Visualizing & gamifying water & energy consumption for behavior change

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Abstract. This paper considers the structural similarities in approaches and lessons learned in the development of applications for behavior change in water and energy saving. We show how the domains of water and energy are related and propose a first set of design guidelines for building such solutions, especially regarding visualization and gamification of water and/or energy consumption. We exemplify how such guidelines can be applied with the designs and prototypes of a gamified application for water saving behavior change from our SmartH2O project. Based on feedback from user and stakeholder workshops and online discussions, we discuss how the initial design guidelines synthesized from the literature have been refined. In a next step, we will validate them by deploying the implemented prototype in real-world trials with several thousand smart-metered households in the UK, Switzerland and Spain.

1 Motivation

Raising consumer awareness and stimulating behavior change in the use of natural resources in different domains (e.g water, energy) has become an important research challenge. Supporting behavior change can be fostered by raising consumers' awareness [2] at individual and collective level, by providing actionable recommendations fitting the consumer's context and relating incentive models to consumption habits and the consumer's community of reference. Existing approaches to water and energy consumption differ in some aspects but also exhibit many common traits and findings: from common challenges and incentive schemes to impact potential (see Section 2). Though this makes sense intuitively, since both resources are often consumed together (e.g. hot water), only few attempts have compared the approaches from both domains. We have performed such an analysis with a specific focus on visualization and gamification, and extracted common elements as general guidelines for designing applications that aim at raising awareness and stimulating behavior change in resource consumption. By applying them in designing applications for water saving in the SmartH2O project [17], we refined them with feedback from users and stakeholders.

2 Lessons from existing work

A number of water and energy conservation applications for consumers employ visualized consumption feedback and gamified social interactions to motivate people to adopt more sustainable lifestyles, with various level of success [6][15]. Common approaches can be identified, based on two main shared challenges:

- How to present consumption information and convey its meaning to users (increase awareness)?
- How to enable and motivate consumers to change their consumption (induce & sustain behavior change)?

The first challenge is often addressed by visualizing consumption information. Common approaches have been data-oriented (e.g. bar or pie charts [6][12][17]), closely connected to the real consumption context (e.g. floor plans [6][12]), metaphorical (e.g. traffic lights and gauges [12][15]), or playful and ambient [10][11], often connected to nature or animal habitats (eco-visualization) [6][8][15]. To visualize consumption effectively, it can be broken down, e.g. temporally or by events and type of consumption. A study on visualizing water consumption identified four eco-feedback design dimensions that should inform visualizations of water consumption: data and time granularity, comparison, and measurement unit [6]. It has shown that study participants valued data granularity at individual fixture level or fixture category [6]. The need to visualize consumption per appliance is also highlighted in energy research [8][9], suggesting that it facilitates long-term sustainable behavior [8].

The use of benchmarks for comparison is important, as they allow users to judge whether their consumption is “normal”, excessive, or economical [15]. Comparing consumption is essential for helping consumers to understand it. A user study on water consumption found out that the provision of different ways of comparison (self-, goal- and social comparison) was highly appreciated by participants, especially self-comparison of a household’s current vs. historical consumption [6]. Goal-comparison was most valued for self-set consumption goals, and least for goals set “top-down” by suppliers or local governments. Social comparison was also popular, especially with similar households and geographic neighbors [6]. In the energy domain, similar kinds of comparisons have been considered if under different terms, e.g. historical for self-comparison, normative for comparison with other households and ‘social’ comparison for comparison against others “in their collective social setting”, e.g. individuals in the same household [1]. Most studies argue that consumption comparison is an effective means for stimulating behavior change, with some controversy over whether social comparison [5] or historical comparison [9] has a greater effect, but a user-based validation of different kinds of comparisons is largely lacking.

To address the second challenge of stimulating consumers to change their behavior, the provision of action-oriented tips for consumption reduction is a common strategy in both domains [3][6][7][9][14]. Actionable tips are needed, as the visualization of consumption information alone doesn't in itself provide practical hints on how to improve it [15]. Consumption behavior tips can be more general or contextualized (e.g. concerning overall consumption or specific consumption areas) [7][9]. Most of them are not personalized, i.e. not adapted to the characteristics of a household or a consumer and their consumption behavior.

To motivate consumers to act upon presented consumption information and tips, gamification is increasingly applied. Studies on gamifying energy consumption have shown e.g. that real prize-like rewards can be effective incentives [10][14] but also that gamified social interaction can foster better behavior, through both competitive and cooperative approaches [3][6]. Whether competition or cooperation works better hasn't really been validated yet, but some work recommends making competition optional and stressing collaboration instead [6]. Similarly, while playful designs can be engaging, special care needs to be taken to adapt visual style to semantic meaning (e.g. more visually appealing the more is saved) and to focus on portraying actionability [6][11].

3 Preliminary design guidelines

Based on this analysis, we extracted a set of preliminary design guidelines for resource consumption awareness applications (see Table 1). They summarize main aspects for the effective design of applications applying visualization and gamification to support reduction of natural resource consumption (water, energy) by raising awareness and stimulating behavior change.

Table 1. Design guidelines synthesized from related work

Design guideline (DG)	Objective
a) Visualize consumption in an understandable form	Raise individual awareness by conveying meaning
b) Visualize specific dimensions of consumption	Raise individual awareness by conveying meaning
c) Visualize comparisons to relevant references	Raise individual & collective awareness by (social) comparison
d) Provide consumption tips	Enable individual behavior change
e) Gamify consumption	Motivate individual behavior change
f) Stimulate social collaboration & competition	Motivate individual and collective behavior change

To explore their applicability and further refine them, we have applied these guidelines in developing a web and mobile application combining smart water meter consumption readings with visualization and gamification within the SmartH2O project [17]. In the next section, we present first insights from our design cycle, in which we have developed a series of mockups and visual prototypes and collected feedback from stakeholders and target users in workshops and an online discussion space.

4 Prototyping & user feedback

We are developing our application according to these guidelines in an iterative user-centered design approach that combines user-driven needs of different stakeholders (user pull), including water consumers and utilities, and state-of the-art technological advances (technology push) [13]. As a first outcome, visual prototypes accompanied by narrative user stories to contextualize the concept were developed and adapted to user feedback in three main iterations.

Raising awareness through gamifying consumption

The first visual prototype (see Figure 1) depicts both a web and mobile version of a gamified application, which is connected to a user's smart meter to measure his household water consumption. It contains a basic visualization showing aggregated consumption, which enables self-comparison, e.g. by providing metrics such as averages and peak consumption at different time-granularities, goal-comparison, and comparison with the average consumption of one's neighborhood. The application is gamified, such that all user actions, including providing information about their household or reading and implementing water saving tips, as well as water saving efforts, are translated into virtual points.

Figure 1. First visual prototype of the gamified portal

With these, users can earn reputational badges for different types of actions, and they can redeem real rewards provided by the utility or external sponsors. To stress the actionability of the approach, users are suggested concrete actions to increase their point score and reach the next badge. Based on their activity and total points, they are also ranked with others on a leaderboard to stimulate social comparison and competition with other households (e.g. from the same town or with similar characteristics). A neighborhood map shows households that are geographically close and that are also participating in the water saving efforts. To facilitate collaboration, users can form and join water saving teams (Figure 1, right). Team members benefit from each other's actions and can work towards common water saving goals. The prototype was discussed in a workshop session with 30 local residents in a Swiss municipality. A main concern from participants was that they wanted to know exactly what benefit they would get out of such an

application, beyond virtual points and saving water to help the environment. An additional feature appreciated by most was the idea of warning alerts in case of e.g. leaks, overconsumption or upcoming shortages and water quality issues. Thus, an important finding was that, to reach a larger audience, more pragmatic users should be considered in addition to those that would embrace hedonic, playful elements like badges, competition and collaboration. But, workshop participation itself was successfully gamified through a raffle which gave away water saving gadgets. This was an effective motivation even for those hesitant towards gamification, which indicates that *gradually introducing new, pragmatic users to the idea of gamification* with real rewards could engage them eventually.

Differentiating pragmatic and hedonic scenarios and users

As a response to this deeper understanding of the target users, the different envisioned features were distinguished more clearly to allow *separate views for pragmatic and hedonic users*. Two versions of the portal prototype are implemented: a basic version that targets more pragmatic, data-affine users by focusing on consumption visualization and practical water consumption alerts and tips and an advanced version which introduces gamification and social features in addition to the central visualization to target more hedonic users (see Figure 2). In addition, to increase pragmatic value, personalized feedback and water saving tips will be provided based on analyzing consumption behavior, to identify consumer classes with shared consumption patterns, household and personal characteristics [16].

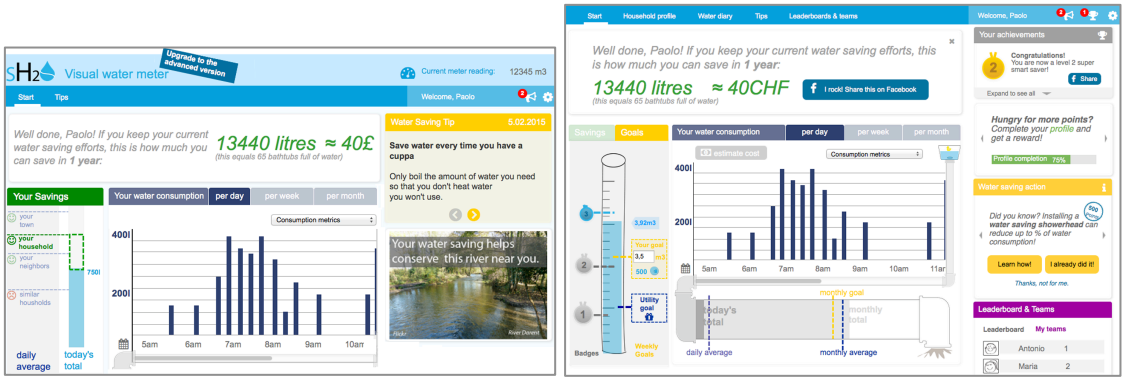

Figure 2. Visual prototypes: basic portal (l), portal with gamified visualization (r)

To differentiate between users that can be motivated by gamification, and those more likely to use social features (optional to address privacy concerns of users who may not want to share information with others), player types have been considered [3]. Table 2distinguishes target user and player types.

Table 2. Target user attributes for the application versions

Application version	Tech. affinity	Data affinity	Playfulness / Player type
Basic portal: visual water meter	Low	High	Low
Advanced portal: gamified meter	High	Low	Achiever, explorer
Advanced portal: social meter	High	Low	Competitor, socializer

Feedback from a second workshop in the UK with 11 participants confirmed the finding that separating the three functionalities is likely to improve user acceptance. While the workshop in Switzerland was attended by residents of all ages, participants in the UK were generally younger (average age ca. 35), more familiar with the concept of gamification, and stated that environmental concern would be one of their strongest motivators (*value-based intrinsic motivation*). Most considered the idea of a mobile app to monitor their water consumption very appealing, especially for quick access and alerts. The notion of competing against neighbors was not found particularly stimulating. However, they would consider competition with family and friends whom they would trust more and would feel more connected to (*embedding in relevant social context*). On the other hand, the idea of pursuing joint goals as a community and of receiving collective rewards sparked enthusiastic responses, e.g. "Could be a good experience, you get to know your neighbors better, especially in urban areas people don't know their neighbors any more, nice to be a kind of community." (*in-group collaboration, intra-group competition*).

Designing actionable consumption visualizations

In a next iteration, a more detailed visualization model was developed, addressing the design guidelines and different dimensions discussed in Section 2 in more detail, e.g. data and time granularity, different types of consumption comparison and different measurement units. Consumption information is visualized at different levels of detail in a way that maps abstract metering data into a form understandable for users, raises consumer awareness and enables them to act upon it accordingly. Overview visualizations provide users with simple messages regarding their water consumption. One widget, e.g., visualizes consumption savings (or water wasted) compared to others (similar households, neighborhood, households in your town), addressing social comparison aspects of the DGs; an ambient eco-visualization targets environmentally conscious users, showing nature reserves affected by users' water consumption (Figure 2).

To visualize consumption in more detail, a water pipe metaphor is used, which conceptually connects to the real consumption context but shows information as a simple bar chart (see Figure 3, left). It displays the total consumption for different time intervals, compared to the average consumption (self-comparison). Monthly goals, set by users themselves or their water utility, are also indicated (goal-comparison). By breaking down smart meter data further with disaggregation algorithms [16], consumption percentages for fixture types and end-use events are also visualized (see Figure 3, right). End-use events are detected automatically or edited manually, e.g. for corrections. Events are visualized as fixture icons corresponding in size to the amount of water consumed. *Actionable consumption behavior tips are embedded in the*

visualization when overconsumption is likely or has occurred, to enable users to change their behavior accordingly.

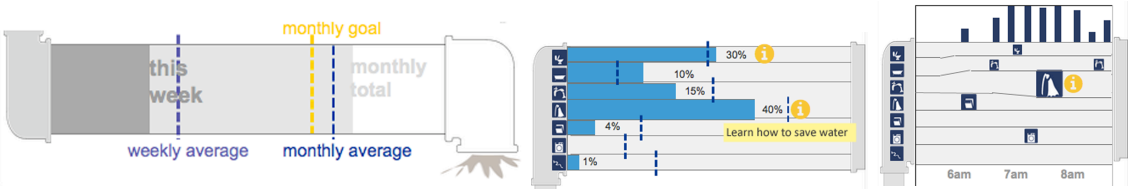

Figure 3. Pipe metaphor: aggregated (left), by fixture (center), by end-use events (right)

Household consumption is visualized in more detail with a bar graph at daily, weekly or monthly level, with metrics like consumption peaks. Embedded in the third prototype (see Figure 2), the visualization was discussed with different stakeholders, including water consumers, utility staff and researchers, in a moderated online visual discussion space for two weeks. Overall, discussion participants showed high interest in the SmartH2O concept and prototypes (the discussion attracted 80 new members and 50 comments during the period). A key user comment on the visualization was e.g. "I would suggest something more 'basic' with an option to switch to more detail/ or advanced mode for the geek ones" *(present interactive layered visualization; simplest by default)*. And, while we considered analogies for the amount of water saved, feedback from the discussion suggests that showing consumed water may have a bigger impact as the numbers are larger: "You could try using analogies like how many olympic-sized pools can you fill with the water consumed. I believe that you can provide a 'productive' shock to the consumers this way" (*visualize different measurement units and metaphors for consumption and saving*).

5 Conclusion & future work

Based on the preliminary experiences from the described design cycle and user workshops, we have refined the design guidelines for visualizing and gamifying resource consumption (water, el. energy) extracted from literature (see Table 3).

Table 3. Refined design guidelines from SmartH2O experience

DG	Refined aspects from SmartH2O design cycle & user workshops		
a	Present interactive layered visualization (simplest by default)	**c**	Goals should be related to concrete actions users can perform
	Use visual metaphors relating to user's consumption context	**d**	Feedback on consumption should be action-oriented and include saving tips embedded in the visualization
b	Present separate views for less vs. highly data-affine users	**e**	Real rewards should engage even more pragmatic users
	Overview of consumption should trigger awareness, and detailed information should point out concrete actions		Separate views for pragmatic & hedonic users should be considered
	Units & analogies should illustrate consumption & savings	**f**	Common goals have the potential to bring e.g. neighbors closer
	Showing consumption rather than smaller savings can raise awareness		Both are promising for different users embedded in the relevant social context: in-group collaboration, intra-group competition

While these design guidelines contain important aspects, they so far reflect our exploratory enrichment of literature findings in which only some of the studies included longitudinal field evaluations (and none large-scale usage). Thus, we

are implementing the two application versions as presented, and validating them with several thousand households in trial areas in the UK, Spain and Switzerland over the next two years. As one of the outcomes of this validation, we hope to extend the guidelines and formulate design patterns.

References

[1] André, A., Bühling, R., et al. Evaluating the effectiveness of visualizations for comparing energy usage data. In FSEA 2014, pp. 9–14.

[2] Darby, D. The effectiveness of feedback on energy consumption. Report. Env. Change Inst., Univ. of Oxford, 2006.

[3] De Luca, V. and Castri, R. The social power game: A smart application for sharing energy-saving behaviours in the city. In FSEA 2014, pp. 27–30.

[4] Ferro, L. S., et al. Towards personalised, gamified systems: an investigation into game design, personality and player typologies. In Proc. IE2013. ACM.

[5] Foster, D., Lawson, S., et al. Wattsup? Motivating reductions in domestic energy consumption using social networks. NordiCHI 2010, ACM, 2010.

[6] Froehlich J., Findlater L., et al. The design and evaluation of prototype eco-feedback displays for fixture-level water usage data. In CHI 2012, pp. 2367.

[7] Gamberini, L., Corradi, N., et al. Saving is fun: designing a persuasive game for power conservation. In Proc. ACE 2011.. ACM, 2011, pp. 16.

[8] Gustafsson, A. Power explorer: a casual game style for encouraging long-term behavior change among teenagers. Proc. ACE 2009, pp. 182–189.

[9] Jacucci, G., Spagnolli, A., et al. Designing effective feedback of electricity consumption for mobile user interfaces. PsychNology J. 7(3): 265–89, 2009.

[10] Kappel, K. and Grechenig, T. "show-me": water consumption at a glance to promote water conservation in the shower. In PERSUASIVE 2009, pp. 26:1.

[11] Laschke, M., Hassenzahl, M., et al. With a little help from a friend: a shower calendar to save water. In CHI'11 Ext. Abstracts. ACM, 2011.

[12] Monigatti, P., et al. Power and energy vis. for the micro-management of household electricity consumption. In Proc. AVI 2010, pp. 325–28.

[13] Novak, J., et al. histoGraph – A Vis. Tool for Collaborative Analysis of Historical Social Networks from MM Collections. In Proc. iV2014, Paris.

[14] Peham, M., Breitfuss, G., Michalczuk, R. The ‘ecoGator’ app: gamification for enhanced energy efficiency in Europe. In Proc. TEEM ’14. ACM, 2014.

[15] Rist, T. Towards a more responsible use of energy through visualization of energy data. In FSEA 2014, pp. 9–14.

[16] Rizzoli, A.E., et al., The SmartH2O project and the role of social computing in promoting efficient residential water use: a first analysis. In iEMSs 2014.

[17] SmartH2O project. EU FP7, No. 619172, 2014-17. URL: smarth2o-fp7.eu/

[18] Valkanova, N., et al. Reveal-it! The impact of a social visualization projection on public awareness and discourse. In CHI 2013. ACM, pp. 3461.