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DOI
10.21606/drs2022.335

Publication date
2022

Document Version
Final published version

Published in
DRS Conference Proceedings

Jun 25th, 9:00 AM

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Citation

van den Berge, R., Magnier, L., and Mugge, R. (2022) Enhancing consumers' willingness to repair electronic products: How design can nudge sustainable behaviour, in Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds.), *DRS2022: Bilbao*, 25 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.335

DRS 2022
Bilbao 25th June — 3rd July

Enhancing consumers' willingness to repair electronic products: How design can nudge sustainable behaviour

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doi.org/10.21606/drs.2022.335

Abstract: Product repair can decrease the ecological burden of consumer electronics by lengthening their lifetimes, but it is still too rarely practised by consumers. Design for behaviour change can motivate consumers to undertake repair activities. An increased level of repair self-efficacy can nudge consumers towards repair. In two experiments, we tested the effects of a fault indication on consumers' willingness to repair washing machines, vacuum cleaners and stick vacuum cleaners. A fault indication is a signal appearing on a product providing information about the occurring failure. For products that are relatively less likely to be repaired by a repair professional, the willingness to repair increased significantly when a fault indication was present. The perceived level of self-efficacy mediated these results. These results remained consistent among different types of product failures. Finally, we provide implications for designers and future opportunities on how to further stimulate consumers' willingness to repair electronic products.

Keywords: design for repair; sustainable consumer behaviour; product lifetime; circular economy

1. Introduction

The way we produce, use, and dispose of products has a damaging impact on our environment. Production processes do not only result in large amounts of CO2 emissions, but they also cause social and health-related issues(Heacock et al., 2016). Moreover, because of the growing demand for electronic products, e-waste is one of the fastest growing waste streams. Future scenarios studies prospect that the amount of e-waste will be doubled in 2050 when no serious action is undertaken to reverse this growth(Parajuly et al., 2019).

The Circular Economy has been proposed as a solution to lower the environmental impact of products. It aims to restore and recover materials used in the production and use cycles to

keep the value of products and materials high across all stages of its lifetime (Ellen MacArthur, 2013). Past research showed that prolonging product lifetimes enables to retain products' initial value more than, for example, product recycling and is therefore the preferred route in a Circular Economy (McCollough, 2009).

By repairing, a product's functional value is recovered, and it can perform its initial utility again. The product is not discarded, and its lifetime is prolonged. Therefore, design for repair has an important role in product lifetime extension to lower the impact of consumption on the environment (Bocken et al., 2014). However, research shows that consumers often have low ability (e.g., time, skills, tools, knowledge) and motivation (e.g., financial, pleasure) to repair whilst both are needed to initiate repair activities (Ackermann et al., 2021; Jaeger-Erben et al., 2021). Consumer studies endorse a lack of repair behaviour and demonstrate that most discarded products were never repaired during their lives (Harmer et al., 2019; Hennies and Stamminger, 2016; Wieser and Tröger, 2018). Inconvenient repair support (e.g., instructions, services) may impede the performance repair activities (Jaeger-Erben et al., 2021). Also, consumers who do not feel able to repair the product themselves, will include labour costs from involving repair professionals in the estimated repair costs. Including these costs makes the repair option appear expensive, especially in comparison to new products with a relatively low purchase price (Brusselaers et al., 2019). These barriers are expected to have a negative impact on consumers' willingness to repair.

Research has proposed several ways to facilitate product repair by design (e.g., Raihanian Mashhadi et al., 2016; Sabbaghi et al., 2016). However, focus has been on a design engineering perspective mostly, demonstrating the technical opportunities of repairable designs. Yet, the fact that a product can be repaired physically, does not mean that consumers will act accordingly (Makov and Fitzpatrick, 2021). In other words, it is essential to investigate factors that increase consumers' willingness to repair. The Theory of Planned Behaviour (Azjen, 1991) concluded that perceived control (i.e., ease or difficulty of performing a behaviour) can influence the intention to execute this behaviour. Perceived control is conceptually related to perceived self-efficacy (i.e., 'can do' attitude (Fuchs et al., 2010)). For repair behaviour, this would imply that if consumers have more repair self-efficacy, they expect to have sufficient capabilities to repair their product, which will increase consumers' willingness to execute repair activities.

This research contributes to the literature by investigating the impact of diagnosing the cause of the failure on consumers' willingness to repair. Specifically, we used a fault indication as an example of a design intervention that can help consumers diagnose what is wrong with the product, thereby increasing their repair knowledge. The proposed hypotheses are tested in two experiments using different electronic products.

The effect of a fault indication on consumers' willingness to repair

An important factor that prohibits consumers from starting repair activities in the first place, is that consumers are often not aware of what is causing the product failure (Bovea et al.,

2017). Research investigating consumers' ability to repair showed that product designs do not support consumers in understanding and diagnosing the cause of the failure or facilitate repair activities (Pozo Arcos et al., 2021; Rosborou, 2020; Svensson-Hoglund et al., 2021). To counter this low level of ability to repair, behaviour change research has indicated the value of nudging. A nudge can be a design intervention that persuades or encourages someone to behave in a specific direction (Thaler and Sunstein, 2008). Recent research on increasing product reparability emphasized the importance of including fault indications as design interventions supporting repair (Tecchio et al., 2016). A fault indication is a signal (e.g., code, text, icon, light) appearing on a product when it is malfunctioning. An example is an error code on a washing machine's display. This signal can provide information about the cause of the failure and consumers can use this information to identify the steps that need to be taken for repair. If consumers know what is wrong with the product, their ability to find out what needs to be done for a successful repair is thus increased. Therefore, it is likely that by providing information about the failure, consumers' willingness to repair will increase. In this way, the fault indication acts as a nudge which enhances consumer ability to repair and consequently, increases their intention to perform repair activities.

Even though fault indications can help consumers to understand the cause of the failure, it is unlikely that fault indications will encourage consumers to repair all sorts of products. In some situations, consumers would be more likely to turn to repair professionals for repair, for example because the product is technically complex or relatively expensive (Sabbaghi et al., 2016). When a professional repairer is contacted to execute repair, there is less need for consumers to know the exact product failure because consumers trust the professional repairer to diagnose the cause of the failure. However, some products are less likely to be repaired by repair professionals. For instance, products that have a relatively low purchase price repair will be relatively costly to repair (Rogers et al., 2021). For these types of products, a fault indication may lower the barrier towards repair. Knowing the cause of the failure, repair actions may seem less challenging because the steps towards repair are easier to define. We therefore hypothesize the following:

Hypothesis 1: The positive influence of a fault indication on consumers' willingness to repair is moderated by the probability to make use of professional repairers. Specifically, if the product is less likely to be repaired professionally, the fault indication has a positive effect on consumers' willingness to repair (H1a). If the product is more likely to be repaired professionally, the presence of a fault indication will not have an effect (H1b).

To explain the underlying process for consumers' increased willingness to repair, we argue that when the failure is known, the consumer feels more competent in defining the steps needed for a successful repair. Literature has shown that when consumers believe in their ability to make sound evaluations, in this case about a potential repair, it results in an

increased level of self-efficacy. The perceived self- efficacy is defined as a 'can-do' attitude and depends on a persons' level of knowledge and expertise, competence, and difficulty to make sound evaluations about the related topic (Fuchs et al., 2010; White et al., 2011). It is likely that when the failure of a product is known, the level of self-efficacy concerning repair of the consumer increases. In the presence of a fault indication, a high level of perceived self-efficacy may thus explain an increased willingness to repair. Reflecting on our first hypothesis, this specifically applies to products for which consumers have a low tendency to consult a professional repairer. Therefore, we hypothesize the following:

Hypothesis 2: The perceived level of self-efficacy mediates the relationship between the presence of a fault indication and consumers' willingness to repair (H2).

2. Study 1

2.1 Method

Study 1 aims to test whether a fault indication on a malfunctioning product stimulates consumers to repair it. To do so, we empirically tested the willingness to repair of two different product categories. The two categories represent products of which consumers are expected to have either a low or high tendency for professional repair. We used an experimental set-up because it allows to isolate and test the specific effects of a chosen intervention (i.e., fault indication). Moreover, it enables to uncover mainstream effects (rather than unique, individual cases) and that are therefore especially interesting for designers.

Study design and development of the stimuli

Study 1 had a 2 (fault indication: absent vs. present) × 2 (product's likelihood to be repaired professionally: low vs. high) between-subject experimental design. Each participant was presented with one of four conditions in a scenario, which consisted of a picture and a short text (figure 1). We chose washing machines (WM) and vacuum cleaners (VC) because these products are used frequently and are considered important to consumers. Also, the market sales and environmental footprint are substantial. The impact of these products can be lowered when lifetime is prolonged by repair if the repair takes place before 'the environmental break-even point' arrives. This is the point in time where the environmental impacts that result from using a product are equal with impacts of a (more energy efficient) replacement product. For WM this is estimated to be around 10 years, and for VC around 6 years (UN environment, 2017).

We chose a washing machine as a product that is more likely to be professionally repaired, because of its high technical complexity in its design and its relatively high purchase price. We chose a vacuum cleaner as a product category that is less likely to be professionally repaired because the purchase price of a new vacuum cleaner is relatively low, making

replacement of a vacuum cleaner more likely when the product starts to malfunction. Therefore, the probability for consumers to turn to a professional repairer is expected to be lower for a vacuum cleaner compared to a washing machine.

The described failure in each scenario ensured that the main function of the product could no longer be performed. When the fault indication was absent, only information about the observed failure was presented. The participant was 'not able to activate the wash programs' of the washing machine, and the vacuum cleaner had 'lost its suction power'. When a fault indication was present, the scenario provided additional textual and visual information about the cause of the failure. For the washing machine, an error code showed 'damaged drum bearings', and for the vacuum cleaner a red light indicated a 'damaged filter'. Additionally, the text referred to information on a (online) manual indicating that the specific damaged part needs to be replaced.

To create the pictorial stimuli, we used examples from existing products. Brand names and logos were erased to prevent participants' associations unrelated to the topic of our study. To reduce the possibility that different associations regarding the product's initial functionality would influence the results, all products were introduced as 'mid-range models' and having 'normal performance' compared to similar products. Earlier research showed that the age of the product is an important factor in the decision to repair (Makov and Fitzpatrick, 2021). A product's value depreciates over time, meaning it becomes worth less and less (Van den Berge et al., 2021). Therefore, the time of ownership was included in the scenario as well. We chose a time of ownership situated between the legal warrantee period of two years, the average use time of the product types (i.e., 8.3 years for washing machine and 6.0 years for vacuum cleaner (Wieser et al., 2015)), and the earlier indicated 'environmental break-even points', in which lifetime extension is a preferred option. Accordingly, we assumed repair could still be a viable and preferred option for a 6-year-old washing machine and 4-year-old vacuum cleaner. An example of one of the scenarios is shown in figure 1.

Scenario 2 – Washing machine – Fault indication Present

Imagine you own a **washing machine**. The washing machine is a **mid-range model,** and you own it now for **6 years**. Until now, it has had a **normal performance** compared to similar types of washing machines.

When you wanted to use the machine today, you noticed **it failed**. You were **not able to activate the wash programs** anymore. The washing machine **indicated fault 5** in its display. **The (online) manual** indicates **'the drum bearings are damaged'** and need to be replaced.

Figure 1. *An example of one of the 4 scenarios shown to the participants in study 1: a washing machine with a fault indication present.*

Participants, procedure, and measures

The study was conducted online using Qualtrics software (Qualtrics.XM, 2022). Participants who did not own the product category under investigation were excluded from the dataset (WM: n=4; VC: n=3). Two participants failed the attention check and were also excluded. This resulted in a total of 139 participants (Age: Mean=41.10, SD=10.61; Gender: Male=54.0%, Female=46.0%, Other=0%). Participants were recruited via Prolific which is an online database representing participants from different nationalities (Prolific, 2022). The minimum age requirement was set to twenty-five years because this made it more likely that participants had bought these products themselves and had possessed them for several years, making a possible repair need a realistic scenario.

After being presented with the scenario, the participants were first asked to evaluate their willingness to repair the product using three items *('How likely/inclined/willing are you to have this product repaired?*' (White et al 2011)) on a seven-point scale (1= 'not at all'; 7= 'very much'). Additionally, the level of self-efficacy was assessed on three seven-point Likert scales (1='strongly disagree'; 7='strongly agree') using the items: *'I feel competent enough to select the best repair actions needed for this product'*, *'I feel that I have the relevant knowledge and expertise to make sound evaluations about the repair actions needed for this product*' and *'I had difficulties evaluating the repair actions needed for this product (r)'* (Fuchs et al 2010). Participants also responded to a three-item seven-point Likert scale to check the manipulation of the fault indication: *'The fault was clear to me'*, *'I would be able to identify the type of failure'* and *'I have had enough information to know the type of failure'* (1= 'strongly disagree'; 7= 'strongly agree'). To check the probability of the product to be repaired professionally, we asked participants how likely they were to have the product repaired by a professional repairer (1= 'not at all'; 7= 'very much').

Finally, we included three covariates in our analysis that may have influenced participants level of willingness to repair. For example, it may be that some participants are more knowledgeable about repair than others. Despite the absence or presence of a fault indication, a high level of repair knowledge may lead to an increased willingness to repair. To measure the level of repair knowledge, the participants ranked themselves on three seven-point semantic differential scale (Lakshmanan and Shanker Krishnan, 2011). Also, on the one hand it is likely that a high level of environmental concern also influences consumption patterns because participants are more aware of their impact on the environment. Consequently, this may have led to an increased willingness to repair. We measured the level of environmental concern on an existing six-item Likert scale (Kilbourne and Pickett, 2008). On the other hand, a high level of technological interest may increase the demand for new products. When a product breaks down, this may lead to a higher replacement tendency because the participant is keen to have a new product. Therefore, we included this factor using an existing seven-item Likert scale (Parasuraman, 2000). The scales and items used can be found in appendix A. The collective means of the multiple item scales were calculated in SPSS and used for the analyses.

2.2 Results and discussion

Manipulation checks

We first checked if the presence of a fault indication had the intended effect on participants' understanding of the failure. We performed analyses of variance (ANOVAs) to test the effect of the fault indication. We used the fault indication as the independent variable and the collective mean of the three-item scale to check the manipulation as the dependent variable. As intended, there was a significant main effect of the presence of a fault indication on the understanding of the product failure for both the washing machine ($M_{WM\ absent}$=3.39 vs. $M_{WM\ present}$=5.42; $F(1,67)=36.65$; $p<0.001$) and vacuum cleaner ($M_{VC\ absent}$=4.02 vs. $M_{VC\ present}$=5.86; $F(1,68)=31.67$; $p<0.001$). These results showed that participants had a better understanding of the failure when a fault indication was present, and thus the manipulation was successful. We also tested our manipulations concerning the probability to make use of professional repair for different product categories. The assumptions of normality of variances were not met for this variable. Therefore, we used non-parametric one-tailed independent-samples Mann-Whitney U tests for the analyses. The results showed that participants were significantly more likely to have a washing machine repaired by a professional repairer than a vacuum cleaner (Mdn_{WM}=6.00, Mdn_{VC}=3.00, U=1286.00, $p<0.001$), cf. table 1, and our manipulations were therefore successful.

The effect of a fault indication on the willingness to repair

To test H1, we used analyses of covariance (ANCOVAs) with the fault indication and product category as independent variables, the level of repair knowledge, level of environmental concern and technological innovativeness as covariates, and willingness to repair as the dependent variable. The results of the covariates did not significantly differ across conditions, cf. table 1. Therefore, we can assume that the different groups represent a comparable sample in terms of personality traits. Continuing our analyses, a main effect was found for the fault indication. This demonstrates that participants were more willing to repair a product with a fault indication (M_{absent}=4.70 vs. $M_{present}$ =5.29; $F(1,132)=6.16$; $p<0.05$). There was no main effect for the product category. More importantly, the results showed a significant interaction effect of the fault indication and product category on the willingness to repair ($F(1,132)$ =4.78; $p<0.05$). Looking at the product categories separately, for the vacuum cleaner the willingness to repair was significantly higher when a fault indication was present ($M_{VC\ absent}$=4.25 vs. $M_{VC\ present}$=5.42, $F(1,65)=11.72$; $p<0.001$). However, for the washing machine this effect was non-significant ($M_{WM\ absent}$=5.12 vs. $M_{WM\ present}$=5.21, $F(1,64)=0.09$; $p>0.50$), shown in figure 2. These findings provide support for both H1a and H1b. Descriptive statistics are displayed in table 1.

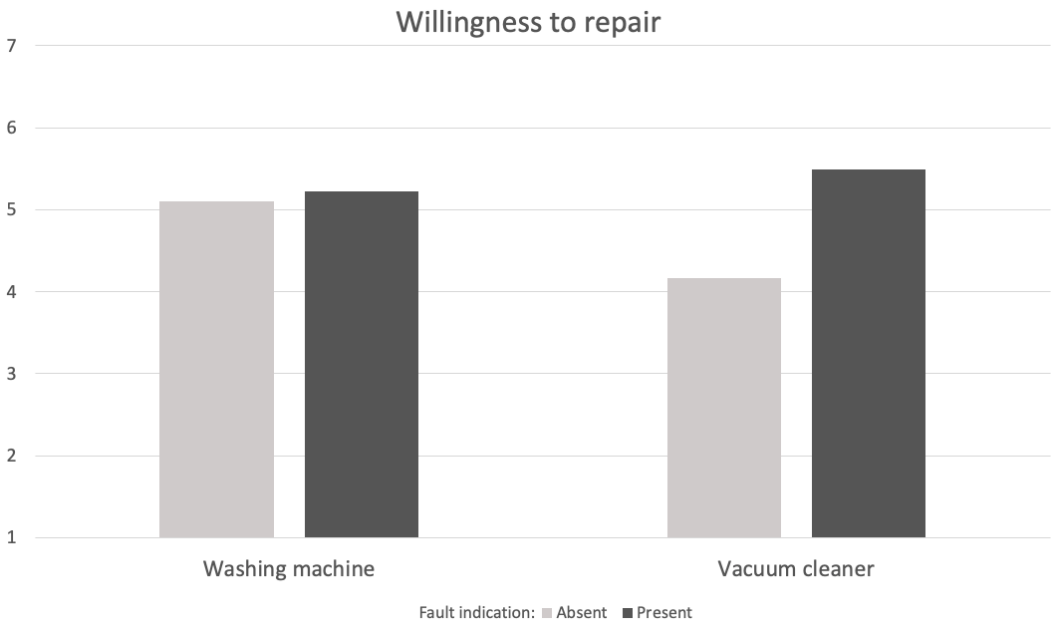

Figure 2. *Bar chart showing the differences in the willingness to repair for the washing machine and vacuum cleaner if the fault indication was absent or present.*

The mediating effect of self-efficacy on the willingness to repair

To test for H2, we first performed ANOVAs with fault indication and product category as independent variables and the level of self-efficacy as a dependent variable. Our results showed a significant main effect for both the fault indication ($M_{\text{FI absent}}$=3.61 vs. $M_{\text{FI present}}$ =4.42; $F(1,135)=9.34$; $p<0.01$) as the product category (M_{WM}=3.71 vs. M_{VC} =4.32; $F(1,135)=5,45$; $p<0.05$) on the level of self-efficacy. No significant interaction effect between the fault indication and product category was found. When looking at the product categories separately, the results showed a significant higher level of self-efficacy for a vacuum cleaner when the fault indication was present ($M_{\text{VC absent}}$=3.77 vs. $M_{\text{VC present}}$=4.88; F(1,68) =8.29; p<0.01), however, this result was not shown for the washing machine ($M_{\text{WM absent}}$=3.45 vs. $M_{\text{VC present}}$=3.96; $F(1,67)$ =1.97; $p>0.10$).

To confirm H2, we performed a moderated mediation analysis using model 7 of the PROCESS macro for SPSS (Hayes, 2013). The aim was to check if self-efficacy mediated the relationship between the presence of a fault indication and willingness to repair and was moderated by the product category, figure 3. The PROCESS results indeed revealed the presence of a moderated mediation (b=0.92; SE=0.41; 95%CI: [0.12;1.74]; $p<0.05$). When the probability for professional repair was low (i.e., in the case of the vacuum cleaner), there was a positive indirect effect of a fault indication on the willingness to repair through the level of self-efficacy (b=0.30; SE=0.17; 95% CI:[0.03;0.69]). When the probability for professional repair was high (i.e., in the case of the washing machine) the positive effect of a fault indication on the willingness to repair through the level of self-efficacy was weakened (b=0.04; SE=0.09; 95% CI:[-0.15;0.22]). Therefore, hypothesis 2 is confirmed.

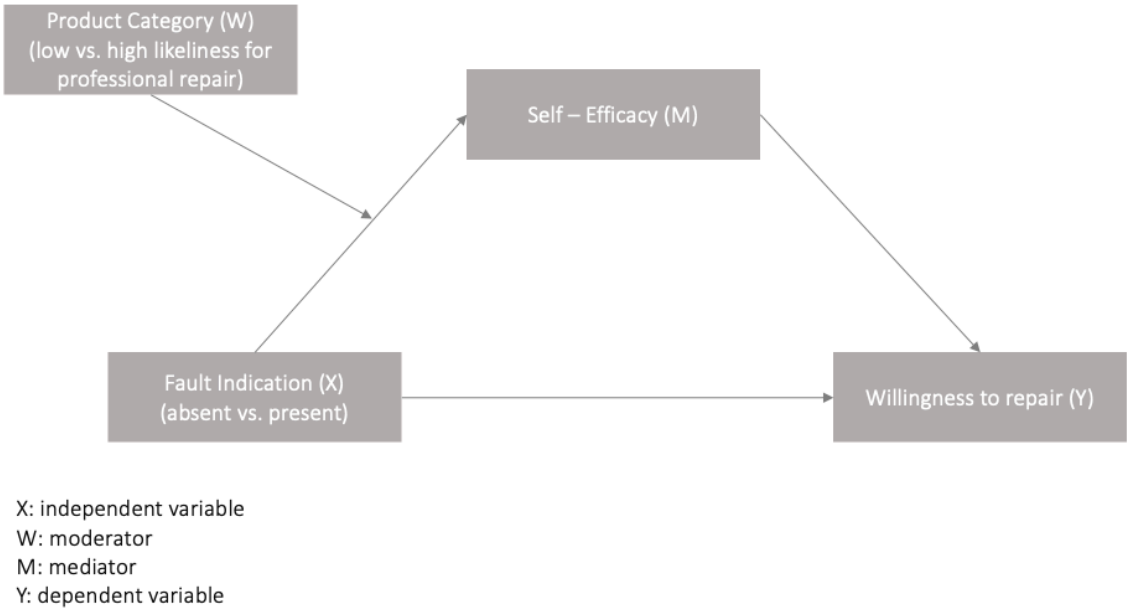

Figure 3. Moderated mediation model of study 1 based on Hayes (2013).

When reflecting on our study, a limitation could be that a 'damaged filter' of a vacuum cleaner was perceived more as a maintenance activity, rather than a pure repair activity by the participants. The 'damaged filter' of a vacuum cleaner may therefore have been perceived as a relatively easy task, that will not take too much time and effort. To validate if fault indications can also be beneficial for other, more complicated failures and repair activities of similar types of products, we chose to replicate the positive effects of failure indication in study 2 using a different type of failure.

3. Study 2

3.1. Method

The main purpose was to validate the findings of study 1 for a different type of failure. We chose a stick vacuum cleaner (SVC) as a comparable product to a vacuum cleaner in terms of a low probability to be professionally repaired. This resulted in a 2 (fault indication: present vs. absent) × 1 (SVC) between-subject experimental design.

Development of the Stimuli

The conditions presented in the two scenarios of the stick vacuum cleaner were similar to those in study 1. The product was introduced as being a 'mid-range model' and having a 'normal performance', and the time of ownership was 3 years which is in line with the vacuum cleaner of study 1. We chose a malfunctioning battery as a failure, ensuring that the essential function of the product could no longer be performed. Desk research on the internet showed that a malfunctioning battery is considered a commonly occurring failure for a stick vacuum cleaner. Additionally, a failing battery is less susceptible to be considered

a maintenance activity and would require more time and effort from the consumer to repair compared to the damaged filter of a vacuum cleaner in study 1. In the condition where the fault indication was absent, the stick vacuum cleaner 'failed' and was 'not able to function anymore'. When a fault indication was present, a red light was shown on the product. The text referred to information in the (online) manual indicating that the battery was damaged and needed to be replaced, figure 4.

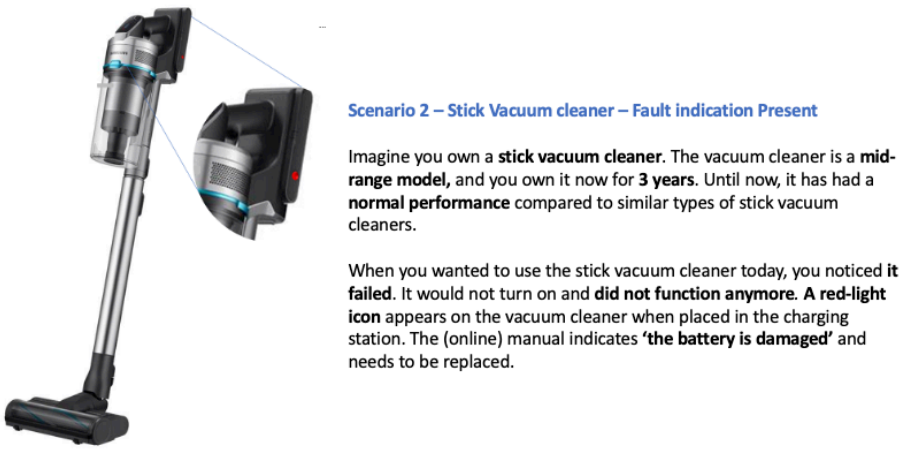

Figure 4 *An example of one of the two scenarios shown to the participants in study 1: a stick vacuum cleaner with a fault indication present.*

Participants, procedure, and measures

Seventy-two respondents (Age: Mean=38.11, SD=8.69; Gender: Male=47,2%, Female=52.8%, Other=0%) participated in this online study. The participants were recruited via Prolific under the same conditions as study 1. Five participants who failed the attention check were excluded from the dataset. As expected, owning a stick vacuum cleaner was less common than owning a vacuum cleaner (55.6% indicated to own a stick vacuum cleaner). As study 1 showed most participants owned a vacuum cleaner, and a stick vacuum cleaner is similar in terms of functionality, we assumed this will not influence our results. Participants evaluated the scenarios on multi-item scales for their 'willingness to repair', level of 'self-efficacy', the 'likelihood of professional repair', 'level of repair knowledge' and completed the manipulation check, cf. appendix A. The measures were identical to those in study 1.

3.2 Results and discussion

Manipulation checks

The data of the manipulation check was not normally distributed; therefore, a nonparametric test was used for the analysis. The manipulation was successful (Mdn_{Absent}=2.33 vs. $Mdn_{Present}$=6.33, U=1152.50, p<0.001) and confirmed that consumers were significantly more able to identify the failure of the stick vacuum cleaner when a fault indication was present. Furthermore, we compared the results of the stick vacuum cleaner

on the probability to be professionally repaired to the products from study 1. When looking at the means of the stick vacuum cleaner and compare them to those of the washing machine and vacuum cleaner, the results showed that the probability of having a stick vacuum cleaner repaired by a repair professional was comparable to the vacuum cleaner (M_{SVC} =4.43; M_{VC}= 3.86 vs. M_{WM}=5.72). Therefore, we can assume that the vacuum cleaner of study 1 and stick vacuum cleaner of study 2 are comparable in terms of probability to be professionally repaired.

Table 1. *The means, standard deviations and significance levels (p-value: *= p<0.05; **= p<0.01; ***= p<0.001); a= nonparametric test result; p= one tailed) of the variables used study 1 and study 2.*

	Study 1						**Study 2**		
	Washing machine			**Vacuum cleaner**			**Stick vacuum cleaner**		
Fault indication	**Absent (n=34)**	**Present (n=35)**	**p-value**	**Absent (n=35)**	**Present (n=35)**	**p-value**	**Absent (n=37)**	**Present (n=35)**	***p*-value**
Manipulation check	3.39 (1.59)	5.42 (1.16)	<0.001 ***	4.01 (1.69)	5.86 (0.94)	<0.001 ***	2.80 (1.58)	5.70 (1.67)	<0.001[a] ***
Willingness to repair	5.10 (1.67)	5.22 (1.69)	0.763	4.17 (1.69)	5.49(1.55)	0.001 ***	4.38 (2.04)	5.19 (1.85)	0.045[a] *
Level of Self -efficacy	3.45 (1.43)	3.96 (1.58)	0.577	3.77 (1.83)	4.87 (1.35)	<0.001 ***	3.36 (1.64)	4.67 (1.67)	0.012 *
Likelihood for Professional repair	5.97 (1.75)	5.49(1.84)	0.048 [a] *	3.83 (2.02)	3.89 (2.32)	0.479 [a]	4.46 (2.13)	4.40 (2.40)	0.471 [a]
Level of repair knowledge	3.43 (1.29)	3.98 (1.62)	0.124	3.77 (1.53)	3.83 (1.43)	0.872	3.39 (1.51)	4.02 (1.62)	0.087
Level of environmental concern	5.98 (1.00)	5.83 (0.98)	0.541	5.87 (1.21)	5.66 (1.10)	0.462	5.85 (1.10)	6.15 (0.82)	0.193
Level of technological innovativeness	4.66 (1.13)	4.55 (1.47)	0.723	4.91 (1.28)	4.54 (1.10)	0.203	4.74 (1.25)	4.99 (1.18)	0.387

The effect of a fault indication on the willingness to repair

We tested whether a fault indication positively increased consumers' willingness to repair a stick vacuum cleaner (H1a). A nonparametric test (Mann-Whitney) was conducted because the data was not normally distributed. We used the fault indication as independent variable and willingness to repair as the dependent variable in the analyses. The results showed a significant main effect on the 'willingness to repair' a stick vacuum cleaner when a fault indication was present (Mdn_{absent}=4.67 vs. $Mdn_{present}$=5.67; U=798.00, p<0.05), which provides further supporting evidence for H1a.

The mediating effect of self-efficacy on the willingness to repair

The assumptions for parametric tests were met for the level of self-efficacy of the stick vacuum cleaner. The results of the ANOVA showed that the level of self-efficacy was perceived significantly higher when the fault indication was present (M_{absent}=3.36 vs. $M_{present}$=4.67; $F(1,70)=6.68$, $p<0.05$). We performed a mediation analysis using model 4 of the PROCESS macro for SPSS (Hayes, 2013) to check if self-efficacy mediated the relationship between the presence of a fault indication and willingness to repair. Analysing the indirect effects, results revealed that self-efficacy mediated the relationship between the fault indication and the willingness to repair (b=0.55; SE=0.27; 95% CI:[0.11, 1.18]), providing further support for H2. The fault indication positively influenced the level of self-efficacy (b=1.01; SE=0.39; 95% CI:[0.23, 1.78]); $p<0.05$) and self-efficacy, in turn, positively influenced the willingness to repair (b=0.55; SE=0.12; CI:[0.29, 0.80]; $p<0.001$).

4. General discussion and implications for design

The results of study 1 demonstrated that consumers seem to be quite willing to repair their products, see table 1. These are promising results for the circular economy. However, the results also showed that a fault indication significantly increased the willingness to repair a vacuum cleaner, but a washing machine. A fault indication will only positively influence consumers' willingness to repair if it is employed on a product that is unlikely to be professionally repaired. Additionally, the mediating effect of self-efficacy showed that fault indications can make consumers feel more competent and knowledgeable to select relevant repair actions. Thereby, self-efficacy is positively influencing the willingness to repair a product. The results of study 2 further demonstrated that for product categories for which consumers are unlikely to go to repair professionals, a failure indication can increase consumers' willingness to repair, also for a variety of failures. Summarizing, we conclude that fault indications are successful in increasing self-efficacy for repair for products that are less likely to be repaired professionally. Therefore, they are useful nudges to encourage consumers to repair these types of products.

Our results showed the importance of design interventions in stimulating more sustainable behaviour. By addressing the consumer perspective, our insights go beyond the engineering perspective adopted in prior research on design for repair. Our results confirm earlier insights that products being physically repairable does not help when consumers are not ready to repair (Makov and Fitzpatrick, 2021). Additionally, we contribute to existing literature by showing that design for repair is also about guiding consumers in their experience towards repair. Support in diagnosing the failure turns an incomprehensible experience of product failure into a more comprehensible one. This gives consumers more control over the situation and therefore a more positive experience. To do so, designers should not only focus on making products more physically repairable, but also on implementing design interventions increasing consumers' repair ability. Our results confirm

this by showing the positive effect of including cues for fault diagnosis on consumer's willingness to repair.

Regarding the expected strength of the effect (Kang, 2021), our research was a successful first attempt to prove this effect. Even though we took diversity of age and gender into account when selecting our sample, we cannot claim that our sample was representative for the vacuum cleaner and washing machine population. Furthermore, we realize that people's responses to hypothetical scenarios may differ from real-life repair intentions. Future research should aim to explore the effects of fault indications in real-life settings using actual product failures and fault indications.

In this paper, we used a fault indication as a design intervention increasing repair ability. However, this does not mean that this is the only design interventions that can trigger this. When designing for repair, it is worthwhile to explore other design interventions that can positively people's self-efficacy. For instance, a step-by step guide for executing repair activities or movies in which repair steps are explained, may have the same positive effect. Future empirical studies could explore what other design interventions could increase self-efficacy and thereby encourage consumers to repair. Furthermore, when aiming to stimulate repair for a wider range of products, it may be interesting to explore if other design interventions can stimulate repair of products. For instance, modular design is an example of a design intervention that makes products easily disassembled for repair activities. As consumers often do not believe products are made to be repaired (Wieser et al., 2015), the perception of a design being modular and may increase consumers' willingness to repair as well. However, the effect of modular design on consumer behaviour is still underexplored (Schischke et al., 2019). Finally, regarding the current lack of available and affordable repair support (Jaeger-Erben et al., 2021) it would be advised to go beyond particular design interventions on a product level. By taking a more system level perspective, research can look beyond the product design and investigate what support on a service, business model or policy level could encourage consumers' repair behaviours. For instance, it may be interesting to explore what specific service design aspects (e.g., pickup service) or business models (e.g., extended warrantees) can increase consumers' willingness to repair, and consequently, encourage repair activities. Also, these outcomes are interesting for policy makers to develop regulations that support consumers in adopting more sustainable behaviour.

Acknowledgements: This research is part of the PROMPT project and funded by the European Union´s Horizon 2020 research and innovation program under grant agreement no. 820331.

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Appendix A – Scales and items

				Cronbach's α	
Measure	Items	Scale	Source	Study 1	Study 2
Manipulation check fault indication	The fault was clear to me	1= Strongly agree 7= Strongly disagree	N.a.	0.89	0.96
	I would be able to identify the type of failure				
	I have had enough information to know the type of failure				
Willingness to repair	How likely are you to have this product repaired?	1= not at all 7= very much	White et al (2011)	0.95	0.96
	How inclined are you to have this product repaired?				
	How willing are you to have this product repaired?				
Self-Efficacy	I feel competent enough to select the best repair actions needed for this product	1= Strongly agree 7= Strongly disagree	(Fuchs et al 2010)	0.85	0.77
	I feel that I have the relevant knowledge and expertise to make sound evaluations about the repair actions needed for this product				
	I had difficulties evaluating the repair actions needed for this product(r)				
Level of repair knowledge	When it comes to repairing products, you are…	1 = Not at all knowledgeable 7 = Highly knowledgeable	(Lakshmanan and Shanker Krishnan, 2011)	0.85	0.86
	When it comes to repairing products, you are …	1 = A complete beginner 7 = An expert			

	When it comes to repairing products, you …	1 = Know much less than most people 7 = know much more than most people			
Level of environmental concern	I am very concerned about the environment	1= Strongly agree 7= Strongly disagree	(Kilbourne and Pickett, 2008)	0.91	0.91
	Humans are severely abusing the environment				
	I would be willing to reduce my consumption to help protect the environment				
	Major political change is necessary to protect the natural environment				
	Major political change is necessary to protect the natural environment				
	Anti-pollution laws should be enforced more strongly				
Level of technological innovativeness	Other people come to you for advice on new technologies	1= Strongly agree 7= Strongly disagree	(Parasuraman, 2000)	0.90	0.87
	It seems your friends are learning more about the newest technologies than you are. (r)				
	In general, you are among the first in your circle of friends to acquire new technology when it appears.				
	You can usually figure out new high-tech products and services without help from others.				
	You keep up with the latest technological developments in your areas of interest.				
	You enjoy the challenge of figuring out high-tech gadgets.				

	You find you have fewer problems than other people in making technology work for you.				