Per-appliance energy feedback as a moving target

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***Abstract*— Energy feedback through interactive technologies is often proposed as a major approach to reduce household energy consumption and carbon footprint. However, this vision is challenged by critics. This paper seeks to inform this debate through a case study of an advanced energy feedback device providing runtime and de-aggregated per-appliance feedback through a smartphone app. This study, based on 15 contextual interviews, aims to investigate how users understand and act on the various levels of feedback received from the device and the resulting impact on user behaviour. We found that appliance detection can be a "moving target" that hampers the intended aims of energy feedback, as it reduces user understanding of the technology. The lack of understanding was further deepened by unrelated supplementary functionality added in the package, in the form of smart plugs. Despite gaining a better understanding of their energy consumption, the users felt limited in terms of their ability to change their behaviour considerably.**

Author Keywords: **Energy feedback; Home energy management; user behaviour; de-aggregated feedback.**

I. INTRODUCTION

In Europe, households account for 25% of the energy-related greenhouse gas emission [6]. Household energy consumption and energy efficiency thus have high saving potential, making it an important target area for policy makers [13]. Currently, IoT based Home Energy Management Systems (HEMS) are gaining popularity by providing high resolution information, control, and automation possibilities to end-users [2].

According to Burgess [3], energy is so-called 'double invisible' to households. Firstly, it is an abstract and invisible force and, secondly, it is a part of inconspicuous routines and habits. This also means that it is difficult for people to connect activities to energy consumption [11]. Before smart meters, households consumed energy within an information void [4], unaware of how much and when different appliances used energy.

Energy feedback brought by (e.g.) smart meters is a key component for achieving behavioural change [9] and reducing carbon footprint [4]. Hence it is also a means to overcome energy's 'double invisibility'. However, the effect of real-time energy feedback is not as simple as cause and effect as energy feedback may be complex to understand and use in practice.

In this paper we look at energy feedback from the perspective of per appliance, or de-aggregated, feedback. The paper addresses the per-appliance feedback based on issues found in previous research on energy feedback [7], [8]. The study is a result of a deployment of the state-of-art smart energy monitor Smappee in two different areas in a Scandinavian city. In total, 25 units were installed and 15 users were interviewed for the purpose of this study.

The aim of this paper is to explore how users of the de-aggregated feedback device called Smappee act upon its service. The goal is to address the following research questions:

- [RQ1] Does Smappee de-aggregated feedback contribute to a better understanding of users' energy consumption?
- [RQ2] Does Smappee de-aggregated feedback contribute to an energy behaviour shift? And if not, what are the main causes preventing it?

The study found that despite improving the users' understanding of their energy consumption, the impact on savings was limited due by the effort required from the users. The "moving target" aspect of appliance labelling led to users losing interest. Additionally, a majority of users quoted a lack of time in order to fully utilize the device.

II. RELATED WORK

Various studies have been conducted within the area of smart meters and their influence on user behaviour [22]. Currently, there is little research on de-aggregated feedback, yet according to Hargreaves [1] users wonder about energy consumption of each appliance. In Hargreaves study, householders turned appliance on and off, checked the total (aggregated) consumption change, and made estimations of how much various appliances consumed. This is pressing as de-aggregated feedback is the only way of providing a direct link between actions and results [2], hence brings awareness of peoples actions.

A determining factor for the success of feedback on behavioural change is the initial motivation of the users [3], [4]. With low motivation, the system will typically remain unused. Kelsey [5] concluded that the major motivation is financial and that the users that are most motivated are the users who are in charge of the household's electric bill. One result that is quite common is that it is usually the man in the household that is motivated and takes charge of the energy feedback system [1], [4], [6].

Users tend to lose interest in the feedback after a while [1], [5], [7], [8]. However, according to Kelsey [5] that could be avoided if the feedback constantly changes in a way that makes the user experience always new. Hargreaves [8] found that the

loss of interest occurred when households had learned about their consumption patterns and after that they only looked at the feedback on special occasions. Participants in the study by Dam [6] used the feedback as a baseline check, usually at bedtime, just to see that the consumption was on a normal level. Other studies showed that the feedback was used as a reminder and motivator, rather than an educational aid [7], [9].

Strengers [18] believes that providing electricity feedback to consumers in order to make them optimize their energy consumption is a perspective designed for the so-called "Resource Man". Instead, a better approach that works for a much larger segment of the society should focus on activities rather than KWh and designing ways to decouple energy from these activities.

Selvefors [3] categorized hinders for adoption of real-time feedback into three barriers: technology, motivational and lifestyle barriers. The technology barrier can be overcome if the feedback is presented in a pedagogical way and that the message is clear for the user. The lifestyle barrier relates to making the feedback into a part of the users' daily routine and lifestyle. According to Kelsey [5] if the users check the energy display frequently, they managed to incorporate it into their daily routines and as soon as they understood the information provided, they started to move towards energy savings. To make it easier to get the feedback into the users' daily routine, the information should be accessible through a routinely used device, such as the smartphone, which is what Wallenborn [4] also concluded. Dam [6] also suggests that integration into a routinely used device is a good idea since the long-term use is uncertain. However, Selvefors [3] found that participants were reluctant to access the information even after such measures are taken.

Studies by Allcott [10] and Dam [6] showed that if household owners were compared to their neighbours in similar households, energy consumption was reduced by 2%. However, people that consumed less before the comparison tended to consume more when they were compared to their neighbours, which is termed the "boomerang" effect. This is because they saw that they were able to consume more energy in order to fit with the rest.

Knowledge about energy can be seen as another type of barrier, a barrier that hinders the change of consumption behaviour supported by feedback. Dam [6] found that users, for lack of better knowledge, chose to set a timer on their refrigerator to reduce the consumption. This shows that even though the motivation for saving exists, it can still be hard to make changes towards energy savings.

III. De-aggregated eco-feedback in Smappee

Smappee is a device with an interactive application running on tablets and smartphones that monitors the users' household energy consumption. It provides real-time feedback of the instantaneous energy consumption (often termed 'real-time' energy use) as well as the amount of energy that is so-called "always-on" (e.g. routers, standby devices etc.). This information is stored in the cloud and the user can explore total energy use history at a high time resolution (5 mins) of their aggregated total energy consumption (see Figure 1). The intention is that people can learn from this data.

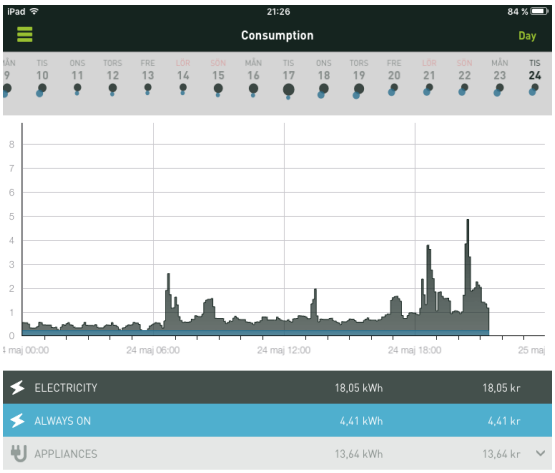

Figure 1 Usage history in the Smappee app

The feature that differentiates Smappee from many other smart home energy monitors is the fact that it recognizes appliances individually using what Smappee calls "non-intrusive load monitoring" (NILM). NILM employs amperometric clamps (one for each electricity phase) clamped around the electrical wires at the fuse box (Figure 2) [11].

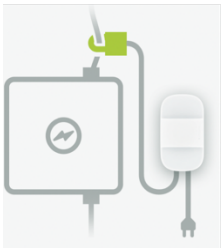

Figure 2 Smappee connected to the main fuse box for a single-phase system (three clamps for three phase system) [Source Smappee installation manual]

Smappee determines the energy consumption of individual appliances by differentiating appliances based on their unique electrical signature (e.g. due to different nature of loads conduction/inductive) generated when turning an appliance on and off as well as the overall power values [12]. Smappee identifies various individual appliances, but the user has to figure out which physical appliance it corresponds to and label it in Smappee. Each appliance is initially labelled by default as a number. To help the users with appliance labelling Smappee logs the on/off events of each detected appliance and shows it in an event-list (see Figure 3). Such de-aggregated energy data provides the user with information about each appliance's consumption as well as how much energy it consumes costs per day, week, month or year.

Smappee also comes with so-called "Comfort plugs" (hereafter referred to as 'plugs'), which are controlled through the application. They allow users to turn the plug on or off or set plug activation triggers such as sunset, sunrise, or based on

geofencing. Even if their functionality seems unrelated to the core energy feedback, we will show that the plugs did play a role in the device understanding and usage.

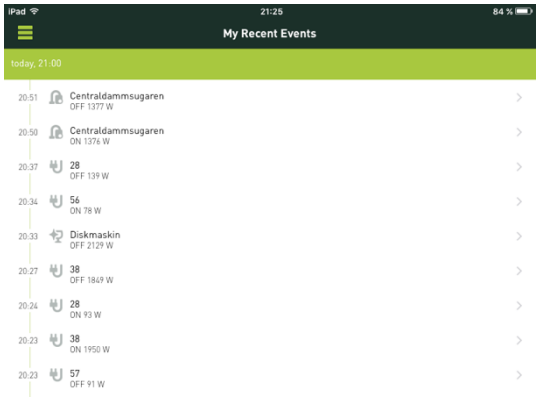

Figure 3 Event list in Smappee app with some appliances labelled and others not labelled.

IV. Method

This study was performed in two dwelling areas (in a Scandinavian city), in 9 apartments and 6 town houses. The households was provided with Smappee kits (energy monitors + comfort plugs, version 2017) at no cost. The energy monitors were installed and commissioned for the residents and the plugs were provided to be installed at their own discretion. As a follow-up to the installation, a support document with detailed information of the various functions was provided. Our data corpus consists of the Smappee accounts containing energy consumption, appliances data and event logs of the households (acquired with consent), as well as interview data performed with one member of each household. The users had access to the system for 6 months (apartments) and 1 year (houses). Table 1 presents an overview of the interviewees background. Both areas have good socio-economic conditions with a positive environmental perspective. In both cases, heating is generally not included in the electricity bill (except for some supplementary floor heating e.g. in bathrooms) and is primarily provided by central district heating.

The aim of the interviews was to gain a deeper understanding of how users understand and act upon de-aggregated energy feedback. The interviews lasted 45 min on average; the shortest lasted 30min and the longest was 1h 30min. The interviews were divided into two parts. The first part was a contextual interview where the participants were asked how they utilized the system and demonstrate the various features frequently used. The second part was semi-structured on topics regarding de-aggregated energy feedback and Smappee practicalities. Table 1 provides and overview of the interviewees, including type of dwelling, age group, household members, working status and prior energy knowledge. The details presented are of the primary users of Smappee. In a majority of the cases (12 out of 15) only one user in the household used the application, in 3 households there were 2 users.

Table 1: Overview of the interviewees in terms of age group, dwelling type, working status and prior energy know-how of the interviewee

User code	Dwelling type	Age group	Household members	Working status	Prior Energy knowledge
1	Apartment	60-75	2	Retired	Low
2	House	40-50	4	Working	High
3	House	40-50	4	Working	Low
4	Apartment	30-40	2	Working	Low
5	Apartment	30-40	2	Working	Medium
6	House	40-50	4	Working	Low
7	Apartment	40-50	5	Working	Low
8	Apartment	30-40	4	Working	Low
9	Apartment	30-40	4	Working	Medium
10	House	40-50	4	Working	High
11	Apartment	60-75	2	Retired	Medium
12	House	40-50	3	Working	Low
13	House	60-75	2	Retired	Medium
14	Apartment	40-50	5	Working	Low
15	Apartment	50-60	2	Working	High

A qualitative thematic analysis of the interviews was performed in several steps. First, we correlated each interview data with the energy use data found in the corresponding Smappee account. The coding was performed inductively after reviewing the interviews. The results were then structured to find the following emerging themes across our data corpus:

- Initial impression
- De-aggregated feedback and user's interaction with it
- User's understanding of Smappee including the appliances recognition
- Smappee use patterns
- Behaviour change
- Socio-economic context

V. Results

At the time of the interviews, all Smappee installations were still in working order. We will begin by describing our analysis themes.

A. First Impression

Most of the participants (14 out of 15) first impression was that it was exciting to see their energy consumption right away. They did not have any previous knowledge about how much they consumed in real-time, only their monthly consumption written on the electrical bill. Another positive impression was that it was accessible through the phone, which allowed them to see their consumption away from home.

However, two participants had direct negative impressions as one wondered *"is this really gonna help me?"* and another "what should I do with this?".

Not surprisingly these participants did not see the use of Smappee in their household. Another similar participant said that it was confusing and hard to understand.

Another common trajectory was that a good first impression was followed by disappointment when actually starting to use Smappee, For instance, one participant said that the start screen, where he could see his real-time consumption, gave him an easy and fast overview. Hence, it looked like Smappee had lots of possibilities and that it was working well with the plugs and the de-aggregated feedback. But then he got disappointed and his impression of Smappee changed, as it was hard to label the different appliances. Other participants also expressed a need for help at this point as it was difficult to understand how to use Smappee in practice.

B. De-aggregated feedback in Smappee

For most (10 out of 15) participants, labelling appliances in Smappee was a difficult process. Five participants never even tried to label appliance and one did not understand that Smappee was able to detect individual appliances. Two of the 15 participants had labelled one appliance but said that they made a mistake when they did that and stopped with that activity. The rest of the participants (8 of the 15) had tried to label as many appliances as possible but stopped when they made a mistake, when it became too difficult, or when they did not think it was worth to continue with labelling. One participant said:

"many were easy, then it got harder and harder and after a while I thought… why am I doing this? The information isn't that interesting".

He continued by saying:

"It is complicated, and it does not give you the reward for trying, because sometimes you make mistakes, and then you get into a loop: 'What was I doing?' and the value of it feels limited".

Most participants chose to label the easiest appliance first, which was most of the times an appliance that could be turn on and off with a switch and consumed a lot of energy. Generally, the appliances that the participants could turn on and off on their own were easier to label compared to the automatically controlled appliances such as refrigerators or thermostat-controlled floor heating. The users who were able to label the refrigerator either sat next to it and heard when the compressor started to work, others had previous knowledge about the fridge electric power and the on-and-off pattern which they recognized in their event list (Figure 3).

Users who had labelled some appliances did that during the first couple of weeks. They said that they initially thought it was fun to walk around and 'hunt' appliances in the house. But they stopped doing that later on, either because they had labelled the ones that were obvious to them, or because they thought it was, in general, too hard to continue.

Ten out of the fifteen participants had some idea of how Smappee detects appliances. Some did not want to tell their view right away since they were unsure, others had thought of it during their time of using Smappee. The general perception was that Smappee measures the electricity used and that it detects the increase and decrease and if Smappee, after a while, measures the same type of increases and decreases it assumes that it is an appliance. However, most of the participants could not understand how Smappee differentiates between two appliances with the same power.

C. The moving target of labelling appliances

One thing that is important to understand in order to use Smappee properly is that a number of "appliances" detected by Smappee may belong to the same physical appliance within the household**.** For example, one participant had noticed that Smappee detected the different stove hobs as different appliances. Another participant described that a few detected appliances in Smappee belonged to the washing machine, since it has different routines in its process of washing. That is why Smappee detects more appliances than there are physical appliances within the household. However, most of the participants had not understood that. One more thing that confused the users is that an appliance can be detected as a new appliance if it is used in a different way. One of the participants had labelled his toaster long before the interview but had recently changed the temperature of the toaster, which made Smappee detect it as a new appliance, he realized that during the interview.

One participant had seen that Smappee had detected appliances and thought that they were too many, she said: *"Ah there are so many appliances, and I don't understand what is what. Then it results in that you stop, because you do not have that much time to engage in electricity stuff"*

When she, during the interview, looked at the information about some of the detected appliances she could not understand how she possibly could determine which physical appliances within the household they correspond to. She thought that there were too many appliances, which made her think it was too big of a job to label them.

She also said that she thought that she was logged into someone else's account and that the appliances didn't belong to her since she did not recognize the number of appliances in the list (see Figure 4). Two more participants, who lived in apartments, thought that the list of appliances was too long, which made them question whether those were their appliances. One of them explained: *"You see how many it shows? I do not have that many. So it probably shows many others within the building".*

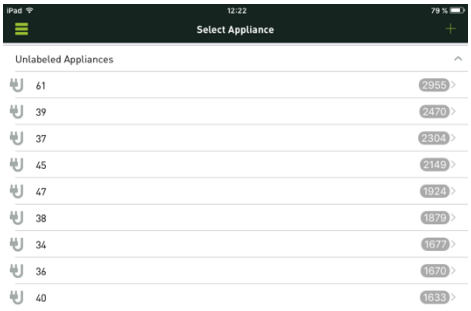

Figure 4 Appliances shown in Smappee before labelling

The interviewee who had best succeeded with the labelling did not look at the information about the appliances more than

once. He said that he learned roughly how much the appliance consumed and how much that energy cost him per month or year. He felt that he acquired the knowledge needed in order to get an overall understanding. He also felt that he had hit the ceiling with Smappee's per-appliance labelling.

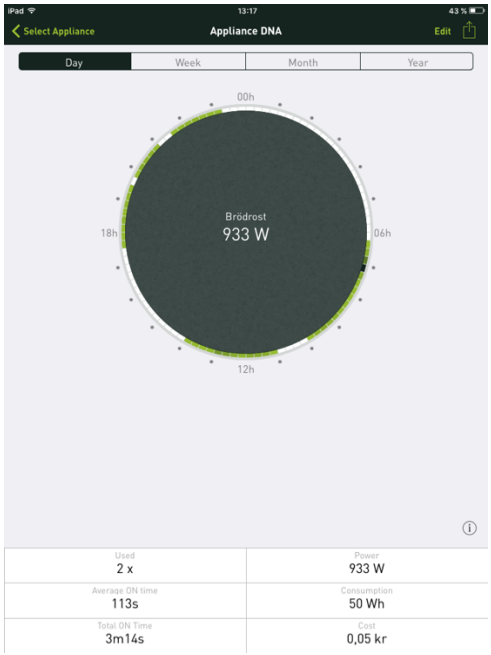

Figure 5 De-aggregated information about one appliance

Only one participant had an ambition to label all appliances within his apartment. He usually looked at the information that depicted in Figure 5, illustrating when the appliances were on during an average day and figured out what appliance it might be. He looked at the "appliance DNA" (figure 5) for the appliances that he had labelled and started to assess whether he thought it was used in a reasonable way. During the interview, he looked at the refrigerator on and off pattern and thought that it was working too much which made him consider buying a new refrigerator. He also noticed that the timer-controlled lights for his aquarium were turned on for a while during the night, which he would adjust.

D. Smappee and the Plugs

The only participant who had not seen that Smappee is able to give de-aggregated information had not used Smappee that much. He thought that we, who conducted the study, were interested in the data and that it was measured through the plugs that were given alongside of Smappee. He had placed one of the plugs where he ironed his clothes and connected the iron to the plug whenever he used it and thought that the iron's consumption was measured.

Two users had a problem to understand the difference between the labelled appliances and the plugs. They thought that they could control appliances in the household once they had labelled them.

One participant described that she had a problem sometimes with turning the plugs on and off and she described that even though she sat very close with her smartphone when she pressed "on" nothing happened. Her interpretation was thus that the smartphone sends a signal directly to the plugs to turn it on or off, while in reality the Smappee box is sending a radio signal to the plugs when it turns on/off, which is independent of where the smartphone is located.

E. Smappee use patterns

Only two of the participants used Smappee on a regular basis, the two of them used it many times a day. The others had used it many times a week during the first couple of weeks but then started to look at Smappee more rarely (cf.[1], [5], [7], [8]), some said that is because they learned the information they needed. The two that use it regularly were both retired. One of them described that he looks at Smappee for the same reasons he looks at Facebook or when he randomly looks at the time table of public transportation: *"It is fun, little dynamic information to keep track, 'Is this real?' 'Has something happened?' Normally nothing has happened. You look at Facebook and you look at Smappee."*

Most of the participants used most frequently the main screen, where their real-time, high resolution consumption and their always-on consumption are displayed. They looked at the real-time consumption in order to get an overview if everything looks correct according to them. One of the participants noticed during the interview that his consumption was low at that moment and said*: "Now it is fun to see that it is just the basic appliances that are on, nothing else."*. One of the participants that had got a routine in using Smappee looked at the real-time consumption every time he went to bed, to know that everything was off. He looked at it during the days also, and if the consumption was high he started to investigate what it was that consumed energy. It worked like a baseline check for him.

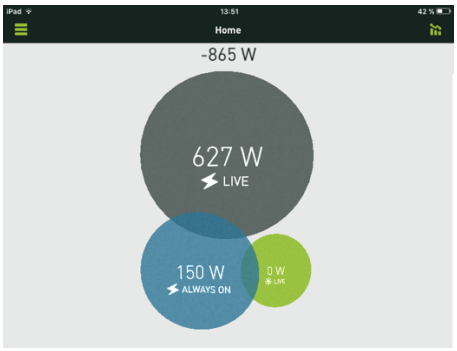

Figure 6 Real time consumption, "always-on" readings and a decrease of 865W by an unlabelled appliance

Some of the interviewees, who did not use the per appliance function in Smappee, made an own estimation about how much appliances consumed by looking at the real-time consumption's increase and decrease when they used an appliance (cf [1]) (see Figure 6). They reported that this gave them enough knowledge about their appliances. They thought it was easier compared to labelling the appliances and get the information from that way.

Some participants looked at their usage history and tried to analyse the diagram and tried to evaluate the peaks, why they occurred and what they might have done during that time. They

said that for them it worked as a "receipt" for their consumption.

The plugs that are delivered with Smappee were not used that frequently in apartments. A common thought of the users who live in apartments is that they are more suited for houses with two floors, where one can turn things off at the other floor without having to walk a long distance to do that. One family, who lived in a house, used the plugs frequently to help with fire safety. Other users used it to turn off their standby consumption, which they became aware of thanks to Smappee.

F. Behavioural change

Almost all of the participants said that they could not change the way they use most of their appliances since the appliances fulfil a practical use that they can't be without. However, just under half of the participants had tried in some ways to change their consumption behaviour due to the feedback from Smappee. One of them had noticed the difference in consumption between boiling water in a kettle compared to a saucepan. So now he only uses the kettle for that purpose. He had also noticed the difference in consumption between the different stove hobs, which made him use the one that best suited the size of the saucepan whereas before Smappee he chose one randomly.

Another participant had seen that his "Always on" consumption increased drastically when he had the floor heating in the bathroom on. He was not aware of how much it consumed. By acknowledging that, he had started to turn it off from time to time. But he admits that he believes that it is just a temporary action and that he thinks that he will continue as normal later on, because it doesn't cost him that much.

One of the users who noticed the difference in real- time consumption when using a certain appliance had seen that the dishwasher is consuming surprisingly much. That knowledge had made him more meticulous when using the dishwasher, ensuring that it is full and he does not use it half empty. He referred to this as: *".. or not to run an empty dishwasher just because the dishes smell"*.

A common thought by the participants was that Smappee worked as a reminder of saving energy by not having appliances turned on when they did not use them.

G. Socio-economic context

One thing that became clear during the interviews was that the participants who used Smappee more often than the rest did so because they had more spare time. The participants who did not use Smappee often, or had stopped using Smappee, said that it was mostly because they did not have time to use it. Some participants expressed that it was hard for them to reduce their energy consumption because they lived in the household with others. Families with children thought it was very hard since the children have their consumption patterns and do not think it is that important to save some energy.

One participant said during the interview when his kid was looking for food: *"The kids kind of open the fridge and look for food whether it is food time or not. Daniel! close the freezer, you cost me money now!"*. The interviews did not show any difference in using Smappee based on economic resources. No one used Smappee because they had a hard time paying their electrical bill and their economic resources had no impact at all. There was no difference between the users in the two city areas in this aspect either, even if the real estate price in the areas is at significantly different levels.

Some participants said that they would use Smappee more often and analyse it more if they would live in a villa (with heating included e.g. with a heat pump). When one has a higher consumption, they thought that they would be more motivated to use Smappee in order to lower their consumption because that would have a larger impact.

VI. Discussion

The main lesson we draw from our study is that even if users express a wish for (Hargreaves [1]) *de-aggregated feedback, it does not add much to the user experience if it is not detecting appliances correctly, completely and in a short start-up period* (a few days). Any imperfection, like the "moving target" effect we have seen, is bound to lower the user trust in the technology and to add one more reason for users not to change their behaviour, or even to keep interest the feedback device. De- aggregated feedback is seen as a good thought by the users, but it is practically too difficult, and unless one has a personal curiosity (cf. the "Resource Man" [18]) the appliance labelling activity will be soon abandoned. The users employ the device in the way that they perceive as manageable and the way they think they get a fair exchange of information considering the effort they have to put in, which is why the total real-time consumption was mostly used in our case in the end, since it does not need any configuration. Generally, our users did not feel that it was worth the effort to label the appliances since the information was not seen as useful enough. Based on this result, we believe that a rough indication about how much appliances consume in comparison with other appliances is the information that users want, especially since they feel it is too hard to understand the de- aggregated information as it is structured now in Smappee.

Even for users with a nearly correct appliance detection, per-appliance feedback did not prevent losing interest in the device over time. Like reported by previous studies, our informants expressed that they learned the information that Smappee provided, which resulted in them not needing to look at the feedback on a regular basis. The information void that Carroll [9] described was thus filled. They only needed to look at Smappee when they felt that they did not know, roughly, how much they consumed in real-time, either because they had forgotten or because it was a special occasion (cf. [8])

Another lesson is that adding supplementary functionality to energy feedback can hamper the energy feedback effects, because the users may wrongly relate it to energy feedback. This was the case with the smart plugs delivered with the device we studied. Along with de-aggregation, the plugs created confusion and false expectations, which in our interpretation reduced expected behavioural effects of energy feedback.

Regarding our first question, de-aggregated feedback did improve energy use understanding for many users. However,

the practices that users had to recourse to are very similar to those found by previous energy feedback research [21]: for example, turning appliances on and off to achieve proper appliance detection. The most common way participants used Smappee was as a reminder and an observer of the household energy consumption. They used the total real-time consumption (thus no per-appliance functionality) to observe whether they had a high or low consumption at the moment and that worked as a baseline check, just as Carroll [9] and Faruqui [7] found. The existence of Smappee reminded some users of turning unused appliances off and the baseline check worked as a reminder if the users had forgot to turn something off.

The three barriers (motivational, technical and lifestyle barrier) described by Selvefors [3] have in general been confirmed by the interviews. The biggest barrier is the technical barrier, since the participants thought it was too hard to use the system, especially to label appliances. The motivational barrier is not just the initial motivation, the motivation to use Smappee before receiving it, but also a motivation to save energy in general. Many participants thought that they could not do a significant saving since they were having an already low consumption. Instead they thought they would be able to save more if they would live in a villa and had a higher consumption. In contrast, the participants who had a slightly higher consumption, thought that they used the appliances they needed and could not control their consumption all that much, some of them had children that independently increased the consumption drastically. The users who were motivated to save energy, did that for ideological rather than financial purposes, which is contradictory to Kelsey [5] who concluded that financial motivation was the major motivating factor.

Most of the participants did not encounter the lifestyle barrier, which involves getting a daily routine in using the feedback, since they stopped using Smappee because of either the motivational or the technical barrier. To have the feedback accessible in the smartphone was seen by the users as an advantage offered by the system, since they could see their consumption wherever they were. But it was obvious during the interviews that the Smappee application 'disappeared' among other apps. The users who actually used the system somewhat regularly had the application icon on their start screen so that they saw it more often. Notifications sent from Smappee, as two participants suggested, could also work as a reminder. The fact that the information was accessible in the smartphone did not seem to help the participants, which is consistent with the result of Selvefors [3].

The socio-economic context, in general, did not have a large impact in this study, except that the retired had more time to use Smappee, which was a significant reason why they used Smappee more than the rest. All participants thought that they did not pay much for their electrical bill. If the study would have been made in an area with less resources, that would perhaps result in another usage of Smappee. This is since the financial motivation for using it would be higher and according to Kelsey's [5].

A similar effect to the boomerang effect [10] was observed. Almost all participants did not know how much they consumed in real-time and when they saw their consumption, some users did not perceive it as being large. As mentioned previously, participants thought that they would use Smappee more often if they had a higher consumption, for instance if living in a villa.

VII. Conclusion

The results suggest that per-appliance feedback presents many of the same issues found in traditional smart meter energy feedback. Typically, here is a degree of enthusiasm in the beginning, with lots of attention to the device, followed by a gradual abandon except for a few enthusiasts who conform to the "resource man" archetype. In other words, adding more information to energy feedback does not necessarily increase its value for users.

Additionally, despite gaining a better understanding of their energy consumption, the users felt limited in terms of their ability to change their behaviour considerably. This was in part due to the mental cost-benefit model of the users in terms of low amount of savings vs. the time effort required.

Another lesson that we draw from the complex processing/intelligence of de-aggregated feedback is that if the intelligence is not 'complete', if there are still aspects that the user needs to figure out by themselves, such lack of completeness can also encourage the formation of an inaccurate conceptual model. Indeed, the Smappee device multiplicity has led to users incorrectly believing that they see devices from their neighbours. We would like to encourage designers to pay attention to emphasizing these "intelligence shortcomings" in the user interface.

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