



SLUTRAPPORT

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Default options as potential tools for promoting energy-efficient behaviour

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Summary

User preferences and behaviour are often pointed out as the main causes contributing to the gap between expected and actual energy use in multifamily buildings. To promote energy-efficient behaviours among diverse building end-users, default options could be less intrusive approaches. This project aimed to acquire a better understanding of the influences that default options have on the users and household energy use. Different default options (i.e. pre-set choices for room temperature, lighting and lighting control, water temperature and flow, and electrical appliances) were tested with a total of 36 participants in the test apartment. The effects of default options on user experience, energy behaviours and energy use were investigated, taking individual psychological factors into account.

The findings showed that the pre-set choices were somewhat acceptable to the users, thereby suggesting their potentials to promote energy as well as resource efficient behaviours. However, habits were found to play an important role in users' interactions with default options. Due to habits, functions and features of relevant appliances and products that could contribute to energy and resource savings were often overlooked.

The interactions with default options led to both increased and decreased energy efficiency. This was mostly driven by motivational factors relating to time efficiency, convenience, comfort and pleasure. Specifically, energy-efficient behaviours were mostly driven by internal motivations to save energy. The designs of electrical appliances, energy-related products and features have shown potential to enhance energy and resource efficiency in buildings. Ideally, it should be easier to override default options to reduce energy use, but it should also require a secondary actuator in case adjustments increase energy use. Easy-to-understand and adjustable features have been found to promote acceptance and use of the default options among the diverse users, and ease energy and resource-efficient behaviours among those with a strong motivation to save energy. To communicate with building end-users about energy and resource efficient functions, the designs can be improved by for example, clear graphical symbols, level markers, indicators and feedback for state changes, and standards for user actions.



Background

How people use energy in buildings affects the overall energy system (Janda, 2011). Human behaviour plays an important role in building energy use despite the implementation of energy-efficient building design and technologies (Paone & Bacher, 2018). For example, energy use in a nearly-zero energy building can be increased through inappropriate and inefficient use of electrical appliances and lighting (Barthelmes et al, 2017). The use of kitchen appliances and lighting has been found to have significant impacts on household electricity use (household EL) (Westin, 2019) and the use of kitchen sink, shower and bathtub together has significantly affected energy use for domestic hot water (DHW) (Wahlström et al., 2008). Therefore, energy behaviours in relation to the use of these household appliances or products are crucial.

In newly built multifamily buildings with similar design and dwelling types, large variations in energy use have been observed for household EL and DHW. Despite different solutions applied to achieve building energy efficiency, the differences in between “high” and “low” users were about 3-4 times for household EL, and 8-19 times for DHW (Mattsson et al., 2022a). This is in line with the variations in household EL and DHW found in measurements of around 1,000 different apartments over a year (Fransson et al., 2019; 2020). Based on these insights, energy saving potentials due to reducing variations in energy use for household EL and DHW would be as substantial as the reduction in heating demand for buildings. Given the complexity of human behaviour and its impacts on the variations in household energy use, a deeper understanding of individuals’ energy behaviours in their dwellings would facilitate the design and development of strategies to reduce of such variations. The importance of understanding the user perspective is emphasized in design practices aimed at achieving energy efficiency for building features, products or interfaces (Mattsson & Johansson, 2022). However, designers may anticipate user behaviours and preferences - what they will want and need based on an assumed common understanding of the user perspective, what sustainable living is, and how it should be operated (Hagbert & Femenias, 2016). To better understand, explain and anticipate user behaviours, knowledge about individual psychological factors together with the design principles such as user experience design, universal design and inclusive design would be desirable.

In previous research, convenience, comfort and pleasantness of the indoor environment were highlighted as individual and internal drivers of energy behaviours (Mattsson et al., 2022a; 2022b). However, it is often that human take the way of least resistance to the situation so that they will not take any action unless they feel that they have to (Lehner et al., 2016). In the context of building energy use, for instance, people will not turn on electric lights if they perceive daylight as sufficient, nor will they adjust water temperature and/or flow if the levels are acceptable. Given this, default options, or pre-set choices of actions, are considered as a less intrusive approach to promote behaviour change that has the potential to optimize household energy use across building end-users during the buildings’ use phase. Ideally, the

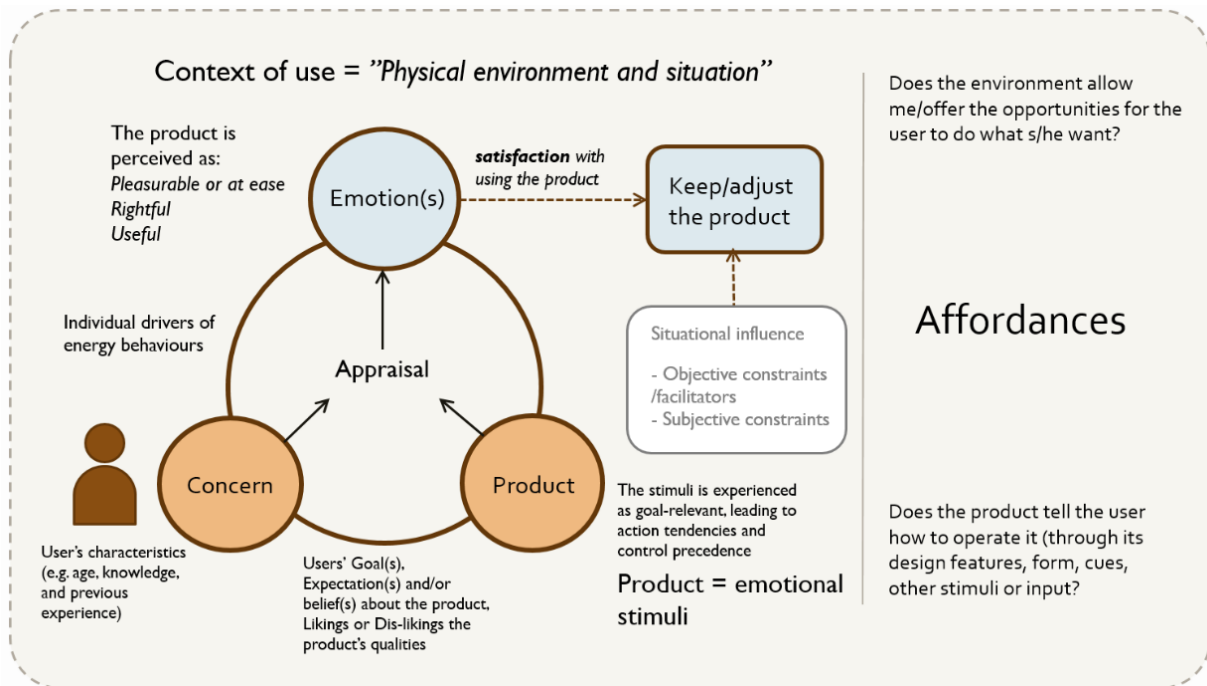


Figure 1. Conceptual framework

The data collection took place in Reality Home, a part of the MoRE Lab, at Lund University ([Reality home | MoRe-Lab](#)). The Reality Home is a fully functional 2-room apartment, with 63 sq.m. and an outdoor veranda (Figure 2). This test apartment is specifically designed for people with impaired mobility, built to Swedish standard and included fully functional household appliances. For this project, relevant household appliances and products providing default settings were reviewed and selected to replace some existing ones in the test apartment. The universal design principles (Story et al., 1998) and affordances (Gibson 1979; Norman, 1998) were also applied to guide the selection.

A total of 36 persons participated in the project. Six persons (2 males, 4 females, 29-60 years) participated in the pilot study and 30 persons (12 males, 18 females, 21-66 years) participated in the main study. About 50% of the participants had either been living or had originated from other countries, and the rest were from Sweden. The participants were informed that the study was voluntary and that their participation would be rewarded with a gift card.

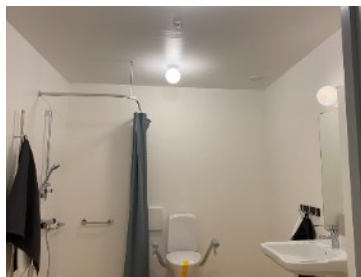


Figure 2. Floor plan (modified from Kiran Maini Gerdhardsson) and indoor environments of the test-apartment

The participants were asked to walk around and at the same time, were informed about the test apartment and its functions. Thereafter, they were asked to perform five activities that required them to experience and interact with the default options as pre-set choices for



indoor temperature, lighting and lighting controls, household appliances, water temperature as well as water flow. The participants were informed that they can override the pre-set choices when performing the activities. Consequently, energy used for household EL and DHW would be influenced by how energy-related appliances or products were used. The activities and energy-related appliances or products studied in this project are summarised in Table 1.

To provide a stronger basis for analyses, a mixed method approach (Creswell, 2003) was applied. First the pilot study (Mattsson et al., 2023; Mattsson & Warell, 2024) was conducted with the six participants to evaluate the assessment method and study design. Thereafter, the method and study design were revised for the main study conducted with the 30 participants.

The participants were divided into two equal groups: (1) control group – the participants were asked to perform the activities as they would usually do, and (2) test group – the participants were asked to perform the same activities but they have to try to minimise the use of energy for household EL and DHW as much as possible; in other word, to use energy for household EL and DHW as little as possible.

The following data were collected:

- background information and perceived indoor environmental quality by self-reports.
- use of the default options, i.e. whether the participant has overridden the default options, when performing the activities, by direct observation.
- experience of the default options after completing each assigned activity by semi-structured interview.
- factors influencing the interactions with default options by semi-structured interview.
- energy used for lighting, electrical appliances and hot water by on-site measurements and calculations.

The observed behaviours (i.e. whether the participant has overridden the default options, when performing the activities), interviewed data on experience of using the default options and energy data were analysed by statistical comparisons and correlation tests. Furthermore, the thematic analysis was applied for mapping individual psychological factors influencing the interactions with default options onto the interviewed data.



Table 1. Activities and energy-related appliances or products

| Activity | Energy-related appliance or product affecting the use of household EL and DHW | | |
|---|---|--|---|
| 1. vacuum cleaning the kitchen floor | <ul style="list-style-type: none"> ○ vacuum cleaner ○ lighting and lighting controls ○ electrical heater and thermostats |  |  |
| 2. washing hands with soap in the bathroom | <ul style="list-style-type: none"> ○ faucet and faucet aerator ○ lighting and lighting controls ○ thermostat |  |  |
| 3. preparing the simple meal (<i>Quesadillas</i>) and a cup of tea in the kitchen | <ul style="list-style-type: none"> ○ cooking appliances: stove, exhaust fan ○ kettle ○ lighting and lighting controls ○ electrical heaters and thermostats ○ kitchen faucet and faucet aerator |  |  |
| 4. reading a short newspaper article, and writing to answer the related questions | <ul style="list-style-type: none"> ○ lighting and lighting controls ○ electrical heaters and thermostats |  |  |
| 5. washing dishes by hands in the kitchen | <ul style="list-style-type: none"> ○ kitchen faucet and faucet aerator ○ lighting and lighting controls ○ electrical heaters and thermostats |  |  |



Results

The assessment methodology was developed to capture users' interactions with default options and their emotional effects through users' goals, expectation and/or beliefs about how energy-related appliances, products or features should work, dispositional liking or disliking their qualities, and relevant individual psychological and contextual factors. In line with the concept of user journey mapping (e.g. Lankmilier, 2021), this visualised interactions between users and default options.

How default options (i.e. pre-set choices for room temperature, lighting and lighting control, water temperature and flow, and electrical appliances) are experienced and used by building-end users?

Experiences and use of default options

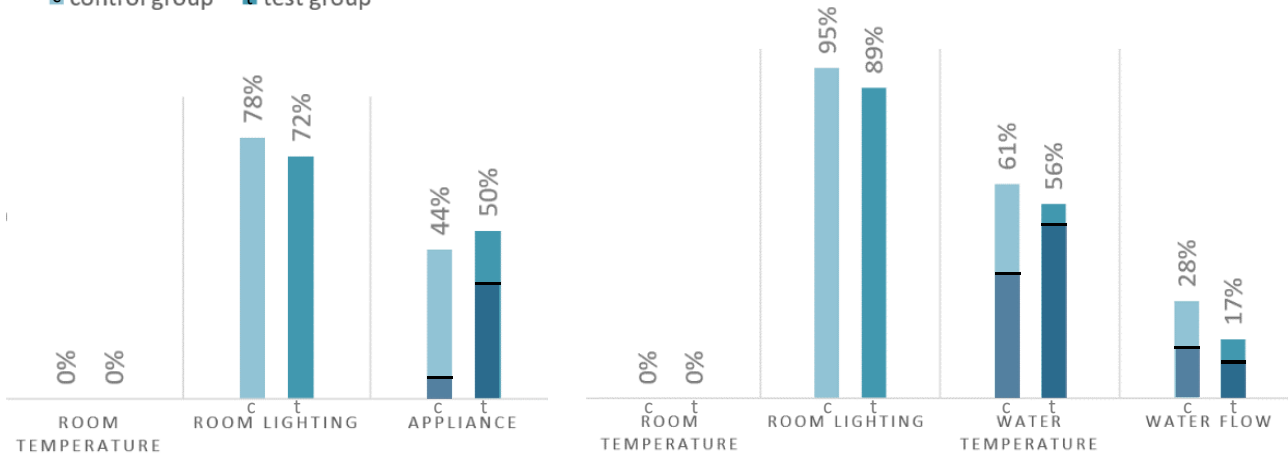
The physical environment, energy-related appliances or products and their features were experienced as facilitating assigned activities by providing guidance on how to carry them out in certain ways, thereby helping participants to achieve the goals related to the respective activities. However, this was still questionable for the vacuum cleaner and the kitchen faucet aerator. The scores for participants' experience of using these two products (M = 3.79 (of a 5-point scale), SD = 0.91, N = 36 for the vacuum cleaner, and M = 3.63 (of a 5-point scale), SD = 0.92, N = 36 for the kitchen faucet) were lower than the other products.

All the products generally received at high scores for ease of use, rightfulness and usefulness, except for the lighting controls, which were perceived as difficult to understand (M = 3.89 (of a 5-point scale), SD = 1.00, N = 33). Spearman's correlation showed that perceived ease of use, rightfulness and usefulness of products strongly associated with the users' experiences of using the products to meet the goals of the respective assigned activities ($p < 0.001$, 2-tailed, N = 180) whereas perceived ease of understanding strongly associated with perceived ease of use ($p < 0.001$, 2-tailed, N = 180). These relations were apparent for the kitchen faucet and aerator.

Overall, adjustments made to the default options for test groups and control groups are summarised in Figure 3.

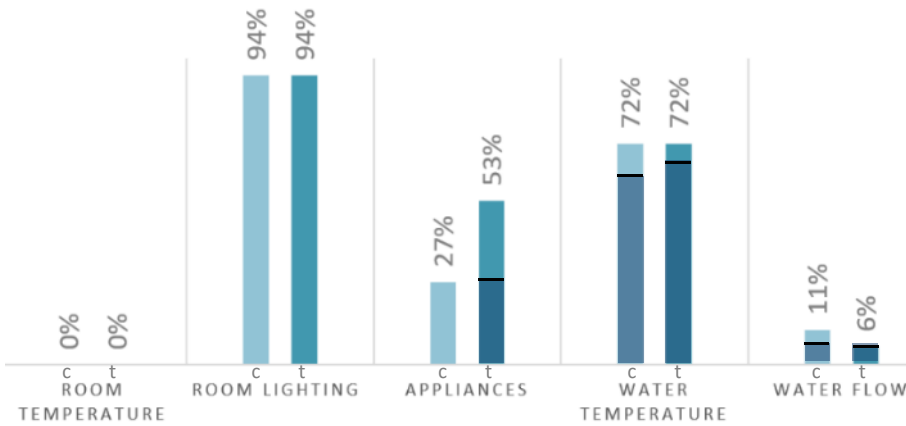


control group test group

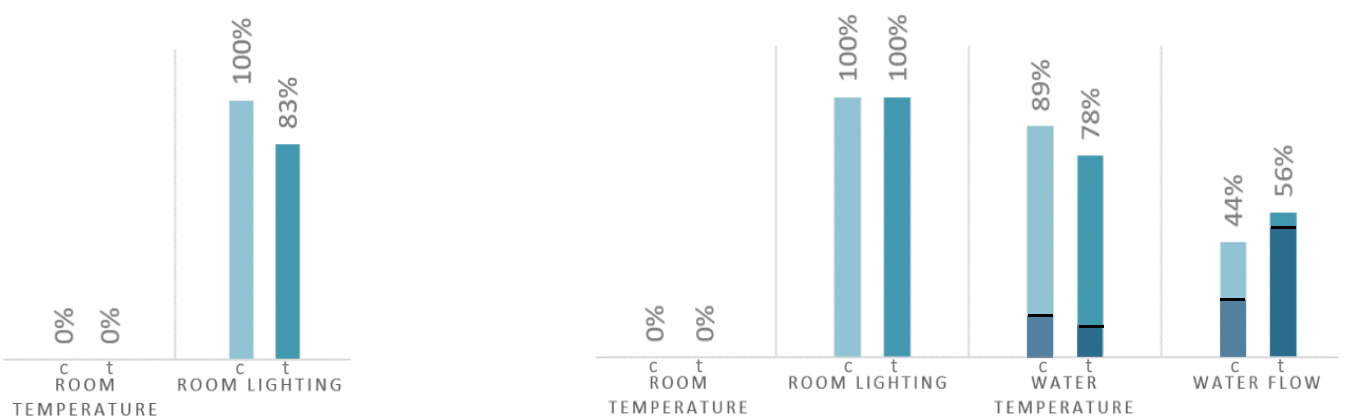


(a) 1. vacuum cleaning the kitchen floor

(b) 2. washing hands in the bathroom



(c) 3. preparing the simple meal and a cup of tea in the kitchen



(d) 4. reading and writing

(e) 5. washing dishes by hands in the kitchen

Figure 3. adjustments made to the default options (areas with darker fill for both groups show the proportions of adjustments made to the pre-set choices, leading to reduced energy use)



Electrical heaters and thermostats

There were no adjustments made to the pre-set room temperatures (between 18 °C and 24°C measured during the project time), i.e. no use of electric heaters. Most participants in both groups have already adopted adaptive behaviour by having suitable clothes or adjusting layers of clothing according to the temperature when performing the activities.



Lighting and lighting controls

Adjustments were always made to pre-set lighting conditions (between minimum average level of about 0.01 lux measured when collecting the data after dark and maximum average level of about 24.39 lux measured when collecting the data on a sunny day). Electric lighting was often turned on to enhance visual comfort as daylight in the test apartment was generally perceived as insufficient by participants in both groups. Kitchen lighting at the counter, sink or kitchen island was always turned on by the participants to improve visibility when performing the different activities whereas general lighting in the living room was turned on for a more pleasant atmosphere. Lighting in the bathroom was often turned on when washing hands.

Though the lighting was used, participants in the test group seemed to make more conscious choices to use the lamps that they considered as necessary for performing each specific activity. A couple of participants only relied on daylight while performing their activities. Most participants only turned on the specific task lamps (i.e. the lamp above the sink in the bathroom when washing hands, the lamps above the stove or the counter when cooking, a reading lamp when reading, and the lamps above the kitchen sink when washing dishes by hands). To use energy for lighting as little as possible, most participants in the test group changed their behaviours (i.e. only turned on essential lamps for the activities, turned off when not needed and make an effort to get access to daylight).



Electrical appliances

Adjustments were made to the pre-set choices for the household appliances studied in this project, i.e. the participants in both groups overrode the 'smart' function of vacuum cleaner and the pre-set temperatures of kettle and stove in the kitchen.

It was also obvious that most participants in the test group seemed to be more aware and conscious in their interactions with default options for the appliances. Despite the 'smart' function of vacuum cleaner, the participants further chose lower effects considered as sufficient. In contrast, the maximum effect was chosen since it was considered as time efficient. Temperatures on the stove were chosen in accordance with the cooking activities (in this case was often medium heat otherwise, high heat was first chosen and later lower to medium or low heat). Some participants turned off the stove earlier and continued using



remaining heat on the stove for the cooking. (it is noted that there was only one option, i.e. turning on/off for kitchen exhaust fan).

Furthermore, the pre-set for kettle temperature were often kept at 90°C or lowered to 80°C. However, the temperature of 100°C was also chosen as preferred temperature. Regardless the temperatures, about 66.70% of participants in the test group filled the kettle with water at the minimum level (0.250 litres), which is sufficient for making a cup of tea. Participants in the control group filled the kettle with water from 0.250 litres to 1 litre.

To use energy for the electrical appliances as little as possible, more than 50% of participants in the test group changed behaviours by seeking for opportunities to save or to waste less energy. These changes were, for instance, preparing the room before vacuum cleaning to use lower effect or less time, measuring water with a cup before filling the kettle and turning off the stove earlier to use remaining heat). There was no use of multi-socket extension to carry out the activities apart from the existing sockets.



Faucet and faucet aerator

Adjustments were made to the pre-set water temperature and water flow in the bathroom and in the kitchen. To wash hands, more than 50% of participants in both groups adjusted the pre-set 'neutral' water temperature while the pre-set water flow was occasionally adjusted. Among the participants who overrode the pre-set temperature, more than half of the control group and 90% of the test group chose lower temperatures. In addition to the individuals' preference, the reason that the participants kept or lower the pre-set temperature was related to time (i.e. the temperatures were acceptable for washing hands just within a short period of time).

In the kitchen, the pre-set water temperature was mostly overridden (i.e. lowered the temperature to make tea and increased the temperature to wash dishes by hands) whereas water flow was rarely adjusted. The reason participants chose cold water for making tea was related to their knowledge that warm water from the tap might contain copper and therefore, not good for drinking. Most participants increased the temperature to its highest setting when washing dishes, especially for removing grease from the pan effectively. Moreover, the pre-set water flow was adjusted to the maximum since it was considered as time efficient. Low-flow effects were sometimes chosen to avoid splashing.

Like the electrical appliances, most participants in the test group seemed to be more aware and conscious of their interactions with the default options and use of the faucets and faucet aerators. Generally, colder temperature and low flow effects were considered as sufficient and therefore, chosen. To remove grease, warm or the warmest temperatures were often chosen while the participants tended to carry out the activity as fast as possible without adjusting the pre-set water flow. Some of the participants wiped out grease from the pan with kitchen towel paper before washing. To use energy for domestic hot water as little as



18 (23)

Energy used for the cooking appliances varied from 0 kWh when the participant decided to make 'cold' quesadillas to avoid using energy to 0.269 kWh when a medium heat was chosen for a 7-minute cooking time. When participants turned off the stove earlier and used the remaining heat for cooking, the energy use could be reduced to 0.191-0.230 kWh. Energy used for kitchen exhaust fan would be about 0.023 kWh (using the default of 200 watts).

When the kettle's pre-set temperature was kept at 90°C, and the water level was at the minimum of 0.250 litres, it took about 1 minute for the water to boil, and the energy use was 0.025 kWh. The energy use increased to 0.049 kWh when the water level was 0.500 litres and the boiling time took 2 minutes, and to 0.100 kWh when the water level was 1 litre and the boiling time took 4 minutes. The energy use decreased significantly when the temperature was changed to 80°C, resulting in shorter boiling times. These reductions were obvious when the water levels were above 0.500 litres. In contrast, the energy use increased to 0.036 kWh for 0.250 litres, 0.060 kWh for 0.500 litres and 0.114 kWh for 1 litre when the temperature of 100°C was chosen and respective boiling times were therefore, longer.



Faucet and faucet aerator

Energy used for DHW was about 0.288 kWh at the pre-set choice of 38°C at the faucet and increased to about 0.493 kWh every time the temperature was increased to the warmest setting. Since most participants chose lower temperatures than the pre-set choice for washing hands within about one minute and for cooking, these activities generally required less energy. When a participant washed dishes by hand using the warmest water temperature setting, the pre-set water flow and 5 minutes for washing, energy used for DHW was 2.465 kWh compared to 1.440 kWh when the pre-set water temperature was kept.

What are individual psychological factors that influence how the users interact with default options and energy behaviours?

The interactions with default options were not solely influenced by the contextual factors in particular, energy-related appliances, products and their features but also by individual psychological factors. Habits and motivations were found to play important roles in the adjustments made to the pre-set choices. *Active use* was often associated with habits and motivated by gain goals (i.e. saving time for cleaning by using maximum effects of the appliances and water at the warmest temperature setting), and hedonic goals (i.e. enhancing pleasantness and comfort by turning on several lamps and having warm water). However, hedonic goals also influenced *Active saving* (i.e. enhancing comfort as well as subjective wellbeing by using low flow water to avoid splashing, using cold water to wash hands due to sensitive skin and having low effects of the appliances to reduce noise and sound). In general, habits were found to influence the participants' interactions with default options. In most cases, the functions and features of appliances that could contribute to energy and resource savings were overlooked because of habits.



19 (23)

Further, the perceived obligations to engage in energy-efficient behaviours and awareness of the negative environmental impacts of energy behaviours were mentioned by a couple of participants as a reason to keep the pre-set choices. The participants also expressed awareness of the adverse consequences of not performing energy-efficient behaviours in relation to environmental impacts. However, these factors did not always influence how they interacted with the default options when other factors like time-efficiency, pleasantness, comfort and convenience were more considered. Previous knowledge and experience were obviously found to have influences. The adjustments made to the pre-set water temperature were due to the previous knowledge or experience that warm water may contain copper and not good for cooking but is more effective in cleaning grease and dirt. Some participants turned off the stove before finishing cooking because they have had experienced that stoves could remain warm even after being turned off. In contrast, the knowledge about energy-efficient light source and less impacts of turning lights off on energy savings was found to influence the adjustments made to the lighting settings. Regarding *Active saving* for lighting, concerns about energy cost and energy waste were often mentioned as reasons for turning off lights when not in use.

Regardless of the instructions given to control and test groups, participants with high levels of internal motivation and strong intentions to save energy actively sought opportunities in the physical environment and through the functions or features of the appliances that can contribute to energy and resource savings. In relation to this, the participants experienced designs of energy-related appliances and products (i.e. vacuum cleaner, faucet, faucet aerator, stove, kitchen exhaust fan, kettle, lamps, lighting control system and devices) studied in this project as both behavioural facilitators and constraints.

Discussion

The use of default options can be considered as less intrusive approach to support energy-efficient behaviours as well as promote behaviour change, thereby having a potential to optimize household energy use across building end-users. This approach could be applied to the development and design phase, and the use phase of buildings. However, it is important to understand the user perspective in relation to design practices. Together with the design principles such as user experience design, universal design and inclusive design, the knowledge about individual psychological factors would help to understand, explain and anticipate user motivations and behaviours.

The project has advanced knowledge on design-user relation acknowledging the influences of building features, appliances, products or interfaces, and individual psychological factors as drivers of energy and resource efficient behaviours thereby, energy efficiency in multifamily buildings. This would benefit building practitioners, building owners, and designers through insights about the use of default options in multifamily buildings. Moreover, the knowledge can facilitate energy simulations taking diverse users and their differences in energy behaviours into consideration. The project also provided an opportunity for the participants

