Sustainability by Design. How to Encourage Users to Choose Energy-Saving Programs and Settings when Washing Laundry

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ABSTRACT

One way to counteract anthropogenic climate change, is to reduce individual energy consumption. An especially energy-intensive everyday practice is doing the laundry. In Germany, laundry accounts for about 5% of domestic electricity consumption. In part, this is because users do not make use of the energy-saving programs offered by modern washing machines. Based on different principles of behavior change, we created four concepts for washing machine interfaces to encourage users to choose energy-saving programs and settings. These concepts were implemented as functional prototypes. An online experiment (N=400) showed that all concepts increased the choice of energy-saving programs compared to a standard machine. Especially effective was to interrupt impulsive actions and suggest alternative choices (concept B) and to restructure the entry of settings (concept E). This demonstrates how small changes in a standard interfaces can significantly increase the probability of energy conservation in a private setting.

CCS CONCEPTS

• **Human-centered computing → Interface design prototyping; Empirical studies in interaction design.**

KEYWORDS

Behavior change, persuasive technology, sustainable HCI, sustainability, sustainable interaction design, laundry washing, empirical study, prototyping

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1 INTRODUCTION

In light of the threatening consequences of anthropogenic climate change, it seems paramount to reduce individual energy consumption. For example, within the European Union as much as 24% of the yearly energy is consumed by individual households [16]. This is due to the many energy-intensive daily routines or activities of consumers within their household, such as a heating, taking hot showers, or doing several courses of laundry a day (e.g., [16]). Thus, one way to counteract the consequences of climate change would be to reduce energy consumption of these activities, for example, by reducing the room temperature, showering more quickly, or by reducing the amount of laundry and its energy consumption. Unfortunately, consumers rarely act accordingly. A possible explanation is that climate objectives are very abstract and future-oriented goals and, therefore, not easily put into practice (e.g., [22, 39]). In addition, the many energy-intensive daily activities offer direct gratification through immediate comfort, which will increase their execution (cf., [3, 39]). Therefore, consumers might need external support to follow and achieve the abstract goal of reducing individual energy consumption. As most of the energy-consuming activities are linked to or achieved through the use of technology, technology design is a possible leaver to foster behavior change and reduce individual energy consumption.

For quite a while now, Human-Computer Interaction (HCI) studies how consumer behavior could be changed through technology [5, 41]. Broadly, two different types of approaches are offered: (1) feedback and arguments to persuade consumers to behave differently (e.g., Persuasive Technology [19]) or (2) situational interventions (i.e., "choice architectures" [52]) to prevent impulsive actions and to disturb unconscious unwanted routines. The underlying assumption of persuasion is that users make rational decisions, but lack the "right" information and knowledge to do so. From a psychological perspective, this approach is based on the precondition of a reflective system in which behavior emerges as the result of conscious decision-making. In the context of sustainable behavior, technologies designed according to this approach, for example, confront the user with information of how much hot water is consumed during a shower [29] or visualize water as a limited amount that decreases [37].

The underlying assumption of situational interventions is that people mostly not act rationally, but are driven by mainly unconscious impulses, automatic routines and limited resources to make conscious decisions. In contrast to a reflective system, these approaches build upon an impulsive system, in which behavior emerges from previously learned schemata. Technologies, which implement this approach, for example, confront users with the choice between a bicycle or a car key to break routines [35] or hide less sustainable choices and even remove them completely [40].

While a number of everyday practices had already been subject to work in HCI (e.g., to save hot water while showering, to save electricity, or to separate waste correctly) doing the laundry as an especially energy-intensive activity has rarely been explored so far. Laundry accounts for about 14% of household electricity consumption in Germany, with about 5% alone for washing and about 9% for tumble drying [14]. Consequently, the EU Commission has set design requirements for manufacturers (e.g., [44]) to counteract the high energy consumption. This includes the mandatory and accessible installation of so-called energy-saving programs for washing machines. While modern washing machines at least in Europe offer such energy-saving programs (e.g., Eco 40-60), they seem to be only rarely used. According to a globally operating machine manufacturer, for example, only 5% of their customers use eco-friendly programs [49]. This implies that a change in consumer behavior towards more sustainable washing needs more support than the "simple existence" of a more sustainable program.

In this paper, we explore how small changes in the design of a washing machine's interface can encourage users to choose energy-saving programs and use in general more sustainable settings. On the one hand, washing, and thus selection of the programs, can be a routine, done with minimal attention. On the other hand, washing can also be done in a conscious and reflective manner. In line with this, based on the approach of dual-process models (e.g., [42, 50]), we developed four experimental interfaces of a washing machine. Dual-process models state that human behavior is determined both by a reflective and an impulsive system of information processing. Accordingly, two of the interfaces were based on the approaches of Persuasive Technology [19] (i.e., approaches targeting reflective behavior) and two on situated interventions [25, 38] (i.e., approaches targeting impulsive behavior). In an online experiment, participants were given two different types of laundry and had to determine which program to use and to actually operate the machine through a simulation of the respective interface (4 experimental, 1 control). We expected an increase in the choice of the eco-friendly programs for all experimental interfaces compared to the standard interface (control). The motivation of the present work is to design interfaces, which include design elements that are based on implications of theoretical frameworks (in our case, the psychological approach of dual-process models), in the so-far rarely addressed context of washing. Specifically, this means that the design of the interfaces included design elements fostering sustainable behavior within an impulsive routine of washing, on the one hand, and within a reflective decision-making process, on the other hand. We aimed at evaluating these interfaces in terms of their impact on sustainable program choice and settings. Moreover, we explored the difference between a conscious decision compared to an impulsive (i.e., automatic) one in terms of design and effect. From a practical perspective, the paper provides examples of washing machine interface designs that not only present sustainability as a possible option (among many unsustainable ones), but actively propose them. Thus, this paper contributes to the field of Sustainable HCI by exploring how different theory-based design approaches to behavior change can contribute to resource conservation in a highly resource-intensive context.

In the following, we address the theoretical background, focusing on dual-process models and corresponding theories from psychology and approaches within HCI, as well as relevant empirical work. Subsequently, we present our four concepts and how their design draws on the described theoretical approaches. Finally, we present our conducted empirical study, including the applied methods and results, focusing on how the developed concepts affect users' sustainable washing behavior. Finally, we discuss our findings, their contribution to theory and practice, as well as their limitations and directions for future research.

2 RELATED WORK

In the following section, we briefly introduce the approach of dual-process models as a suitable theoretical framework to understand different HCI approaches for sustainable behavior interventions. Subsequently, we describe common HCI approaches to sustainable behavior change as well as areas in which they are already applied.

2.1 Dual-process models and determinants of individual behavior

To understand the causes of human behavior and how it can be influenced, it appears worthwhile to look into basic behavioral theories. In psychology, a widespread framework to explain human behavior are so-called dual-process models [42, 50].

Dual-process models assume a *reflective* and an *impulsive system* of information processing that both determine human behavior. In the *reflective system*, behavior is elicited as the result of a decision-making process characterized by reasoning and the use of knowledge. Advantages and disadvantages of a behavioral option are weighed and integrated to come to a decision that leads to actual behavior. This process requires a high amount of cognitive capacity and is based on the assumption that humans are rational beings. Yet, oftentimes, individual behavior is not solely based on a rational decision process (e.g., [53]), as individuals do not always have sufficient cognitive resources to reflect on their behavior or sufficient self-control (e.g., ego depletion [43]) to resist everyday temptations [25, 42]. Even when knowledge about the correct behavior is available, individuals mostly prefer to follow routines rather than supposedly superior (i.e., sustainable) behavioral options, especially in the context of daily activities [53]. Therefore, dual-process models assume another system that determines behavior - an *impulsive system*. In the impulsive system, behavior is elicited by perceptual input (i.e., stimuli) that activates learned (i.e., paired) behavioral schemata. This process is fast and requires little or no cognitive effort. Since behavior is not thought through but rather triggered by stimuli, behavior controlled by the impulsive system requires less attentional resources. Other theories in psychology related to sustainable behavior also reflect this basic model that both reflected and conscious decisions, as well as the link between perceived behavioral opportunities and actual actions, determine behavior. For instance, although still a highly cognitive approach, the *Theory of Planned Behavior* [1], contains both strongly reflective elements (Attitude and Social Norms) and elements that include contextual opportunities (Perceived Behavioral Control with a direct link to actual behavior) to explain the formation of intention and behavior.

Through both systems, impulsive and reflective, dual-process models can be used to explain both habitual and intentional behavior. In other words, the dual system models explain both situations in which people tend to weigh, reflect, and adapt, and situations in which they tend to get things done, and just act without much reflection. From an HCI perspective, dual-process models provide two perspectives for designing behavior change technologies. On the one hand, one can address behavior change by forming a rational decision by providing information and arguments that persuade and direct a decision. However, this strategy will reach its limits when people act habitually (i.e., with almost no attention) and do not possess enough attentional resources or self-control. Therefore, on the other hand, one can also address behavior change through contextual changes that directly influence behavior by offering or even encouraging behavioral options. For such an approach, the formation of an intention or conscious decision is unnecessary since the context presents some behavioral options in such a way that their choice becomes more likely and the choice of other options less likely. Both approaches, forming rational decisions or influencing behavior through contextual changes, can be addressed using interactive technology and are part of research within HCI.

2.2 Behavior Change in Sustainable HCI

Taking the approach of dual-process models as a basis, we see two different design approaches for interactive technologies for behavior change in HCI. Technologies that intend to address knowledge, insight, and rational decision processes, and technologies that change contexts and intend to affect routines. Both ways of changing behavior toward sustainability are already being used in work and approaches in HCI. Here a basic distinction can be made between two approaches: Persuasive approaches and situated interventions.

Persuasive approaches. Persuasive approaches of behavior change [18, 37] try to support a change in behavior by addressing the intentions of an individual. By means of information and appeals, individuals are guided to reconsider their intentions and, ideally, show a sustainable behavior. Typical methods based on persuasive approaches are feedback (e.g., [37]), goal setting (e.g., [21]), or social comparison (e.g., [11, 17]).

A specific product that follows the persuasive approach in the context of sustainable behavior is the *Show-me* [29], a display placed in the shower that uses LEDs to display the water consumption during showering.

Situated interventions. Situated interventions, on the other hand, seek to change behavior by breaking routines and presenting (sustainable) alternatives to a concrete situation [25]. Situated interventions change the context and thus materially shape behaviors, e.g., through *nudging* [38]. Through a particular choice architecture [38], certain behaviors can be suggested to persons without exerting coercion. By providing behavioral alternatives, i.e., implementation intentions [22], situated interventions can question habitual behaviors and ultimately break routines. One approach in HCI that materializes implementation intent are *Pleasurable Troublemakers* by Hassenzahl et al. [25]. According to Hassenzahl et al., *Pleasurable Troublemakers*, with their empathetic nature, actively and situationally point out unsustainable behaviors to individuals and provide them with more sustainable alternatives without imposing them. By applying the approach of materialized implementation intentions, they can motivate individuals to act more sustainably and achieve specific sustainability goals.

An example of this is *Keymoment* [35], a key rack on which the bicycle key and car key hang side by side. If one reaches for the car key (as usual), *Keymoment* drops the bicycle key on the floor. Picking it up, one must choose between one of the options. This way, the sustainable alternative is instilled into the routinized behavior through the context, with *Keymoment* as part of it.

2.3 Sustainable HCI

Under terms such as "Sustainable HCI" or "Sustainable Interaction Design", there are already numerous publications in the HCI community on changing behavior in private households toward sustainability. Mostly, the research presented addresses the sustainable use of certain resources such as energy and water [24].

Regarding the topic of sustainable energy and power consumption, there are a large number of papers that address this topic in general without focusing on a specific context or device (e.g., [46–48, 51]). Other papers focus on specific domains and devices such as lighting (e.g., [28, 36]), home and entertainment appliances (e.g., [23, 34]), laundry washing and drying (e.g., [7, 12, 28]), heating (e.g., [11, 27]) and transportation (e.g., [20, 35]).

With regard to the topic of water consumption, there are publications on the activity of showering (e.g., [29, 33, 37]) and washbasin use (e.g., [2, 6]), in addition to publications without a specific contextual focus (e.g., [51]).

Although there is a lot of work on motivating sustainable and resource-conserving behavior, the topic of sustainable laundry care is rarely, if ever, addressed. This is quite surprising, since sustainability plays a major role in this context and, in addition, an interactive object is available in the form of the washing machine. For this reason, the present paper aims to fill this gap by examining the specific design of a washing machine interface and its impact on the sustainable laundry care practices of private households. In this way, concepts and solution strategies are to be found that are particularly valuable in encouraging people to behave (i.e., wash) more sustainably.

3 FOUR BEHAVIOR-CHANGING WASHING MACHINE CONCEPTS

Based on the aforementioned approaches in HCI, we designed four washing machine interfaces intended to encourage users to select more sustainable wash settings (see table 1). We define sustainable washing settings in terms of eco-programs (i.e., Eco 40-60 or Easy-care) and/or lower wash temperatures, as these settings have the largest impact on energy consumption. Two of the concepts are based on the approach of Persuasive Technologies (i.e., assuming a reflective decision), whereas the other two are based on the approach of situated interventions (i.e., assuming an impulsive behavior). The design and interaction of all concepts is generally based on an existing washing machine interface of a globally operating manufacturer (i.e., Default/control condition). The design (e.g., aesthetic) and interaction (e.g., framework and structure) of all concepts are generally based on an existing washing machine interface from a global manufacturer. Here we adopted the settings commonly available in European washing machines (cotton, Eco 40-60, easy-care, delicates, quick), the temperature in °C (cold, 20, 30, 40, 50, 60, 75, 90), and extras (quick, prewash, water plus). Accordingly, the default settings and options are based on the washing machines used in Europe and the regulations that apply there. The settings and options available in Asia or North America, for example, may differ (e.g., the temperature settings in North America are often only low, warm, or hot). Since it is becoming more common for most manufacturers to use a large touch interface for interaction, we also decided to use such a model as a reference. In the following, we briefly introduce all concepts and interfaces and how their design reflects one of the different systems (i.e., a reflective or impulsive). For an overview of how the concepts work, please see the link for a video figure (https://vimeo.com/750047436).

4 EMPIRICAL STUDY

4.1 Prototype implementation

To make all four experimental concepts and the default concept accessible to participants in an online study, we built five fully interactive prototypes using Axure (axure.com), a design and prototyping tool. We integrated the functional prototypes into an online-survey. The prototypes are fully interactive and can be operated with a computer mouse. To determine the CO_2 equivalent[1] for all settings possible (program choices, temperatures, extras), we used a rather simple model. We determined the electricity consumption (in kWh) and water consumption (in liters) of the different settings using real measurement data from a global washing machine manufacturer and summed the respective CO_2 equivalents. We based the CO_2 equivalent for electricity consumption on the electricity mix in Germany in the year 2021 [26] where 485g CO_2 equivalent were emitted per kWh. For tap water consumption, we used data from 2020 [31] where 0.35g were emitted per Liter. It should be noted that the absolute figures vary at different times and in different countries (e.g., due to types of energy production). However, these differences, being only absolute, do not affect the statistical differences between our conditions. The CO_2 equivalent was then used as a basis for fictional consumption points, which are used in the concepts *Comparison* (D) and *Budgeting* (C).

4.2 Participants

The study was conducted in summer 2022 in the form of an online questionnaire using LimeSurvey (www.limesurvey.org). We recruited the sample via Prolific (www.prolific.co), where participants were compensated for their participation. Participants were screened for fluency in German and living in Germany. The platform ensured that each participant could participate only once and only in one condition. Overall, 400 participants (47.8% female, 51.2% male, 1.0% diverse) took part in the study and were randomly assigned to five conditions. Thus, each condition included 80 participants. The sample's average age was 30.74 years (*SD* = 9.63 years, *Min* = 18 years, *Max* = 71 years), and their households in average consisted of 2.37 members (*SD* = 1.24, *Min* = 1, *Max* = 8).

4.3 Procedure and measures

The survey was carried out in German and consisted of four parts. All participants received the same questionnaire, only the prototypes differed in the five conditions with the *Default* concept (A) representing the control condition and the concepts *Alternative* (B), *Budgeting* (C), *Comparison* (D), and *Starting from laundry* (E) representing the experimental conditions. On the recruitment platform we announced the study as a study on laundry washing.

(1) The **first part** introduced the functionalities of the above-presented functional prototypes to participants. Additionally, participants were asked to read a scenario, including a first laundry task. In this, we asked participants to imagine being part of a two-person household and wash (task 1) normally soiled cotton towels and bed linen using the prototype. After setting the washing machine as they wished to, a popup window with a code appeared. We asked participants to copy this code into a text field in the questionnaire and continue with the questionnaire. The specific code made it possible for us to track the choices they made with regard to the washing program, temperature, revolutions per minute, and activated extras. Right after, we asked them to answer questions about the anticipated cleaning performance (measure as specified below) and their final choice of program. Subsequently, this procedure was repeated with the same prototype with a second different washing task. In the second task (task 2) we asked participants to wash normally soiled cotton T-shirts and sweatshirts. We have chosen these two washing tasks because, on the one hand, they are compatible with all programs of the prototypes and, on the other hand, they potentially have different hygiene requirements. Bed linen and towels are often associated with 60°C, whereas T-shirts and sweatshirts are also washed at 30 or 40°C. Both tasks should thus better reflect the different requirements for laundry washing in everyday life.

After they had interacted with the washing machine twice, in the **second part** of the survey **(2)** participants were asked to answer various questions aiming at assessing participants affect (see

[1]To make the potential impact of different sources on climate change comparable, the International Panel on Climate Change (IPCC) of the United Nations has set CO_2 equivalents as a measuring unit. CO_2 equivalent is the number that indicates how much any gas contributes to global warming over a certain period of time (usually 100 years) compared to the same amount of CO_2. This allows comparison of almost all energy consumptions in terms of their contribution to global warming, even if they do emit other gases than CO_2.

Table 1: Overview of the Default concept (A) and the four washing machine concepts (B-E) assigned to the two behavior change approaches

<table>
<tr><th colspan="2">Default (concept A/control condition)</th></tr>
<tr><td>

</td><td>The concept serves as the control condition for the study and is similar to the interface of an existing washing machine of a globally operating manufacturer. The washing programs available are the four most frequently used by private households (i.e., Cottons, Easy-care, Delicates, and Quick [32], as well as the legally prescribed Eco 40-60 program. In addition, depending on the selected washing program, users can select the washing temperature, the spin speed, and one of three available extras (water plus, prewash, quick). The possible combinations of programs, washing temperature, and spin speed correspond to those of the reference machine.</td></tr>
<tr><td>

Situated interventions
(i.e., assuming an impulsive behavior)
Technologies present options in a Choice Architecture. Sustainable options are pre-structured or non-sustainable options are even removed. This facilitates and guides a choice in a goal-oriented way.

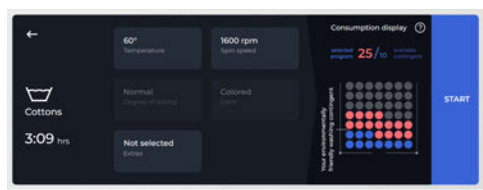
</td><td>

Persuasive approaches
(i.e., assuming a reflective decision)
Technologies persuade with the help of information, feedback, or arguments. In this way, users should make an informed and rational decision.

</td></tr>
<tr><th>Alternative (concept B)</th><th>Budgeting (concept C)</th></tr>
<tr><td>

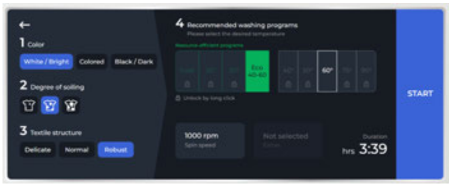
Users can initially select any settings (see Default concept). By pressing the Start button, a popup window appears that suggests a sustainable alternative setting that matches the previously made settings (if there are more sustainable settings). To compare both options, the popup shows settings, estimated consumption, and duration [37]. This information is directly related to the choice situation to encourage users to make sustainable choices [21]. In this way, the concept aims at making users stop and question unreflective behavior (i.e., settings) while offering a sustainable alternative (i.e., similar to the concept of Implementation Intention or Pleasurable Troublemakers [25]).

</td><td>



Users can freely select any settings (see Default concept). To the right of the actual touch surface, the expected consumption is displayed in the form of colored circles (consumption points). 1 consumption point represents 21 g CO_2-equivalents. This is roughly 0.04 kWh of electricity and 60 liters of water. Settings with high energy consumption are displayed with many consumption points and settings with low energy consumption with fewer. In addition, an available budget is also displayed (blue circles). The budget refills over time but is also spent using the machine (similar to a bank account). The budget shown here (and in the later study) represents the consumption of a sustainable wash program (i.e., Eco 40-60 emits ~208g CO_2 equivalent and is therefore displayed with 10 consumption points). The budget reflects limited resources, and both frequency and intensity make a difference in resource consumption. Thus, this direct feedback shows that different settings make a difference in consumption.

</td></tr>
</table>

<table>
<tr><th>Starting from laundry (concept E)</th><th>Comparison (concept D)</th></tr>
<tr><td>


In contrast to conventional washing machines (e.g., as in concept A-D), in which all possible settings are displayed, concept E starts with entering the laundry that needs to be washed. Subsequently, users specify whether it is colored or white clothes, how much they are soiled, and how resistant (i.e., robust) to mechanical movement of the machine they are. Following this, the interface suggests a washing program based on these inputs. However, if users do not accept the suggested settings, they can always unlock other settings by pressing the relevant button for a long time. This freedom of choice is essential to preserve the autonomy of users and avoid reactance [8]. The concept thus seeks to break learned behavioral schemata and (possibly unsustainable) washing routines of users when operating the washing machine.
</td><td>


Similar to the Budgeting concept, the Comparison concept displays consumption points based on the settings made. In addition, the display shows the average consumption of comparable other households next to the selected personal consumption. Below the current consumption data, the display shows the consumption data of the last four washed machines. This allows users to compare their consumption with other users and previous washes. Thus, the concept uses feedback, comparison, and social comparison (e.g., [11, 17, 21, 21, 37]) as persuasive principles.
</td></tr>
</table>

below for a detailed description of the scale used and its properties) as well as their experience and evaluation of the prototype (measures as specified below). In the **third part (3)**, we asked participants to provide information about their household as well as some demographic data. Finally, the **fourth part (4)** consisted of a measurement of participants' motivation toward the environment (for a detailed description of the scale, see below) before the survey ended with the option to share further comments. We did not provide any indications regarding the topic of sustainability in parts 1-3 of the experiment. Neither the scenario (i.e., *"washing laundry for a two-person household"*) nor the washing tasks (i.e., washing cotton bed linen and towels or cotton T-shirts and sweatshirts) contain any references regarding sustainability. Within both the scenario and the two tasks washing laundry was framed as an everyday task (e.g., *"[...] As in every household, laundry is generated here as well. [...] You want to wash this basket of laundry now"*). Only in the fourth part of the survey, where we measured participants' motivation toward the environment (with items such as *"I like the feeling when doing things for the environment"* or *"I would feel bad if I didn't do anything"*) there were indications that sustainability might be an aspect of the study. Therefore, this scale was included at the end of the survey and presented after the assessment of the dependent variables (e.g., choice of program as well as prototype experience and evaluation).

4.3.1 Affect. Participants' experienced affect while using the washing machine prototype was measured by means of the *Positive Affect Negative Affect Schedule's* (PANAS; Watson et al. [55]), German translation after Krohne et al. [30]. Participants were asked to indicate on a 5-point scale of 1 (not at all) to 5 (extremely) to which extent they experienced the specific facets. The internal consistency for the positive affect was good (Cronbachs α = .89) and acceptable for the negative affect (Cronbachs α = .79) (cf.,[4]). The non-significant intercorrelation indicates independence of scales (r = .086, p = .085).

4.3.2 Prototype experience and evaluation. Participants were asked to which extent (1 = not at all; 5 = completely) they agree to eight self-constructed items about their experience and evaluation of the washing machine concepts used in the study. Right after both laundry tasks, we asked participants to rate the *cleaning performance* of the choice they had made to clean the specific type of laundry ("The laundry has become clean through the washing process"). Since the participants only imagined washing clothes, they should rather anticipate the cleaning performance of their settings here. Thereby, we wanted to make sure that participants did not associate eco-programs with lower cleaning performance. Afterward, we assessed the prototypes' *everyday suitability* ("I can imagine using this washing machine in everyday life"), participants' *experience of fun* ("I enjoyed operating the washing machine") and its *ease of use* ("Operating the washing machine was easy"). Furthermore, we asked participants to rate the *perceived level of freedom* ("I was able to set the washing machine the way I wanted to") and the extent of *perceived behavioral influence* ("I had the feeling that the washing machine wanted to influence my behavior"). Afterwards, we assessed participants' *reflection on sustainability* during the interaction ("I thought about energy and water consumption when selecting wash programs") and the *perceived enablement of sustainable practices* ("The washing machine has given me the opportunity to wash in a resource-saving way").

4.3.3 Involvement in laundry washing. To assess participants' perceived responsibility for laundry washing in their own homes (*"In my household, I am responsible for laundry washing"*) as well as their perceived expertise (*"I have expertise in laundry care"*) and interest in laundry washing (*"I am interested in laundry care"*) we applied self-constructed items to be rated on a 5-point scale of 1 (do not agree at all) to 5 (agree fully).

4.3.4 Motivation toward the environment. To assess participants' underlying motivation for environmental behavior, whether it was rather intrinsic or extrinsic (controlled) or even a lack of motivation (i.e., amotivation), we used the *Motivation Toward the Environment Scale* (MTES) by Pelletier et al. [45] in a version we translated to German. Since all experimental prototypes require a certain level of motivation, it was important to check that participants were not strongly extrinsically motivated or even amotivated. The scale consists of six subscales with four items each, whereby each subscale represents one of the different forms of motivation as stated by the self-determination theory by Deci and Ryan [13]. Thus, the MTES covers a range from intrinsic, self-motivated reasons to carry out environmental activities to amotivation that entails not carrying out such activities at all. In the present study, participants indicated on a 7-point scale of 1 (not at all) to 7 (completely) to which extent they agree to the statements. To create scores for each of the different forms of motivation for every participant, means were calculated for the corresponding items of the different subscales. The internal consistency of all subscales was satisfactory, with good values for the scales Intrinsic Motivation (Cronbachs α = .88), Integrated regulation (Cronbachs α = .88), Introjected Regulation (Cronbachs α = .89) and Amotivation (Cronbachs α = .88) as well as acceptable values for Identified Regulation (Cronbachs α = .77) and External Regulation (Cronbachs α = .76) (cf.,[4]).

5 RESULTS

In the following, we briefly present the results of our empirical study. First, we present preliminary findings focusing on affect or motivation toward the environment as control variables. In this, we explore whether there were any differences in mean affect or motivation toward the environment regarding the participants of each concept condition, to rule out potential confounding effects with regard to these variables. We then present key findings regarding effects of concepts on program choice and CO_2 equivalent (total and for both washing tasks). Finally, we elucidate other findings concerning the interrelation of concepts and perceived degree of freedom and perceived influence on participants' behavior, as well as the extent to which participants thought about sustainability when interacting with the concept.

5.1 Preliminary findings

5.1.1 Involvement in laundry washing. Prior to our main analyses we explored whether participants in the different conditions differed with regard to their perceived responsibility for laundry washing in their own homes as well as their expertise and interest in washing. Overall, participants' ratings of responsibility for laundry washing at home (*M* = 3.93, SD = 1.14) as well as their expertise (*M* = 3.33, SD = 1.00) and interest in washing (M = 2.91, SD = 1.10) were above scale average. Furthermore, conducted Kruskall-Wallis Tests did not show significant differences in the distributions of responsibility for laundry washing at home (χ^2 = 2.781, p = .595), nor expertise (χ^2 = 4.051, p = .399) or interest in laundry washing (χ^2 = 2.926, p = .570), across the conditions. Therefore, we did not consider these variables in further analyses.

5.1.2 Motivation toward the environment. The Motivation Toward the Environment Scale indicated that overall participants' motivation toward the environment was mostly identified (*M* = 6.17, *SD* = .73), intrinsic (*M* = 5.51, *SD* = 1.01), introjected (*M* = 5.14, *SD* = 1.34) and integrated (*M* = 4.79, *SD* = 1.27). Participants were less externally motivated (*M* = 2.72, *SD* = 1.12) and amotivated (*M* = 1.96, *SD* = 1.15) toward the environment. Thus, among participants, sustainable behavior is highly integrated or highly internalized. Thus, sustainable behavior is highly integrated or highly internalized among participants, which is conducive to the prototypes' effect (which do not motivate extrinsically or even punish). Conducted Kruskall-Wallis Tests did not point to significant differences in the distributions of Intrinsic Motivation (χ^2 = 6.521, p = .163), Integrated Regulation (χ^2 = 6.660, p = .155), Introjected Regulation (χ^2 = 4.018, p = .404), External Regulation (χ^2 = 2.768, p = .597) or Amotivation (χ^2 = 7.043, p = .134) across the conditions. The first analysis of Identified Regulation pointed to differences across the concepts (χ^2 = 13.266, p = .010), however, post-hoc tests (Dunn-Bonferroni tests) showed that none of the pairwise comparisons were statistically significant. Therefore, we did not consider the scale in further analysis.

5.1.3 Affect. On a descriptive level, while using the five washing machine prototypes, participants' positive affect corresponded to the scale mean (*M* = 3.00, *SD* = .78), whereby their negative affect was below scale mean (*M* = 1.15, *SD* = .27). Results of Kruskal-Wallis-Tests indicated that neither participants' positive affect (χ^2 = 3.226, p = .521) nor negative affect (χ^2 = 9.315, p = .054) differed across the five conditions. Participants' affect state was therefore not considered further.

5.1.4 First impressions of the prototypes. Overall, participants' rating of the cleaning performance was above scale mean for the first wash cycle (*M* = 4.49, *SD* = .63) as well as for the second wash cycle (*M* = 4.53, *SD* = .60). Furthermore, the rating of everyday suitability (*M* = 4.39, *SD* = .81), experience of fun (*M* = 4.21, *SD* = .85) and ease of use (*M* = 4.66, *SD* = .57) were above scale mean. The analysis with Kruskal-Wallis-Tests did not reveal significant differences between the concepts for the perceived cleaning performance in the first (χ^2 = 8.814, p = .066) or second (χ^2 = 4.616, p = .329) laundry task. Also, no significant differences could be identified in the rating of everyday suitability (χ^2 = 8.634, p = .071), experience of fun (χ^2 = 4.861, p = .302) or ease of use (χ^2 = 6.088, p = .193).

5.2 Main findings

As the study's main aim was to explore the effect of different washing machine concepts on sustainable setting, analyses mainly focused on the effect of the concepts on the choice of the washing program and settings as well as the CO_2 equivalent with it. In the following, we present findings in this regard.

5.2.1 Choice of program. First, the washing programs that participants chose were examined on a descriptive level. The effect of the concepts on the choice of the program was considered for two different tasks to further explore generalizability of findings throughout the domain of washing. In the first laundry task, participants with the concepts *Default* (A) or *Comparison* (D) most frequently chose the cottons program, followed by the Eco 40-60 program (see figure 1 for an overview of program choices). In the case of the other three concepts (*Alternative, Budgeting, Starting from laundry*), more sustainable options were chosen, with the concept *Alternative* (B) standing out in particular due to the frequent choice of the Eco 40-60 program, and the concepts *Starting from laundry* (E) due to the frequent choice of Easy-care program (also a further low energy program).

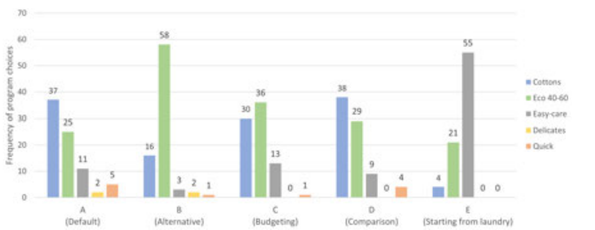


Figure 1: Frequency of chosen programs in the first laundry task across the five concepts

Considering the second washing task on a descriptive level (see figure 2 for an overview of program choices), participants with the *Default* concept (A) most frequently selected the cotton program. In addition, participants with the *Alternative* concept (B) again selected the Eco 40-60 program most frequently, although it was selected less frequently across all concepts in the second task. Despite the general decrease in the selection of the Eco 40-60 program, participants tended to make more sustainable choices in the second washing task, particularly by selecting the Easy-care program, such as with the concept *Starting from laundry* (E).

To assess the relation between the five conditions (A-E) and program choice (Cottons, Eco 40-60, Easy-care, Delicates, Quick), we performed a chi-square test of independence for both tasks using a 5x5 contingency table. The relation between these variables was significant for both washing tasks, (task 1) χ^2 = (16, N = 400) = 170.32, p = .000 and (task 2) χ^2 = (16, N = 400) = 168.89, p = .000. This shows that program choice differed between the different concepts (i.e., interfaces). To further assess the difference between the four experimental conditions (concepts B-E) compared with the control condition (concept A), we performed a chi-square test for independence for both tasks using a sub-table of the original 5x5 contingency table. The relationship between these variables was significant for both washing tasks, (task 1) χ^2 = (1, N = 400) = 3.25, p = .043 and (task 2) χ^2 = (1, N = 400) = 5.661, p = .0010. Thus, in the four experimental conditions (concepts B-E), participants significantly more often chose the eco-program compared to the control condition (concept A)

5.2.2 Total CO_2 equivalent. As explained in previous sections, we determined the associated CO_2 equivalent in grams based on participants' choices in washing tasks according to the related electricity and water consumption. Considering the total CO_2 equivalent participants would have emitted over the two washing tasks, those using the *Default* concept (A) would have emitted 603.31g CO_2

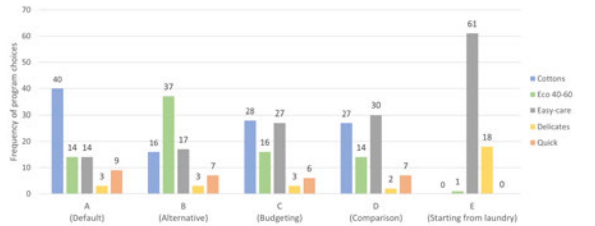


Figure 2: Frequency of chosen programs in the second laundry task across the five concepts

equivalent (SD = 189.89) in average. In the experimental conditions the average total CO_2 equivalent emitted would have been 472.90g (SD = 155.94) with concept *Alternative* (B), 501.02g (SD = 178.86) with *Budgeting* (C), 583.13g (SD = 196.06) with *Comparison* (D) and 387.79g (SD = 115.26) with *Starting from laundry* (E). Thus, the *Default* condition (A), which is comparable to a common washing machine, would have led to the highest total CO_2 equivalent. Exemplary statements of participants on reasons for their choice of program hint at potential explanations of this pattern, especially when focusing on those who chose particularly unsustainable options (e.g., "*I always wash bed linen and towels at 90 degrees, whether they are very dirty or slightly dirty.*" [P8; concept A]; "*For reasons of hygiene, I always wash towels etc. at 60°. It's a matter of habit, that's how my mom showed me in the past.*" [P68; concept A]).

To determine if there were significant differences in the total CO_2 equivalent between participants in the four experimental conditions (concepts B, C, D, E) and the control condition (concept A), we calculated Mann-Whitney-U-Tests. The analysis showed that participants using the concepts *Alternative* (B), *Budgeting* (C), and *Starting from the laundry* (E) would have emitted statistically significantly less CO_2 equivalents than participants using the *Default* concept (A). No significant differences were found when comparing the concept *Comparison* (D) with the *Default* concept (A). Table 2 gives an overview of the results.

Table 2: Differences in total CO_2 equivalent with concepts A, B, C, and D compared to concept A

Comparison	M_{Rank}	U	z	r	p
Default (A) Alternative (B)	98.69 62.31	1744.50	-4.976	.393	< .001
Default (A) Budgeting (C)	95.75 65.25	1980.00	-4.164	.329	< .001
Default (A) Comparison (D)	83.76 77.24	2939.00	-.891	.070	= .373
Default (A) Starting from laundry (E)	112.99 48.01	601.00	-8.875	.702	< .001

Note. M_{Rank} = Mean Rank. U = Mann-Whitney-U. z = Z-score. r = Effect size of Pearson's r. p = Asymptotic significance (2-tailed).

5.2.3 CO_2 equivalent per task. For further analysis of differences in the CO_2 equivalent, we distinguished between the two laundry tasks and looked into participants' responses to the open-ended questions in the survey right after each laundry task to get some qualitative first impression into their decision-making.

Overall, on a descriptive level, participants' choices were accompanied with an average of 286.84g CO_2 equivalent (*SD* = 148.98) in the first laundry task and 222.79g CO_2 equivalent (*SD* = 77.17) in the second laundry task. This result indicates the difference between the two washing tasks, where the first task was to wash towels and bed linen, and the second was to wash T-shirts and sweatshirts. Figure 3 gives an overview of the average CO_2 equivalent in each of the laundry tasks across the five different concepts.

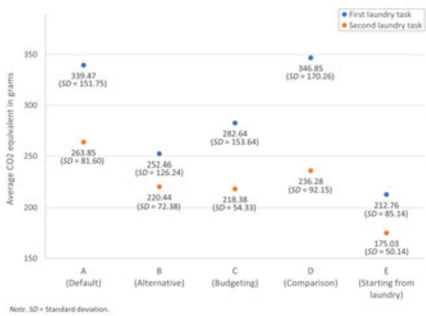


Figure 3: Average CO_2 equivalent consumed with each concept in both laundry tasks

We used further inferential statistical analyses (Mann-Whitney-U-Tests) per laundry task to determine if there were significant differences in CO_2 equivalent between participants in the four experimental conditions (B, C, D, E) and the control condition (concept A). Table 3 gives an overview of the results.

As can be seen in table 3, the analysis revealed statistically significant differences in CO_2 equivalent between the concept *Alternative* (B) and the concept *Default* (A) in both laundry tasks, whereby participants using the concept *Alternative* would have emitted statistically significantly less CO_2 equivalent than participants using the concept *Default*. Some explanatory statements helped to get some insights into participants' decision-making processes when using the concept *Alternative* (e.g., "*When the washing machine suggested an option with fewer emissions, I went for it.*" [P245; concept B]; "*The emissions saved by the Eco program convinced me.*" [P259; concept B]).

A comparison of the CO_2 equivalent of participants using the concept *Budgeting* (C) with those using the concept *Default* also indicated significant differences. Participants using the concept *Budgeting* would have emitted less CO_2 equivalent than those using the concept *Default* in both laundry tasks. We identified comments that helped to get further insights into how some participants based their decision on the eco feedback implemented in the concept *Budgeting* (e.g., "*The contingent display convinced me to use the Eco mode.*" [P211; concept C]; "*I wanted it to be a particularly eco-friendly wash-cycle, so I lowered both the spin count and the water temperature to match the points displayed and the points available to me.*" [P210; concept C]).

When comparing the concept *Comparison* (D) with the concept *Default*, results differed with regard to the laundry task. In the first task, no statistical significant differences in CO_2 equivalent could be found. However, in the second laundry task, participants using the concept *Comparison* would have emitted statistically significantly less CO_2 equivalent than those using the concept *Default*. We looked for examples in participants' comments to better understand the low or even absent effect of the concept *Comparison*. Some seemed to be more convinced by the eco feedback (e.g., "*In the end, I chose Eco because the system indicated that it would be much more appropriate for my household and I assume that it would also be better for the environment.*" [P364; concept D]) than others (e.g., "*I took note of the consumption, but for clean laundry and personal hygiene I do not compromise.*" [P326; concept D]).

Finally, there were statistically significant differences in the consumed CO_2 equivalent between concept *Starting from laundry* (E) and the concept *Default* in both laundry tasks. Participants using the concept *Starting from laundry* would have emitted statistically significantly less CO_2 equivalent than those using the concept *Default*. The concept *Starting from laundry* therefore resulted in the lowest amount of CO_2 equivalent consumed in both laundry tasks and consequently had the largest effect of all concepts. Participants' comments indicated how their decision was influenced by the interaction (e.g., "*I was wavering between 40 and 60 degrees, but decided on the basis of the recommendation for 40 degrees.*" [P143; concept E]; "*I let the washing machine guide my choice of program.*" [P89; concept E]. The option to unlock other settings than the ones suggested by the machine might not have been clear for everyone (e.g., "*There was no other option to choose from.*" [P110; concept E]; "*After selecting the type of clothing and its degree of soiling, I am apparently no longer authorized to make any further great settings.*" [P104; concept E].

5.3 Other findings

Besides the objective measures as described before, further subjective variables were assessed. For correlation analyses, the total amount of CO_2 equivalent participants consumed in both laundry tasks was used. To estimate potential differences between the concepts with regard to these variables, Kruskal-Wallis Tests and post-hoc tests (Dunn-Bonferroni tests) were used.

5.3.1 Level of freedom and influence on behavior. Participants' perceived level of freedom correlated positively with the total CO_2 equivalent consumed (r = .101, p = .044). Further analyses indicated that participants' responses differed in dependence of the concept used (χ^2 = 16.603, p = .002). Subsequent post-hoc tests showed that only the concepts *Starting from the laundry* (E) (M_{Rank} = 166.86) compared to *Default* (A) (M_{Rank} = 227.94), z = 3.616, p = .003, r = .286, as well as concepts *Starting from the laundry* (E) and *Comparison* (D) (M_{Rank} = 217.32), z = 2.987, p = .028, r = .236, differed significantly, with *Starting from the laundry* (E) rated as the one with the lowest level of freedom. Furthermore, the extent of perceived behavioral influence correlated negatively with participants' CO_2 equivalent (r = -.218, p < .001). The results of a Kruskal-Wallis Test showed that the perceived behavioral influence differed between the concepts (χ^2 = 65.429, p < .001). Table 4 gives an overview of the pairwise comparisons that indicated significant differences. The results not only show that the concept *Default* (A) was rated the lowest of all

Table 3: Differences in CO_2 equivalent with concepts A, B, C and D compared to concept A in both laundry tasks

	Task 1					Task 2				
Comparison	M_{Rank}	U	z	r	p	M_{Rank}	U	z	r	p
Default (A)	93.61	2151.00	-3.636	.287	< .001	94.07	2114.50	-3.722	.294	< .001
Alternative (B)	67.39					66.93				
Default (A)	91.50	2320.00	-3.019	.239	= .003	93.31	2175.00	-3.506	.277	< .001
Budgeting (C)	69.50					67.69				
Default (A)	81.57	3114.50	-.293	.023	= .770	90.16	2427.50	-2.643	.209	= .008
Comparison (D)	79.43					70.84				
Default (A)	109.00	920.00	-7.853	.621	< .001	109.76	859.00	-8.024	.634	< .001
Starting from laundry (E)	52.00					51.24				

Note. M_{Rank} = Mean Rank. U = Mann-Whitney-U. z = Z-score. r = Effect size of Pearson's r. p = Asymptotic significance (2-tailed).

concepts, but also that some of the experimental conditions differed significantly among each other with regard to the perceived behavioral influence when using the washing concepts.

5.3.2 Reflections on sustainability and enablement of sustainable practices. Participants' extent to which they reflected on sustainability during the interaction correlated negatively with their CO_2 equivalent (r = -.269, p < .001). Further analysis pointed to significant differences between the concepts with regard to this measure (χ^2 = 10.264, p = .036), however, post-hoc tests revealed that none of the pairwise comparisons was statistically significant. The perceived enablement of sustainable practices correlated negatively with the equivalent of CO_2 equivalent as well (r = -.128, p = .010). As there were indicators for significant differences between the concepts (χ^2 = 15.053, p = .005), we further analyzed the results. Pairwise comparisons revealed significant differences between concept *Default* (A) (M_{Rank} = 185.63) and concept *Alternative* (B) (M_{Rank} = 232.18), z = -2.833, p = .046, r = .224, as well as between concept *Starting from laundry* (E) (M_{Rank} = 173.28) and concept *Alternative*, z = 3.584, p = .003, r = .283, with concept *Alternative* being the one with the highest rating, which means that it was perceived as the one that most enabled sustainable practices.

6 DISCUSSION

The main objective of our present work was to develop washing machine concepts that can encourage users to do laundry in a more sustainable manner and empirically explore to what extent and in what way these developed concepts affect user behavior concerning sustainable washing behavior (i.e., choose eco-programs such as Eco 40-60 or Easy-care and/or sustainable settings such as lower wash temperatures more frequently).

Our study results showed that participants most frequently tended to select eco-programs with all four experimental machine concepts that followed various behavior change approaches. Whereas with a standard washing machine, they most frequently tended to select the cottons washing program. Additionally, our results show that participants' settings would cause statistically significantly less CO_2 equivalent with each of the four experimental concepts compared to a standard washing machine. Hence, a more general finding of the present study is that small changes in the design of washing machines is a very promising approach and could very likely reduce individual energy consumption. Namely, all four experimental concepts come with only minimal changes compared to the standard machine surface but still differ in CO_2 equivalent. In addition, results indicate that all but one of the experimental concepts did not come with the perception of less freedom in behavior and that the interactions with the experimental concepts were not experienced differently with regard to positive or negative affect compared to the standard machine. These results could further speak for the developed concepts as tangible solutions to encourage more sustainable consumer behavior in the domain of laundry washing. In the following, we will discuss our results in detail, draw connections between them, and reflect on further implications.

6.1 Different approaches come with different results

As expected, the *Default* concept (A) would have led to the highest total amount of CO_2 equivalent. Moreover, both concepts that follow a persuasive approach (the *Comparison* and *Budgeting* concepts) and those that follow a situational intervention (the *Alternative* and *Starting from laundry* concepts) resulted in lower CO_2 equivalents compared to the standard (*Default*) machine. In the following, we briefly discuss the results in light of these two theoretical approaches.

The impact of persuasive approaches. Based on our results, the concepts *Budgeting* (C) and *Comparison* (D) resulted in less CO_2 equivalent compared to the *Default* concept (A), persuasive concepts as used in our study seem to have an impact on changing behavior compared to a standard washing machine. This is in line with previous work on persuasive technology in other domains (e.g., [37] [21]). However, both persuasive concepts come with less potential in supporting behavior change compared to both situated interventions, as a greater statistical effect is observable in comparing situated interventions to default versus persuasive to default. A potential explanation could be that both persuasive concepts hardly interrupt washing routines but mainly provide information and feedback. Such a rhetorical and cognitive approach thus requires much attention and reflection. This might be challenging

Table 4: Differences in perceived behavioral influence between different washing concepts

	M_{Rank}	Significant comparisons	z	r	p
Default (A)	124.78	Default (A) / Alternative (B)	-7.060	.558	< .001
Alternative (B)	250.68	Default (A) / Budgeting (C)	-4.415	.349	< .001
Budgeting (C)	203.51	Default (A) / Comparison (D)	-3.154	.249	= .016
Comparison (D)	181.03	Default (A) / Starting from laundry (E)	-6.602	.522	< .001
Starting from laundry (E)	242.51	Comparison (D) / Alternative (B)	3.906	.309	= .001
		Comparison (D) / Starting from laundry (E)	-3.448	.273	= .006

Note. M_{Rank} = Mean Rank. z = Z-score. r = Effect size of Pearson's r. p = Adjusted significance (Significance values were adjusted by the Bonferroni correction for multiple tests).

for users in a task like laundry washing which might not be an important and meaningful experience for them. Furthermore, both persuasive concepts provide no clear alternative options, and users must search for a (sustainable) alternative themselves. Participants could only see differences by experimenting, changing settings, and comparing before and after.

Situated interventions. Based on our results, situated interventions, as applied in the concepts *Alternative* (B) and *Starting from laundry* (E), came with less CO_2 equivalent compared to the *Default* concept (A). This is in line with further research on situated interventions (e.g., [34] [54]). Regarding CO_2 equivalent, the concepts *Starting from laundry* (E) stood out to be more effective than a standard machine. A possible explanation for the effects observable with these concepts could be their strong focus on interrupting (non-sustainable) routines. In both concepts, users still had options to choose from, but the system provided explicit recommendations for sustainable action that were easy to follow. Both could be explained as interrupting routinized behavior by trouble-making [25] and simplifying the decision-making process by reducing the cognitive resources required [42]. In other words, the hurdle (i.e., conscious decision) to choose a different program than the recommended one was higher (especially for those using the concept *Starting from laundry*.) According to the frequency of eco-program (i.e., Eco 40-60 and Easy-care; see figures 1 and 2) selection, participants mostly accepted the suggestions they received from both situated concepts. However, it should be noted that in both concepts that follow the approach of situated interventions, users were free to choose different settings than the recommended ones at any given time. Given these results and possible explanations, the approach of situated intervention for affecting users' behavior toward sustainable washing appears promising.

In sum, both persuasive concepts and situated interventions turned out to have the desired effect concerning sustainable washing behavior. Thus, if one had to choose between one of the two approaches and the overall aim is to save as much CO_2 equivalent as possible, our results stand in favor of concepts that interrupt users in their routines and present sustainable alternatives, as is the case with situated interventions. This indicates that washing laundry is a rather routine process to which less attention is paid than is required by persuasive approaches. These results are in line with those of, for example, Bourgeois and colleagues [7], who found that behavior change was more likely to be achieved with situational interventions (Bourgeois et al. call their interventions "proactive suggestions" and "contextual control") than with feedback (i.e., a persuasive approach). Related to Costanza et al.'s [12] findings, which imply that washing is a rather conscious and rational practice, our results do not support this finding since the most effective interventions assume washing to be an impulsive (e.g., less conscious) routine. However, in line with Costanza and colleagues, which also consider differences in how participants approach washing as a practice, we also believe that washing is a highly individual practice that some people approach more and others less consciously. Overall, our findings indicate, even if preliminary, that incorporating behavior change approaches in the design of washing machines can contribute to sustainable washing behavior compared to concepts simply including the option of an eco-program (i.e., Eco 40-60). Therefore, we believe more needs to be done than simply offering users the option of eco-programs that correspond with the current EU regulations.

6.2 Starting with small changes

Although participants chose settings that led to a lower CO_2 equivalent with all experimental concepts, none of the concepts were perceived differently in the ratings of positive and negative affect compared to a standard machine. In addition, results indicate that all but one of the experimental concepts did not come with the perception of less freedom in behavior. Only in the case of the concept *Starting from the laundry* (E) participants felt less freedom in behavior compared to the *Default* concept (A). Since the focus of our study was not on the experiential level nor on exploring the limits of paternalism through washing machines, it should be noted that we intend to give only preliminary indications here. However, our results suggest great potential to support behavioral change through the design of behavior-changing washing machines without negatively affecting the users' general experience when using the machine. Still, further variables relevant for the general user experience need to be explored, and particular boundaries of how far intervention could go here require further systematic investigation.

6.3 The big picture in view

Although washing accounts for a large proportion of domestic energy consumption and the use of washing machines is prevalent worldwide, it is only one of the countless energy-intensive everyday practices that need to be adjusted toward a more sustainable practice. While the focus of our study was clearly on washing, we are aware of the discourse and criticism in the context of behavior change technologies [9]. We agree that a more holistic approach is needed that considers users in their different roles (e.g., as citizens, voters, or activists), including the political level. In addition, we believe that behavior-changing technologies should not only focus on isolated behaviors in a specific domain for individuals but rather address groups of people and, for example, facilitate spillover effects that affect other domains too. Thereby, one can definitely criticize our present work. Lastly, we did not focus on a holistic practice, but on a small part of it, as Brynjarsdottir et al. [10] criticize. Still, work like the present one represents a starting point where users could perceive their influence on sustainability. It appears that the applied methods supporting behavior change in the context of washing machines are quite promising to help users reduce their energy consumption without affecting their experience of laundry washing in a negative manner. Given the necessity to find short-term and effective solutions to climate change, the present results are a potential approach. Manufacturers of washing machines could use the present results to make short time adjustments (i.e., without changing the mechanics and electronics of machines, of their business model, etc.) to their interaction concepts. In contrast, developing a completely new generation of washing machines usually takes at least 4-5 years. If one assumes a completely new practice of washing, the development time is even hard to estimate. How the design of behavior-changing technologies, in general, can contribute to the transformation of such a Big Picture requires further systematic investigation. Moreover, it is essential to reflect on such findings from an ethical perspective to ensure that they take all stakeholders' perspectives (i.e., autonomy) into perspective since behavior change technologies always raise political and ethical issues [15]. In this sense, in the design of our concepts, for example, we deliberately decided not to use approaches such as gamification or nudge. These approaches often rely on extrinsic motivation gates or change default settings in a way that users have no opportunity to understand or reflect on their behavior. Neither insights nor a transfer to other situations is probably likely. Still, detailed ethical reflections in this field are necessary to weigh the benefits and downsides of technology design for behavior change in various domains. On this basis, an overall future goal for the Sustainable HCI community could be to develop yet unknown behavior change approaches through technology concept design while considering ethical challenges.

Finally, with our work, we contribute to HCI theory by exploring the application of different approaches to behavior change through concept design in the domain of washing. Our results offer insights on the suitability of such approaches to foster behavior change in the sense of sustainable washing behavior. That is, we could illustrate that situated interventions are an especially promising approach in the domain of laundry washing. For HCI practice, our present work provides tangible examples of how to design washing machine interfaces that could foster sustainable washing behavior. Moreover, it offers preliminary insight into how small differences in design can already come with differences in user behavior in the context of sustainable laundry washing. Such needs to be explored in future field studies, as well as how contextual factors can be taken into account to promote external validity.

6.4 Limitations and Future Work

The present work comes with methodological and conceptual limitations. On a methodological level, our data is based on an online study. Therefore, the situations of interaction with the prototypes could only be standardized to a certain level. Furthermore, individuals' attention during the study could not be monitored. Additionally, due to the online character of our study, the practice of laundry washing is only simulated, the calculated CO2 equivalents also only represent theoretical calculations that are solely based on the practice of laundry washing. Overall, it should be noted that the applied scales, which were translated from the original to German, were not explicitly validated in separate studies. On a conceptual level, exploring laundry washing based on an online study comes with the challenge of not considering contextual factors that can play a role in the choice of washing settings (i.e., program choice). For example, in real life, participants might perceive time pressure and, therefore, generally choose more time-efficient programs, although they realize that they might not be the most sustainable. In a similar manner, in real life, the choice of program might be influenced by participants' involvement in the laundry in question. For example, when asked to wash their own laundry, participants might be more careful and therefore choose less sustainable programs. Therefore, field studies should be conducted to foster external validity of results. Moreover, while the washing tasks we included in the study involve very common and frequently washed types of laundry, there surely are types of laundry, such as silk or wool textiles which might not be suitable for eco-programs. This should be considered regarding the generalizability of our results. Finally, as we did not consider multiple time points of measurement, possible novelty and observation effects should be considered, and longitudinal studies are needed to explore the potential of such design interventions to have a lasting effect on behavior change toward sustainability. Furthermore, future work should explore the application of other behavior change approaches in the domain of laundry washing and explore how behavior change approaches in HCI could contribute to a sustainable transformation from a more holistic perspective. Similarly, as we only focus on laundry washing as a domain of application, parallel studies need to be conducted in other domains relevant to individual energy consumption to foster generalizability of insights and sustainable behavior on a broader level. For example, it should be explored whether findings could be similar for tumble dryers and dishwashers. In addition, future field studies should take a detailed qualitative approach to the experience of users.

7 CONCLUSION

In the present paper, we presented an empirical study that investigated how washing machine concepts as means could affect people's behavior to foster sustainable laundry washing. For the study, we created four washing machine concepts based on both persuasive approaches and situational interventions, which we implemented in functional prototypes.

We were able to show that all four concepts were able to affect participants washing behavior toward a more sustainable practice, as in total, the settings chosen by the participants interacting with the four experimental concepts caused less CO_2 equivalent than the concept resembling a standard washing machine. Our results offer theoretical implications for the applications of behavior change approaches in the field of Sustainable HCI. Particularly, they indicate that applying approaches of behavior change, especially situational interventions, in the concept design of washing machines can foster sustainable behavior of users. On a practical level, our findings, among others, imply that it appears worthwhile to reevaluate and alter current standards of washing machine concept design, which only offer users the option to use an eco-program. In sum, future research needs to consider the interrelations in question within field studies and longitudinal designs to foster external validity and generalizability of results. Moreover, the HCI community needs to further systematically explore various domains and technologies that come with the potential to foster sustainable user behavior by means of behavior-changing approaches to support a holistic societal transformation toward more sustainable behavior in everyday activities and, in turn, a general reduction of individual power consumption.

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