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Visser, Mirjam; Schoormans, Jan

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Get rid of the eco-button! Design interventions to steer sustainable use of washing machines

Mirjam Visser *, Jan Schoormans

Delft University of Technology, Department of Industrial Design Engineering, Design, Organisation and Strategy, Landbergstraat 15, 2628 CE, Delft, the Netherlands

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ABSTRACT

To reduce energy consumption of households, many appliances contain eco-settings, which when used, reduce energy consumption. However, the effectivity of the eco-settings in reducing energy consumption is hardly tested. Other design for sustainable behaviour strategies like coercion and feedback might be more effective. To test the effectivity of these three design for sustainable behaviour strategies in reducing the energy consumption of washing machines a 2 × 2 factorial design experiment is conducted. A total of 779 European washing machine users were asked to set washing machine controls for three laundry baskets on one of four control panels. The results showed that eco-settings of the washing machines were used for only 15% of the laundry cycles. Respondents presented with coercion or feedback controls consumed 15% less energy compared to those who were allowed to decide whether to use eco-settings. Few people understood the relation of water temperature and the duration of washing machine programs on energy consumption. Feedback can support their decision processes and prevent unintentional and unsustainable settings. Our research shows that energy efficient washing machines are not necessarily leading to energy reductions because eco-settings are only used in a minority of cases. In this survey, only 6% of the potential 44% savings was realised. The results suggest it would be more effective to always use energy efficient settings, preferably together with feedback and scripting of program menus that solicit the use of short cold cycles. For energy efficiency to be effective, a product must be designed for sustainable behaviour of the user./

1. Introduction

In 2019, households represented 26.3% of the total energy consumption of the European Union (EU), of which 14% was used by household appliances (Eurostat, 2021). To reduce this consumption, the EU implemented increasingly challenging eco-design legislation to force producers of household appliances to innovate and attain increasingly higher energy efficiency. Eco-settings and -programs that provide users with an option to run appliances in a more energy efficient mode are familiar features in this quest. The higher energy efficiency when running in eco-mode usually comes to performance loss, like increased durations of washing cycles in washing machines or less acceleration in cars. After switching off the appliance or the engine of a car, the eco-settings are usually resetting to a not sustainable defaulted mode. The next time the appliance will be used again, it requires a conscious action on the part of the user for the eco-mode to be activated. From a sustainable point of view however, it is important that consumers use the included eco-modes otherwise the energy savings will not be realised.

Appliances are becoming more energy efficient, but also more complicated. Irrational or poorly informed behaviour with respect to appliance energy consumption may be a tangible setback in the path towards a more energy efficient world. This is an area of interest and concern for legislators who seek energy savings (Sivitos et al., 2015). Most eco-design legislation and producer responses have focussed on technological innovation and not on how the consumer uses the appliances. When about 80% of the appliance environmental load of products like irons, vacuum cleaners (Visser et al., 2018) and washing machines (BSR, 2009; Van Der Velden et al., 2014) is realised in the use phase the behaviour of the user is of utmost importance. Thus, if eco-design features in appliances are not being used, not all potential of energy efficiency and other eco-design targets will be realised.

This research aims to contribute to understanding how design for behaviour in product designs can be applied to reduce energy consumption in the current washing machines that, in the EU, are equipped with eco-programs.

* Corresponding author.
E-mail addresses: m.c.visser@tudelft.nl (M. Visser), j.p.l.schoormans@tudelft.nl (J. Schoormans).

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1.1. Product design for sustainable behaviour

Many of the daily actions people take are habitual, automated actions that are difficult to change (Godin et al., 2020) and are a mediating factor in behavioural change (Bhamra et al., 2011; Shove, 2003). Design research has defined several design strategies to promote sustainable behaviour (Bhamra et al., 2011; Boks, 2012; Lilley, 2009). Design for sustainable behaviour aims to break habitual behaviour and, in some cases, teach new more sustainable behaviour. Possible strategies can be categorized in order from product in control towards user in control. When the product is in control, the product determines behaviour, for instance, by using 'intelligent systems' that use sensors and automatically use the most sustainable settings, or it coerces behaviour by offering no option to make a mistake or act unsustainably. With the product in control, products can be optimized to deliver the most sustainable performance. Defaults, the path of least resistance, proved to be an effective strategy to steer behaviour in many different settings (Hankammer et al., 2021). It is assumed that a default set to the intended choice is more effective because people tend to stick to the status quo. Change incurs cost in money, time or effort. People, therefore, often only adjust product settings if prompted to do so. When machines offer no or few adjustment options, people make less mistakes, but without feedback they miss learning effects that might lead to more sustainable behaviour in other situations or with other products (Bhamra et al., 2011; Wever et al., 2008). Legislators and producers are reluctant to use coercion to reduce energy consumption (Varone and Aebischer, 2001). Indeed, many consumers prefer products that give them some freedom of choice. At the other end of the spectrum, where the user is in control, a product provides feedback to enable users to make an educated choice. Feedback systems showed especially effective if they provide instant and easy to understand information (Kobus et al., 2015). A strategy that offers the best of both sides combines persuasion with eco-choices supported by scripting. Sustainable scripting is defined as the design of a product guiding the user, in a more or less forceful way, to sustainable behaviour (Jelsma and Knot, 2002). Feedback can be one element in the script to prevent users from skipping a sustainable option for other than sustainability reasons. For scripting to be effective, it should be easy, fun and intuitive to use.

1.2. Washing machines

This study uses washing machines that are sold in Europe. Washing machines is a good product category for testing the usage of eco-settings and the effectivity of coercion and feedback on energy consumption of a household appliance. If used in a sustainable manner, by washing more often on energy efficient settings, energy consumption could even be halved. Washing machines are found in nearly every household in Europe. The different models washing machines on the European market need to be produced according to eco design regulations (European Commision, 2019) and offer options for more sustainable behaviour like eco-settings, short cold cycles and temperature control.

Clean washing results are the product of water temperature, duration of the washing machine cycle (including washing, rinsing and spinning), water consumption as well as mechanical and chemical action (Boyano Larriba et al., 2017). To increase energy saving, motors and insulation are improved. However, most of the energy efficiency comes from eco-programs that use reduced water temperatures and increased duration of the washing programs. Modern energy efficient washing machines use 30–60 min longer washing cycles at around 10 °C lower temperatures. Modern washing machines with an EU energy label A (Boyano Larriba et al., 2017) consume on "Eco 40–60" less than 50 kWh per 100 cycles. When both low temperatures and eco-settings are used, the washing machines are even more energy efficient. For example, using reference washing machine (Miele, 2021), 8 kg cotton laundry consumes on eco (40–60 °C) only 0.75 kWh (for the data seen Table A.1. in Appendix A) but when washing the same load on eco 20 °C it would even save an additional 53%.

1.3. Sustainability and doing the laundry

As indicated above, the behaviour of users is crucial in realizing the intended benefits of energy efficient washing machines. About 80% of washing machines environmental load is realised in the use phase and the result of energy consumption and detergents.

The environmental burden of washing laundry depends largely on how and how often the consumer does his or her laundry. This has been a topic of many researchers worldwide. (Alborzi et al., 2017a, 2017b; Boyano Larriba et al., 2017; Pakula and Stamminger, 2010; Shove, 2003; Sohn et al., 2021; Yates and Evans, 2016). Washing rituals differ over countries (Alborzi et al., 2017a; Boyano Larriba et al., 2017). Some wash by hand, others cold or hot, in top loader or front loader. Some wash at home other use coin services or use a laundry service.

Further, social norms are differing over countries and play a major role in standards of cleanliness and which washing method is considered giving the cleanest results (Shove, 2003). In some countries this will be by washing by hand, in others by using the most technologically advanced washing machine (Klint et al., 2022).

The environmental burden of washing depends largely on personal decisions. Is an item considered dirty or not? When is the machine full enough to be switched on? Which program should be used? These all affect the final energy consumption of households. The most effective reduction in energy consumption would come from doing the laundry less often or wash cold(er) (Yates and Evans, 2016). But social norms and habits are notoriously hard to change (Shove, 2003; Yates and Evans, 2016). Klint et al. (2022) suggest technology can play a role in changing the laundry habits by steering towards more sustainable behaviour and choices.

1.4. Washing machines features and product design for sustainable behaviour strategies

Currently the washing machines in Europe are obliged to have an eco-washing program for 40–60 °C programs or an eco-switch or -button to gain market access. Eco-buttons are therefore a familiar feature in washing machines nowadays. However, the effectivity in energy reduction of washing machines succeeds or fails with the choice of users to use these eco-settings. There might be other washing machine features or product design strategies to steer more users towards sustainable behaviour. Based on the design for sustainable behaviour strategies research of several authors (Bhamra et al., 2011; Lilley, 2009; Tang and Bhamra, 2012; Wever et al., 2008) we expect two washing machines features to be promising alternatives to eco-settings.

The first feature is coercion. If users would always wash on eco and/or lower temperatures, there might be an even greater potential reduction of energy than will be realised by eco-settings which need to be set intentionally. Coercion as a feature is currently not available on the European market. Such a feature would run every washing program in the eco-mode. In that case the eco-button is omitted while there is no option to run in any other mode than eco.

The second feature is feedback. A product feature that shows feedback is offered in some current washing machines. However, in most cases they only report the (remaining) duration of the selected program cycle. Bocken et al. (2018) included in their pay-by-use washing machine feedback in the monetary cost of a cycle and in a monthly bill with a report per program setting. They reported changes in habits like a 30% lower number of washing cycles and reduced temperatures. Feedback on energy use is further known to result in the consumer's reduction of energy consumption in both household energy monitoring systems (van Dam et al., 2010) and cars (Allison and Stanton, 2019). To use feedback to steer to energy efficient washing, every setting could show the relative difference in energy reduction between the user and the proposed machine settings.

In this survey we test the effectiveness of present eco-buttons as well as the design for sustainable behaviour strategies of coercion and feedback in reducing energy efficiency in washing machines. In this study, the product feature coercion offers no other option than to use the energy-efficient programs as opposed to the freedom of choice when an eco-setting is available. The product feature feedback shows the percentage energy consumption saved or gained during a program cycle by using or not using the eco-settings or adapting the cycles' temperature.

Section 2, Methods and materials, describes the used methods, stimuli and experiment design. Section 3 describes the results, which are discussed in Section 4. Section 5 presents the conclusions.

2. Methods and materials

To test the effect of design for sustainable behaviour strategies "coercion", and "feedback" on energy consumption of washing machines, a 2 (no coercion/coercion) x 2 (no feedback/feedback) factorial design of a washing machine control panel was used. Four control panels were tested in this experiment. Each control panel version was presented to 200 European washing machine users. They all set three standardized laundry baskets.

The questionnaire was designed in Qualtrics. The experiment was conducted via the internet. The respondents were selected as well as answered the questionnaire via the British survey platform Prolific. Analysis of the data was performed in SPSS.

2.1. Stimuli design

The four designs of the control panels were made, based on the settings of an Energy Label A Miele WEF 375 WPS washing machine with a capacity of 8 kg (Miele, 2021). According to the EU Energy Label Regulations (European Commision, 2019) washing machine producers are obliged to calculate and present their energy consumptions for standard settings. The program temperatures/duration combinations and the resulting energy consumptions of the Miele manual were used and extrapolated for the remaining settings in the four control panels. Appendix A presents all potential different settings per model and fabric with their responding program length (in hours and minutes) and both absolute as relative energy consumption (in kWh).

Washing machines that use eco-settings are washing 10 °C lower than presented on control panels. In this research, both coercion and chosen eco-settings are calculated accordingly.

The eco-setting was interpreted as "no-coercion"; users have the option to use or not to use an energy efficient setting for their selected washing program. After each washing cycle, the setting returns to the defaulted "no eco" as is practice in most eco-button options in washing machines.

Both coercion and no-coercion versions had the same program settings but with the difference that all program cycles in the coercion version were performed on eco. Both coercion and no-coercion in eco-mode proposed 20 °C washing cycles. Respondents could still make temperature adjustments or use short cycles.

When feedback was used this was presented as the relative difference in energy consumption (in kWh) between the user's choice and the proposed standard machine setting for the fabric program.

All models offered the option of a short cold cycle. They were the same for each fabric program i.e., 20 min at 30 °C consuming 0.33 kWh. The machine controls were designed for the three most often used settings for fabrics (Boyano Larriba et al., 2017): cotton, handwash/-wool/silk and synthetic/mix. The 2 × 2 control panels were simplified designs (Fig. 1) with just the three fabric program settings, an option to choose a short program and an option to adjust the temperature. This would keep the process of setting the control panels brief (around 60 s per cycle), and easily understandable, both relevant to validity. Fig. 1 shows the control panels used in the four different experimental cells as they were presented at the start of the experiment.

Different types of laundry require different washing machine settings, for example, the setting for washing towels is different from the setting for washing underwear. To collect data that represent the choices users make when doing their daily washing, three different laundry baskets were defined for the study. Participants were asked to select settings for the following three laundry baskets:

- Coloured bedsheets and towels
- Freshen-up t-shirts, blouses and men shirts
- T-shirts, underwear, sportswear and jeans.

2.2. Instruction to the respondents

Each respondent was first given a summary of the experiment and asked for their consent to use their data for this and future research and education purposes. They also confirmed they are regular washing machine users. Thereafter, they answered a few control questions to verify that they were English speaking, between 28 and 75 years old and European citizens, indicate the number of people in their household and how many children under 18 years were part of their household.

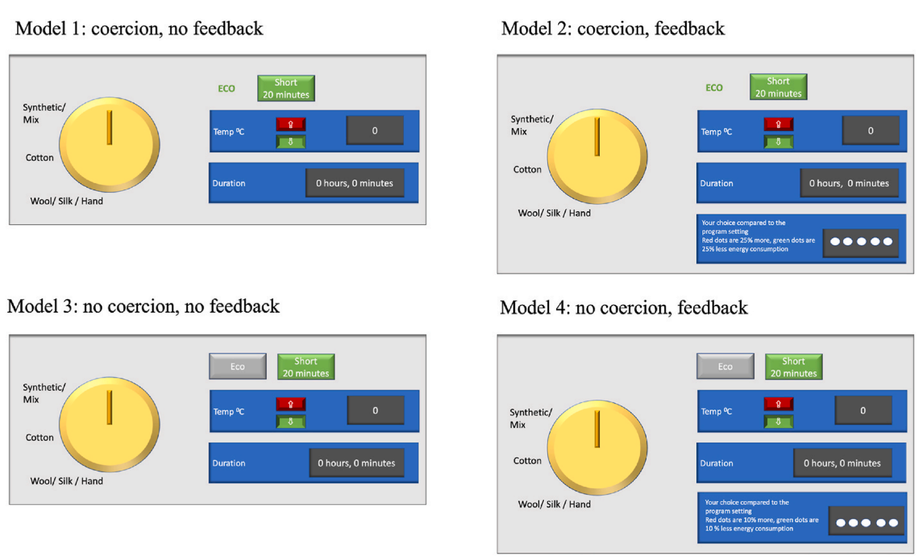

Fig. 1. Stimuli 2 × 2; No coercion/coercion, no feedback/feedback.

Next, each respondent was presented, in random order, with the three laundry baskets and was asked to set the washing machine for each of the laundry baskets according to the following script (Appendix B presents an example for Model 2 coercion/feedback);

1. Please select a program for the laundry basket mentioned below (cotton, handwash or synthetic).
2. For this laundry basket, do you select "Short 20 min at 30°"? (Yes/No) (if feedback was included in the assigned model, then feedback was presented for both options in this and all following questions).
3. For no-coercion only: Please select whether you like to use the eco-setting or not for this laundry. You can adjust the laundry temperature in the next step. (Yes/No).
4. You see your control panel: do you want to select another temperature and duration? A temperature/duration combination is chosen.

Respondents might make choices based on an incorrect assumption about the effect of certain control settings, related to the relation between temperature, duration and energy use. Therefore, after setting the control panel for all three laundry baskets, respondents were asked to answer two control questions to determine whether they understand the relationship of temperatures and duration to energy consumption:

1. Put in order from least energy consuming to most energy consuming (in random order presented 20°, 30°, 40°, 50°)
2. Put in order from least energy consuming to most energy consuming (in random order presented; five different combinations of eco/no-eco, temperature and duration.

2.3. Data collection

The British survey platform Prolific provided 800 respondents. The respondents were pre-screened according to age (28–75 years old), country of residence (all European countries), gender (female, male, other), fluency in English and only frequent users of washing machines were selected. Because the respondent base of Prolific leans heavily on respondents from the United Kingdom (UK), respondents from the UK were limited to 25% per experimental cell. Each of the four cells was presented to 200 respondents. After giving consent and completing the questionnaire, each response was loaded into Qualtrics. Respondents earned 0.75£ to complete the questionnaire, which took about 4 min ($M_{response}$ = 248 s, $SD_{response}$ = 134).

2.4. The demographics

Trials showed it would take at least 60 s to perform the task in a reliable way. It was expected that people who took a very long time to do so (over 1000 s) probably were not understanding or not focusing on the task at hand. Therefore, we decided to exclude the 21 respondents who were using less than 60 s or more then 1000 s to complete the questionnaire. The demographics spread of the final sample of 779 persons was:

- Age: $Mean_{Age}$ = 37.6 years old, SD_{Age} = 9.8.
- Gender; 50.0% female, 49.9% male and 0.1% other.
- Country: UK 25%, Portugal 19%, Italy 13%, Poland 12%, Spain 7%, Greece 5%, France 4%, Germany 3% and the remaining respondents spread across the remaining European countries.
- Household size; $Mean_{\#persons}$ = 2.7, $SD_{\#persons}$ = 1.3. Largest groups; 2-person household (35%); 3-person household (27%), 4-persons (18%), 1-person (14%).
- Number of children under 18 years in household: 0 (69%), 1 (16%), 2 (11%), >2 (4%), $Mean_{\#kids}$ = 0.49, $SD_{\#kids}$ = 0.85.

3. Results

3.1. Effects of coercion and feedback on energy use

A two-way between-groups analysis of variance was conducted to examine the impact of coercion and feedback on energy consumption (in kWh).

Coercion showed a significant positive effect on reducing energy consumption by 11.0% ($F(1, 779) = 43.7$, $p < .001$).

Feedback also had a significant positive effect and reduced energy consumption by 5.3% ($F(1, 779) = 8.7$, $p = .003$).

Fig. 2 shows the estimated marginal means of the different models. Model 3, (no coercion and no feedback), is comparable to both the reference washing machine and most recent commercial models on the market. It has the highest energy consumption (M_3 = 1.64 kWh, SD_3 = 0.03) for washing three laundry baskets. The effect size, measured in difference between the means, with Model 1 is 14.0%, with Model 2 is 15.2% and with Model 4 is 8.5%.

There is a significant interaction observed between coercion and feedback ($F(1, 779) = 4.4$, $p = .035$). The positive effect of feedback in reducing energy consumption is larger for the no-coercion cells (8.5% reduction) than for the coercion cells (1.4% reduction).

The use of short cycles had a significant and large positive effect on reducing energy consumption (F(1, 779) = 487, p < .001). Using three short cycles reduced the energy consumption by 50% compared to washing without using short cycles.

Regarding the effects on demographics, the results showed a significant main effect on energy consumption found for country (F(1, 779) = 8.6, *p.* = .004). Moreover, a significant main effect was observed for number of under-18-year-old persons in the household (F(1, 779) = 10.7, *p.* = .001), families with children under 18 years washed less energy-efficiently. No significant main effects on energy consumption were found for gender (*p.* = .37), age (*p.* = .04, Eta 0.006) or household size (*p.* = .36).

3.2. Eco-settings usage

In two cells (Cell 3, no feedback on energy consumption and Cell 4, feedback on energy consumption) an eco-button was present. A total of 31.5% of the respondents chose the eco setting at least once out of the three laundry baskets – 26.3% of those in the no-feedback cell and 37.1% of those in the feedback cell. A Chi-square test for independence (with continuity correction) indicated a significant relation between

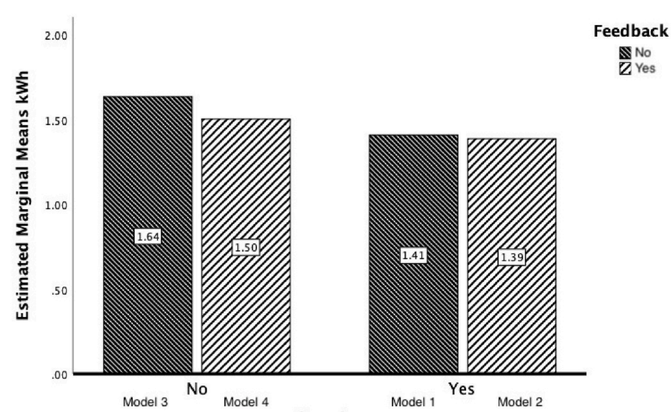

Fig. 2. Estimated Marginal Means in kWh for Model 1 (N = 193, Mean 1.41, SD 0.03), Model 2 (N = 198, Mean 1.39, SD 0.03), Model 3 (N = 192, Mean 1.64, SD 0.03) and Model 4 (N = 196, Mean 1.50, SD 0.03). Covariates appearing in the model are evaluated at the following values: Age = 37.61, Gender = 0.50, Country Coded = 15.55, Household size = 2.72, # of Kids = 0.49, Short total = 1.43.

eco-settings and feedback cells (χ^2 (1, n = 445) = 5.51, p. < .001, eta 0.12) meaning that feedback encourages more people to select at least once the eco-setting however with a small effect size.

A total of 14.5% of the laundry baskets within the no-coercion cells were washed with the use of the eco-button. No significant difference was observed on eco-setting usage (p. = .46) between feedback type.

3.3. Temperature settings and short programs

For only 14% of the laundry baskets, the proposed washing temperature setting was accepted and no change in the programs setting, either in temperature or wash at the short program, was applied (Table 1).

Cramer's V = 0.28). When using coercion to use 20 °C as a proposed washing temperature only 7.3% of the respondents accepted the proposed temperature setting. Without using coercion more people used the proposed programs settings.

The significant effect of coercion on temperature setting is large (χ^2 (6, n = 2340) = 350, p. <.001, Cramer's V = 0.39). The significant effect of feedback on temperature settings is medium (χ^2 (12, n = 2340) = 194, p. <.001, Cramer's V = 0.20).

Short programs were popular, 53.8% of all set programs was a short program (χ^2 (3, n = 2340) = 206, p. <.001) the effect size on energy consumption reduction is large (Cramer's V = 0.30). However, coercion without feedback led to only half the number of repondents selecting short cycles compared to the other models.

The interaction's effect between coercion and the number of short cycles ($F(3, 779) = 11.5$, p. <.001) on energy consumption is significant. Respondents in the no coercion cells ($M_{coercion}$ 1.45, $SD_{coercion}$ 0.05) more often selected short cycles than those in the coercion cells ($M_{no\text{-}coercion}$ 1.40, $SD_{coercion}$ 0.05), a small mean difference of 3.9%. There is no significant interaction effect between feedback and the frequency of short cycles (p. = .60).

Offering feedback to respondents had a significant and medium sized positive effect on the use of short programs (χ^2 (1, n = 2340) = 90, p. <.001, Cramer's V = 0.20).

4. Discussion

4.1. The effectivity of coercion and feedback on energy consumption

As demonstrated in Section 3.1. both coercion and feedback show more potential to reduce the energy consumption of washing machines than using eco-settings. Eco-settings were only selected for 15% of the laundry baskets. Model 3 (eco-button without feedback) is a simplified version of the reference machine. In this model, the three laundry baskets together consumed about 1.64 kWh. All other models had better energy performance; Model 1 showed an additional reduction of 14.0%, Model 2 an additional reduction of 15.2% and Model 4 an additional reduction of 8.5% compared to Model 3.

Short programs use only 70% of the average energy consumption of laundry cycles. Therefore, most of the energy savings of Models 2, 3 and 4 would have been realised from the short cycles rather than by eco-settings. Most of the energy savings from Model 3 were realised from the 59.7% short-cycles rather than from the 26.3% of eco-button usage.

Using coercion in washing machines showed an average reduction of 11.0% on energy consumption compared to models with eco-settings. It should be noted that coercion as well as eco setting in no-coercion cells effectively washed at 10 °C lower than was communicated on the control panel. This tactic is common and explained in washing machine manuals but customers are seldom aware of this (Consumentenbond, 2020). Consumers seldom read manuals or skip content (Mehlenbacher et al., 2002) with the consequence that they might choose too low temperatures for their intended washing results. The 14.6% difference in energy consumption between no-feedback models (1 and 3) results from this 10 °C difference between the temperature on the control panel and the actual washing temperature. This research strongly supports focusing communication not on energy efficiency but on performance, in this case clean and save clothing, to overcome the negative bias of some consumers that laundry does not come clean at lower temperatures.

Feedback showed a significant effect. Using feedback reduced the energy consumption by 5.3%. While it is somewhat lower than by coercion, feedback has the additional advantage that it teaches people how to save energy (Wever et al., 2008). Moreover, the control questions of this research showed that most respondents do not understand the dynamics of energy consumption. Only one out of five respondents ranked combinations of temperature and durations correctly from low to high energy consumption. Other research also noted that users have difficulty comparing the energy consumption of different washing programs (Alborzi et al., 2017b). Using feedback can remedy this and guide the user towards correct, fact-based settings in washing programs.

The potential additional reductions in energy consumption of between 5 and 15% by using coercion and/or feedback systems, instead of eco-settings, are impressive numbers because they are mainly graphical design changes. Scripting by including coercion to make washing energy efficient and include both feedback and menu-sequencing to solicit the use of short cold cycles would, as this results support, be likely far more effective than the current optional eco-settings. Further, the changes can be realised without much effort, investment in innovation or major technical changes in washing machines which makes it worthwhile to try it out in pilot series with little risk.

4.2. Eco-settings usage

The default choice of the eco-setting was, as in most washing machines on the market, "no-eco". In the experiment, the choice to set the program to "eco" was asked directly after people rejected the option of a short program. At that point, they were shown the consequences of choices on temperature and duration, and when feedback was a feature, also on the relative effect on energy consumption. Respondents chose to use eco-settings only on one out of seven washing cycles (Section 3.2). Thus, from the reference Miele washing machine, likely only about 1/7th of the communicated 44% reduction between eco 40–60 (0.75 kWh) and 60 °C (1.35 kWh) will be realised. In practice, it would probably be even less since only 8% of the laundry baskets was washed at temperatures higher than 40 °C. Further, other than in real life situations, the respondents of the experiment were actively pointed to the eco-setting. If the default were set to "eco", this would probably have been about

Table 1
Percentage of users who made adjustments to the machine standard temperatures or selected a short program.

	Coercion	Feedback	Program Starting temp	−20 °C	−10 °C	No change	Short program	+10 °C	+20 °C	+30 °C	+40 °C	Total
Model 1	Yes	No	20°C	0%	0%	8%	28%	22%	30%	2%	10%	100%
Model 2		Yes		0%	0%	6%	63%	14%	10%	1%	6%	100%
Model 3	No	No	Cotton 40°C, other 30°C	0%	5%	19%	60%	8%	8%	0%	1%	100%
Model4		Yes		1%	3%	20%	64%	7%	4%	0%	0%	100%
% Total				0%	2%	14%	54%	13%	13%	1%	4%	100%

A Chi-square test for independence showed a significant association between temperature adjustments and the coercion and feedback cells (χ^2 (18, n = 2340) = 531, p. <.001) and the effect size was large (Table 1: Percentage of respondents making temperature adjustments from the proposed starting temperature per washing cycle (Model 1 (N = 579), Model 2 (N = 594), Model 3 (N = 576) and Model 4 (N = 591)).

double, as is similar to the effect shown in research on green/grey energy (Pichert and Katsikopoulos, 2008). In their study, respondents less frequently switched to unsustainable options when presented with an eco-friendly default. Thaler and Sunstein (2021) recommend using the preferred setting as the default because users tend to accept the default unless prompted to act. The results in Sections 3.1. and 3.2. support their advice to use the sustainable solution as the default setting.

4.3. Use of proposed temperature settings and short programs

Less than 14% of all respondents accepted the proposed setting of the washing machine (Section 3.3). This is low, especially when using the coercion models (Model 1 without feedback and Model 2 with feedback), with 8% and 6%, respectively. The difference can be explained by the difference in starting temperature between coercion models (all fabrics at 20 °C) and no-coercion models (cotton 40 °C, other programs at 30 °C). It appears that many people perceive 20 °C as too low to guarantee a clean result. Literature on nudging (Hummel and Maedche, 2019; Lehner et al., 2016; Schubert, 2017; Thaler and Sunstein, 2021) mentions that low settings can nudge people towards preferred behaviour. The proposed 20 °C in combination with the long program might be such a prompt. Alborzi et al. (2017b) found that European consumers are willing to save water and energy in a laundry washing but are reluctant to use long program cycles since they do not believe that the long cycles could be energy-saving. This might explain why short cycles showed so popular in our survey.

The short program was a popular setting and used in 53.8% (Table 1) of all laundry baskets. Research published in 2017 (Alborzi et al., 2017b) showed about 18% of the laundry in new machines was washed in a short cycle. Alborzi et al. surveyed actual washing machine usage over a period. Their respondents also washed laundry baskets that are not represented in the three laundry baskets defined in the current study.

Short programs on low temperatures are among the most energy efficient program settings. In this research, as with the reference highly efficient Miele machine, a reduction of 30% on the mean energy consumption was realised. Many people appear to accept that short programs with low temperatures will be effective. Especially when laundry is not too dirty, as in the second laundry basket that merely needed to “freshen up t-shirts, blouses and shirts” 66% of all customers chose to use the short program. However, even 29% of the baskets “washing bedlinen and towels” were washed with a short program. Short cold cycles are even more often used when no coercion is applied. One could consider short cycles an effective alternative to eco-buttons. Scripting to steer to promote the use of short cycles can be applied in combination with coercion and feedback systems.

The control questions indicate that 83% of the respondents ranked temperatures correctly in the right order from low to high energy consumption. However, when presented with both temperature and duration, only 20% of the respondents ranked the settings in the correct order. Boyano Larriba et al. (2017) suggest it would be ideal if customers understood the relation between temperature and duration on washing performance and energy consumption. Feedback might solve this problem, but practice shows that behaviour change remains difficult (Alborzi et al., 2017b; Klint et al., 2022).

4.4. Energy efficiency due to demographics

Two demographics significantly influenced the energy efficiency of laundry (see Section 3.1) in our experiment: The number of children under 18 years old in the household and the country of residence. Having children in the household makes a difference and, in the experiment, added five to six percent to the energy consumption per washing cycle. The country of residence also made a difference, which is in line with other research (Boyano Larriba et al., 2017; Sohn et al., 2021). Ireland, Portugal and Spain seem to wash energy-efficiently. Users in the Baltic states, Finland, Germany and Greece on the other hand seem to wash relatively energy-inefficiently. The difference between the two groups was quite large with about 30%. Climate does not appear to be a differentiator. The difference might be caused by differences in historic and cultural backgrounds as well as in energy prices. While additional research is needed to clarify the differences, there appears to be a potential for change across Europe.

4.5. Implication for legislation

In our experiment, only one out of seven laundry baskets on eco-setting machines were washed with an activated eco-setting, which resulted in realizing only 6% instead of the 44% calculated energy saving from our reference best in class Energy label A washing machine. Energy efficiency is an important factor reducing energy consumption but if in practice hardly any laundry is washed with the energy efficiency options, it is not effective in reducing energy consumption. We showed using coercion with energy efficient settings as a baseline is more effective. If it is possible, as is promoted by producers, to wash more energy-efficiently and achieve the same washing result, why offer the option of less energy efficiency? The fact that the program offers the option to not use eco-settings suggests that eco-settings offer lower performance. Washing machines are utilities and consumers buying criteria, sustainable usage and satisfaction depend highly on their perceived performance (Visser et al., 2015). The option of not using an eco-setting will likely encourage people to, sometimes unintended, unsustainable behaviour. This research's results suggest removing the eco-settings and always offer energy efficiency combined with feedback and scripting to encourage users to use short cold cycles would be more effective.

4.6. Implications for designers and producers

The combination of modern washing machines and detergents is suitable for cleaning laundry at low temperatures of a maximal 30 °C (Laitala et al., 2011). However, many consumers still do not seem to trust this advice. Laitala et al. suggested that the energy efficiency potential of current washing machine technologies remains unused. As is supported by this research, which showed only one out of seven laundry baskets was washed by use of the eco-setting. Furthermore, it showed that coercion, feedback as well as the use of short cold cycles in machines are likely more effective tools to reduce the energy consumption of washing machines, even independently of technological improvements.

This research (section 3.3) also showed that only one out of five people understands the relationship between eco-settings, temperature and duration on energy consumption. This is supported by Boyano Larriba et al. (2017). Feedback can guide consumers to the best setting for their laundry basket at hand. The results of this research show that coercion and feedback together with menu scripting that encourages users to use short cold cycles is more effective to reduce energy consumption than the current eco-setting option. It would also make setting a program easier.

Feedback might even teach users sustainable behaviour beyond the washing machine. This research supports the effectivity of design for sustainable behaviour strategies, such as coercion, feedback and scripting, to increase the sustainable usage of washing machines. While the ideal is to have a design tool for sustainable behaviour interventions, these interventions are difficult to standardize and must be tested, prototyped and fine-tuned to avoid unwanted behavioural effects, as was also noted by Bhamra et al. (2011).

4.7. Limitations of the dataset

The spread of the respondents over Europe was not heterogeneous. The British research platform Prolifics' pool of respondents living in the United Kingdom is about four times as large as those who live in continental Europe. The size of the respondent group from the United Kingdom was fixed at 25% but is still significant compared to the population in the rest of Europe. The spread of respondents in continental Europe is not equal to the population spread of those countries either. This is solved by controlling for country of residence in the analysis, but this might shift results when a larger sample with a different mix is selected. However, this heterogeneity is considered acceptable due to the large sample size of about 800 respondents.

The 30% difference in energy consumption between the respondents of different countries suggests this might arises from culture and historical washing habits and social norms (Klint et al., 2022). One should be careful to apply the results directly to regions outside of Europe which might have even different habits and norms.

The washing machines available on the European market are all front loaders and designed and produced according to European eco-design legislation (European Commision, 2019). The conclusions of this research will likely not apply to top-loader machines which, usually, wash on cold temperatures but consume more water and detergents (Amasawa et al., 2018).

4.8. Implications for research

This research did not address the cultural influences and habits on washing processes. Our results showed a difference of up to 30% between countries within Europe. There is much to be gained if the reasons for this difference in energy consumption are better understood. Therefore, habits and decision-making processes over different countries need to be researched. Setting choices of consumers might be influenced by variables like type of machine and detergent, expected cleaning results, importance of energy efficiency, cost or environment, level of dirt, urgency or time pressure to combine several laundries in a day, frequency.

The difference among countries might also be a result of energy price differences. Low energy prices might encourage users to wash less energy efficient. This is another potential avenue for research.

It is even better for the environment to avoid washing the laundry as much as possible but cleanliness standards (Shove, 2003) and washing habits turn out to be sticky and social norms hard to change (Godin et al., 2020). Feedback on the cost of a choice potentially makes a difference. As this was shown by Bocken et al. (2018) but in their case the feedback was given by presenting the cost in monthly bills. A month feedback time might be less effective compared to instant feedback. The gains of shorter feedback needs to be tested.

The effectiveness of design for sustainable behaviour strategies must still be tested for a wide range of other product categories and even services. As is also suggested by Bhamra et al. (2011).

Eco-settings as a default are also used for other appliances and cars. Currently, most eco-buttons have an unsustainable default and reset automatically to this after each use. Frequent users of the eco-setting in cars probably do not always remember to set the car in energy efficiency mode when driving off. Defaulting towards "eco" would likely lead to more energy savings but needs to be tested.

5. Conclusions

This research showed that the effect of legislation to increase energy efficiency is highly depending on user behaviour and use of the optional eco-settings. Energy efficiency does not necessarily result in energy reduction. We showed it likely that only a small part of the intended energy savings of the EU Eco-design legislation for washing machines will actually be realised.

Of the three tested design for sustainable behaviour strategies the familiar eco-settings showed to be the least effective in reducing energy consumption. That eco-settings after a washing cycle default to the less efficient settings might be a major reason for low effectivity in reducing energy consumption.

Few respondents understood the relationship between program settings, energy consumption and washing results. Adjustments, whether made for reasons of energy efficiency or cleaner laundry, will often not lead to the intended results. There seems to be a need for feedback systems to remedy this and encourage users to more often make energy reducing choices.

This research showed offering washing machines with coercion and feedback systems and scripting to seduce people to use short cold cycles might to be far more effective in reducing energy consumption than offering eco-setting which default on less energy efficient settings.

We conclude that eco-buttons are not an effective product design intervention to reduce energy consumption of washing machines.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data is available via 4TU.Researchdata: by doi.org/10.4121/19017794

Appendix A

Table A.1
Washing machine data

Temperature(°C)				Duration (hours:min)			% Difference with machine			kWh		
	Cotton	Synthetic	Hand	Cotton	Synthetic	Hand	Cotton	Synthetic	Hand	Cotton	Synthetic	Hand
Short	30	30	30	00:20	00:20	00:20	−6%	−18%	83%	0.33	0.33	0.33
Coercion (M1 & M2) or M3 & M4 with eco												
Start	20	20	20	03:45	02:05	00:49	0%	0%	0%	0.35	0.40	0.18
20	20	20	20	03:45	02:05	00:49	0%	0%	0%	0.35	0.40	0.18
30	30	30	30	03:41	02:02	00:45	14%	13%	11%	0.40	0.45	0.20
40	40	40		03:39	01:59		114%	45%		0.75	0.58	
50	50			03:24			137%			0.83		
60	60			03:09			186%			1.00		
No coercion (M3 & M4) and no eco												

(continued on next page)

Table A.1 (*continued*)

Temperature(°C)				Duration (hours:min)			% Difference with machine			kWh		
Start	40	30	30	02:33	01:59	00:39	0%	0%	0%	0.83	0.50	0.23
20	20	20	20	02:39	02:02	00:45	−52%	−10%	−13%	0.40	0.45	0.20
30	30	30	30	02:36	01:59	00:39	−10%	0%	0%	0.75	0.50	0.23
40	40	40		02:33	01:56		0%	64%		0.83	0.82	
50	50			02:31			20%			1.00		
60	60			02:29			63%			1.35		

according to Miele WEF 375 WPS Manual.
M = Model#.

Appendix B

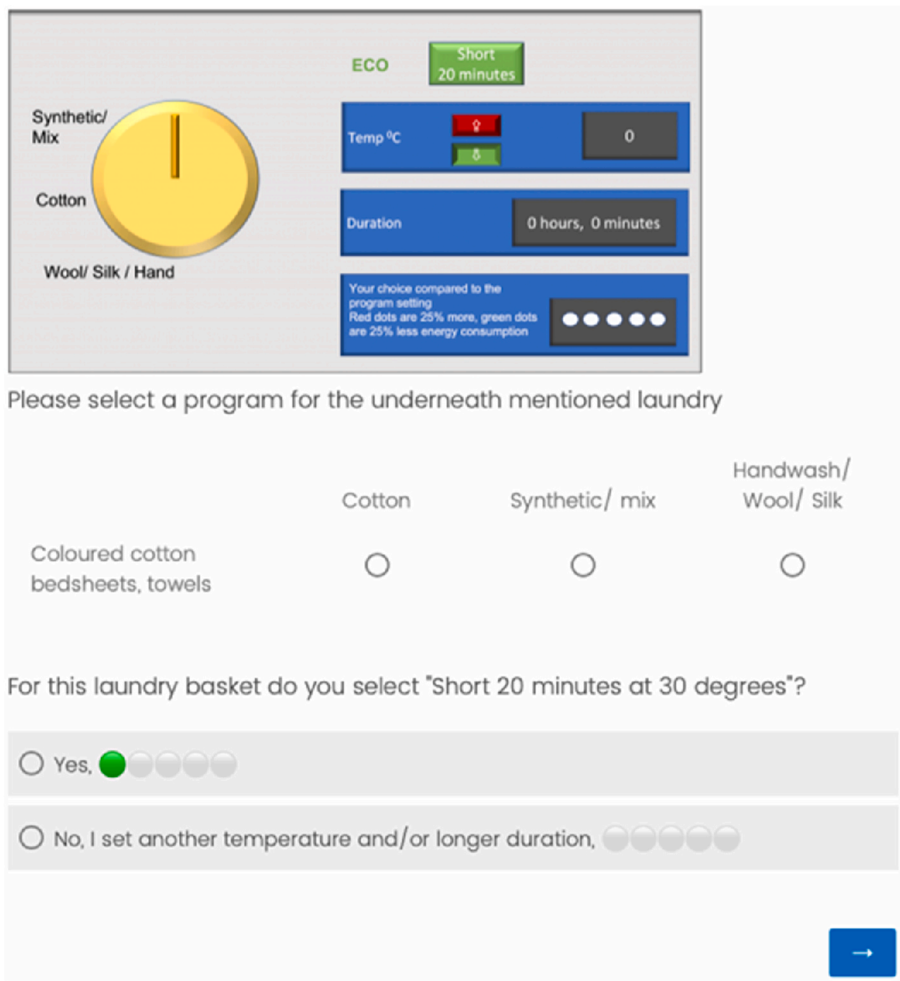

Fig. B.1. Script example Model 2 (Coercion & Feedback) Screen 1.

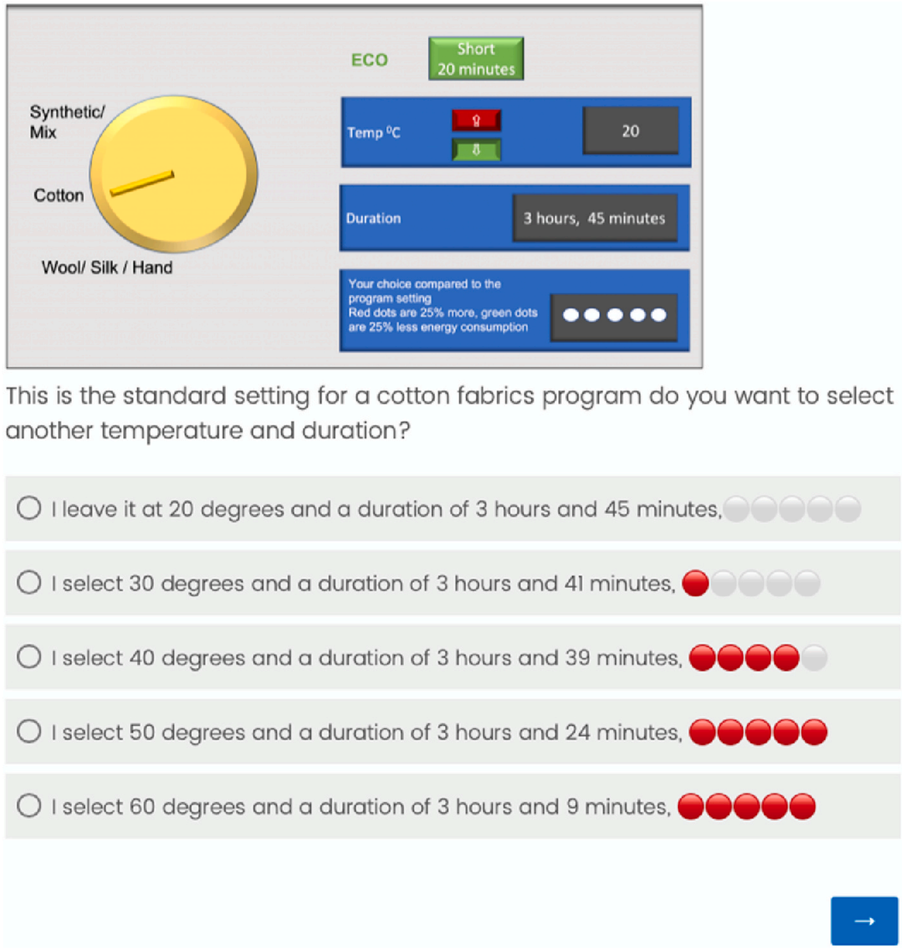

Fig. B.2. Script example Model 2 (Coercion & Feedback) Screen 2

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