REPORT ON DELIVERABLE 3.4.1

DAIAD@know Prototypes for Trials

PROJECT NUMBER: 619186
START DATE OF PROJECT: 01/03/2014
DURATION: 42 months

DAIAD is a research project funded by European Commission's 7th Framework Programme.

Dissemination Level	Public
Due Date of Deliverable	Month 23, 31/01/2016
Actual Submission Date	22/01/2016
Work Package	WP3 Water Consumption Interfaces
Task	Task 3.4 DAIAD@know prototypes
Type	Prototype
Approval Status	Submitted for approval
Version	1.1
Number of Pages	19
Filename	D3.4.1_DAIAD@know_prototypes_for_trials.pdf

Abstract

This report presents the design and implementation of the *Prototype Deliverable D3.4.1 "DAIAD@know Prototypes for Trials"* which will be used to deliver localized, actionable information and stimuli to consumers for their water consumption in the context of the DAIAD project. The document outlines the changes in the LCD which where tested in a design study.

History

version	date	reason	revised by
0.1	8/01/2016	First draft	Thorsten Staake
0.2	11/01/2016	Revisions and improvements in various Sections	Anna Kupfer
0.3	18/01/2016	Revisions and improvements in various Sections	Samuel Schöb
0.4	19/01/2016	Minor edits, addition of figures	Thomas Stiefmeier
1.0	22/01/2016	Final version	Spiros Athanasiou
1.1	29/06/2016	Revisions: design decisions, evaluation, and conclusion	Anna Kupfer, Samuel Schöb

Author list

organization	name	contact information
UNI BA	Anna Kupfer	anna.kupfer@uni-bamberg.de
UNI BA	Thorsten Staake	thorsten.staake@uni-bamberg.de
UNI BA	Samuel Schöb	samuel.schoeb@uni-bamberg.de
AMPHIRO	Thomas Stiefmeier	stiefmeier@amphiro.com
ATHENA RC	Spiros Athanasiou	spathan@imis.athena-innovation.gr

Executive Summary

This report presents the design of the localized feedback prototype DAIAD@know. The structure of the display follows the insights resulting from Task 3.1 "Design studies" and Task 3.3 "Localized feedback and stimuli".

The insights from the literature and the results from own empirical testing provide a congruent picture of an archetypical in-situ feedback design. It consists of timely, informative feedback with a small number of components that further motivate and guide the saving effort. We operationalized the feedback that is described in this deliverable as follows. Numerical, true real-time feedback that is displayed while the shower is in progress serves as a key measure to address salience by informing users in 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 did not include a within-household competition on the in-situ display, as a previous field study did not show stronger effects from the competition. However, we did include goal setting information as a means to direct saving efforts and to increase the competition "against oneself".

This said, the "informative elements" (that enable or support rational decision making) are given more weight than "nudging features" that appeal to changes partly outside the realm of conscious decision making. In this perspective, the in-situ feedback did not change much over the predecessor display, though different stimuli have been investigated. The conservative modifications are also justified as the current "best in class feedback" seems to be near-optimal – in fact, no other study has been published to date that showed stronger savings. Moreover, the moderate adjustments make it easier to track changes in the effect size back to the plethora of other new features that materialize in the accompanying apps and services.

Abbreviations and Acronyms

Hz	Hertz
kWh	Kilowatt hours
LCD	Liquid Crystal Display
PCB	Printed Circuit Board

Table of Contents

1. Introduction

This report presents the design and implementation of the *Prototype Deliverable D3.4.1 "DAIAD@know Prototypes for Trials"*. The DAIAD@know prototypes convey knowledge regarding water consumption at the fixture level in residential settings.

The remainder of the document is structured as follows:

In Section 2, we very briefly revisit the reasoning for selecting the feedback stimuli of choice that was discussed in detail in *Deliverable 3.1.1. Design Studies*.

In Section 3, we provide general technical information about the LC Display.

In Section 4, the LC Display of the localized feedback prototype is described for all stages of operation.

Section 5 depicts a roadmap for further evaluations after the Trials that will be discussed in detail in *Deliverable 3.1.2 Updated Design Studies*.

The proposed designs of the localized feedback display form the basis for the subsequent work to be carried out. It is subject to modifications and adjustments, if needed, depending on the learning from the trial and the cost-benefit evaluation of the potential advancements.

2. The DAIAD@know Prototypes for Trials

This section briefly outlines the reasoning for selecting the feedback stimuli of choice. The design decisions follow the results and insights obtained within the *Deliverable 3.1.1. Design Studies* from M7. The feedback stimuli therefore include (i) real-time feedback; (ii) injunctive normative feedback; (iii) a metaphorical representation of normative feedback; (iv) add-on information for increased comfort. As the display selection is dynamic (i.e., can show different information depending on the state of water flow), attention is paid to provide only information that is relevant for the actual state.

> (i) Real-time feedback: Addressing the salience bias is an extremely effective tool to support and motivate a target behavior. 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 is provided as numerical information (volume in liters) during the shower. After the shower, when the flow has stopped, the display alternates between water 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) and is thus to be preferred over comparisons to the average.
>
> (iii) Metaphorical representation of normative feedback: The normative feedback is coupled to a pictogram of a polar bear that sits on a 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) 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.

Further deliberate design choices include granularity at which the information is provided. The numerical feedback (volume in liters) is shown with one decimal. The decimal has virtually no informative value, yet it is changing rapidly at a normal flow rate (at 1.67 Hz) and thus suggests a sufficiently high level of urgency. The concept is related to “framing” that has shown to achieve strong effects in related studies.

Comparisons on a within-household level have been omitted for two strong reasons. First, it is likely to create negative feelings among those household members who tend to use more (and thus constantly loose). In a previous study, it does not led to stronger savings but to a “crowding out”, probably as under-performers began to rate water consumption as a not important target behavior. Moreover, it also appeared to trigger higher consumptions among efficient users as they are already wining with their current behavior.

3. Technical Aspects about the LCD

Physically the display is placed onto a carrier printed circuit board (PCB) via two rows of in total 32 through-hole pins (28 segment pins and 4 backplane pins) on the top and bottom of the display. The PCB (roughly the size of the display) offers enough space for the electronics including the host controller that is in control of driving the display. The host controller includes a hardware LCD driver module that can take care of the waveforms required for each of the 32 pins depending on the resulting segments state (on/off). In order to not damage or degrade the display during operation the waveforms are such that they alternate the polarity with which each segment is driven. Figure 1 shows an example waveform that is using two backplanes and Figure 2 shows the LCD driver module (taken from the host controller's official documentation).

We wanted to allow the display to be reconfigured at a later stage (e.g., to activate baseline mode in the trials or to change the intervention). However, we did not want to transfer the low level complexity onto a higher level and introduced the option to configure the display on a more content-based view. This not only makes it possible for the study designers to come up with display control features, but also made it possible to retain the configuration on the limited available memory of amphiro b1. We now have the option to change the display via the Bluetooth interface described in D2.3.1. We now have the option to toggle the display content up to four times at a configurable delay. Each toggle uses its own configuration to drive the display and each configuration is given by the tuple (see Figure 5):

- What is shown in top of the LCD? (e.g., temperature, string, efficiency, nothing, ...)
- What is shown in the middle of the LCD? (e.g., temperature, volume, energy, nothing, ...)
- What is shown in the bottom of the LCD? (e.g., bear, efficiency, waves, ice and bear, nothing, ...)

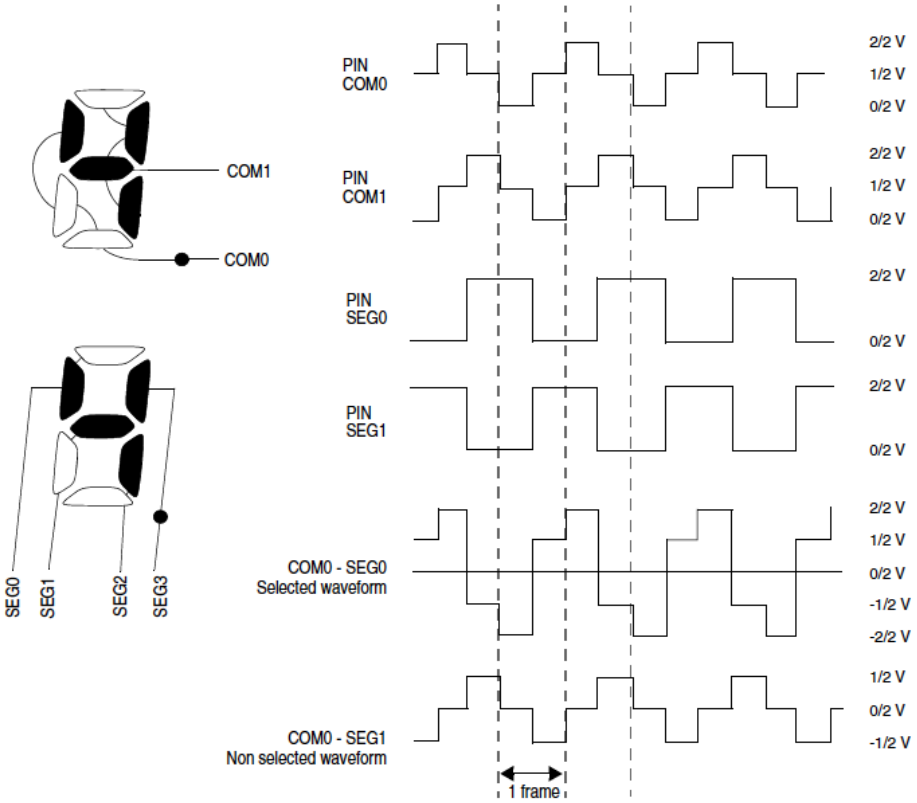

Figure 1: Display steering control signals

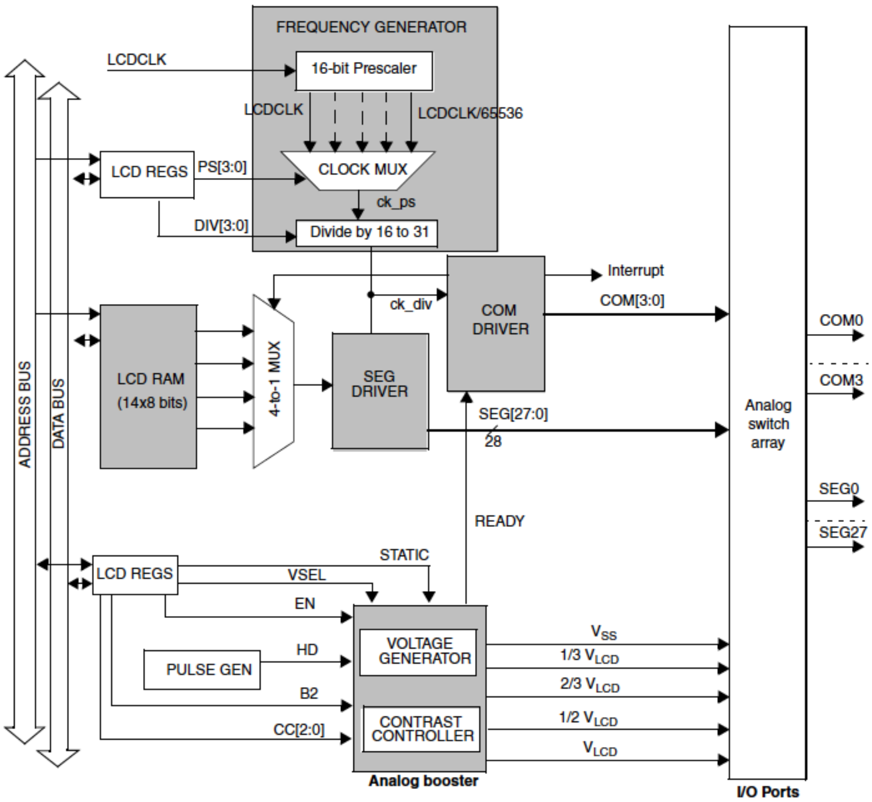

Figure 2: Display driver

The LCD type is transflective, meaning that the light source to provide the contrast is the ambient light. The ambient light passes through the display only if the segment is not activated. Behind the display, a reflective layer reflects the light making the non-active segments and the area not covered with segments brighter than the active segments. Since lighting is always available while showering the transflective type works very well. Furthermore, the transmissive type requires an additional electric lighting source (e.g., LED) behind the display, which was (from a power budget point of view) not feasible.

The contrast is high over a wide viewing area: the contrast ratio Cr (ratio of brightness on compared to the brightness off) is typically 6.0 at angles Θ=20° and φ=90°. The viewing area is ψ=-40° to 40° and Θ=-15° to 40°. Figure 3 shows the definition of the viewing angles.

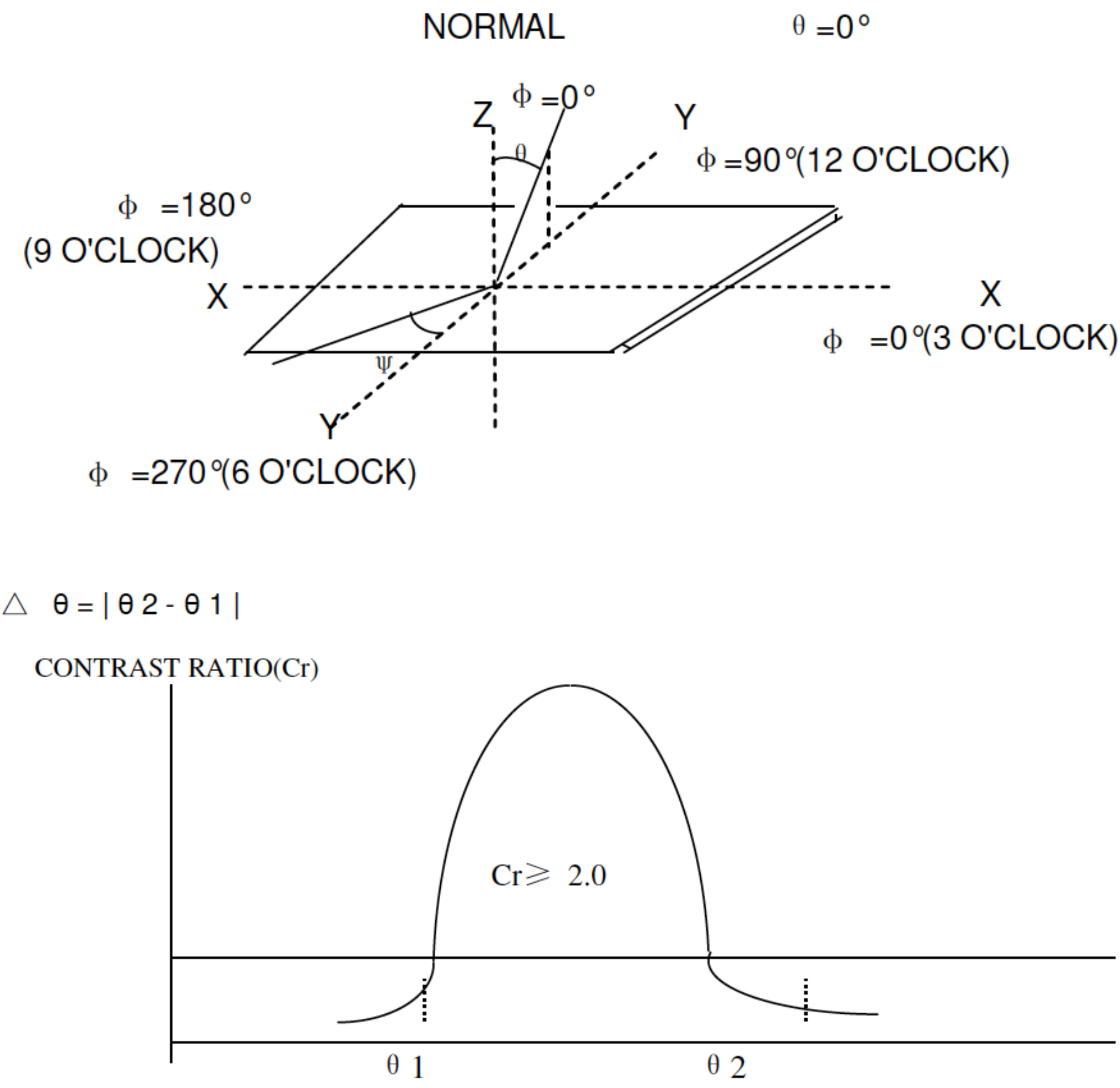

Figure 3: Viewing angles and contrast definitions

For the visualization of real-time feedback, the predefined segments allow various configurations. All in all, it contains 105 segments (see Figure 5):

- Top:
  - symbols for degree Celsius and Fahrenheit
  - descriptive words such as good, poor, top, save, go, stop, etc.
  - Four alphanumeric 16-segments displays (which can toggle)
- Center:
  - the symbols for memory (Mem), Liter, Gallons, kWh
  - 3,5 large decimal 7-segment displays with three colons
- Bottom:
  - polar bear
  - parts of an ice shell
  - rain drops
  - waves

Each segment can be turned visible or invisible (except for the waves and rain drops which are automatically grouped and linked due to restrictions of the controller's pin). Thus, it allows us to virtually display all behavioral cues that have been identified for the short-list in the previous tasks (goals, social norms, etc.).

Figure 4: DAIAD@know component

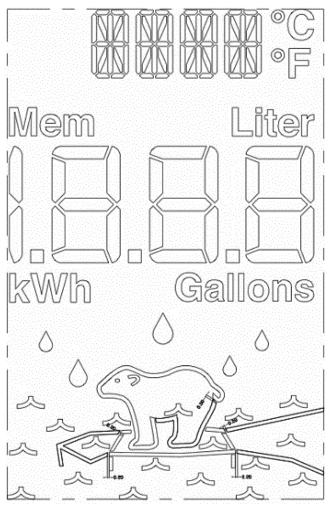

Figure 5: Segment overview

4. The LC Display Implementation

The table below outlines the possible design of the feedback interface as used in the trials.

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 would 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.
X	Goal Information		What is shown: The text "goal" in the 16-segment display + the target volume on the 7-segment display in liter (with one decimal). When is it shown: In the treatment group, it is shown: In the treatment group, after the baseline phase has been finished (shower N*10), when the shower begins, for 30 seconds. In the control group, temperature is shown during the entire experiment. Alternatively: A sticker on the device, as this allows the goal to be constantly visible; many users reported that they

			frequently did not see their goal.
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”. 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: In the treatment group, after the baseline phase has been finished (shower N*10), when water is flowing, for 50% of the time alternating in 3-second intervals with 3. Never in the control group.
3	Feedback mode, water running, phase 2		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: In the treatment group, after the baseline phase has been finished (shower N*10), when water is flowing, for 50% of the time alternating in 3-second intervals with 3. Never in the control group.
4	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: In the treatment group, after the baseline phase has been finished (shower N*10), when water is not flowing, for 50% of the time alternating in 3-second intervals with 5. Never in the control group.

5	Feedback mode, water off, phase 2		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: In the treatment group, after the baseline phase has been finished (shower 10), when water is not flowing, for 50% of the time alternating in 3-second intervals with 4. Never 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.
- Showers extractions are concatenated 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.

Figure 6: The DAIAD@know prototype for Trials (front view)

Figure 7: The DAIAD@know prototype for Trials (side view)

Figure 8: The DAIAD@know prototype for Trials (Pairing mode)

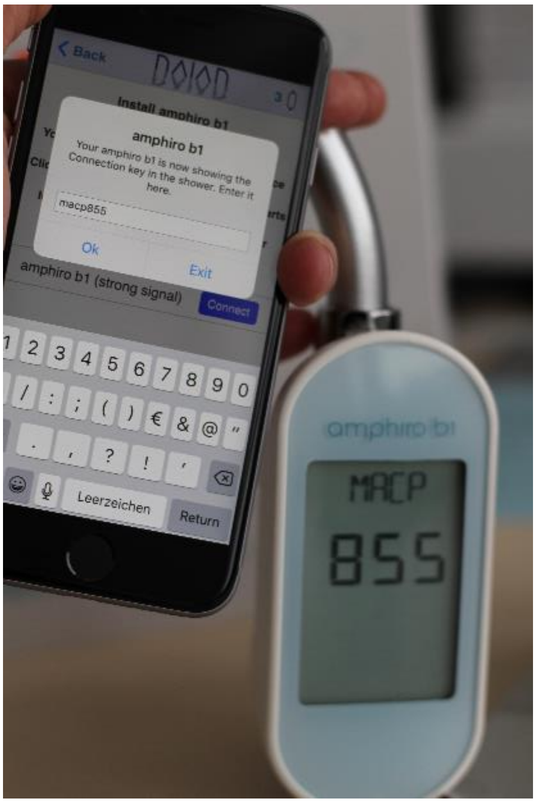

Figure 9: The DAIAD@know prototype for Trials (Pairing with DAIAD@home)

5. Evaluation of the prototype

This deliverable introduces the localized feedback design at the fixture-level of the shower. Participating households will receive the sensor DAIAD@feel with the integrated DAIAD@know feedback layer.

The displays provide real-time feedback to the participants with already proven design elements from diverse field studies of over 1'000 participants (such as [ST+16, TG+14, TT+13, TT+15]) and already evaluated within *Task 3.1 "Design studies"* (for further information please consult *Deliverable 3.1.1 Design Studies*).

Feedback elements will be evaluated again in the context of the Trials in a completely new context: accompanied by a smartphone application with detailed deferred feedback. The evaluation will be performed through surveys at the end of the Trials by all participants. The detailed approach and results constitute *Deliverable 3.1.2 Updated Design Studies* which will be submitted in M36. The following description provides a rough overview and roadmap on the evaluation process.

The results of the evaluation of the elements and the usage of specific design elements will deliver new insights for an improved design in terms of usability and appeal:

(a) First of all, a post-experimental survey will investigate **the understandability** of each element of the DAIAD@know prototype (Temperature, water consumption, energy consumption, polar bear animation).

(b) Secondly, **the interest** of the participant in each element will be surveyed, too.

(c) Finally, the complete artefact will be evaluated accordingly to certain **properties** (comprehensible, vague, exactly, effective, useful, pleasant, relaxing, ordinary, interesting, exciting, new, emotional, entertaining).

This survey-based information will be combined with an investigation among non-users (external, not yet involved individuals) investigating usability and user acceptance of different elements and interfaces of the localized and deferred feedback means. The usability scales from Deliverable 3.1.1 will serve as a first input for such tests.

Finally, the user acceptance and adoption of the artefacts is currently under investigation within several projects [PH+16] and future research will follow accordingly to [KA+16].

6. Conclusions

The DAIAD@Know prototypes for the Trials in will be able to provide real-time information at the shower level to all participants. During Baseline, no actionable information will be provided to participants. The same applies for control groups, when the devices will automatically turn into treatment phase. In the treatment phase – whenever water is flowing and for a couple more minutes thereafter – the displays provide:

- Factual feedback
- Injunctive normative feedback
- Metaphorical feedback
- Additional information

In the course and after the Trials, the efficiency of the feedback information on water consumption in comparison to the deferred feedback will be evaluated. Furthermore, researchers survey interest and understandability of the elements, too. All insights will serve to improve the DAIAD@know prototype after the Trials for future exploitations. Our prototype also allows full flexibility over the display configuration (via Bluetooth) that enables further empirical research on real-time feedback design even beyond the scope of the DAIAD project.

7. References

[KA+16] Kupfer A., Ableitner L., Schöb S., Tiefenbeck V. Technology Adoption vs. Continuous Usage Intention: do Decision Criteria Change when Using a Technology? 22nd Americas Conference on Information Systems (AMCIS), San Diego, CA, USA, August 11-13, 2016.

[PS+16] Peters, A., Hanss, D., Sartorius, C. Determinants of adopting technological feedback devices and water conservation behaviors. In: Heinrich C. Mayr, Martin Pinzger (Hrsg.): INFORMATIK 2016, Lecture Notes in Informatics (LNI), Gesellschaft für Informatik, Bonn 2016

[ST+16] Staake,T., Tiefenbeck, V., Schöb, S., Kupfer, A. Effects of Real-Time Feedback on Hot Water Use, Final Report on the Amphio-PWN Study, 2016.

[TG+14] Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Schoeb, S., Staake, T. ewz-Amphiro Study: On the Effectiveness of Real-Time Feedback: The Influence of Demographics, Attitudes and Personality Traits, Final Report to the Swiss Federal Office of Energy, Bern, 2014.

[TT+13] Tiefenbeck, V., Tasic, V., Schoeb, S., Degen, K., Goette, L., Fleisch, E., Staake, T. Steigerung der Energieeffizienz durch Verbrauchsfeedback bei der Warmwassernutzung. Abschlussbericht der ewz-Amphiro Studie, ETH Zürich/Bits to Energy lab, 2013.

[TT+15] Tasic, V., Tiefenbeck, V., Schoeb, S., Staake, T. Short-term spark or sustained impact? Investigating the long-term effect of real-time feedback, European Conference on Information Systems 2015 in Münster, Germany, 2015.