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The influence of a modular design and facilitating cues on consumers' likeliness to repair electronic products

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Abstract: Modularity represents a promising design strategy for product lifetime extension. Yet, the fact that products are physically designed to be repaired via such a modular design, does not mean consumers will act accordingly. Past research demonstrated promising results with current modular smartphone users. However, these users may not necessarily reflect the average consumer because modular products are not (yet) the norm. Two experiments were set up to test the effect of modularity on consumers' likeliness to repair and to investigate which specific design cues can encourage consumers to execute DIY ('do-it-yourself') repair. The first study shows that a modular design increased the general likeliness to repair and decreased the task difficulty compared to a conventional design. Interestingly, the likeliness to use professional repair increased for modular smartphones, while the likeliness to DIY repair remained low. For DIY repair, consumers thus may need more support. The second study shows that facilitating design cues on the inside of a modular smartphone increased consumers' likeliness to consider DIY repair. Our results are relevant for practitioners aiming to increase electronic product DIY repair.

Introduction

The growing amount of electronic product waste (e-waste) is becoming increasingly problematic worldwide (Parajuly et al., 2019). Repair has been addressed as a promising strategy to counter the environmental issues resulting from our current consumption and production patterns (Bocken et al., 2016). However, repairing electronic products when they are malfunctioning or broken is not yet common (Magnier and Mugge, 2022). Consumers encounter many barriers to repair, such as high costs, lack of spare parts, and limited knowledge and ability (Ackermann et al., 2021; Jaeger-Erben et al., 2021; Nazlı, 2021; Rogers et al., 2021; Svensson et al., 2022). Prior research implied that consumers' limited ability to repair may be caused by the way products are designed (Raihanian Mashhadi et al., 2016). For instance, smartphone casings are often glued, which takes more time and effort to disassemble.

Modularity has been addressed as a design strategy to enhance the physical reparability of products (Mestre and Cooper, 2017; Mugge et al., 2005; Schischke et al., 2019). A modular product consists of independent 'building blocks' (modules) and is designed in such a way the modules can be easily replaced or repaired when malfunctioning (Bonvoisin et al., 2016). In addition to enhancing repair, modularity potentially allows consumers to keep their products up to date with new technologies via upgrades, thereby increasing lifetime expectations (Den Hollander, 2018; Ülkü et al., 2012). Therefore, modularity can be beneficial for slowing down resource loops (Bocken et al., 2016). Yet, the fact that products are physically designed to be repaired, does not mean consumers will act accordingly (Makov and Fitzpatrick, 2021).

A study on current users of modular smartphones demonstrated a strengthened perceived ability for DIY ('do-it-yourself') repair (Amend et al., 2022). However, these users may not reflect the average consumer because modular products are not (yet) the norm. Many consumers are accustomed to involving professionals to repair electronic products, such as smartphones and washing machines (Magnier and Mugge, 2022). A modular design would make it easier for consumers to repair products themselves, which is often cheaper and faster, but also demands a change in their current behavior. We contribute to the literature by investigating the impact of a modular design on consumers' likeliness to get the product repaired as well as to conduct DIY repair.

The likeliness and perceived difficulty to repair modular products

At present, consumers generally do not believe products are designed to be repaired (Van den Berge et al., 2022; Wieser et al., 2015), and their likeliness to consider repairing a malfunctioning product is low (Magnier and Mugge, 2022). This low likelihood to repair is partly due to the associated difficulty of the repair task (Pozo Arcos et al., 2021; Svensson et al., 2022). Research showed that a high perceived difficulty reduces the attractiveness of a task because it may seem unfamiliar to the consumer (Pocheptsova et al., 2010). A modular design is intended to counter this negative perception of repairing consumer electronics. The fact that the modules can be easily disassembled may result in a more attractive repair task because it would be less effortful and time-consuming. Therefore, we expect that modularity will decrease the perceived difficulty of the repair task, which will positively influence consumers' likeliness to repair. Accordingly, we hypothesize:

H1: Consumers are more likely to repair an electronic product with a modular design than one with a conventional design

H2: The perceived difficulty of the repair task mediates the effect of modularity on the likeliness to repair

Study 1

Method

The experiment had a 2 (product category: washing machine vs. smartphone) x 2 (product design: conventional vs. modular) between-subject design. Washing machines and smartphones are commonly owned and the environmental impact decreases when their current average lifetime is prolonged (Bakker and Schuit, 2017). Furthermore, the perceived ability to repair these products is low (Jaeger-Erben et al., 2021). We decided to include a 'workhorse' product (i.e., valued for its functional utility) and an 'up-to-date' product (i.e., susceptible to changes in appearance or technology) to consider differences in repair attitudes among product categories (Cox et al., 2013; Pérez-Belis et al., 2017).

We created four scenarios using commonly occurring failures. For the washing machine, the drum bearings were worn out, and for the smartphone, the battery was not working properly (Thysen and Berwald, 2021). We deliberately chose a defect that resulted in a reduced product performance rather than a complete breakdown. The latter may urge immediate action because daily routines are disrupted. Since we aimed to investigate the effect of modularity, we wanted to limit the influence of urge in the repair consideration of the participants. To ensure repair would still be considered a valuable option (Van den Berge et al., 2021), the moment the defect occurred was defined between the mandatory warranty period and average use time (Wieser et al., 2015) (washing machine: 6 years; smartphone: 2 years and 2 months). We used the same brandless product pictures for the conventional and modular scenarios, cf. figure 1. The products were introduced as mid-range models with normal performance. For the modular conditions, the scenario textually explained the product consisted of several independent smaller parts (modules), which can be easily replaced or repaired when malfunctioning.

Figure 1. Pictorial stimuli of Study 1.

Participants were recruited online via Prolific. All participants (n=155) were from the UK, above 25 years old (Mage=38.79, SD=11.22, Male=49.7%, Female=48.4%, Other=1.9%), and indicated to own a washing machine/ smartphone. All passed the attention check.

Participants evaluated the scenarios on their general likeliness to repair ('How likely/inclined/willing are you to have this product repaired?'; 1=strongly disagree; 7=strongly agree; α=.97 adapted from White et al., 2011) and perceived difficulty of the repair task ('Repairing the product described in the situation above ...is easy/hard; …is easy/hard to complete; …will take little/much time; α=.88; adapted from (Pocheptsova et al., 2010) on 7-point scales. We additionally included two single items to measure the likeliness for DIY and professional repair, 'How likely are you to repair this product yourself/have this product repaired by a professional repairer?' (1='not at all'; 7='very much'). Finally, the participants completed a manipulation check on the degree of modularity ('This product is made of modules that are easily replaceable', 'It is easy to replace malfunctioning parts in this product', 'through its design, this product supports the replacement or repair of malfunctioning parts' (1 = strongly disagree; 7 = strongly agree; α=.91).

Results

We conducted bootstrapped (5000 samples) parametric tests as these are fairly robust when the assumption of normality is violated (e.g., Blanca et al., 2017). An independent sample t-test with product design as the independent variable and the degree of modularity as the dependent variable showed our manipulation was successful ($M_{conventional}$=3.88 vs. $M_{modular}$=6.36, t(153)=-12.58,p<.001).

We performed three two-way ANOVAs with product design and product category as independent variables and the three types of repair likeliness as dependent variables. For the general likeliness to repair participants were significantly more likely to repair the modular than the conventional product ($M_{conventional}$=4.15 vs. $M_{modular}$=5.35; F(1,151)= 17.86;p<.001), confirming H1. Furthermore, a marginally significant main effect suggested a higher general likeliness to repair washing machines than smartphones ($M_{washingmachine}$=5.02 vs. $M_{smartphone}$=4.48; F(1,151)=3.68;p=.06). No significant interaction effect was found.

Interestingly, the modular design did not significantly increase the likeliness for DIY repair. Instead, participants were more likely to professionally repair a modular product compared to a conventional one ($M_{conventional}$=4.54 vs. $M_{modular}$=5.59; F(1,151)=11.20; p<.001). More specifically, the marginally significant interaction effect between the product design and product category on likeliness to professional repair (F(1,151)=3.05; p=.08) suggests that a modular design is more influential in enhancing professional repair for smartphones. Even though the general likeliness to repair significantly increased for modular washing machines, the effect of modularity on professional repair likeliness was not significant. Nevertheless, the means are in the expected direction, cf. table 1.

	Washing machine		**Smartphone**	
	Conv. (n=39)	Mod. (n=40)	Conv. (n=40)	Mod. (n=36)
Degree of modularity	3.90 (1.45)	6.37 (.84)	3.88 (1.42)	6.36 (1.12)
General likeliness to repair	4.52 (1.84)	5.53 (1.59)	3.78 (2.03)	5.18 (1.51)
Difficulty of the task	4.76 (.96)	3.63 (1.39)	4.00 (1.56)	2.90 (1.54)
DIY repair likeliness	1.95 (1.75)	2.28 (1.84)	2.40 (2.16)	2.81 (2.23)
Professional repair likeliness	4.97 (2.08)	5.48 (1.88)	4.10 (2.19)	5.69 (1.53)

Table 1. Descriptive statistics of the four conditions of Study 1.

Finally, we performed a mediation analysis to check whether the perceived difficulty of the task explains the effect of the modular design on the likeliness to repair. Using PROCESS model 4 (Hayes, 2013), the indirect effect showed significant results (b=.28; BootSE=.11; 95%CI:[.08,.05]). Specifically, modularity negatively influenced the perceived difficulty of the task (b=-1.09; SE=.23; 95%CI:[-1.54;-.64] p<.001), which in turn had a positive effect on the likeliness to repair (b=-.26; SE=.10; 95%CI:[-.45;-.06]; p<.05). Our results thus indicate a partial mediation, confirming H2.

Discussion

The findings of study 1 showed that modularity increased the general likeliness to repair, which was explained by a decreased perceived difficulty of the repair task. However, a modular design only influenced the likeliness to consider professional repair. This is surprising as we often implicitly assume that modular designs would encourage DIY repair, as the replaceable modules would make repair easier to conduct and could also save expensive labor costs. Therefore, exploring what would increase the likeliness to DIY repair modular smartphones is interesting to explore further.

Design cues and the likeliness to DIY repair modular products

Even though modular products encourage repair, consumers do not feel sufficiently able to do such repairs themselves. Instead of consulting a professional repairer, designers may further support them to increase their perceived ability to conduct DIY repair. Research suggested that design interventions (i.e., affordances) can be useful to prompt consumers to adopt sustainable behavior (Bhamra et al., 2011; Ohnmacht et al., 2018). Affordances are defined as "action possibilities in the environment in relation to the action capabilities of the user" (Gibson, 1977). It prompts a specific use or interaction with the user, for example, a handle on a door invites you to open it.

Repair affordances thus represent the repair action possibilities in the relation between the user and a malfunctioning object. For example, for repair consumers generally need to open the product, diagnose the problem, relate this to the correct component, and replace this component with a new one. All are repair affordances, and if modular products do not sufficiently support consumers in these actions, DIY repair is unlikely to happen. To increase the ability for DIY repair, signifiers, which are physically perceivable cues, are needed to support the specific repair steps and can make them more easily processed (Norman, 2008).

Different types of cues can be designed to bring about repair affordances. For example, a cue on the outside that indicates where to open the product could make it easier to start the repair task, or a cue inside the product could make the to-be-repaired component easier to identify. Therefore, we hypothesized the following:

H3: Consumers are more likely to DIY repair a modular product when the design includes explicit repair cues

Study 2

Method

The experiment used a 2 (outside cue: present vs. absent) x 2 (inside cue: present vs. absent) between-subject design. We focused on smartphones because these are often replaced even with minor defects, and DIY repairs can cut repair costs. Additionally, some examples of modular/ repairable smartphones are available on the market (e.g., Fairphone, Nokia) making our insights relevant to practitioners.

In line with study 1, the smartphone was introduced as a mid-range model with normal performance. The time of ownership was 2 years and 2 months, and brand names were removed, cf. figure 2. In all scenarios, the smartphone had a modular design with a failing battery. We included two types of cues. One was a notch (i.e., inlet) on the smartphone's exterior, which can be used to open the device. One was an icon on the inside indicating the smartphone's components (e.g., battery), which was shown on the website/(online) manual. Participants were recruited similarly to Study 1. All owned a smartphone (n=158, Mage=41.37, SD=13.56, Male = 50%, Female = 50%, Other = 0%), and passed an attention check.

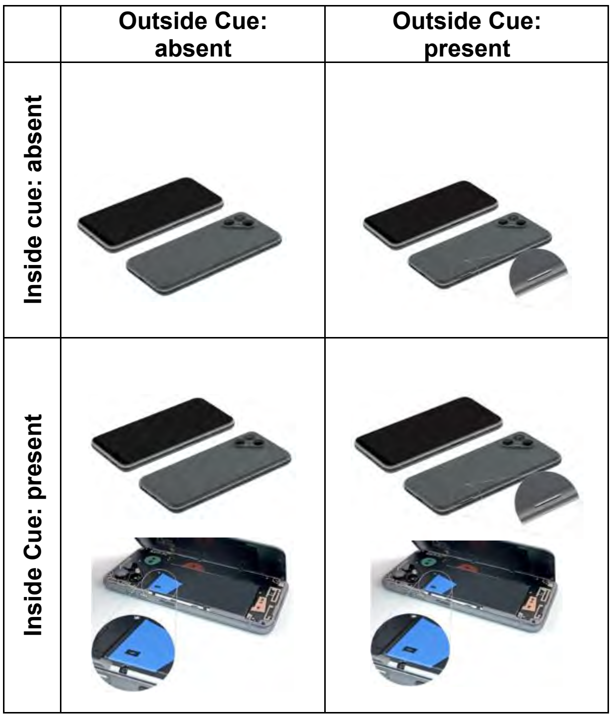

Figure 2. Pictorial stimuli of Study 2.

Similar to study 1, we measured the general likeliness to repair (α=.94) and the perceived difficulty of the repair task (α=.90). We measured the likeliness for DIY and professional repair on 3-item scales ('How likely/inclined/willing are you to repair this product yourself' α=.97/to have this product repaired by a professional repairer?'; 1='not at all'; 7='very much' α=.96). We checked our manipulations on 3-item scales (1=strongly disagree; 7=strongly agree) for the outside cue ('It is immediately evident/clearly indicated where this smartphone can be opened', 'I do not expect to have difficulties to open this smartphone'; α=.88) and the inside cue ('It is immediately evident/clear how different components could be identified inside this smartphone', 'I do not expect to have difficulties to identify different components'; α=.92).

Results

We performed two bootstrapped independent t-tests with the cues as the independent variables and the accompanying manipulation check as the dependent variable. The results showed that both manipulations were successful (M_{no_OutCue}=4.31 vs. M_{OutCue}=6.21, t(156)=-9.17, p<.001; M_{No_InCue} =4.06 vs. M_{InCue}=5.50, t(156)=-6.34, p<.001).

	Outside cue: absent		**Outside cue: present**	
	Inside cue: absent (n=40)	**Inside cue: present** (n=41)	**Inside cue: absent** (n=37)	**Inside cue: present** (n=40)
Manipulation outside cue	3.61 (1.54)	4.99 (1.34)	6.20 (.85)	6.22 (.95)
Manipulation inside cue	3.72 (1.63)	5.64 (1.04)	4.42 (1.64)	5.35 (1.46)
General likeliness to repair	5.29 (1.70)	5.90 (1.20)	5.50 (1.58)	6.08 (1.29)
Difficulty of the task	2.59 (1.26)	2.46 (1.31)	2.38 (1.09)	2.38 (1.30)
Likeliness DIY repair	4.06 (2.23)	4.84 (2.18)	4.32 (2.28)	5.42 (1.91)
Likeliness Prof. Repair	4.05 (1.83)	3.85 (1.99)	4.35 (2.03)	3.57 (1.86)

Table 2. Descriptive statistics of the four conditions of Study 2.

We performed three two-way ANOVAs with the cues as independent variables and the three types of repair likeliness as dependent variables. In general, participants were more likely to repair the modular smartphone in the presence of an inside cue compared to when such a cue was absent (M_{No_InCue}=5.40 vs. M_{InCue} =5.99; F(1,154)=6.61; p<.05), which was not the case for the outside cue. The interaction was also insignificant. The ANOVA with the likeliness for DIY repair as a dependent variable showed similar results and participants were thus more likely to perform DIY repair when an inside cue was provided (M_{No_InCue} =4.19 vs. M_{InCue}=5.13; F(1,154)=7.46; p<.01), which was not the case for the outside cue. The interaction was insignificant as well. The likeliness for professional repair did not significantly change by both cues, cf. table 2.

Discussion and implications

Our research confirms the potential of modular design to stimulate repair (Mugge et al., 2005; Schischke et al., 2019), and that technically repairable products do not automatically lead to repair behavior (Makov and Fitzpatrick, 2021). Our empirical findings showed that consumers need support in their repair ability. We demonstrated that a repair cue that facilitates the consumer during the repair task would be most effective to encourage DIY repair.

Although our study provides interesting insights into how to successfully implement modularity, our results do not explain why the inside cue was more effective than the outside cue. Reflecting on our stimuli, participants could have experienced more support via the icon, as it facilitated the repair act itself, compared to facilitating where to start the repair via the notch. Therefore, for a modular product, the opening may not be considered a big constraint, and the focus should be on cues that support during the repair act. Finally, we must note that the visual information (i.e., a picture of the inside of the smartphone) of the inside cue scenarios could have additionally supported consumers. Processing fluency theory addresses the importance of (visual) declarative information to ease the task (Schwarz et al., 2021), and this thus may have helped to envision the repair steps and to reassure them that performing a repair is within their capabilities. To stimulate DIY repair of modular products, we, therefore, recommend including clear declarative information in addition to explicit repair cues in the design.

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