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DAIAD@know Prototypes

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Abstract

This report presents the design and implementation of the *Prototype Deliverable D3.4.2 "DAIAD@know Prototypes"*, i.e., the updated and final versions of the DAIAD@know prototypes, integrating improvements derived from our Trials feedback and evaluation, as well as the ongoing research and development work of T3.1-3.

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Executive Summary

This report presents the design of the localized and deferred feedback *Prototype Deliverable D3.4.2 "DAIAD@know Prototypes"*, i.e., the updated and final versions of the DAIAD@know prototypes, integrating improvements derived from our Trials feedback and evaluation, as well as the insights resulting from Task 3.1 *"Design studies"*, Task 3.2 *"Sustainability Dashboard"* and Task 3.3 *"Localized feedback and stimuli"*.

Insights from the literature and past user studies provide a congruent picture of an archetypical feedback designs which we implemented within DAIAD@know. We evaluated these feedback designs in different settings during the project and included quantitative and qualitative feedback into the finalization process of our prototypes. Our goal had been to combine informative elements with nudging features in order to reach *persistent* saving effects and a *rewarding* user experience.

The final prototype of the in situ-feedback in the shower consists of timely, informative feedback with a small number of components that further motivate and guide saving efforts. We operationalized the feedback that is described in this deliverable as follows. Numerical, real-time feedback is displayed while the shower is in progress, serving as a key element to address *salience* by informing users in a plain and easy to memorize way. The feedback is extended by an efficiency rating from A to G that serves as *injunctive normative feedback* and provides an *anchor point* for performance evaluation. A polar bear animation that is coupled to the efficiency rating adds an *emotional*, "sweet" note that also considerably increases the *recall value* of the product. We also included *goal-setting* as a means to direct saving efforts and to increase the competition "against oneself". The conservative modifications are justified as the current "*best in class feedback*" seems to be near-optimal; in fact, no study has been published to date that showed stronger savings.

Finally, within the project we also started to investigate the possibility and feasibility of using a *novel localized feedback instrument*. Specifically, we studied the potential of *smartwatches* as an additional DAIAD@know component, as they can increase the salience of feedback information. We have focused on the Apple Watch (*market share of 45% [Go16]*) due to its very recent technical evolution (new OS version) that allows the connectivity with the b1 BT radio.

Abbreviations and Acronyms

kWh	Kilowatt hours
LCD	Liquid Crystal Display
OS	Operating System
UI	User Interface

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1. Final DAIAD@know prototype

1.1. Stimuli selection

In this section, we briefly outline the reasoning for selecting the feedback stimuli and interfaces of DAIAD@know. For the final localized feedback artifact, we took into consideration results from our DAIAD Trials, additional large-scale studies, as well as experiences from previous studies.

First, in the online survey of our Design Studies (n=215)[1], the post-experimental survey of the additional study in the Netherlands (n=547)[2], as well as the post-experimental survey for the DAIAD Trials (n=15+54)[3] we learned that individuals are generally more than satisfied with the current design of the localized DAIAD@know. Study participants and online survey participants agree that the information shown on the b1 is **simple, practical, interesting, and easy to read as well as easy to comprehend**. Also, in comparison to the deferred feedback, the conservation behavior and appeal to the trial participants is significantly larger[4]. Additionally, as we learned, the usage of the feedback device induces very often an intuitive goal setting behavior. We want to enhance this behavior and help others to engage into a goal-directed conservation behavior while using the localized feedback artifact. For that reason, we added a fixed goal[5].

So, we chose to include another nudging feature to the informative information that is already shown on the in-situ feedback display. Thus, the major components of the finalized localized feedback prototype include the following components/concepts:

(i) Real-time feedback: Addressing the salience bias is an extremely effective tool to support and motivate a target behavior [TT+16]. A previous pre-study has shown that feedback that is delivered during the action is considerably more effective than feedback that is delivered immediately when the resource-consuming behavior is finished. We have thus rejected the simpler to implement ex-post feedback in favor of feedback that is already delivered when the shower is ongoing. The numerical feedback consists of information on volume in liters during the shower. After the shower, when the flow has stopped, the display alternates between water consumption in liters and energy consumption in kWh.

(ii) Injunctive normative feedback: A rating is provided from A to G that serves as an anchor for the users. This feedback has been shown to reduce the magnetic effects to the middle (as it would occur for descriptive normative feedback alone) and is thus to be preferred over comparisons to the average.

[1] More information about the Design Studies can be found in D3.1.2 "*Updated Design Studies*"

[2] More information about additional study in the Netherlands can be found in D7.3 "*Trials Evaluation and Social Experiment Results*"

[3] More information about the Trials can be found in D7.1 "Trial A Report", D7.2 "Trial B Report" and D7.3 "*Trials Evaluation and Social Experiment Results*"

[4] More information about the water consumption data analysis can be found in in D7.3 "*Trials Evaluation and Social Experiment Results*". This is due to the increased visibility which limits notably the salience bias.

[5] More information about the comparison of fixed and tailored goals can be found in D3.3.1 "*Localized feedback artifact for Trials*"

(iii) Metaphorical representation of normative feedback: The normative feedback is coupled to a pictogram of a polar bear that sits on an ice shell that melts with growing consumption. It has no additional information content over the efficiency ratings, yet interviews have shown that it increases the emotional binding between many users and the device and increases the recognition value of the device.

(iv) Goal: A fixed-goal of 25l is shown on the device's display in combination with the current volume of water used for the shower. It is supposed to guide intuitive conservation behavior.

(v) Add-on information for increased comfort: Add-on information is limited to water temperature that is only shown during the water is flowing. It is unlikely to reduce consumption, yet it an often-demanded feature among users. This, it was included to increase user acceptance and adoption.

1.2. Final DAIAD@Know Prototype

1.2.1. The LC Display Implementation

The table below outlines the interfaces of the final localized feedback prototype which were implemented as suggested by the input from D3.1.2 "*Design Studies*" and D3.3.2 "*Updated Localized Feedback Artifacts*.

The first LCD implementation (0-Pairing Process) shows the code that is triggered by the application to establish the pairing between the DAIAD@feel sensor with the DAIAD@know system component. Section 1.2.2 explains in detail the different steps taken during pairing.

The next LCD implementations (1-Baseline and control group) show possible interfaces that can be used for further studies or experiments for baseline measurements or control groups in experimental settings (with no actionable information to observe usual behavior). These views must be activated with the help of the mobile application.

The standard DAIAD@know localized feedback shows the display settings number 2 to 6. Three display configurations toggle while water is running through the device and another two configurations are shown when the water flow stops until all harvested energy from the shower is depleted.

No	Brief description	Display setting	Explanation
0	Pairing process		What is shown: A unique paring key consisting of four characters on the 16-segment display plus a number between 0 and 1999 on the 7-segment display. It allows for 663 million different keys, what, for shower data, should be sufficient. Moving text or alternating text for longer keys have been ruled out for the sake of better usability. When is it shown: After detecting a pairing command from a smart phone via Bluetooth 4.0 or after turning off the water before one liter has passed the device. It is shown for about 1 minute.
1	Baseline and control group		What is shown: Only temperature is shown (in degrees Celsius), but no consumption feedback is given. Leaving the entire display blank may completely remove the value for the test users and would increase the likelihood of incompliant behavior. When is it shown: In the treatment group, during the first 10 showers. In the control group, temperature is shown during the entire experiment.
			What is shown: As another possibility, we can also set off the complete display, how it was used as baseline (phase 1) configuration during the DAIAD Trials.

No	Brief description	Display setting	Explanation
2	Feedback mode, water running, phase 1		What is shown: Water volume in liters in the large 7-segment display with one decimal. The update frequency is about 1.7 Hz at normal flow, which induces a sufficient level of "urgency". Additionally, a fixed goal "25L" in the 16-segment display part is shown to make it comparable to the current consumption. When is it shown: When water is flowing, for one third of the time alternating in 3-second intervals with 3 and 4. If applied in an experimental setting: never activated in the control group. Alternatively: The goal can be changed with the mobile application.
3	Feedback mode, water running, phase 2		What is shown: Water volume as in 2. Temperature information is shown on the 16-segment display. The polar bear is shown with the shell size corresponding to the efficiency level A to F; for G, the bear disappears. When is it shown: When water is flowing, for one third of the time alternating in 3-second intervals with 2 and 4. If applied in an experimental setting: never activated in the control group.
4	Feedback mode, water running, phase 3		What is shown: Water volume as in 2. Efficiency class from level A to G is shown on the 16-segment display. The polar bear is shown with the shell size corresponding to the efficiency level A to F; for G, the bear disappears. When is it shown: When water is flowing, for one third of the time alternating in 3-second intervals with 2 and 3. If applied in an experimental setting: never activated in the control group.

No	Brief description	Display setting	Explanation
5	Feedback mode, water off, phase 1		What is shown: Energy consumption contained in the water assuming a T_0=10°C and an average efficiency rating of the water heating system. The unit is Wh or kWh. Efficiency class from level A to G is shown on the 16-segment display. The polar bear is shown with the shell size corresponding to the efficiency level A to F; for G, the bear disappears. When is it shown: When water is not flowing, for 50% of the time alternating in 3-second intervals with 6. If applied in an experimental setting: never activated in the control group.
6	Feedback mode, water off, phase 2		What is shown: Water volume as in 2 (yet, the total volume of water for the last shower). Efficiency class from level A to G is shown on the 16-segment display. The polar bear is shown with the shell size corresponding to the efficiency level A to F; for G, the bear disappears. When is it shown: When water is not flowing, for 50% of the time alternating in 3-second intervals with 5. If applied in an experimental setting: never activated in the control group.

Further design issues are as follows (the design is subject to the feasibility given the highly specialized embedded system in amphiro b1):

- The display stays on for about 2 minutes after the flow has stopped to allow for revisiting the information.
- Shower extractions are concatenated (i.e., summed up) if they occur within a time window of less than 2 minutes.
- Showers that are started more than two minutes after the most recent shower are counted as new showers.
- More phases (e.g., also showing energy during water is running) led to information overload in a usability test and was rejected in favor of better ease of use.

The amphiro b1 also offers other possible display configurations (e.g., monetary information, carbon dioxide emission information, or flow rate) as outlined in more detail in chapter 3 in D3.3.2 "*Updated Localized Feedback Artifact*" which can be used in future settings.

1.2.2. Pairing Process

The first connection of the DAIAD@feel sensor and the DAIAD@know localized feedback with the rest of the DAIAD system requires a pairing process.

Figure 1 shows how the pairing is initiated. In the settings section of the DAIAD app, the user selects the pairing function and brings the smartphone in the Bluetooth range of the (running) amphiro b1. Then the user initializes the pairing with the button "Add a new device" (Figure 2). In the case Bluetooth is not yet activated, the application activates the Bluetooth module (Figure 3) and the user can proceed to the device searching process (Figure 4). At every step, textual explanations help the user to understand what is happening and what she should do. In this case, for example, the application explains that the user shall turn on the water for setting the b1 in an operational mode to proceed with the connection.

When the application has found the localized feedback artifact, the screen of the application explains that the user must enter the code displayed on the localized feedback artifact. In order to increase usability, the entering field of the 8-digit code imitates the visualization on the localized feedback device and explains with an exemplary image which code section (code 1 from the upper part and code 2 from the lower part of the localized feedback device) has to be entered in which field of the application (Figure 5, Figure 6). After having inserted the correct code, the pairing was successful and the user can rename the localized feedback device to distinguish multiple installed sensors (Figure 7).

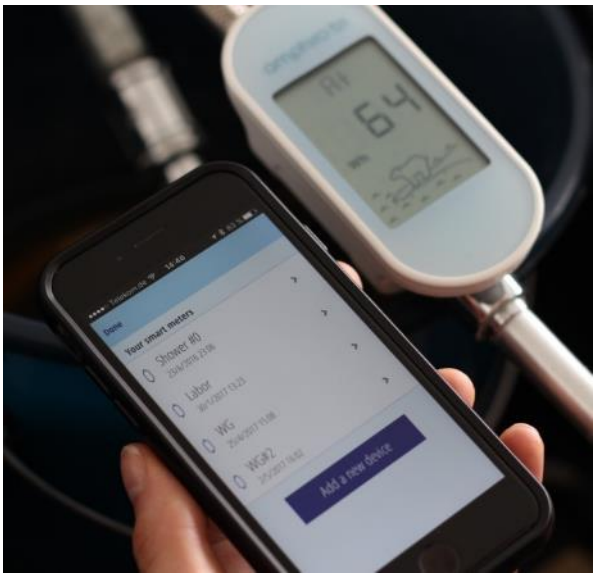

Figure 1: For pairing, the mobile device must be held within Bluetooth range to connect to the amphiro b1

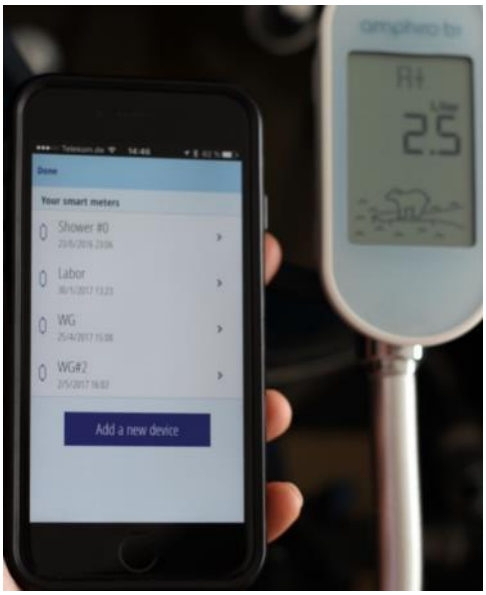

Figure 2: The DAIAD app allows to add and connect several shower sensors

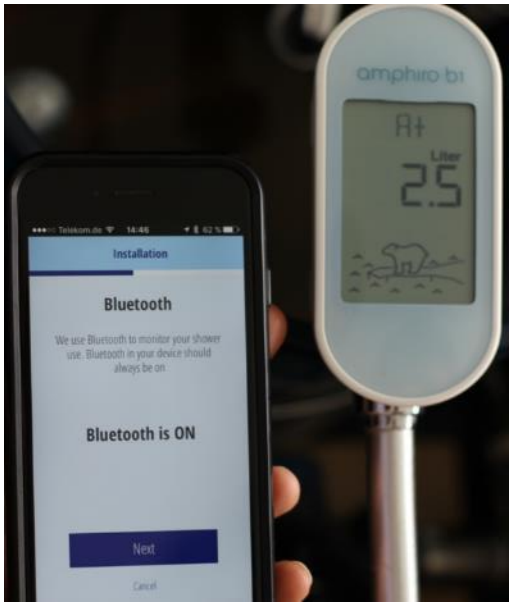

Figure 3: The user is reminded to always keep Bluetooth on

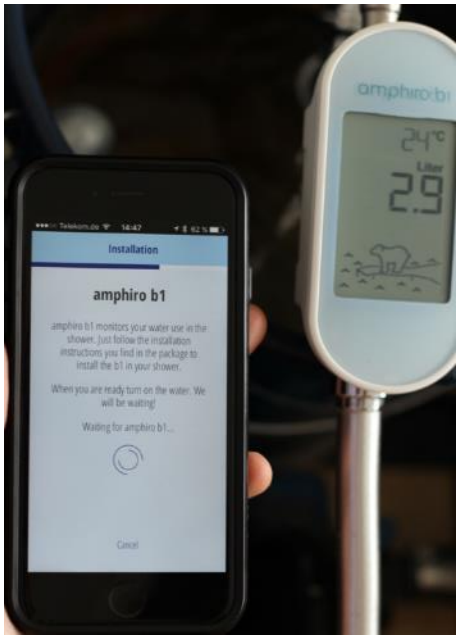

Figure 4: The app waits for the shower meter's Bluetooth signal

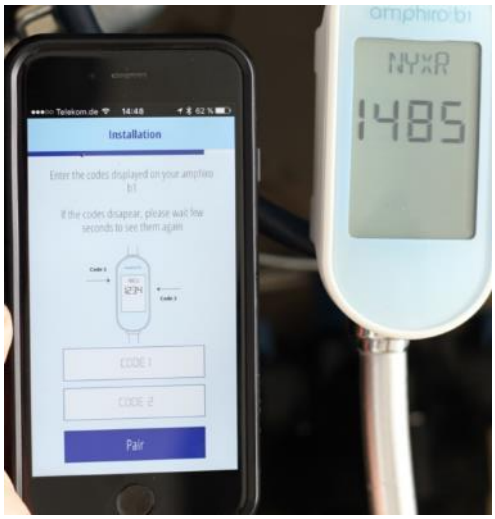

Figure 5: Once a Bluetooth connection was found, the amphiro b1 shows a pairing code.

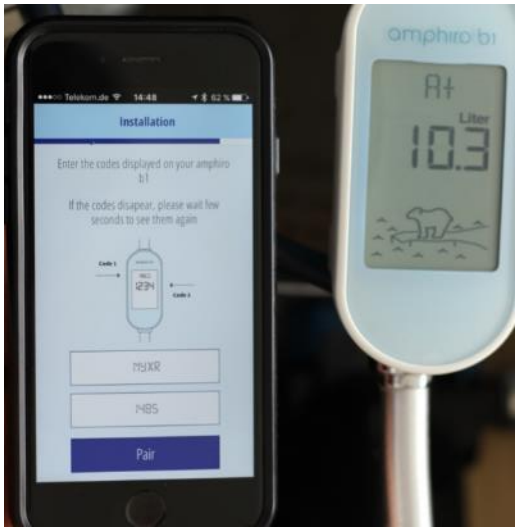

Figure 6: The pairing code has to be entered in the app to complete the pairing process.

Figure 7: As a last step, the user can assign a name to the newly added device.

2. Localized feedback via the Apple Watch

Nowadays, more and more technologies for private consumers are developed and appear on the market. From pedometers and wristbands, to smart home technologies. Worldwide, the sales of wearables are forecasted to increase by 60% between 2015 and 2016 (from 75 million sold devices to 125 sold devices [Sta17]). In Germany, over 20% individuals track personal data in at least one area [Spl16]. So, there is a noticeable trend that might be interesting for bringing consumption feedback and energy awareness to households. On the one hand, such devices provided new possibilities of user interactions and feedback. On the other hand, a plethora of new requirements apply. Technical aspects (such as battery usage, screen size, limited computing capacity) and structural issues (navigation, gestures and interactions, privacy, design) must be taken into consideration [Se16, Dev16a, LQ13, CDT12, Di14, Bl14, Dev16b, Dev16c, Ri15, Pa13, Dev17, Su17].

During the DAIAD project we evaluated several with emerging technologies to investigate possible new localized feedback means for the DAIAD@know component, with emphasis on the *wearable mobile device* market, as it consists and *ideal interface* for delivering *always available real-time feedback at the point of consumption*. However, the capabilities of smart watches (Android, Apple, proprietary) were significantly lacking throughout the duration of the project, and rapidly improved during the final 12 months, with several *waterproof* smartwatches becoming available, and only very recently providing the required access to the full Bluetooth stack required for connection with the amphiro b1 device. Specifically, Apple watchOS 4 (*announced M40, 5th June 2017*) supports the CoreBluetooth API required to communicate with the amphiro b1, and with the Apple Watch Series 2 (*available since mid-2016*) already waterproof, we finally had the opportunity of harnessing the Apple Watch as a DAIAD@know localized interface, and actually rapidly developing a prototype application in the context of WP4.

In this context, we focused on providing a clear outlook for what can be achieved after the DAIAD project for further steps of the going-to-market phase. We first intensively researched the Apple Guidelines and literature for developing an Apple Watch App (see Appendix 1), best practices, and psychological aspects for feedback information. In the following, we prepared four major use cases: the opening of an existing application on the smart watch, a notification informing the user of a goal, a notification informing the user about new shower data that has been transferred from the amphiro b1 to the server, a notification in case that the last connection between the mobile application, and the b1 was a long time ago combined with the last use case where the user initializes this connection.

The corresponding use case diagram (Figure 8) visualize the expected behavior of the Apple Watch app and illustrates the interaction of the user with the system. The use cases and actors are depicted with their respective dependencies and relationships, and is divided by three system limits: The watchOS app, the smartphone iOS app (DAIAD & amphiro b1 connect) and the amphiro b1. The use cases shown in green of the watchOS app use data of already existing functions of the amphiro b1 and the smartphone app. The existing functional scope is expanded by the use cases marked in red. The actor (shown on the left) interacts with the smartphone or the Apple Watch by opening the app or receiving a notification.

After opening the application, the user gains insights on historical consumption, comparisons with other users, and general information on the last shower. The information can be highlighted in an alarming color in case that the consumption was rather high (or positive reinforcement in the case of conservations). This function corresponds to the concept of *lightweight push* which calls for a balance between Push and Pull information [FC+09, BS78]. In this sense, besides of the information available on pull (when opening the application), the user is also enabled to receive notifications on push. With the goal to avoid too much information overload, the number and the triggers of notifications are limited.

The diagram shows five different types of notifications (remind to update data / show status of amortization / remind to update goal / visualize weekly report / inform about new data). After the watchOS app is opened, it is possible to call up seven different use cases (visualize cold shower challenge / set a goal / visualize weekly report / visualize a ranking of household members / visualizes average shower consumption / visualize efficiency / visualize historic shower data), which in turn are extended by further sub functions through extend relationships. Include relationships allow access to contained use cases. For example, it is possible to allocate a person to a shower from the historical shower data and to store the value into the database.

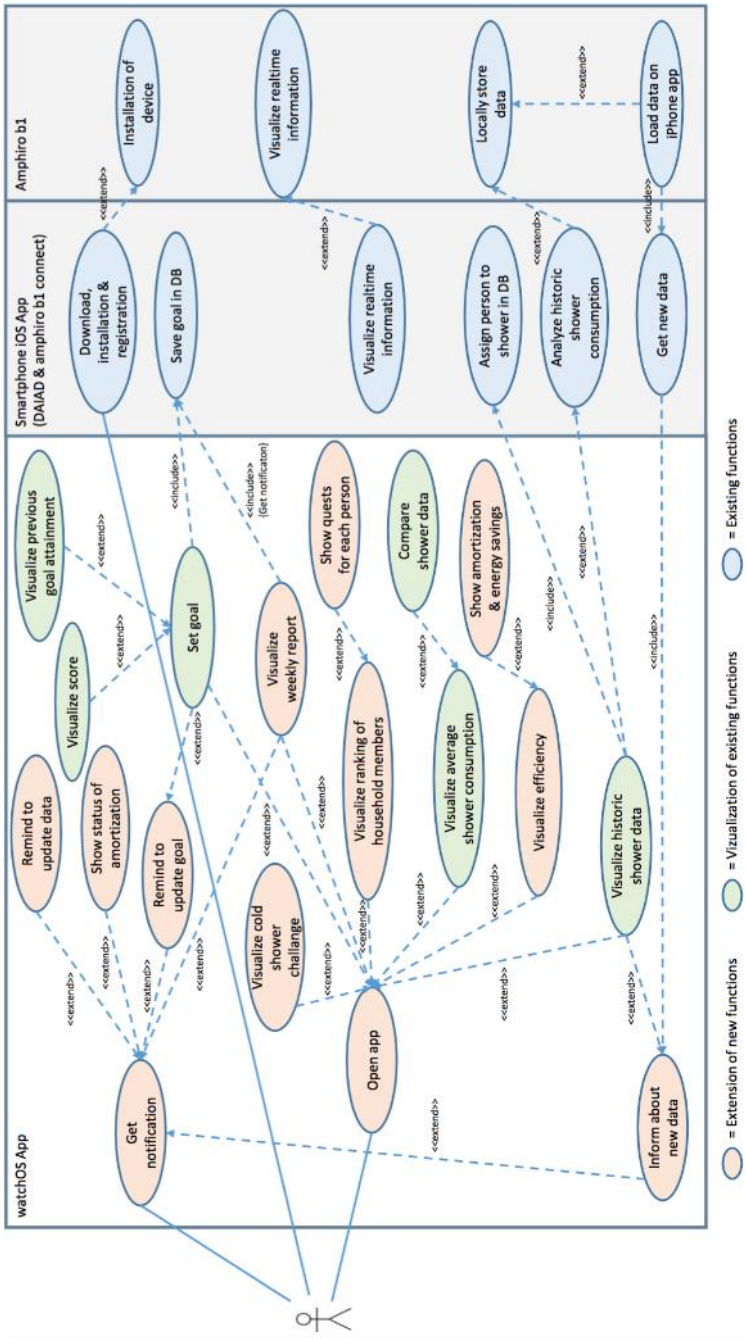

Figure 8: Use Case Identifications from Florian Ott

3. Appendix

3.1. Appendix 1: Design Principles of the Apple Watch

3.1.1. Components

Complications [FH95, Dev16]: as already described in previous deliverables, one major concept of the Apple Watch is based on complications, also called shortcuts for additional information already displaying usable information (such as temperature, weather, time).

Notifications [Dev16, Ca15, Si15]: Notifications represent another component. They can be received by the user without searching (in a bag, in a room, etc.) and checking the smartphone screen. This element increases significantly salience, which is vital for consumption feedback. Notifications are only sent to the Apple Watch, when the smartphone is not actively used. They can be triggered by an iOS app, the WatchKit extension, or a server-side command. It is relevant to decide the notification type when implementing one to be sure that it reaches the user in the right moment. Apple offers a two-step notification. First, the user sees a notification in the *short look* view (extremely condensed information). Second, when keeping the user's arm in a certain position or touching the *short look* notification the *long look* view is triggered and more information or user interaction is offered.

Watch Apps [Dev16]: They can be linked with an iOS App with the help of the *Connectivity Frameworks*. Also, data transfer is supported. They represent a complement and not a copy of the iOS app or an independent application. This insight is very important when developing use cases.

Glances/Dock [Mc16]: So-called Glances make information quickly available for a user via an additional overview. The new concept of Docks replaces the concept of Glances. First, the Dock provides condensed information for activated Apple Watch apps. Second, it helps to switch between different Apple Watch Apps. It resembles to a program manager.

3.1.2. User Interface Elements [Si15]

The following Table depicts the major UI elements that can be used for developing and designing an Apple Watch App.

Buttons	• To perform actions triggered by the user • Include texts or images
Images	• Elements visualizing images or animations • PNG format is preferred
Labels	• Labels represent text within an Apple Watch App • Varies from a word to multiple rows • Color, size, and font can be set
Groups	• They structure elements and labels

	• Attributes help to specify position and size of groups • All elements in a group have the same horizontal and vertical orientation
Maps	• Realize geographic maps • Not interactive within the Apple Watch application
Movies	• Realize visualizations and playing video data
Pickers	• Realize a list of selections • Selection happens via the watch crown
Separators	• Separators help to distinguish content • Only color can be changed
Switches	• Has a unique state (on/off) • User can change the state by touching or swiping (transferrable to translate a yes/no reaction) • Further information about the switch can be added close to the switch
Sliders	• Settings can be changed by touching the display (example: sound volume tuning for the iTunes App)
Tables	• Represent content and other elements in a table form • Only one column is possible • Configured as dynamic
Timers	• Can start and end a timer (shown by a label)

Table 1. Overview of the User Interface Elements of the Apple Watch According to [Si15]

3.2. Appendix 2 – Possible User Interfaces

The first set of interfaces is shown in Figure 10 and Figure 9. Figure 10 focuses on showing the interfaces in combination with the interaction of the user who can swipe between major functions and scroll within the functions. Another possibility to interact with the application is clicking on a button or element to get detailed information.

Figure 9 focuses on showing the complete information for each function. First, the mockup shows historical information about a set of showers to the user. The major sections/columns represent the use cases described above. When starting the application, the user first sees a list of the last ten showers with additional information (shower ID, who showered, volume of water used, temperature, and the energy efficiency class). By swiping the second section appears: the user sees aggregated information on the average volume of consumption, average temperature, and average duration of all showers registered with the amphiro b1. Additionally, the user can compare her consumption with all amphiro b1 users and the most efficient ones. Third, the next section displays information on the efficiency of the shower behavior (visualizing the number showers according to their efficiency grading and savings in term of energy and water). Fourth, a goalsetting function is integrated. The user can set a water consumption goal and she is informed how many times all amphiro b1 users kept their consumption beyond the goal. A small diagram with the last ten showers and the goal (or better called budget or limit) is indicated with a line. This section

also includes game-like elements: awards. Fifth, a ranking between all amphiro b1 users of a household is established. Finally, the last section shows tasks for each household members using the amphiro b1. These tasks are personalized saving tips.

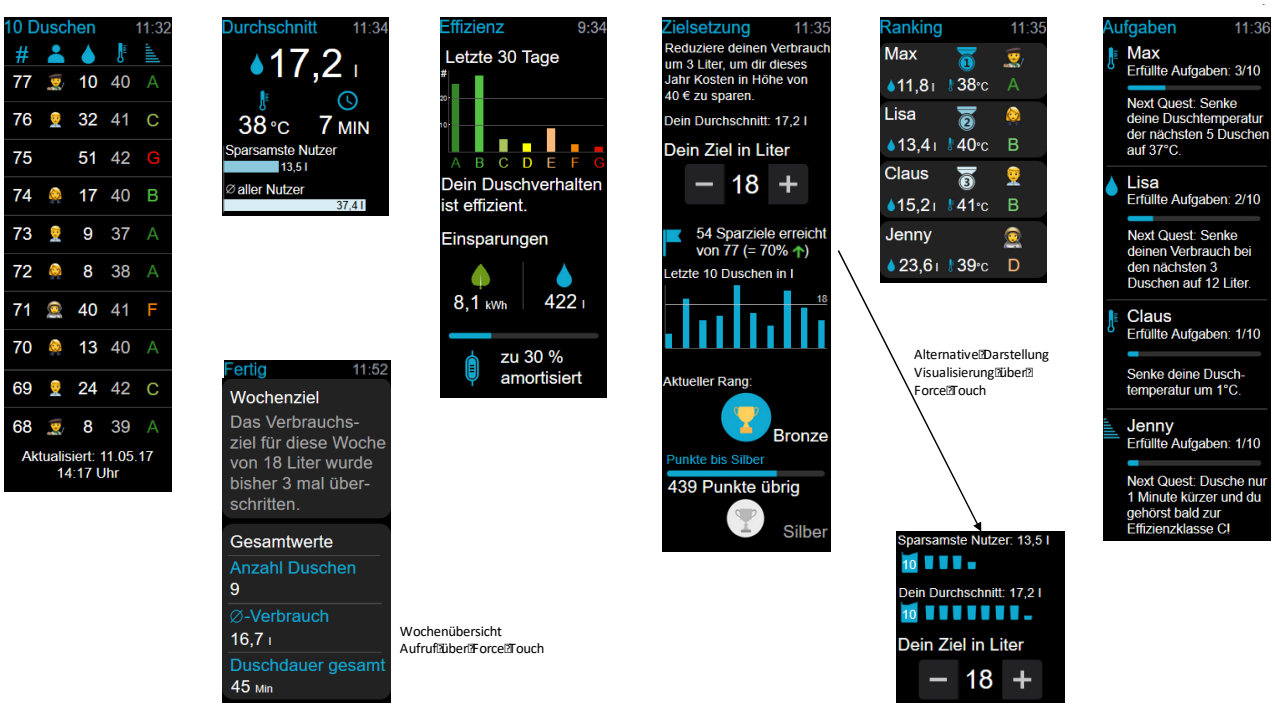

Figure 9: Mockup of possible UIs for the Apple Watch

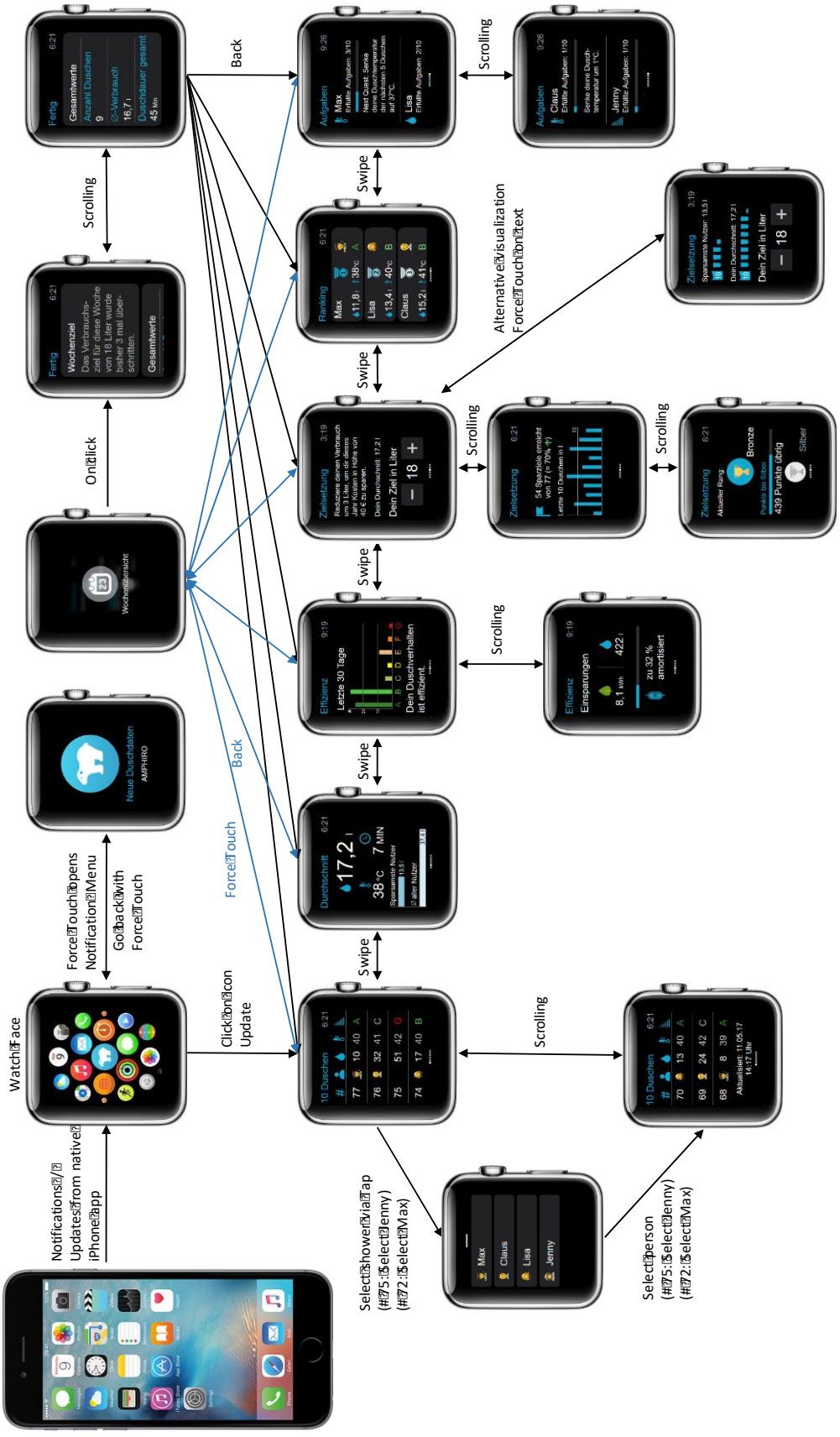

Figure 10: Mockup of possible UIs for the Apple Watch

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