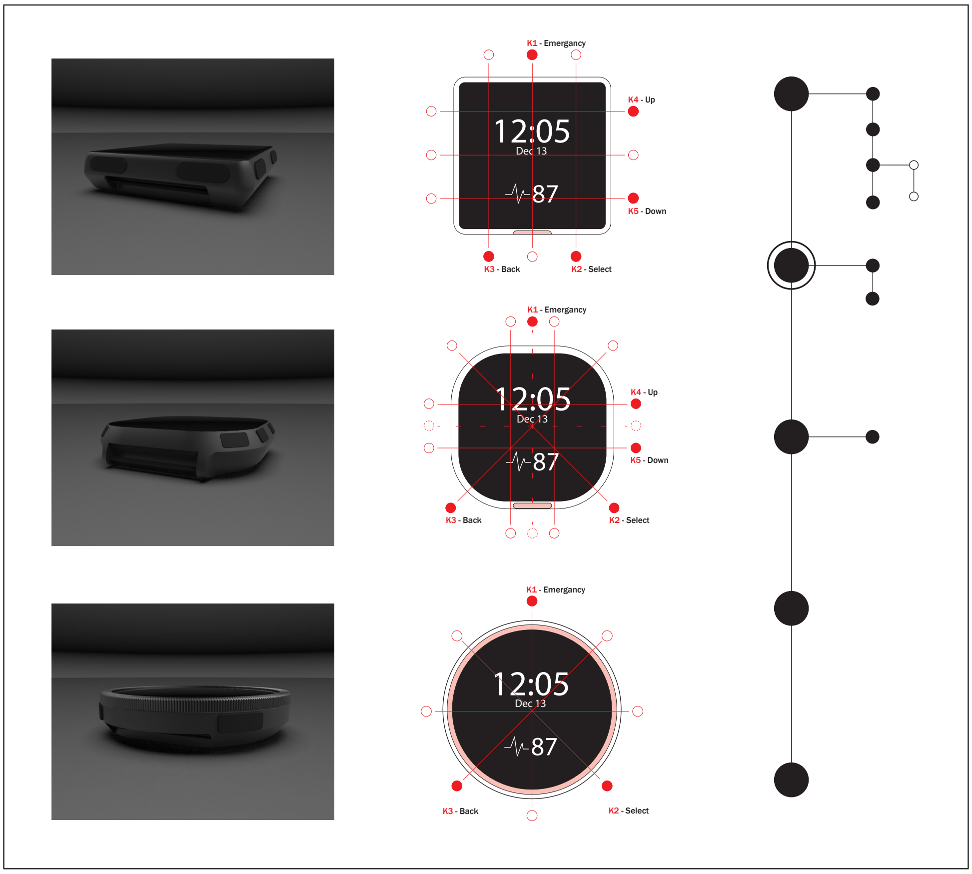
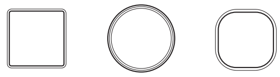


Figure 4.15: *Summary of the third concept catalogue. For each concept it includes a rendering of the model, a buttons layout, and a UI structure. Author's own illustration, 2021.*

The resulting layout should fulfill the demands mentioned previously, which is: (i) placement of the five needed buttons (except for the round concept, having the functionality from two of them in the dial), (ii) adequate spacing, and (iii) no reuse of axis. Also, the aim was to (iv) dedicate sides of the body to a clear function and consider the relationship between buttons.

Furthermore, a Pugh evaluation was presented (See Figure 4.16), which pointed out that the qualities of the *square (A)* and the *rounded (C)* concepts were similar. The suggestion was that by combining the two similar concepts into one, more concentrated work can be put in the following refinement phase.



Category	Criteria	A	B	C
Complexity	1.5	4	3	1
Expression	3.1	4	4	4
	3.2	4	6	6
	3.3	9	6	12
	3.4	2	3	2
	3.5	2	3	3
	3.6	3	9	15
Comfort	5.5	10	20	15
DfA / Usability	6.1	20	10	20
	6.2	15	10	20
	6.4	15	12	9
Total		88	86	107

Figure 4.16: *A summary of the first Pugh evaluation. Shown in the left column are the overarching categories. For the individual criterion, see Appendix I. Authors own illustration.*

4.3.3.3 Feedback Session III

The last feedback session consisted of a digital meeting where the results shown in the previous section (See Section 4.3.3.2) were presented, and then discussed among a product manager and senior designers of Sony.

The suggestion to scale down to two concepts was agreed upon. Further, a major discussion point was, while the suggested layouts did seem to fulfil the requirements set after the previous session, they did neglect reachability and ergonomics. Key layouts should be given further attention.

4.4 Phase 3: Evaluation and Refinement

This phase improves upon the two remaining concepts by a process of refinements. It includes ensuring the concepts comply with literature and standards, preparing comparable presentation material in form of renderings and low-fidelity wireframes, as well as diversifying the physical embodiment.

Following, user testing was conducted to verify the user experience, and to provide a basis for the selection of the final concept. For the final concept, expert testing followed, to help decide on the final form and styling of that concept.

4.4.1 Layout Refinement

The two remaining concepts present variation in interactive mediums, where the *square* utilizes buttons only, while the *round* also integrates an interactive dial, in turn reducing the number of buttons needed. In order to optimize each concept in terms of interaction, each layout needs refinement on e.g. placement of buttons, their internal order and organization. To improve on ergonomics, literature and mock-ups were relied on.

4.4.1.1 Literature

Literature findings present a range of guidelines to refine the button layouts. Accompanying each statement, a reference is included to a specific guideline (given by the letter) withdrawn from a specific ISO-standard (given by the number). (See further reference in Section 2.12).

- Buttons can be pressed without excessive deviation from natural hand position **(9241-410:A)**
- Button can be pressed without loss of control **(9241-410:B)**
- Controls allows manipulation regardless of physical limitations, meaning the main control is located on an accessible surface **(21054:A)**
- Controls can easily be separated with change in shape, color, tactile point or marking **(21054:B)**
- Each control has only one function, to reduce cognitive burden **(21054:C)**
- Controls of similar functions are logically arranged in proximity **(21054:D)**
- Controls providing a reference point can easily be identified, with change in shape, color, tactile point or marking **(21054:E)**
- Controls for a main function are easily separated from other controls **(21054:F)**
- Controls are clearly marked with visual symbols, text or tactile symbols facilitate use with limitations in vision **(21054:G)**
- An input device shall not interfere with its own use **(9241-410)**

Professionals, designers at Sony, additionally suggest:

- Differentiate buttons on the same side, in case of different functions
- No opposing force on the same axis
- Dedicate sides of body to a function
- Keep buttons separated

4.4.1.2 Mock-Up: Cardboard

Producing cardboard mock-ups enabled early testing of physical layouts. Compared to relying on visual material, strain in fingers and lower arm was be tested. Thus, natural hand-placement was determined.

The mock-up consisted of cardboard cut according to the following estimated dimensions. Following, pins were moved around, each representing one of the *buttons to test*.

Concept Circle	**Concept Square**
Approximate dimensions: • d = 50 mm • h = 12 mm *Buttons to test:* 1. Select 2. Back 3. Emergency	*Approximate dimensions* • s = 44 mm • h = 12 mm *Buttons to test:* 1. Select 2. Back 3. Emergency 4. Up 5. Down

The cardboard bodies were taped to a watch to be worn and tested (See Figure 4.17). The mock-ups allowed the creation of a type of heat map (See Figure 4.18), which indicates which areas of the device are accessible. The stronger colors represents a higher reachability. The heat maps in combination with literature findings (See Section 4.4.1.1) allows suggestions on layout for each concept.

Figure 4.17: *Cardboard mock-Ups. The black pins were used to test the reachability of different layouts. Author's own picture, 2021.*

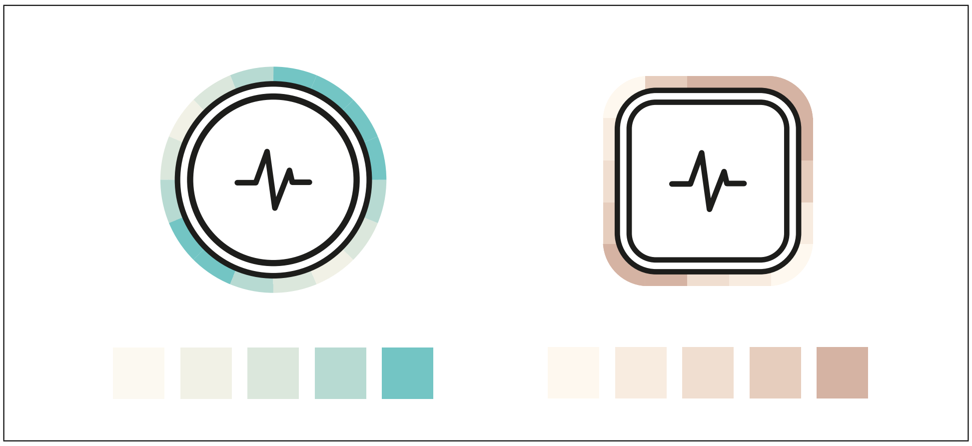


Figure 4.18: *Heat map. It shows areas of high and low reachability. Author's own illustration, 2021.*

4.4.1.3 Layout Suggestion

Both concept layouts allow for a rested wrist. The button placement is centered around areas of unrestrained and natural reach (See Figure 4.19). Meanwhile, the emergency button (R3/K2) is placed in an area which in daily use should not be mistaken. This is due to being placed in a position which needs unnatural deviation and is hidden from both sight and natural occurrence of fingers.

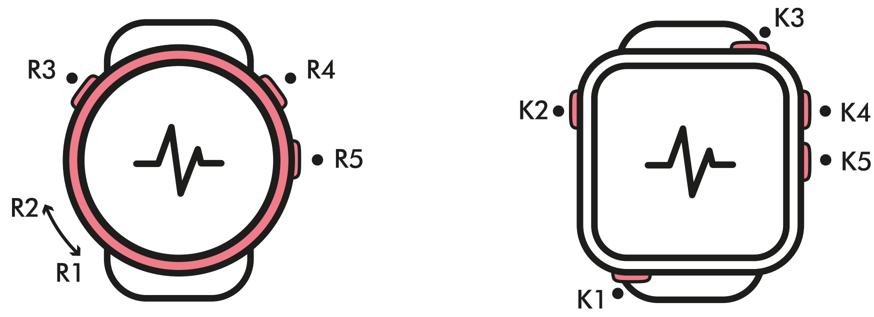


Figure 4.19: *Key layouts. It shows the location of each button and interactive medium. Author's own illustration, 2021.*

Concept: Circle

The *select* (R4) and *back* (R5) buttons are separated but in proximity of each other, which means no major deviation from hand placement is needed when using them both. They are ideally operated with the index finger, the most dexterous. The thumb will have a stable, natural resting position on the opposite side of the device. Either the thumb or the index finger can, without major movement, be used to operate the jog dial (R1 & R2). Furthermore, a stronger pinch grip is allowed, for the weaker hand (See Figure 2.4).

Concept: Square

Navigating through the structure is primarily carried out with the *up* (K4) and *down* (K5) buttons on the right-hand side, where the index finger will be resting, the most dexterous. Meanwhile, the *select* (K1) button is positioned close to the natural resting position of the thumb. The *back* (K3) button is symmetrically placed on the mirrored side, not to be confused with any other function but well within reach of the index finger.

The predicted natural hand placement and interaction was later verified in user testing, simultaneously to decide which of the two concepts is preferable (See Section 4.4.4.1).

4.4.2 Form Refinement

The suggested layouts can be embodied in numerous variations, and as previously mentioned, the expression of the final product is a fundamental function. The *form analysis* and *boards* (See Sections 4.2.2.3 & 4.2.2.4) were utilized in the production of a variation of forms and styles.

4.4.2.1 Form Analysis Implementation

Form was diversified based on the form analysis (See Section 4.2.2.3). In short, the form analysis identifies two suitable languages. The contemporary and organic *Breakout Surface / Friendly Volume* contributes to the character of the form language, while the traditional *Clear Geometrics / Proportions* provides a utilitarian and functional impression. Sketches representing different expressions were produced (See Figure 4.20).

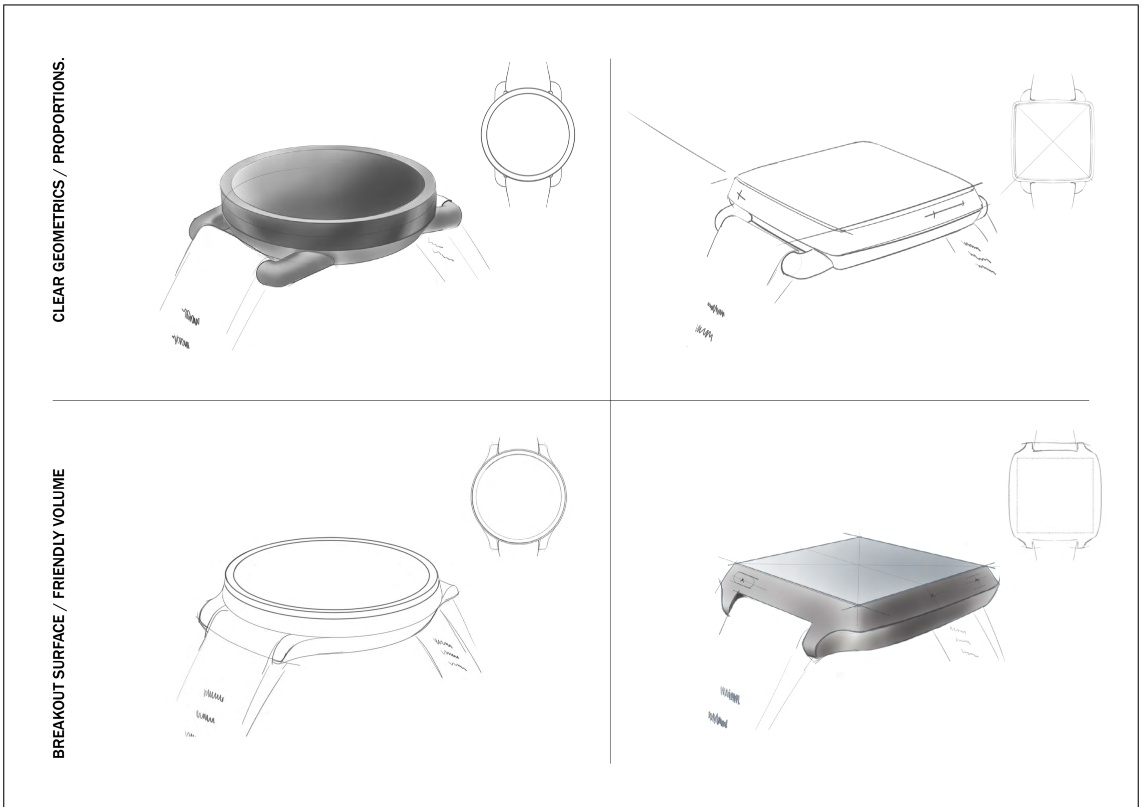


Figure 4.20: *Form Analysis Implementation. Four concepts of form, embodying two types of layouts, in two types of design languages. Author's own illustration, 2021.*

4.4.2.2 Form Suggestion

Note*: The user testing (See later Section 4.4.4.1) was carried out in parallel to the form refinement and determined the square concept to be discontinued. Thus, the variations in form are all based on the round concept, moving forward.*

Form was further diversified in modeling, where the two sketches of the round concept were turned into four versions. (See Figure 4.21) A broad variation was beneficial to improve the chances of finding a form language suitable and approved by the client.

Figure 4.21: *Four concepts of form. Author's own illustration, 2021.*

As seen in Figure 4.21, each variation utilizes the same general button layout previously determined, while variations can be seen in general form, lugs, buttons and dials.

4.4.2.3 Mock-Up: 3D-Printing

The four forms were tested and adjusted by 3D-printing (See Figure 4.22). It allowed hands-on testing of volumes and ergonomics, as well as aesthetics expressions and proportions. Prints were used to give a tangible perspective of the different variations, and in turn allow modifications and iterations. Finally, the conclusive prints were used in presenting the different forms during the *expert testing* (See Section 4.4.6.1).

Figure 4.22: *Four concepts of form, 3D-printed. Author's own image, 2021.*

Only the bodies were printed, in PLA. The wrist bands were borrowed directly from the previous generation of device.

4.4.3 UI Refinement

Note (Same as in Section 4.4.2.2)*: The user testing (See later Section 4.4.4.1) was carried out in parallel to the UI refinement and determined the square concept to be discontinued. Thus and already said, the illustrations are all based on the round concept, moving forward.*

Ideas on the UI structure and the mapping to physical buttons have existed throughout the iterations. However, it was determined that literature should be more heavily referenced to provide a sounder user experience. Furthermore, current and new ideas must be adjusted to seamlessly suit the physical layout. In turn, all decisions on how the UI should be formed can be compiled into an initial, low-fidelity UI wireframe, presenting all the fundamental aspects.

4.4.3.1 Literature

Fundamentally, the user interface was decided to be of *Satellite Posture* (See Theory 2.4). Mainly due to the use pattern of the device, where task complexity is minimal compared to the use of a smartwatch. Main actions consist of information reading, navigation and some value input. (In comparison, higher complex tasks could be writing e-mails or browsing the web). Thus, the interface should be designed to be used briefly and infrequently. Meaning, it should consider users with a low level of experience. Further, it will have similarities to those of *Transient Posture*, meaning the interface should aim for *simplicity, explicitly and rich visual cues* (Cooper et al., 2014, p. 215-235).

Further, the following decisions fall in line with the decided posture of the interface. Each with reference to relevant sections of the *2 Theoretical Background*. The number given is a reference to the section in where each guideline is found.

- Minimize the number of views **(2.6 Excise:A)**
- Use few levels of hierarchy in the structure, max 2 **(2.6 Excise:D)**
- Have the least amount of data on each screen, without the loss of valuable info **(2.9 Principle:G)**
- Use full-size screens, giving info on a single type of data. Use *select* for details and history **(2.4 Transient Posture)**
- Provide a signpost, an on-screen constant which will indicate the current location **(2.6 Excise:B)**
- Visual layout corresponds to physical input **(2.6 Excise:C / 2.9 Principle:D)**
- Combine the signpost, visual feedback on input, and correspondence to physical input into one constant element **(2.7 Idiomatic)**
- Allow for an accessibility mode. Being a monochrome interface, the mode will mainly increase sizing **(2.2 Design for Accessibility)**
- The text will use the fewest words possible without abbreviations **(2.2 Design for Accessibility)**
- Let the most important element on the screen stand out in size **(2.9 Principle:B)**
- Create a grid which is utilized for all screens. To ensure a continuous and thought-out layout **(2.9 Principle:C)**
- Use a maximum of two typefaces with specified font sizes **(2.9 Principle:C)**
- Facilitate a simple mental model, by adjusting movement according to physical directions and form **(2.5 Mental Models)**
- Make carousel-flow non-circular **(Cooper et al., 2014, p. 511)**

4.4.3.2 Wireframe - Low-Fidelity

From the ideas presented during the first concept iterations, together with guidelines based on literature (See Section 4.4.3.1) a first draft of a low-fidelity UI can be presented (See Figure 4.23). It aims to give a general idea on navigation, structure, information presentation, and visual hierarchy.

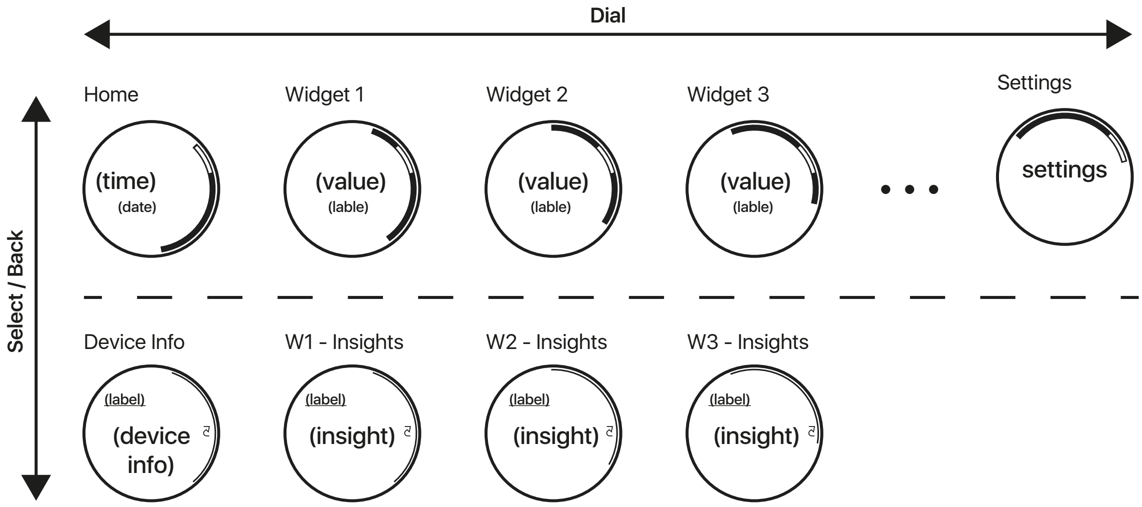


Figure 4.23: *The low-fidelity wireframe, it shows the UI structure, an internal visual hierarchy, and the navigation between the views. Author's own illustration, 2021.*

At its core, it will consist of a carousel of view, with the home view being the first view and the settings being the last. In between, widgets specified by the use case are added, e.g. *Glucose*, *Heart Rate*, *Steps* etc. This centralizes the navigation to the main feature of the device, the dial, and simplifies the user mental model by providing natural movement in correspondence with physical input. It also prepares the UI to integrate a wide variety of functions, due to the wide variety of use cases. To keep the information easy to read, everything non-essential is tucked into an *insight*-panel which can be reached by pressing *select* on the corresponding widget. Thus, it keeps each widget glanceable, and visual exhaustion minimal. Any manipulation within the *insights*, as scrolling in a log or table, is again done by "jogging" the dial. The signpost (See the half circle on the display in Figure 4.23) provides a constant visual element, both indicating the current location in the structure, as well as logically map software and hardware by showing possible actions in proximity to the corresponding buttons.

4.4.4 Evaluation I

The first phase of evaluation compares the two concepts *Square* and *Circle*, with the aim:

1. Verify that the interaction of each concept works as intended
2. Determine the degree of fulfilment in each desirable aspect of the *Specification of Product*

Following, the results of the second part can be inputted into a new Pugh matrix, allowing a decision to be made on which concept to move forward with. Additionally, open ended feedback was collected, and used as a basis in refinement to improve the selected concept.

4.4.4.1 User Testing

Participants, theoretically representing their segments (See Theory 2.13), were invited through social media groups, forums, and other organizations (E.g. Facebook-pages for members of national organizations and local interest groups). Requests for participants were openly posted. The segments contacted were based on the predefined targets, *healthcare*, *outdoor leisure* and *hazardous workplaces*. If an individual was considered to fall within a target groups, and was interested in participating in the study, no further selection was made. By representing a target group, their opinions on the usability of the two concepts being tested were considered relevant.

Participants and their representation.

1. Healthcare and outdoor leisure (Diabetes + windsurfer)
2. Healthcare (Diabetes)
3. Healthcare (Diabetes)
4. Outdoor leisure + Healthcare (Windsurfer + working in healthcare)
5. Outdoor leisure (Climber)
6. Hazardous workplace + Outdoor leisure (working in trucking, solo, including heavy lifting + climber)

Each participant receives a package sent by mail, including two semi-functional mock-ups, representing each of the two concepts being tested (See Figure 4.24). Additionally, instructions and a short background was provided (See Appendix E).

Figure 4.24: *Two concepts printed and assembled with clickable buttons. Author's own illustration, 2021.*

The interview was prepared to validate the usability of each concept, and to determine the degree of fulfilment for each of the desirable aspects of the *Specification of Product.* For the full interview material, see Appendix F, including which criterion of the specification the individual questions were examining. It also states if a question was included to test assumptions on interaction. The answers were noted during the interviews. For the full result, see Appendix G.

In the summary (See Figure 4.25) the values of the first aspect, *verification of interaction*, is a result of the number of positive answers compared the total of answers. In both the two later aspects, the percentages are in comparison between both concepts, and shows the participant's preference.

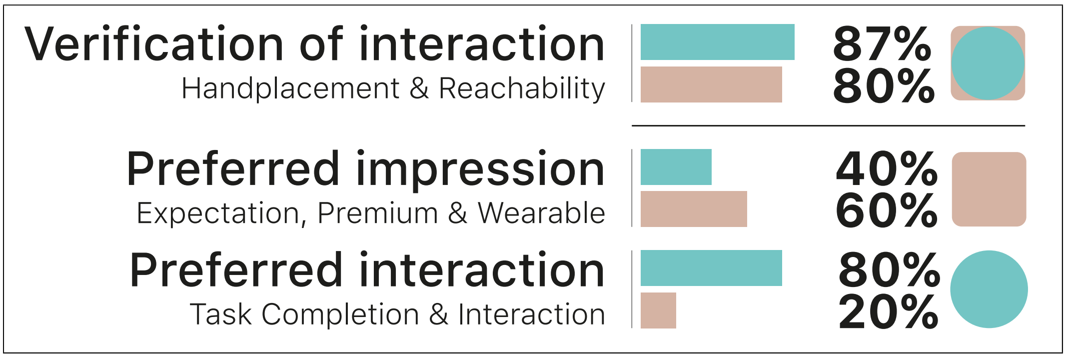


Figure 4.25: *Summary of user testing results. Most interactions happens as expected. Meanwhile, while the first impression of the square concepts is preferred, the round concept is preferred in interaction. Author's own illustration, 2021.*

First and foremost, it can be concluded that the interactions in high regard function as expected. Reassuringly, even though it was the first user interaction with the device, on average 83% of the interactions were carried out using expected fingers and grips. Consensus was that the intended interaction in general seemed comfortable and ergonomic, excluding the action of reaching the emergency button which was deliberately placed out of reach. Furthermore, while the style and shape of the square concept is in correlation with the participant's expectation, the round concept was preferred in terms of interaction.

The results of the user opinions on individual aspects were inserted in the second Pugh-matrix, meaning the user preferences on a specific criterion in turn determines the *degree of fulfilment* for that criterion. Again, the connection between question and criterion is referenced in Appendix F. A summary of the result is shown in Figure 4.26, and determines the round concept as the overall preferred alternative.

A few other key points which should be considered during the refinement phase were collected with the open-ended questions of the interview:

- Two participants consider the round concept to seem *show off*. The expression given by the different colored ring, and the overall size is contributing to this
- The buttons are less visible on the round concept, therefore they should be

larger and more protruding

- While the general button layout is appreciated, the two right buttons can be adjusted in height
- Providing a bezel with distinct color could be appreciated in some use cases

Note on uncertainty: *One of the participants' evaluation should be considered uncertain, due to stating a disapproval of the round concept since "not wanting to rely on touch", in contrast to the square concept. This indicates a misunderstanding of the basic function of the concept. The misunderstanding was not corrected due to avoiding infringement on the interview integrity. The answers provided are not included in the above result, but would not affect the final decision.*

4.4.4.2 Pugh Matrix

The figure (See Figure 4.26) is a summary of the second Pugh evaluation, and shows points as the product of *degree of fulfilment* and *value of importance* given in each category. For the full table of evaluation, see Appendix J. The value given as *degree of fulfilment* in each category corresponds to the percentage of participants which favoured that concept, during the user testing.

The final score was in distinct favor of the round concept and was considered to be decisive in determining which of the two concepts best fulfills the *Specification of Product*. In turn it can be decided that the round concept, majorly due to the highly valued aspects of usability, was the concept to move forward with.

Category	Criteria	Square	Round
Complexity	1.5	4	1
Expression	3.1	6	6
	3.2	4	6
	3.3	12	6
	3.4	3	3
	3.5	4	2
	3.6	3	15
Comfort	5.5	15	15
DfA / Usability	6.1	10	20
	6.2	10	20
	6.4	9	9
Total		80	103

Figure 4.26: *Summary of the second Pugh matrix. Shown in the left column are the overarching categories, for individual criterion, see Appendix J. Author's own illustration, 2021.*

4.4.5 Refinement I of Final Concept

The section is included to keep a chronology, however, the results of the first refinement process have previously been presented in the *Form Refinement* (4.4.2) and *UI Refinement* (4.4.3). These processes were carried out in parallel to *Evaluation I* (4.4.4). This is a result of an effort to keep the workflow efficient. Please, refer to these sections for an update on the current state of the concept.

4.4.6 Evaluation II

During the second evaluation, not only the layout (See Figure 4.19) will be presented, but the current low-fidelity UI suggestion (See Figure 4.23) and the suggested form variation (See Figure 4.21) will be considered. The aim was to, in collaboration with the client, compile and verify a final concept.

4.4.6.1 Expert Testing

In preparation of the expert testing (See Method 3.3.3) the four 3D-printed form mock-ups (See Section 4.4.2.3) were collected, and brief instructions on the test, the layout, the UI and the form, were produced (See Appendix H).

The models and instructions were openly displayed at the client office for two weeks. Individuals, in some way involved with the previous generation of the product, either by supplying the product or being involved in the development of it, were asked for feedback. These individuals have previously been presented with the objectives of the project, thus, defining them as experts. Opinions could be noted in a notebook located at the display, or communicated during a digital meeting at the end of the period.

4.4.6.2 Expert Testing - Feedback

The current state of the layout and UI were accepted, and it was concluded that the alternative form C is generally preferred (See Figure 4.21). Numerous aspects were considered in open discussions, and the selection is an agreement of a form that participating designers considered most suitable.

Positives

- Overall proportions
- Angle of lugs
- Striking edge
- Buttons
- Slanted grip of dial

Suggested refinements

- Increase dial surface
- Slightly round the edge at the centerline
- Add material between buttons and dial, to feel less squeezed
- Less bulky lugs, less interference with buttons
- Keeping the edge on top, but making the entire underside rounded. Giving organic shapes against the skin, and clear geometry on the interaction
- Buttons looks fine size-wise, but decrease bevel to increase usable area

Other

- Different dials and colors could dramatically change appearance
- Could try to refine form between lugs and body
- A new thinner band could be used

4.4.7 Refinement II of Final Concept

Based on expert testing feedback (See Section 4.4.6.2), adjustments were made (See Figure 4.27).

A. Surface area of dial increased by close to 40%

- Increase in overall diameter (2mm)
- Slight decrease in screen size (0,5mm)
- Raised screen (0,7mm)

B. Increased balance between different elements

- Increased space: lugs/buttons
- Increased space: centerline/buttons cutouts
- Increased space: lugs/centerline

C. Bottom surface made completely smooth

- Instead of making the back completely rounded, the “tangency weight” is lowered to achieve a quicker disappearance of the surface. It should make it feel slimmer.

D. Refinement of lugs

- Slightly decrease in diameter, to feel less heavy
- Increase in angle. Allows increase in overall diameter, but also make lugs less prominent
- Break in surface tension where lugs meet body

E. New straps to accommodate changes

- Thickness to match lugs diameter
- Decrease width by 2 mm, to allow lugs kept tighter together

F. Minor/Other

- Slight rounding of centerline

- Decrease in chamfer of buttons. Makes them seem larger
- Adjusted cutouts for buttons, should essentially accommodate a finger

Figure 4.27: *Final refinements. The new version is shown closest to the viewer and on the right. Major changes are in the rounded back, the angeling of the lugs, and their spacing from the buttons. Also, the surface area of the dial has been increased. Author's own illustration, 2021.*

4.5 Phase 4: Visualization

The final phase of the project aims to showcase the final result. It shows all aspects and features of the hardware design, through 3D renderings, and all material produced as guidelines to facilitate full production of the UI.

4.5.1 Hardware: Modeling/Rendering

The process included the production of a virtual 3D model representing the final form and layout, which was used to render presentation images.

The renderings shows a hero shot of the final hardware form (See Figure 4.28). Further, the backside is shown (See Figure 4.29) to display the rounded form, but also relationship between lugs, the break in the surface, and buttons. Finally, various dials are shown for the different contexts of the pre-defined target groups, healthcare, leisure and industry (See Figure 4.30).

Figure 4.28: *The final hardware design. Author's own illustration, 2021.*

Figure 4.29: *Buttons, back, lugs and surface break. Author's own illustration, 2021.*

Figure 4.30: *Various dials. The one closest to the viewer is designed for the industry. Behind it, with accent coloring, is the dial for leisure activities. The softer dial on the right is for the healthcare domain. Author's own illustration, 2021.*

4.5.2 UI: Guidelines/High-Fidelity Wireframe

A selection of elements from the interface were produced in full resolution, and at full detail to be used in the high-fidelity wireframe. Furthermore, general guidelines were also documented, which forms the basis for the remaining graphic work.

4.5.2.1 High-fidelity wireframe

While the current medium, a printed report, is not suitable to showcase the interactive flow of the high-fidelity wireframe, it was produced to verify and present the solution (See Figure 4.31). In software, interaction with the product can be simulated, and the flow of views visualized.

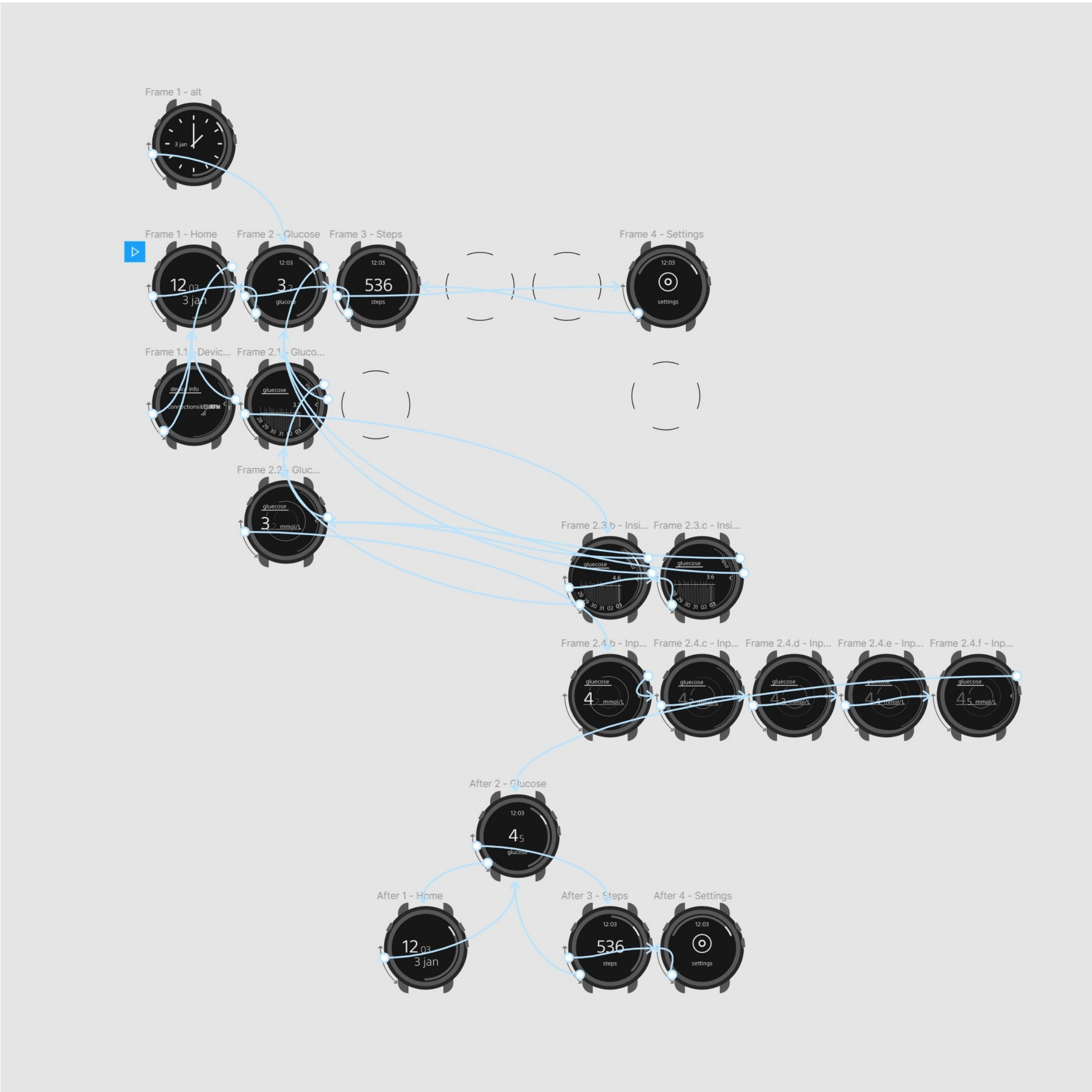


Figure 4.31: *High-fidelity wireframe. In its software, Figma, an interactive mock-up can be displayed, showing different elements of the UI and the navigation between them. Author's own illustration, 2021.*

4.5.2.2 UI Guidelines

Instead of the time-consuming process of creating every view and interaction of the UI, the *guidelines* create the basis on which the entirety of the UI could be produced. This section will give a complete overview of the user interface design, by dividing it into the components: structure, layout grid, and font.

Structure and flow of information

The structure (See Figure 4.32) mainly consists of minimal and glanceable views on a linear carousel structure. Starting at the *home* view, and ending at the *settings*, the views, or widgets, in between them are decided by the user's specific needs. Each view represents a function, activity, or value. The main interaction element of the device, the dial, is used to navigate through the carousel, which does not wrap around to be kept as simple as possible.

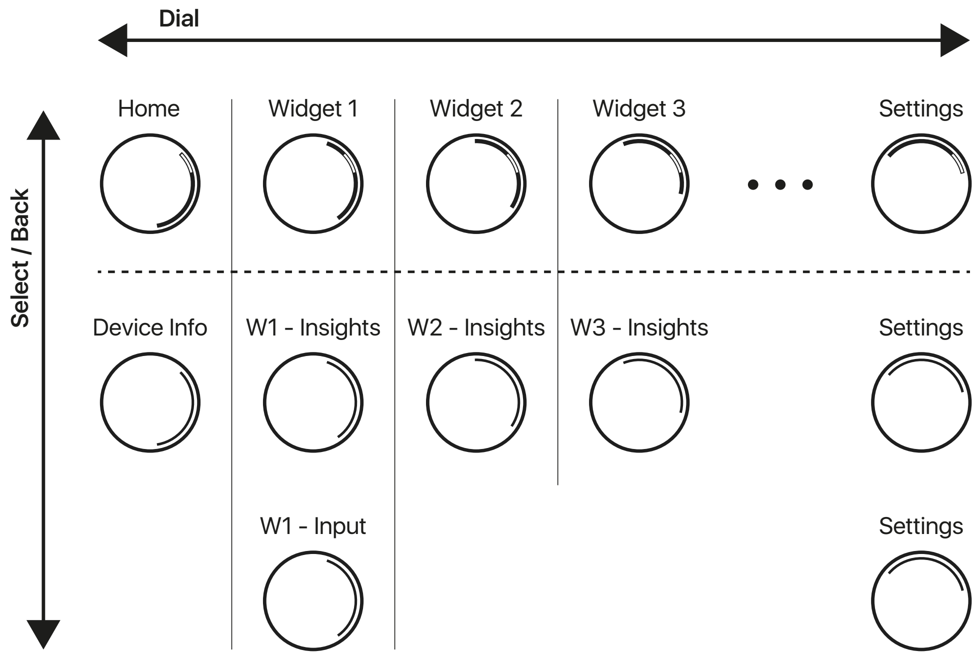


Figure 4.32: *UI Structure. It shows the relationships between different views, and the navigation between them. Author's own illustration, 2021.*

To keep each view minimal and non-cluttered, any associated additional information for that view is stored in a subcategory of *insights*. It is reached by pressing the *select* button on the relevant view. In the new insights view, additional information can be shown, as history of values, comparisons etc. Since moving into the insights view, navigation through the main carousel is deactivated, and the main interaction element of the device, the dial, is instead used to scroll through any values on the current view.

Furthermore, if additional functionality is needed to the relevant widget, a linear process can be started from the insight view by pressing the *select* button again. Depending on the function of that specific widget, this could e.g. start the process of inputting a value manually, setting up an external sensor related to the specific widget, or start an activity.

In short, the dial takes us between the *main* views, the widgets, which only displays minimal and essential information. The sub-view for each widget, the *insights*, displays additional information, and history can be scrolled through. If needed, a linear process, a *task*, can be started from the insights view.

Signpost, interaction indices and physical mapping
Throughout the navigational structure, a constant *signpost* aids the user (See Figure 4.33). At all times, the signpost visually indicates where in the structure the user is located. Furthermore, integrated into the signpost, all possible actions are shown. It is done by mapping visual cues to the physical placement of a corresponding button. Visually, the signpost consists of a half-circle following the bezel of the display, which represents the carousel. The bright capsule inside the half-circle has two functions. Partly, it indicates where in the carousel the user is currently located. Further, it also indicates that a press of the *select* button will move into the structure from the carousel, into the insights view (given that view exists for the specific widget).

Moving into the insights view, the half-circle is deactivated, visualized by shrinking and turning passively gray. Thus, the user gets an indication that moving through the carousel is not possible at the given moment, but instead has to press the now indicated *back* button to return to the main view. In case an additional process can be started from the insights view, such as inputting a value manually, or setting up a sensor related to that value, a text indication will display at that location of the *select* button. If no additional process is available, only the *back* button will be indicated in the interface.

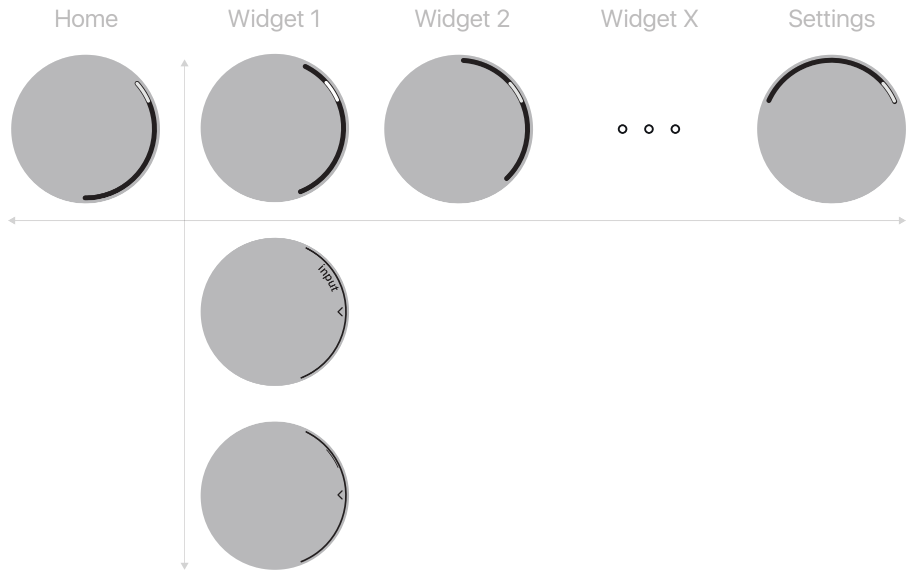


Figure 4.33: *The signpost. It indicates to the user the current location in the structure, and possible actions at all times. Author's own illustration, 2021.*

Layout grid

The layout grid ensures continuity and similar visual hierarchies from view to view. Some constant objects and text boxes are explicitly marked on the grid, meaning these are included in each view regardless of content. However, there is enough space to place elements more freely as well. As seen in Figure 4.34 only the placement of the main text box is explicitly defined. Remaining space is left open, to be adjusted according to the individual needs of the view. The 1.57 inch, or 40 mm, display is divided into a 40 x 40 grid. If a text box is not explicitly defined, any element should be placed according to the grid. Furthermore, the striped outer area around the bezel is constrained to the signpost.

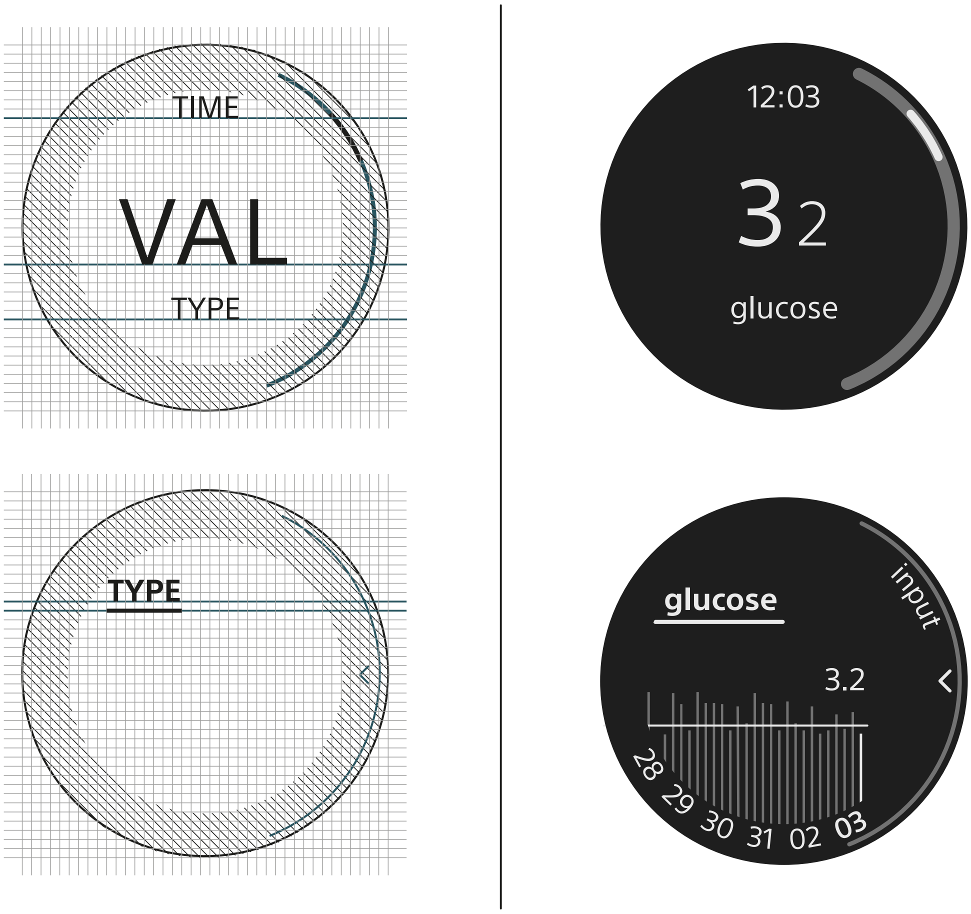


Figure 4.34: The grid. It work as template in development of the individual views of the UI. Thus, it ensures continuity and clarity. Author's own illustration, 2021.

Font

The font used is SST, developed for legibility in UI at Sony, making it suitable for the application. Three sizes and three styles give nine (minus one, due to falling short in legibility) variations of creating a visual hierarchy (See Figure 4.35).

Figure 4.35: *UI Font. 3 sizes, 3 versions. Author's own illustration, 2021.*

The font sizes begin with the minimum font height of 3.75 mm, in turn corresponding to ∽10.7 pt, which is considered legible till the age of 60 without spectacles (See Theory 2.8). The other sizes follow in a pattern of 2 x 3.75 mm and 3 x 3.75 mm, to keep clear distinctions between the sizes. The font types are *light*, *roman* or *bold*.

***Note**: The font sizes used in all illustrations of the UI would correspond to a minimum of 3.75 mm on a 45 mm display. However, at a late stage of the hardware refinement, the screen size was reduced to 40 mm, meaning current illustrations have a font size slightly too small.*

5

Conclusion

This chapter summarizes the key findings of the project, by concisely showcasing and explaining the final concept. In this chapter, the concept is divided into its major components, hardware *layout* and *form*, and *user interface*.

5.1 Hardware Layout

The final hardware layout (See Figure 5.1) determines a major portion of the product usability. It should be easy to visually and cognitively distinguish between the different interactive elements, and their purpose, while facilitating an ergonomic experience.

Figure 5.1: *Layout Overview. The heat map of reachability, indicates how the final layout was selected. Next to the illustrations is a final rendering of the layout. Author's own illustration, 2021.*

The prominent *dial* (R1, R2) is designed to establish itself as the main interactive element of the device. It cares for most of user interactions, including navigation, information browsing and numeric input. Furthermore, the circular form is used to facilitate the understanding of how the navigation and movement through the UI structure will function, thus, simplifying the mental model. This is done by making movement, animations and flow of information follow the circular form. The ring-shaped form does also provide the possibility to grip, for the weaker or gloved hand.

The two main buttons, the *select* button (R4) and the *back* button (R5) are placed in proximity to the natural and ergonomic position of the dexterous index finger. The buttons are spatially and visually grouped by their relational placing but have a sensible spacing to easily be differentiated. While the grouping of the two indicates that they are used together, the hierarchical statement of the higher button, the *select* button, will naturally be recognized as the positive of the two opposites. In effort to haptically reinforce the relationship, the select button is given a tactile dot, which also makes it easy to find even when visibility is low. Since the buttons never are used simultaneously, it is sensible to assume they can both ideally be used by the index finger.

Lastly, the infrequently used *emergency* button (R3) is deliberately placed out of natural reach. By putting it spatially, and visually, on the opposite side of the body, the risk of accidental activation is minimized.

The concluding interaction allows for a firm grip, with a natural hand placement, and a supported arm. Additionally, by inviting the user to the suggested grip, the hand will never cover the display.

5.2 Hardware Form

The physical form of the device must provide some fundamentally important aspects. It should express a desirable *character* suitable to the context, it should make a strong connection to its *identity* and the brand, and most importantly, it should give unambiguous indicators in the expression of its *functions* (See Figure 5.2).

Figure 5.2: *Hardware Overview. A collage of the final hardware of from different angles. Author's own illustration, 2021.*

It was early determined that in effort to make this uniquely used wearable better fit its context of use, a suitable *character* for the product would be a combination of two identified languages. The contemporary, *close-to-human* and inviting expression, in combination with a tool-like, *utilitarian*, and functional approach. It leads to the clear centerline reaching around the horizontal line of the body, marking the utilitarian and pragmatic face, in contrast to the organic and human-friendly underside. The latter does not only contribute to the overall expression, but does pose a real functional value, where only soft and rounded shapes will ever meet the skin. It makes it more comfortable to wear, even for those with more fragile skin. The division of the wearable into a utilitarian surface and an organic backside also makes a strong connection to other wearable devices made by the brand. Thus, also representing its *identity*. Furthermore, the strong lugs contribute to the geometric and utilitarian expression of the device and give a more robust appearance. The blending of lugs and body is deliberately put to a minimum, not to lose the value of the hard geometric shapes. Instead, a subtle break in surface clearly marks the distinct placement of the lugs, without infringing on the integrity of the geometric forms. Additionally, spacing between all geometric elements has been given extra care to ensure all surfaces are their own, and feels well placed.

The affordances are already determined by the layout design, however, the signifiers being the visual cues provided by the form, are crucial in a user-friendly product clearly expressing its *functions*. The traditional, easily recognizable, round buttons are clearly marked with deep cutouts. Being formed to accommodate a fingertip, in combination with the placement in proximity to natural finger positions, it will provide a natural invitation to the user. Furthermore, the edge of the body, dividing the two sides of the character, naturally protects against accidental input. Meanwhile, said button cutouts subtly make the buttons as visible as possible, from the users' point of view. The dial also provides a significant signifier, designed to invite a grip, while putting a major imprint on the overall expression. In combination with being allowed modularity, and being the main interactive element, the dial presents a major opportunity in expression. While the buttons are made from metal, to increase the notability and premium of the device, dials are presented in different materials depending on use cases. The dial used in the industry is rough and hard, in metal, with larger surface areas to be easily manipulated by the user with gloves. It is also slightly raised from the display, to provide some functional protection of the screen. While it is believed the user in the outdoor leisure context will appreciate a similar dial in physical form, it is suggested accent coloring is integrated into the dial. Apart from providing a more suitable, sporty, expression, the inclusion of accent coloring in the dial can pose a real functional value, similar to the coloring of the sailors watch. Finally, the dial used in the healthcare industry is toned down, to increase the human friendly appearance, and provide a soft and grippy touch, to the fragile human hand.

5.3 User Interface

The final user interface is made to be brief and glanceable, aiming to minimize visual and cognitive exhaustion. Information is easy to read, possible actions few and meaningful, and navigation through structure in accordance with the user's mental model. Furthermore, the user can always rely on strong visual cues, in the signpost. At each view, it should always be clear which action can be taken, and where in the structure the user is located (See Figure 5.3).

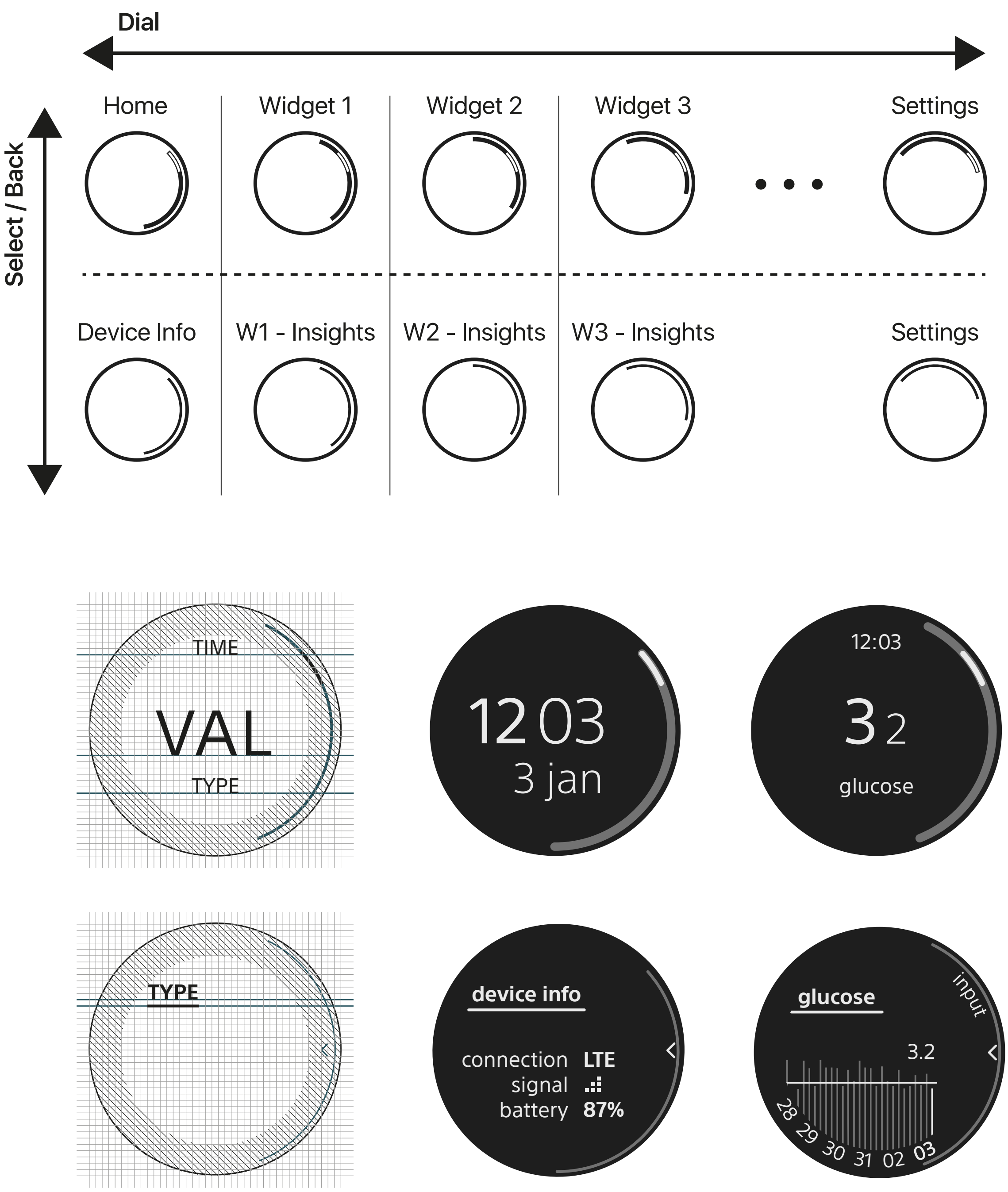


__Figure 5.3:__ UI Overview. It shows the UI stricture, with its internal relationships, and the final views that will build the UI. Author's own illustration, 2021.

The signpost, visualized as a portion of a circle along the bezel, provides several of the functions fundamental in decreasing the cognitive burden. It provides visual cues at all times, indicating to the user the current location in the UI structure, and possible actions at each view. Meanwhile it is dynamically resizable to allow a unified interface even with a variation in number, and types, of widgets. All in effort to be as meaningful as possible to the specific user. It also makes a strong connection to the physical body, binding the components of the device together into a unified and coherent experience. The circular form of the the dial is also leveraged in the views of scrolling through and inputting data, where the flow follows the shape.

The structure and navigation is also centralized around the dial. The linear carousel flow makes navigation intuitive and reduces the risk of error. It also contributes to the dynamic inclusion and variation of user specific widgets. Further, the structure enables the making of glanceable and streamlined views, where a selection of important information can be emphasized, by allowing secondary information being tucked away in the *insights* view.

The visual hierarchies further help emphasize essential information and are made to clearly lead the user through the information. It is achieved by constraining the typefaces and styles. Further, the UI is designed to avoid any small, hard to read, text. Even the smallest sections of information are readable at the age of 60 years without the need of glasses, according to ISO standards.

6

Discussion

This concluding chapter discusses several aspects of the project. First, the credibility of the result is examined, and questionable aspects are brought up. Furthermore, it should be determined if the result does in fact match the original objective, and the degree of fulfillment. Also, aspects of sustainability and ethics are discussed. Lastly, if the project would be continued, recommendations on where focus should be prioritized are included.

6.1 Analysis of project credibility

Overall, the project should be considered credible, and effort has been made to be as thorough as possible. However, a few factors could have negatively affected the soundness of the result.

1. **Solo project** - A team member could have helped in many aspects, especially in expanding the space of possible solutions

2. **Participants in user study** - More users in numbers, and diversity, should have been collected. Research suggests a minimum of 12 participants to reach a high level of certainty, but in the end only 6 were interviewed

3. **Robustness of evaluation** - While obtaining an overview of the entirety of the project, it seems the translation from research to evaluation could have been provided more time. It would not necessarily affect the outcomes of the project but would provide a more solid basis of evidence

4. **Low experience in UI design** - User interface designs have not been the focus of the bachelors. Thus, much have been relied on literature and expert input

5. **Product of Specification** - Incidents where a criterion is valued differently by different stakeholders have occurred. A sound methodology to weight different opinions against each other would have been beneficial

6. **COVID-19** - Due to the ongoing pandemic, all work is done from the home. In itself, it does not affect the project in any high degree. However, as a result, many organizations are at a lower activity and some individuals at higher risk are more isolated. Furthermore, participants can not be physically met during interview. In short, it constrained the user testing to distant phone interviews

6.2 Was the objective fulfilled?

To determine if the objective was fulfilled, one should ask if the *Specification of Issue Under Investigation* is answered. As the specification in turn asks **What is the optimal solution to said problem?** the *Specification of Product* should also be examined. If the latter specification is fulfilled, the solution should be optimized, assuming the specification is done correctly.

Each question of the *Specification of Issue Under Investigation* was answered at some point over the course of the project.

- What is the previous solution, and what overarching problem does it solve?
    - How is the service designed?
    - How is the previous physical device designed?
    - How is the previous user interface designed?

- What is the optimal solution to the given problem?
    - How should the physical device be designed?
    - How should the user interface be designed?

The set of questions on the previous solution are treated during the pre-study, while the remainder of the project work towards getting as close as possible to the *optimal solution*. The service design was investigated in *Mapping of System and Users*, while the previous device was mapped in the *Functional Analysis*, and the interface and its interaction were analyzed in the *HTA*. (A re-design of the service is never suggested, being outside of the scope of the project). In effort to provide the optimal solution to the problem, an exhaustive re-design in physical form and interaction is presented in the previous chapter as the main output of the project. It should, in turn, present an as optimal solution as possible. That being said, there are aspects that could be further investigated. Please, see the last section.

The *Specification of Product* is fulfilled, which can be determined by comparing the solution with all required criteria. Further, efforts have been put to maximize each desirable criterion. Therefore, the project should be considered successful. However, the accuracy of the *Specification of Product* can be questioned, and if it actually specifies the most desirable product. In short, it was formed by the mapping of functions and usability of the previous product, then re-doing the development work, hoping that a more focused effort would yield an improved result. Positively, the author sincerely believes major improvement can be seen within user experience and usability, compared to the previous generation. However, it is possible that the development work should have started at a point sooner in the process, and also that the service design should have been reconsidered. Thus, the usefulness of certain physical functions could have been revalued.

6.3 Sustainability and Ethics

Important in all types of product development are the factors of sustainability and ethics. This section discusses the result of this project in relation to the three components of sustainability: *social*, *economic*, and *ecological*, as well as ethical aspects.

Due to the nature of the proposed product, and the state of the concept it is concluded in, it is difficult to discuss both the aspects of *economic* and *ecological* sustainability. Concrete material choices are left to be made, and leaves a driving factor in the overall ecological footprint of the product. Further, a cost analysis is yet to be made. These are processes suggested for the *continued investigation* (See Section 6.4). These suggestions also include conducting a Life Cycle Analysis, mapping all the processes and their effects, from cradle to cradle.

However, there are unique opportunities in this case that should be mentioned. The modularity of the mechanical dial does allow effective re-purposing, due to being highly defining in suiting each device to its use case. In combination with the business model applied by mSafety, in where different service-providers with specific use cases are the primary clients. Meaning, a contract could be made to allow recollection of physical devices, and through refurbishment switch the dial for an alternative service-provider.

While these aspects, economical and ecological sustainability, are being moderately omitted in the proceedings of the project, it should be stated the project does instead revolve heavily around the human being and the interaction. Meaning, that *social* sustainability receives a major focus throughout the report. From the initial declaration of *Usability* and *Design for All*, to the concrete inclusion of the definition in the fundamental *Specification of Product*, and in heavy accordance with ISO-standards, and also the inclusion of critical users in the *User Testing*, the project should be considered sustainable from a social standpoint.

Further, there are no identified concerns on ethical aspects. Being a tool primarily developed to aid in the monitoring of chronically ill people, the fundamental function of the product is of good nature. The main function being **Monitor Well-being, Continuously and Remotely** clearly states this. Furthermore, the device is developed with a clear priority of being as user-friendly to as many people as possible, which makes it in all aspects inclusive. However, since the project is not brought to a completely finished state, ethical controversies could arise in e.g. the selection of materials, and other economic factors. This responsibility would be in the hands of those who bring the development of the project further.

6.4 Suggested continued investigation

This section lists short declarations of focus areas and actions, in where the authors suggests the project should head if more time was given.

A Cost and comparison
The final solution is believed to improve on the user experience, compared to the previous generation. However, one should not forego the increase in mechanical complexity. It should be estimated what the increase in cost of manufacturing is, as well. Only then, the concrete value of the solution can be determined.

B Material selection and LCA
While material selection also will have a major impact on finish and feel of the product, rough material and manufacturing selections would allow for analysis of the product life cycle, or a Life Cycle Analysis (LCA). In turn, it would allow for development within the product's life cycle, and adjustments to the current concept can be made to improve upon sustainability aspects.

C Service design
The service design has only been understood as a remote part of the project, and not been further developed. The author is therefore not in place to comment if development work would prove beneficial, but it is possible. It is recommended it would be further investigated.

D Band design
The band design should be considered an integral part of the product. The band does contribute to the overall experience, in both expression and function. Being part of a device designed to be easy to use in a variety of difficult scenarios, the ideal solution would likely utilize a non-traditional band design. Furthermore, limiting the use to a non-integrated band might be too constraining on the overall watch body, having to accommodate the band.

E Abstract
To make the project more realistic, in both time consumption and expectations, it was limited to be wrist worn. The same decision does also make sense when developing a generational upgrade, not an innovation. As a result, the deviation from a *traditional* smartwatch is rather minor. Meanwhile, it is possible there are vastly different concepts which could prove more useful for the specific use cases. After all, the resemblance to a typical smartwatch is uncalled for, since the devices have rather different uses. Instead, the problem could have been re-analyzed to a more abstract level of problem definition, to possibly find less typical solutions in terms of how it is worn, how information is communicated etc.

F Component Selection
The project ends several steps before a product is ready for manufacturing. However, the process of off-the-shelf component selections could benefit the project overall, if done in parallel to the product development. Technological improvements, smaller formats and new functionality could have been considered, and could affect the final result and form.

G Validation of the UI component
Two of the three major components of the concept, the hardware layout and form, are in some way tested thoroughout the project. Meanwhile, the user interface solely relies on literature. If more time was given, it is suggested a study is prepared to test this aspect of the concept.

H Validate with users'
While users and experts were involved in the development process it would have been of value to validate the solution, after all its integral parts have been compiled. Furthermore, some users, such as severely chronically ill, or elderly, could not be reached during the project due to circumstances (COVID-19). It would be of great value to receive further opinions.

Bibliography

Astell&Kern. (2019). *Acro l1000.* [Photography]. Retrieved from https://www.astellnkern.com/eng/content/shop/features.asp?mcg=CG110060&mpos=2&scg=CG213060&spos=0&tcg&tpos=0&gcode=SC28930

Bluewater. (2020). [Photography]. Retrieved from https://unsplash.com/photos/mufygNHZ2FA

Bohgard, M., Karlsson, S., Lovén, E., Mikaelsson, L.-A., Mårtensson, L., Osvalder, A.-L., ... Ulfvengren, P. (2015). *Arbete och teknik på människans villkor* (3rd ed.). Box 20133, 104 60, Stockholm: Prevent.

Brown, D. (2019). *Design studies.* [Photography]. Retrieved from https://www.behance.net/gallery/73875969/Design-Studies-2018

Carnoy, D. (2019). *Sony wh-1000xm3.* [Photography]. Retrieved from https://www.cnet.com/reviews/sony-wh-1000xm3-review/

Cheung, D. (2019). *Playdream.* [Photography]. Retrieved from https://www.daniel-cheung.com/#/project-stream-playdream/

Cooper, A., Reimann, R., Cronin, D., & Noessel, C. (2014). *About face: The essentials of interaction design* (4th ed.). 10475 Crosspoint Boulevard, Indianapolis, IN 46256: John Wiley & Sons, Inc. Retrieved from https://www.academia.edu

Cunha, G. (2017). [Photography]. Retrieved from https://unsplash.com/photos/4zwozQxDbD4

Dang, P. T. (2016). *Daydream view.* [Photography]. Retrieved from https://phanthaodang.com/

Druber, J. (2020). *Sony srs ws-1.* [Photography]. Retrieved from https://9to5toys.com/2020/02/03/sony-srs-ws-1-wearable-speaker-feel-the-music-with-wireless-immersion-video/

Ellis, C. (2020, November). Best fitness trackers. *Techradar*. Retrieved from https://www.techradar.com/uk/best/best-fitness-trackers

Fitbit. (2021). *Fitbit inspire 2.* Retrieved from https://www.fitbit.com/global/se/products/trackers/inspire2

Grabowska, K. (2018). [Photography]. Retrieved from https://unsplash.com/photos/sRAWQyoUiVQ

Griffin, A., & Hauser, J. R. (1993, Winter). The voice of the customer. *Marketing Science*, *12*(1), 2-27.

Guttenberg, S. (2015). *Technics su-c700.* [Photography]. Retrieved from https://www.cnet.com/news/amped-up-the-technics-su-c700

-integrated-amplifier/

Henderson, R. (2019). *Sony wf-1000xm3.* [Photography]. Retrieved from https://www.pocket-lint.com/headphones/reviews/sony/148703-sony-wf-1000xm3-review-in-ear-wire-free-headphones-anc

Heyninck, R. (2019). *Google chromecast 3.* [Photography]. Retrieved from https://www.behance.net/gallery/82681037/Google-Chromecast-3

International Organization for Standardization. (2008, March). *Design criteria for physical input devices* (Vol. 2008; Standard). SIS Förlag AB, SE 118 80 Stockholm, Sweden. Retrieved from https://www.sis.se/

International Organization for Standardization. (2011, March). *Tactile dots and bars on consumer products* (Vol. 2011; Standard). SIS Förlag AB SE-118 80 Stockholm, Sweden. Retrieved from https://www.sis.se/

International Organization for Standardization. (2016, August). *Guidance on tactile and haptic interactions* (Vol. 2016; Standard). SIS Förlag AB, SE 118 80 Stockholm, Sweden. Retrieved from https://www.sis.se/

International Organization for Standardization. (2019, October). *A method for estimating minimum legible font size for people at any age* (Vol. 2019; Standard). Ch. de Blandonnet 8, CH-1214 Vernier, Geneva. Retrieved from https://www.sis.se/

International Organization for Standardization. (2020, March). *Controls consumer products* (Vol. 2020; Standard). SIS Förlag AB, SE 118 80 Stockholm, Sweden. Retrieved from https://www.sis.se/

Johannesson, H., Persson, J.-G., & Pettersson, D. (2013). *Produktutveckling: Effektiva metoder för konstruktion och design* (2nd ed.). 113 98 Stockholm: Liber AB.

Junyoung, J. (2016). *Hammer dryer.* [Photography]. Retrieved from https://www.behance.net/gallery/55478479/HAMMER-DRYER

Karlsson, I. M. (2007). *Kurskompendium: Lyssna till kundens röst.* Unpublished Manuscript, Department of Design and Human Factors, Chalmers University of Technology.

Kozuch, K., & Prospero, M. (2020, December). Best smartwatches. *Tom's Guide.* Retrieved from https://www.tomsguide.com/uk/us/best-smartwatches,review-2156.html

Kumar, A. (2018, May). An interaction design framework to cover all your bases. *UX Collective.* Retrieved from https://uxdesign.cc/a-interaction-design-framework-to-cover-all-your-bases-1e616a954827

Lade, B. S. (2018). [Photography]. Retrieved from https://unsplash.com/photos/wC-bFnBdqxA

Lisbin, T. (2019). [Photography]. Retrieved from https://unsplash.com/photos/xatP2A1TGuU

nopicnic. (n.d.). *Kitchen/lab.* [Photography]. Retrieved from https://www.nopicnic.com/kitchengear

Norman, D. (2013). *The design of everyday things* (2nd ed.). 250 West 57th Street, 15th Floor, New York 10107: Basic Books.

Orellana, V. H., & Savvides, L. (2020a, November). Best fitness trackers 2020. *CNET*. Retrieved from https://www.cnet.com/news/best-fitness

-trackers-2020-fitbit-apple-watch/

Orellana, V. H., & Savvides, L. (2020b, December). Best smartwatches 2020. *CNET*. Retrieved from https://www.cnet.com/news/best-smartwatches-2020-apple-watch-6-se-fitbit-garmin-samsung-galaxy-amazfit/

PANTER&TOURRON. (n.d.). *Holy.* [Photography]. Retrieved from https://www.pantertourron.com/

Peckham, J. (2020, November). Best smartwatches. *Techradar*. Retrieved from https://www.techradar.com/uk/news/wearables/best-smart-watches-what-s-the-best-wearable-tech-for-you-1154074

Prospero, M. (2020, December). Best fitness trackers. *Tom's Guide*. Retrieved from https://www.tomsguide.com/uk/us/best-fitness-trackers,review-2066.html

Renner, F. (2016). *Product visualization.* [Photography]. Retrieved from https://www.behance.net/gallery/42997799/Product-Visualization

Samsung. (n.d.). *Vl5.* [Photography]. Retrieved from https://design.samsung.com/global/m/contents/vl_series/index.html

Samsung. (2021). *Samsung galaxy watch 3.* Retrieved from https://www.samsung.com/se/watches/galaxy-watch/galaxy-watch3-45mm-mystic-black-lte-sm-r845fzkaeud/

Sargu, V. (2017). [Photography]. Retrieved from https://unsplash.com/photos/ItphH2lGzuI

Sjöström, O. (2018). [Photography]. Retrieved from https://unsplash.com/photos/y-GMWtWW_H8

Sony PS-F9. (n.d.). [Photography]. Retrieved from https://i.imgur.com/cJ3B5hY.jpg

twelvemonthly. (2017). *Hot/cold.* [Photography]. Retrieved from http://www.12monthly.com/july-2017/

What Hi-Fi? (2020). *Sony ps-lx310bt.* [Photography]. Retrieved from https://www.whathifi.com/reviews/sony-ps-lx310bt

Wikberg Nilsson, A., Ericson, A., & Tornlind, P. (2016). *Design: Process och metod* (1st ed.). Studentlitteratur AB, Lund: Författarna och Studentlitteratur.

Österlin, K. (2016). *Design i fokus: Varför ser saker ut som de gör?* (4th ed.). 113 98 Stockholm: Liber AB.

Ümit Yıldırım. (2020). [Photography]. Retrieved from https://unsplash.com/photos/Ass0DusYDk4

A

Function Analysis

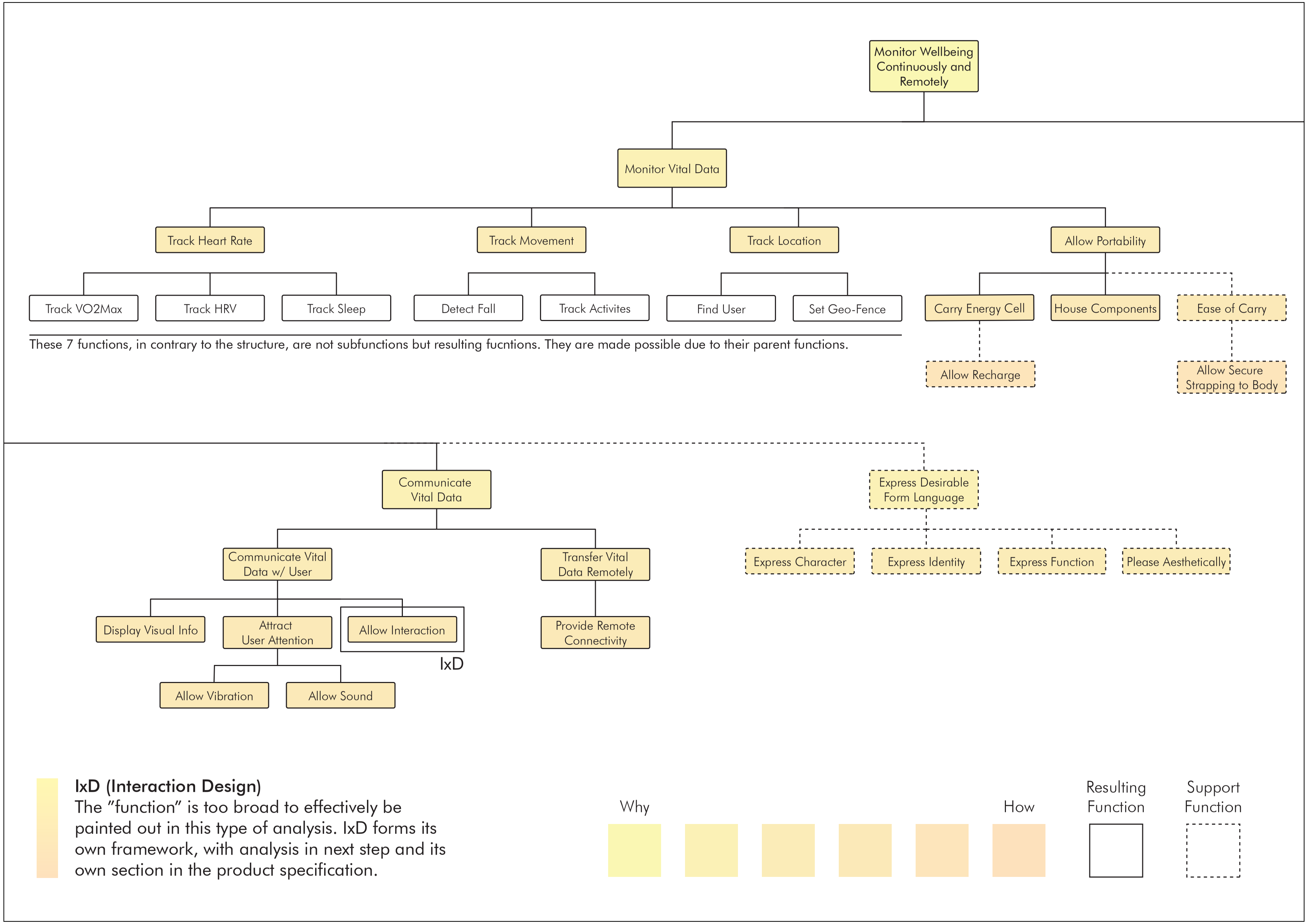


Figure A.1: *Function Analysis. Author's own illustration, 2021.*

B

HTA

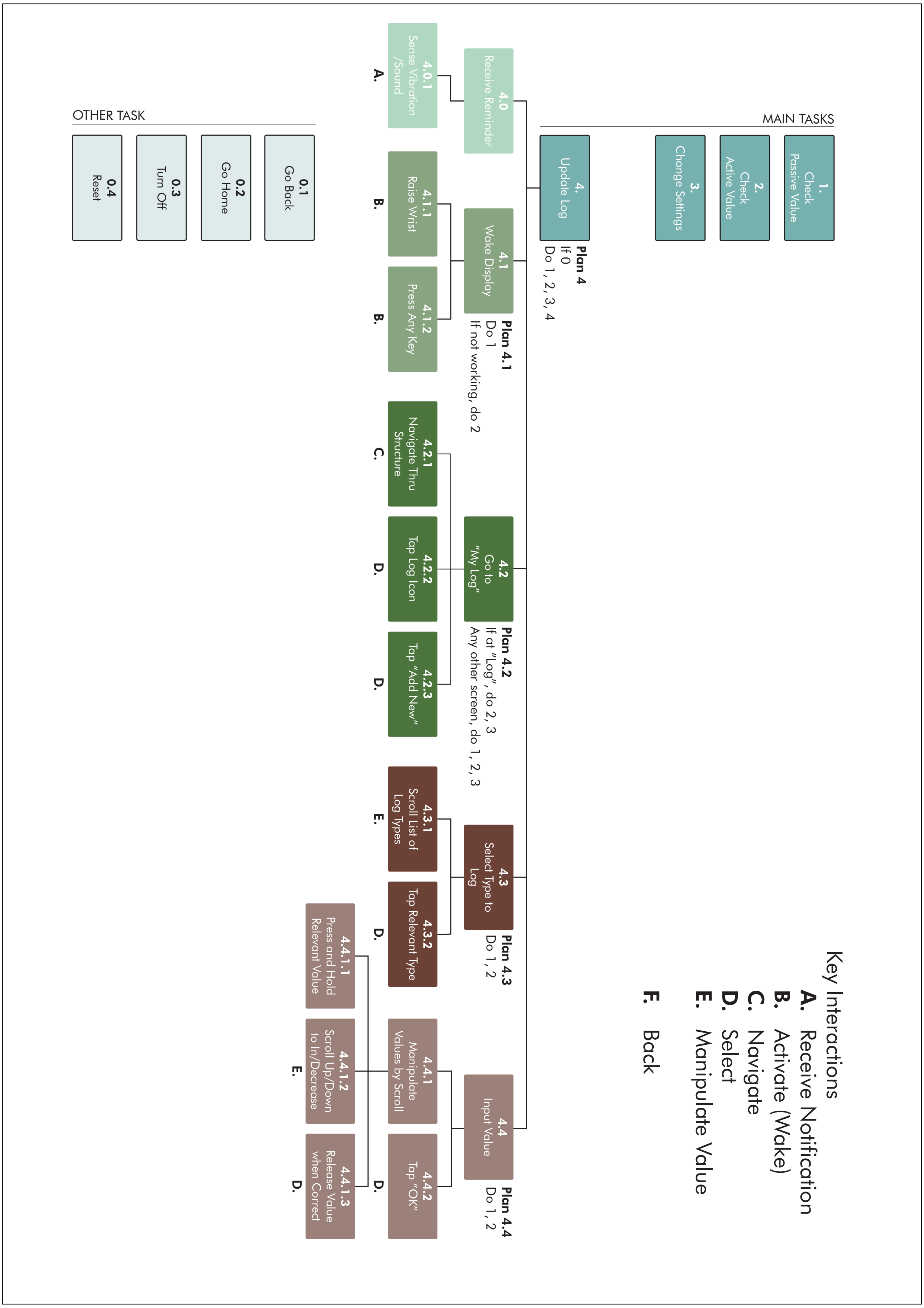


Figure B.1: *Hierarchical Task Analysis. Author's own illustration, 2021.*

C

Trend Analysis

Unfiltered lists		
15-dec	Smartwatch	Fitnesstracker
Techradar	Apple Watch 6	Fitbit Charge 4
	Samsung Galaxy Watch 3	Fitbit Charge 3
	Fitbit Sense	Garmin Vivosmart 4
	Apple Watch SE	Huawei Band 3 Pro
	Samsung Galaxy Watch Active 2	Fitbit Inspire HR
	Apple Watch 3	Garmin Vivosport
	Garmin Vivoactive 4	Honor Band 5
	Amazfit Bip	Xiaomi Mi Band 4
	Fossil Gen 5	Amazfit Bip
		Garmin Vivofit 4
Tom's Guide	Apple Watch SE	Fitbit Charge 4
	Samsung Galaxy Watch 3	Fitbit Charge 3
	Apple Watch 6	Fitbit Sense
	Fitbit Versa 3	Garmin Forerunner 245
	Samsung Galaxy Watch Active 2	Garmin Venu Sq
	Fitbit Versa Lite	Garmin Forerunner 25
	Fossil Sport	Apple Watch Series 3
	Honor Magic Watch 2	Fitbit Inspire HR
	TicWatch Pro 3	Amazfit Band 5
	Apple Watch 3	Amazon Halo
		Garmin Vivoactive 4
		Fitbit Versa 2
CNET	Apple Watch 6	Fitbit Charge 4
	Apple Watch SE	Fitbit Inspire 2
	Fitbit Versa 3	Xiaomi Mi Band 4
	Samsung Galaxy Watch Active 2	Apple Watch Series 3
	Garmin Venu Sq	
	Amazfit Bip S	

Figure C.1: *Trend Analysis Catalogue. (Peckham, 2020) (Ellis, 2020) (Kozuch & Prospero, 2020) (Prospero, 2020) (Orellana & Savvides, 2020b) (Orellana & Savvides, 2020a)*

D

Concept Catalogue I

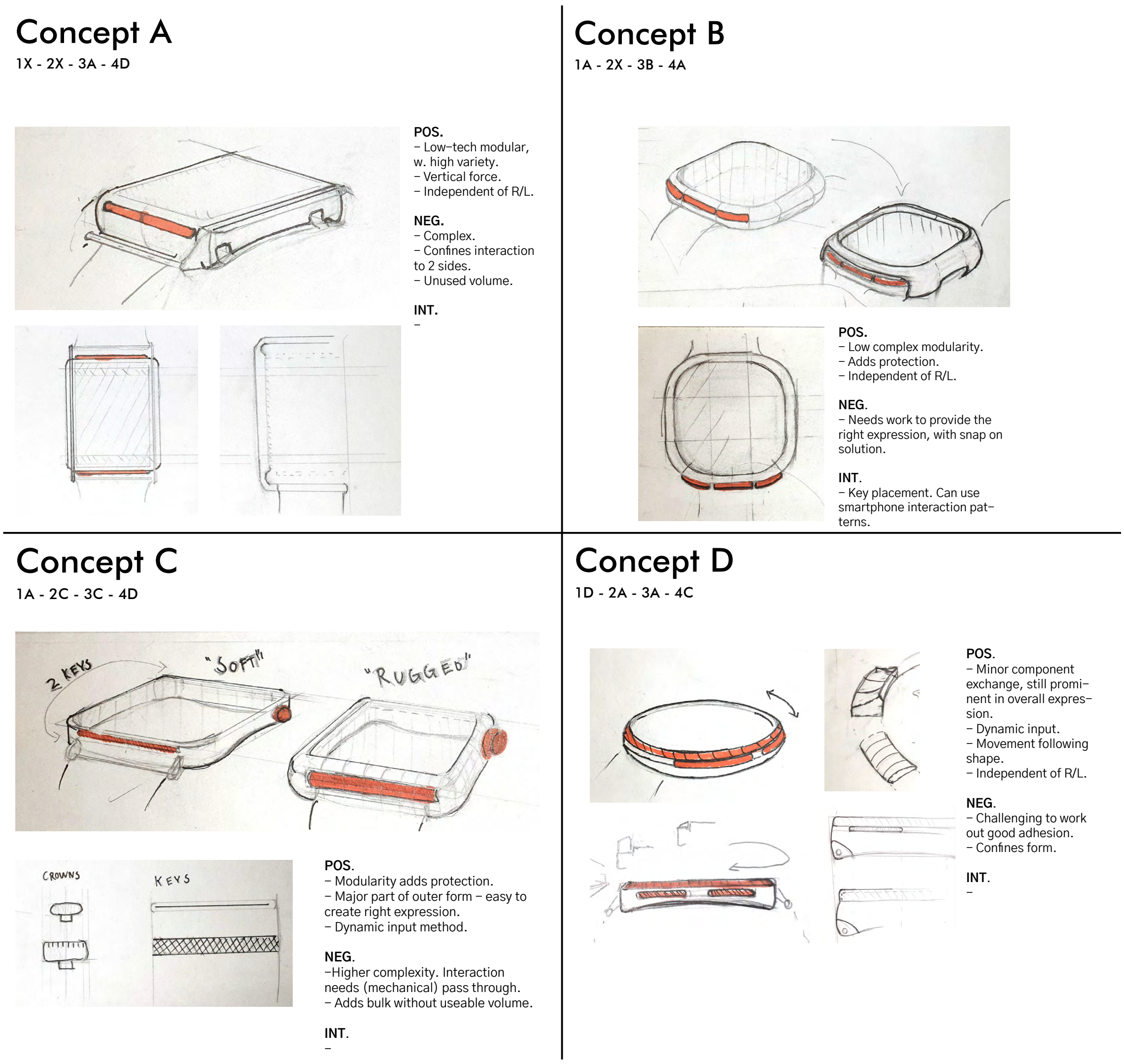
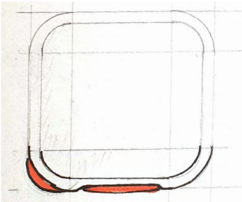


Figure D.1: *Concept catalogue 1, part 1. Author's own illustration, 2021.*

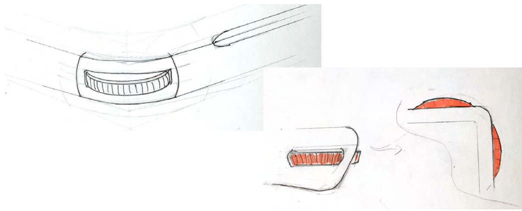
Concept E
1D - 2B - 3B - 4X



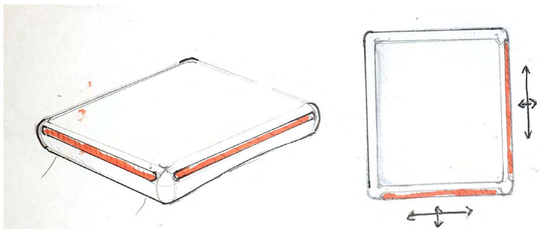
POS.
– Dynamic input.

NEG.
– Complex.
– Demands open device.

INT.
– Natural hand placement.



Concept F
1B - 2X - 3D - 4B

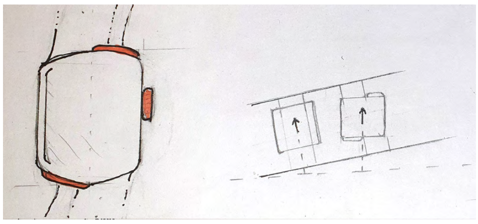


POS.
– Movement following shape.

NEG.
– Touch sensitive surface won't function when touch screen do not function.

INT.
–

Concept G
1A - 2C - 3B - 4A

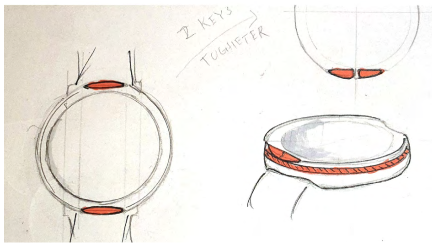


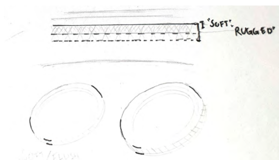
POS.
– Dynamic input.
– Strap placement provides room for keys.

NEG.
– Non modular.

INT.
– Original, but strap placement will "overtake" aesthetic.

Concept H
1B - 2D - 3A - 4C



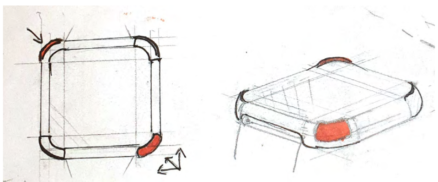


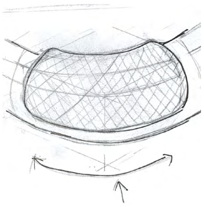
POS.
– Dynamic.
– Movement following shape.
– Independent of R/L.

NEG.
– Limited variety.
– Confines form.

INT.
–

Concept I
1E - 2A - 3C - 4C



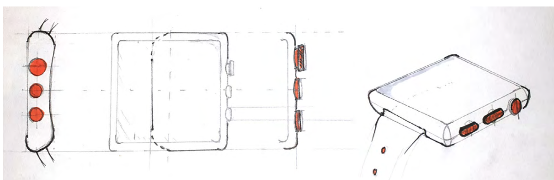


POS.
– Lower complex dynamic input.
– Input with movement.

NEG.
– Accidental input.

INT.
–

Concept J
1C - 2A - 3D - 4B



POS.
– Dynamic input.
– Open expression. No feature on beforehand defining it.

NEG.
– Not adding much, not modular.

INT.
– Could be the basis for a simply more modern gen 2.

Figure D.2: *Concept catalogue 1, part 2. Author's own illustration, 2021.*

E

User Study: Instructions

Introduktion till användarestudie

Först, tack för att du deltar i denna studie!
Detta informationsblad ämnar till ett ge dig en inblick i hur studien kommer att fungera (del 1), men även i den tänkta produktens kontext (del 2) och hur dess användning (del 3) ser ut.

Läs gärna Del 1 innan intervjun. Övriga delar är inkluderade för om intresse finns.

Del 1: Studien

Modellerna som för närvarande är påväg till dig syns på illustration A, till höger.

Denna typ av modell undersöker den fysiska layouten av interaktionsmedel på klockan (det vill säga, knappar och dylikt). Respektive interaktionsmedel är märkta med en grå färg. Då enheten många gånger kommer användas under omständigheter då "touch"-interaktion ej är tillförlitligt (i kraftigt regn, med handskar, etc.) så utvecklas den för att vara fullt funktionell med endast de fysiska interaktionsmedlen.

Observera, medan knappar på båda modellerna har fått sin funktionalitet i form av att de kan klickas, så saknar den ring som kan vridas på den runda modellen en återfjädring till utgångsläge.

Studien syftar till att identifiera de av det två knapplayoutern som kan anses mest användbar.

Intervjun
Intervjun som väntar kommer endast röra konkreta frågor kring dina intryck av modellerna. Alltså, vi kommer ej gå in på din person. Vetskapen om att du hade kunnat vara en potentiell användare, gör i sig självt dina intryck och åsikter värdefulla.

Avfall och återvinning
Modellen är 3D-printad i biologisk nedbrytningsbar PLA, gjord av förnyelsebara material. Detta slängs i brännbart.

Mötesbokning
Med denna information är du redo att boka en telefonintervju! Det kan göras via följande länk:
https://calendly.com/edvin-nielsen/anvandarstudie

Illustration A

Illustration B - Knapplayout

Illustration C - Handplacering
Denna illustration kan vara bra att ha vid intervjutillfället.

Figure E.1: Part 1 of user study introduction. Author's own illustration, 2021.

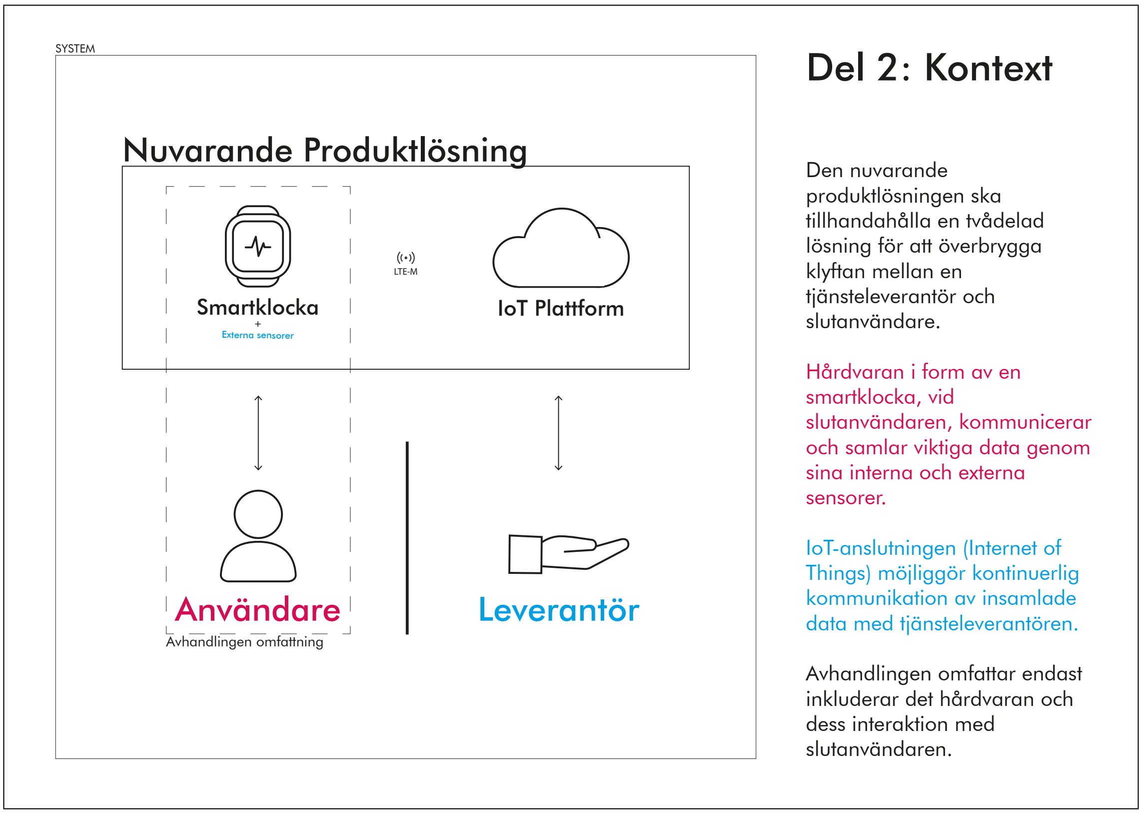


Figure E.2: *Part 2 of user study introduction. Author's own illustration, 2021.*

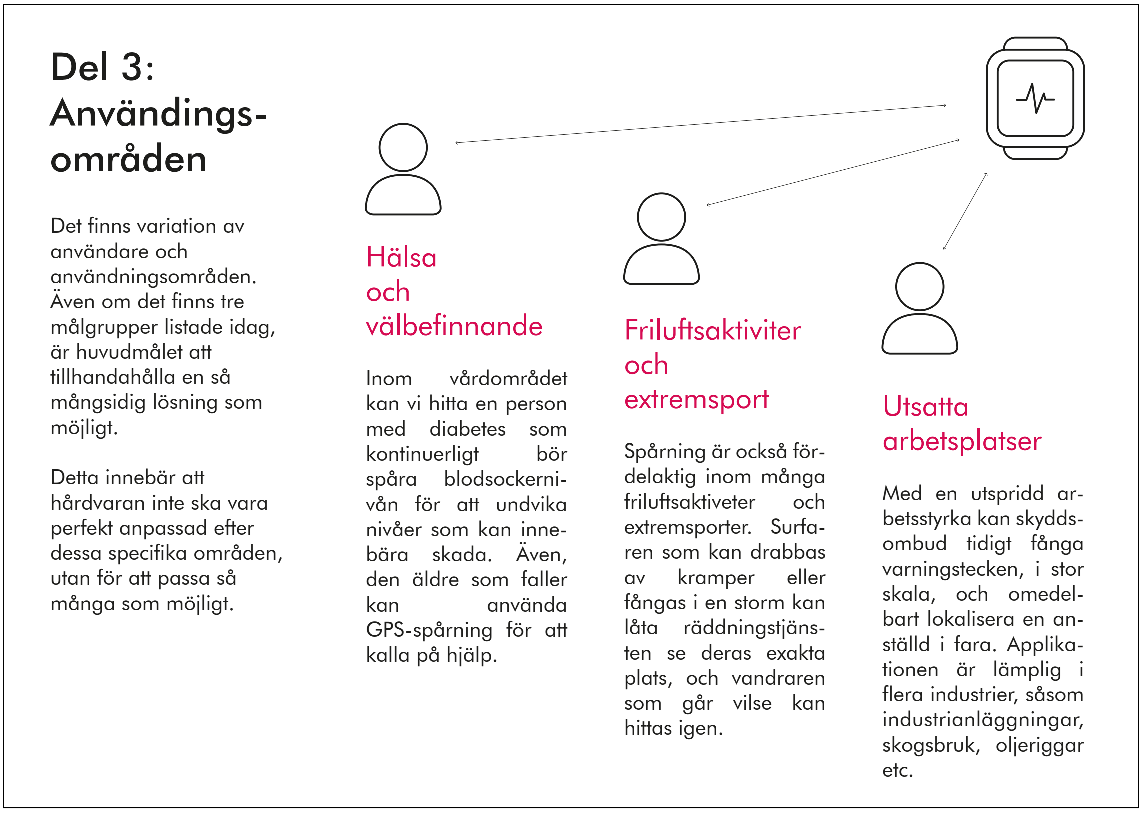


Figure E.3: *Part 3 of user study introduction. Author's own illustration, 2021.*

F

User Study: Question Form

På grund av viss problematik i monteringen av konceptet med den runda formen, vill jag be dig att lägga denna modell med vänster hand. Lägg höger tumme och testa att vrida med denna fram och tillbaka.

0. **Kan detta göras utan motstånd? (Kalibrering)**
   Är du höger eller vänsterhänt?

Denna ring ska i själva verket ha ett fast utgångsläge i mitten av de två ändlägena, och lätt fjädra tillbaka till detta utgångsläge. (Förklaring till brist i ring) Då kan du lägga de båda modellerna framför dig. Du får gärna känna på dem.

1. **Först, helt fritt, har du några första intryck att dela med dig av?**
2. **Med den kunskap du har om hur produkten ska användas, vilken påminner mest om vad du hade förväntat dig? (3.4)**
3. **Om du skulle köpa en av dessa enheter i butik, vilken skulle du anta vara dyrare? (3.1)**
4. **Som de ser ut idag, vilken hade varit troligast att du dagligen hade burit, om du tvunget skulle välja en? (3.2, 3.-)**
   b) Varför?

Nu kommer jag be dig att sätta på en av klockorna. Välj fritt.

5. **Vilken har du på dig?**

Jag kommer be dig att knappa in följande sekvens. Referera till rubrik ”Knapplayout”. Det är igen fara om du skulle råka trycka på del knapp, bara följ med så gott du kan När du har knappat in sekvensen, låt din hand vila kvar på klockan.

Fyrkantig: K1, K3, K4, K5. Rund: R1, R2, R4, R5

6. **Om vi nu ser i PDFen, under rubrik ”Handplacering”. Vilka positioner har de fingrar som du använde mot klockan just nu. Ex. lillfinger klockan 9. (Konfirmera handplacering)**
7. **Vi testar igen, en knapp åt gången. Vilket finger använder du till respektive knapp. (Konfirmera handplacering)**
8. **Upplevde du att någon knapp var obekvämt att nå. Vilken? (6.2)**
9. **Kände du någon gång sträckningar i handleden? (6.2)**

Då byter vi klocka.

10. **Om vi nu ser i PDFen, under rubrik ”Handplacering”. Vilka positioner har de fingrar som du använde mot klockan just nu. Ex. lillfinger klockan 9.**
11. **Vi testar igen, en knapp åt gången. Vilket finger använder du till respektive knapp.**
12. **Upplevde du att någon knapp var obekvämt att nå. Vilken?**
13. **Kände du någon gång sträckningar i handleden?**

Nu när vi testat de båda klockarna:

14. **Vilken föredrar du att interagera med? Kan vara att den känns mest naturlig, etc. (6.3)**
15. **Om du under några omständigheter använder handskar, i arbete eller andra aktivitet. Föreställ att du har dessa på dig, skulle du välja annorlunda då? (6.2)**
16. **Vilken skulle du anse bekvämast? (5.5)**
17. **Har du avslutningsvis några synpunkter du vill dela med dig av?**

Figure F.1: *Form used during interviews in user testing. In parenthesis are references to corresponding criteria in Specification of Product. Author's own illustration, 2021.*

G

User Study: Answers

Parti.	Q2	Q3	Q4	Q5	Conf, rund	Conf, fyrkant	Finger, rund	Finger, fyrkant	Reach, rund:	Reach, fyrkant	Q14	Q15	Q16
A	Fyrkant.	Rund.	Fyrkant.	Rund.	Ja.	Ja.	Ja.	Ja.	Nödknapp.	Ingen.	Rund.	Rund.	Lika.
B	Fyrkant	Fyrkant	Fyrkant.	Fyrkant.	Delvis.	Delvis.	Delvis.	Delvis.	Nödknapp.	Nödknapp.	Fyrkant	Fyrkant	Lika.
C	Fyrkant	Fyrkant	Rund. U	Rund.	Ja.	Delvis.	Ja.	Ja.	Ingen.	K5. Sträckning.	Rund.	Rund.	Rund.
D	Rund	Fyrkant.	Rund. Ti	Rund.	Ja.	Ja.	Ja.	Ja.	Nödknapp.	Nödknapp + K1.	Rund.	Rund.	Lika.
F	Fyrkant	Fyrkant	Fyrkant	Rund.	Ja.	Ja.	Delvis.	Ja.	R5.	Nödknapp.	Fyrkant	Fyrkant	Fyrkant
G	Fyrkant	Rund	Rund. F	Rund.	Ja.	Ja.	Ja.	Ja.	Ingen.	Nödknapp.	Rund	Rund	Lika

	Q1
A	Föredrar den fyrkantiga formen, då skärmen känns stor och tydlig.
B	Ganska stora, men bra med tydlig skärm. Känns användarvänligt.
C	Displayer är stora, ev. för stora. Fykantig lite mer klumpig, även för många knappar.
D	Den runda tilltalar mest. Påminner om klockor i vattensport. Passar även in i vården. Trivs med stor display.
F	Klassisk smartklocka. Robusta, tåliga.
G	Ser bra ut. Fräck funktion, med ringen. Vettig båda två.

	Q17
A	Ser värde med ringen, om det finns konkret nytta. Det är främst uttrycket, med den olikfärgade ringen som besvärar.
B	Knapparna hamnar lite i skymundan på runda, känns som är svårare navigera utan att se på.
C	-
D	Stora siffor. Hög ljusstyrka. Vattentät. Stöttålig. Klara färger. GPS.
F	Borde vara större knappar, för lättare att komma åt. Och mindre markerade kanter på klockan, så den ej fastnar.
G	-

Figure G.1: *User Study Results. Author's own illustration, 2021.*

H

Expert Study: Instructions

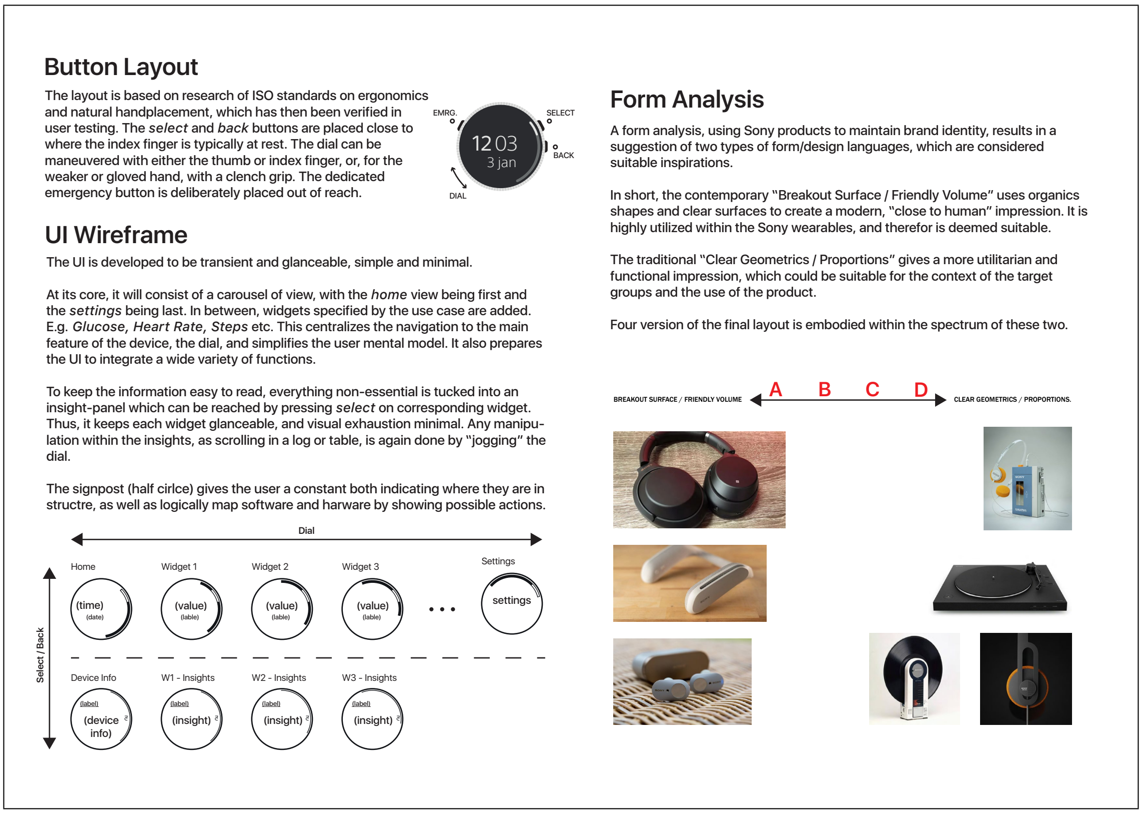


Figure H.1: *Expert Study, instructions, part 1. Author's own illustration, 2021.*

Renderings

Notice:
- The UI signpost (half-circle) should match up with the *select* button for each concept, as in A.
- The dial is interchangeable, meaning each concept will have further variability in expression.
- The 5th model in the box with gray buttons, not shown in the images, is an older "functional" mock up. The dial should spring back to a mid-point.

Feedback

If you are not meeting with me in the following weeks:

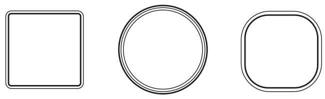
Feel free to leave any comment and impressions in the attached notebook, which could help in making a decision moving forward.

- First impression?
- Which do you prefer, or see as most suitable?
- A feature you like/do not like?

Figure H.2: *Expert Study, instructions, part 2. Author's own illustration, 2021.*

I

Pugh 1



Criteria		Value	Concept		
1. Physical Functionality			A	B	C
1.4	Monochromatic Display	**2**	-	-	-
1.5	Low Mechanical Complexity	**1**	4	1	3
3. Aesthetic					
3.1	Express Character	2	2	2	2
3.2	Express Identity	**2**	2	3	3
3.3	Express Functionality	**3**	3	4	2
3.4	Please Aesthetically	**1**	2	2	3
3.5	Premium Expression	**1**	2	3	3
3.6	Adaptable Expression	**3**	1	5	3
4. IxD					
4.9	Low Interface Complexity	**4**	-	-	-
5. Body Attachment					
5.5	Comfortable to Wear	**5**	2	3	4
6. Design for All + User Friendly					
6.1	Comfortable to Manipulate	**5**	4	4	2
6.2	Intuitive Interaction	**5**	3	4	2
6.3	Mistake Forgiveness	**4**	-	-	-
6.4	High Readability	**3**	5	3	4

Figure I.1: *Pugh matrix evaluation 1. Author's own illustration, 2021.*

J

Pugh 2

Criteria		Value	Concept	
1. Physical Functionality			Square	Round
1.4	Monochromatic Display	**2**	-	-
1.5	Low Mechanical Complexity	**1**	4	1
3. Aesthetic				
3.1	Express Character	2	3	3
3.2	Express Identity	**2**	2	3
3.3	Express Functionality	**3**	4	2
3.4	Please Aesthetically	**1**	3	3
3.5	Premium Expression	**1**	4	2
3.6	Adaptable Expression	**3**	1	5
4. IxD				
4.9	Low Interface Complexity	**4**	-	-
5. Body Attachment				
5.5	Comfortable to Wear	**5**	3	3
6. Design for All + User Friendly				
6.1	Comfortable to Manipulate	**5**	2	4
6.2	Intuitive Interaction	**5**	2	4
6.3	Mistake Forgiveness	**4**	-	-
6.4	High Readability	**3**	3	3

Figure J.1: *Pugh matrix evaluation 2. Author's own illustration, 2021.*