



# The role of Signifiers and Affordances in facilitating DIY Repair

# Abstract

The rapid growth of electrical and electronic equipment (EEE) has led to a significant increase in electronic waste (e-waste), highlighting the need for more sustainable product lifecycles. Repair is a key strategy within the circular economy, yet consumers often replace products even when repair is feasible, particularly in the domain of small household electric appliances.

This project explores how product design can encourage do-it-yourself (DIY) repair by making repair opportunities more visible, approachable, and intuitive through the use of affordances and signifiers in the product embodiment. A mixed-method approach was applied, including a literature review, field research at Repair Cafés, product analyses, and user interviews. Based on these insights, a set of design principles for facilitating DIY repair was developed and applied in a case study of an electric shaver.

The findings show that repair affordances form the structural foundation of repairability by reducing physical and cognitive effort, while signifiers play a crucial role in communicating the intended repair actions to users. By making repair actions perceivable, interpretable, and trustworthy, signifiers reduce psychological barriers and increase user confidence. Together, affordances and signifiers transform repair from an uncertain and intimidating process into a more guided and accessible experience.

These results demonstrate the importance of integrating both structural and communicative design strategies to support consumer repair behaviour, contributing to more sustainable product use and reduced e-waste.

## Disclaimer – Use of Artificial Intelligence

*Throughout this project, artificial intelligence (AI) tools were used to support the research and writing process. Specifically, the language models ChatGPT (paid Go subscription – OpenAI, GPT-5.3) and Google Gemini (Google AI Pro student license – Gemini 1.5) were utilized to assist in structuring findings, exploring design directions, clarifying the project scope, and reviewing and refining written text.*

*These tools were employed as supportive aids only. All core ideas, analyses, design decisions, and conclusions presented in this thesis are my own. The outputs generated by AI were critically evaluated, verified, and, where necessary, adapted to ensure accuracy, relevance, and academic integrity.*

## THE ROLE OF SIGNIFIERS AND AFFORDANCES IN FACILITATING DIY REPAIR

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GRADUATE STUDENT  
Finn Kasse

GRADUATION COMMITTEE  
Prof.dr.ir. Ruth Mugge  
MSc. Gianni Orsini

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# Summary

The rapid growth of electrical and electronic equipment (EEE) has led to a significant increase in electronic waste (e-waste), emphasizing the need for more sustainable product lifecycles. Although repair is a key strategy within the circular economy, consumers frequently replace small household electrical products even when repair is feasible. This behavior is driven by a combination of practical barriers, such as difficult disassembly, and psychological barriers, including uncertainty, low confidence, and fear of causing damage.

This thesis explores how product design can reduce these barriers by leveraging affordances and signifiers within the product embodiment to support do-it-yourself (DIY) repair. Affordances define what actions are physically possible, while signifiers communicate how and where these actions can be performed. Together, they aim to make repair more accessible, understandable, and approachable for users.

A mixed-method approach was applied, combining literature review, field observations at Repair Cafés, product analyses, and user interviews, alongside iterative design exploration. Based on these insights, a set of Design Principles for Easy DIY Repair was developed, see Figure 1. These principles focus on structuring repair actions, guiding user interaction, and increasing perceived safety and confidence by aligning affordances and signifiers within the product.

The principles were evaluated through a case study involving the redesign of an electric shaver. The redesign emphasized reversible disassembly, improved access to internal components, and the integration of clear interaction cues to guide users through the repair process. The design was explored through prototyping, user testing, and expert discussions.

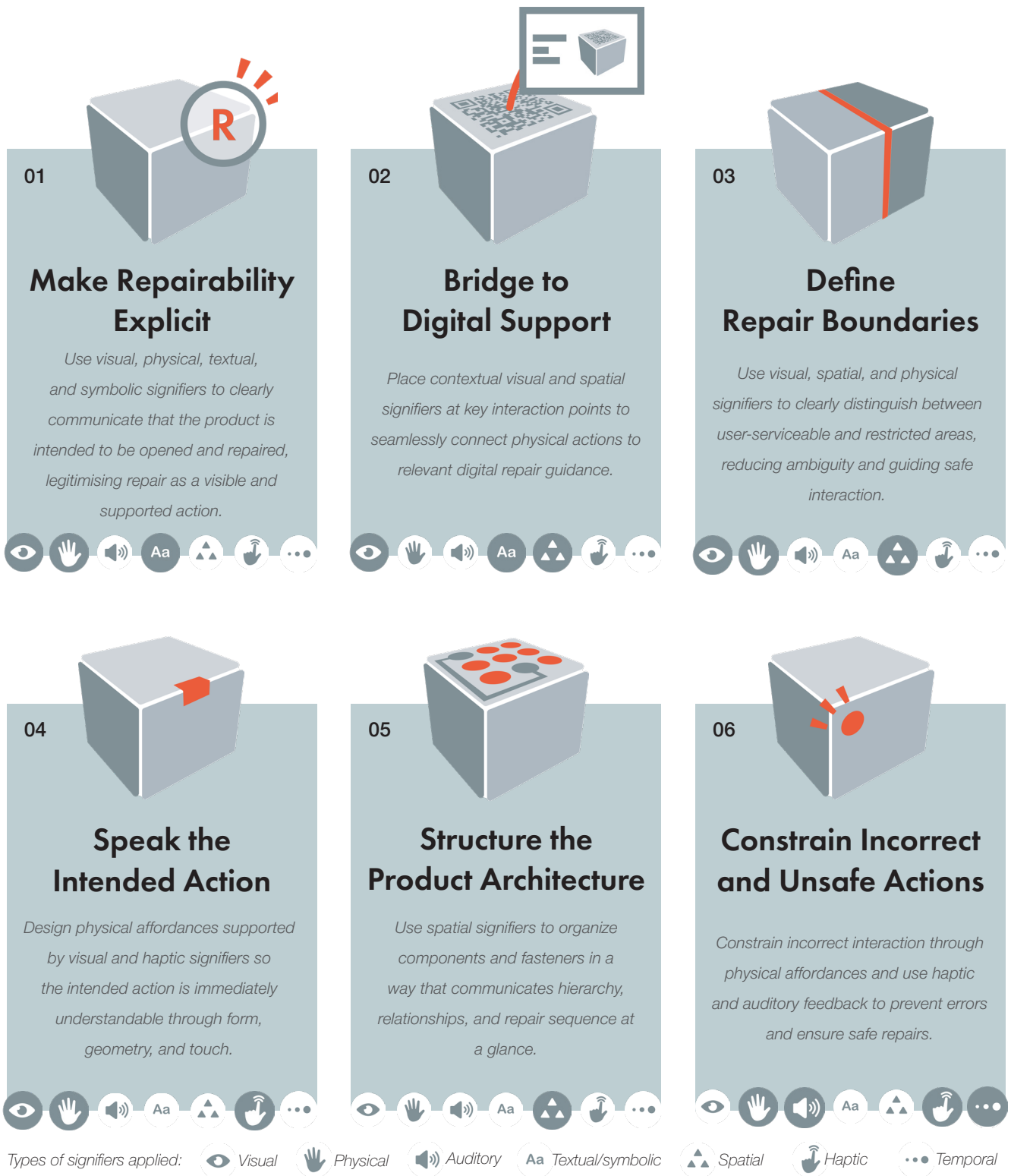
The findings show that affordances and signifiers play a complementary and interdependent role in enabling DIY repair. Affordances provide the structural foundation by reducing physical and procedural effort, while signifiers make repair actions perceivable, interpretable, and trustworthy, thereby

reducing psychological barriers and increasing user confidence. Their impact is strongest in interaction-focused stages such as disassembly, reassembly, and navigation within the product.

At the same time, the results reveal important limitations. More cognitively demanding stages, particularly fault diagnosis, remain difficult to support through product design alone. Additionally, trade-offs can arise between accessibility and safety, and the effectiveness of signifiers depends strongly on their execution and users' prior experience.

This thesis concludes that affordances and signifiers are essential in bridging the gap between technical repairability and user capability, transforming repair into a more guided and approachable experience. However, they should be understood as a foundational layer rather than a complete solution, and are most effective when complemented by additional support systems, such as digital or AI-assisted guidance.

By demonstrating how repairability can be embedded in product embodiment through both structural and communicative design strategies, this research contributes to the development of more sustainable, user-centered products and supports the transition toward a circular economy.



**Figure 1.** Set of Design Principles for Easy DIY Repair, presenting six principles that support accessible, safe, and understandable repair through the application of affordances and signifiers in product design

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# Introduction

# 1. Introduction

## 1.1. E-waste problem

The rapid growth of electrical and electronic equipment (EEE) production has led to a significant increase in electronic waste (e-waste), now recognized as one of the fastest-growing waste streams globally (Baldé et al., 2024). In 2019, approximately 53.6 million tons of e-waste were generated worldwide, with less than 13% being recycled. The remainder often ends up in landfills or incinerators, posing severe environmental and health risks due to hazardous materials such as lead, mercury, and cadmium (Andeobu et al., 2021; Chakraborty et al., 2022).

Among all categories of EEE, small equipment, including products like vacuum cleaners, toasters, radios, small power tools, kettles, and e-cigarettes, is the largest contributor to global e-waste, accounting for nearly one-third (20 billion kg) of all e-waste in 2022 (Baldé et al., 2024). Figure 1 shows the total e-waste generated by EEE category. Many small appliances are discarded while still functional or repairable, with studies showing that nearly half of all disposed kettles, for example, were still working at the time of disposal (Sandez, Ibáñez-Forés, et al., 2023).

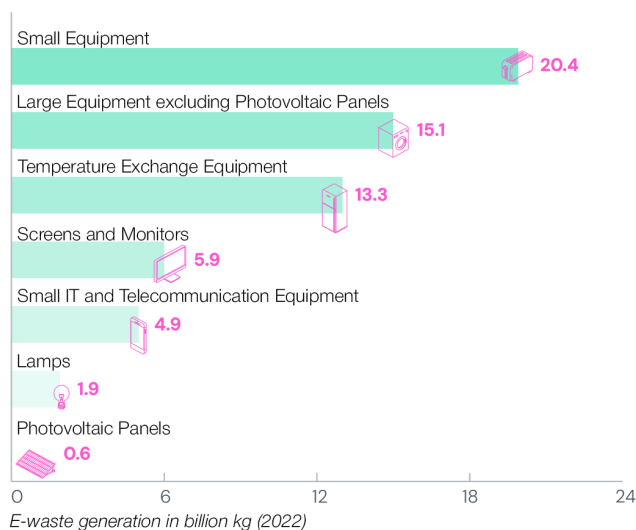


Figure 2. Total e-waste generated by type of EEE (Baldé et al., 2024).

The rapid growing of e-waste is driven by production and consumption patterns of consumer electronics in recent years (Shahabuddin et al., 2022). According to the Ellen MacArthur Foundation (2023) we live in a take-make-waste economy, where products and

materials are not used to their full potential: resources are extracted, processed into short-lived products, and discarded long before their functional lifespan is exhausted.

## 1.2. The circular economy

Reducing e-waste is critical for minimizing environmental pollution, conserving valuable resources, and mitigating health risks (Chakraborty et al., 2022). The circular economy (CE) provides a promising framework to address these challenges. The CE is an economic model that stimulates a closed-loop system of materials, aiming to eliminate waste, circulate products and materials, and regenerate nature. It seeks to keep products and their components at the highest possible value for as long as possible (Pouyamanesh et al., 2023; Xavier et al., 2021). In the context of e-waste, CE practices such as reuse, repair, remanufacturing, and recycling are essential for sustainable management (Gaur et al., 2024; Pouyamanesh et al., 2023). Repair, in particular, is a key strategy within the CE, as extending the lifespan of products can reduce the use of finite resources, lower emissions, and delay the impacts of disposal and replacement (Gaur et al., 2024; Sandez, Ibáñez-Forés, et al., 2023; Sonego et al., 2022).

## 1.3. Repair culture

In recent years, various initiatives such as the right-to-repair movement, evolving EU legislation, and community-led efforts like Repair Cafés have aimed to strengthen repair culture and make repair more accessible to consumers, see Figure 2. These efforts provide valuable support, create awareness, and increase the technical reparability of products. However, such repair strategies generally focus on improving the infrastructure of the repair process or take a design engineering perspective and address technical aspects of the product design. Even if a product is technically repairable, it does not mean that users will act accordingly (Van den Berge et al., 2023a). The repair and maintenance principle demands a strong role of the consumer, as he or she decides if and how the product is repaired or maintained (Ackermann et al., 2018). Many consumers still choose not to repair their products. Particularly



Figure 3. Celebrating 15 years of Repair Café in The Hague (Waalboer & Stichting Repair Café International, 2024).

in the domain of small household electric consumer products, users often replace broken items rather than attempt self-repair, even when repair is feasible (Van den Berge et al., 2023a).

A range of psychological and practical barriers discourages users from engaging in repair, such as a lack of information, low confidence, limited skills, perceived obsolescence, and the phenomenon of fixophobia: the reluctance or fear to attempt a repair (Islam et al., 2021; Sandez, Ibáñez-Forés, et al., 2023; Sonogo et al., 2022; Tackling Fixophobia, 2024). Moreover, most products are not designed with the user's perception of repairability in mind, and current product embodiments rarely communicate that repair is possible, feasible, or intended (Terzioğlu, 2021; Van den Berge et al., 2023a). As a result, many technically repairable products remain unused in drawers and cupboards after breaking, simply because the first step toward repair feels too demanding or too uncertain for users.

#### 1.4. Opportunity for improving DIY repair of electric consumer products

Small household electric consumer products offer substantial potential suitable for do-it-yourself (DIY) repair when consumers receive appropriate support and guidance, as they are portable, not overly complex and relatively safe (Torca-Adell et al., 2025). Strengthening the perceived repairability of these products may therefore play a crucial role in shifting consumer behaviour toward more sustainable practices.

The product embodiment is the first thing users encounter when something breaks, long before they search for a manual, visit a website, or seek external support. However, there is still very limited knowledge about how the product itself can support and encourage DIY repair. Existing research in design for repair predominantly examines engineering and technical elements such as fasteners, materials, and component accessibility (Islam et al., 2021; Sonogo et

al., 2022), whereas far less attention has been given to how products communicate their reparability. Yet most consumers are unlikely to attempt repair if the product does not clearly communicate that repair is possible (Van den Berge et al., 2023a). This highlights the opportunity for designers to shape not only the technical reparability of a product but also the user's immediate perception of that reparability through the product's design.

## 1.5. Research objectives

In this project, I investigate how product design can encourage consumer DIY repair behaviour by making repair opportunities more visible, approachable, and intuitive. Specifically, I explore how affordances and signifiers can influence consumers' experience during the DIY repair process. Affordances refer to the action possibilities that a product offers, while signifiers are the visual or physical cues that allow users to perceive these possibilities. A product requires signifiers to communicate its purpose, structure, and operation

(Norman, 2013).

My hypothesis is that many repairable products do contain the affordance of reparability but lack the signifiers needed to make that affordance perceivable to users. As a result, repair becomes hidden, ambiguous, or intimidating.

This project examines whether making repair affordances more perceptible through signifiers can enhance consumer self-efficacy, reduce fixophobia, and ultimately motivate users to initiate DIY repair.

The overarching research question guiding this thesis is: *What role can signifiers and affordances play in reducing psychological and practical barriers in the DIY repair process of small household electrical products?*

To answer this question systematically, four research objectives are explored:

RO1

### Understanding the concept of affordances and signifiers in product design.

Q1.1 What are affordances and signifiers in product design theory?

Q1.2 How can the concept of affordances and signifiers be used to influence user perception, interpretation, and behaviour?

RO2

### Understanding the DIY Repair Context.

Q2.1 What contextual conditions and actors must be considered when designing for DIY repair?

RO3

### Understanding barriers within the DIY repair process.

Q3.1 What does the DIY repair process look like?

Q3.2 What psychological and practical barriers do consumers experience during the DIY repair process?

RO4

### Exploring how affordances and signifiers can be strategically applied to reduce barriers throughout the DIY repair journey.

Q4.1 How can affordances reduce practical and functional barriers in the repair process?

Q4.2 How can signifiers reduce cognitive and psychological barriers in the repair process?

Q4.3 How can affordances and signifiers be integrated within product embodiment to guide, reassure, and structure the repair journey?

## 1.6. Project approach

To investigate how product design can encourage user repair of electrical consumer products, a mixed-methods research approach was adopted.

First, a literature review was performed to establish a theoretical foundation on affordances, the role of signifiers, the barriers to repair, and the repair journey.

To connect these concepts to real-world product reparability, visits were made to several Repair Cafés, where informal conversations with and observations of both repairers and product owners provided practical insights into common repair challenges and user experiences. Additionally, an evaluation of current household electric consumer products was carried out to identify the problems consumers encounter when attempting repair. An evaluation of products designed for reparability on the market was also conducted, focusing specifically on the presence and effectiveness of reparability signifiers. Interviews and surveys within my social circles were conducted to understand which household products are frequently broken, which are rarely repaired, and the reasons why.

After I answered the research question “What role can signifiers and affordances play in reducing barriers within the DIY repair process?”, I summarized the findings in an overview of design principles for easy DIY repair through the concept of affordances and signifiers.

## 1.7. Case study

To increase the practical relevance of this project, validate the proposed design principles, and explore how affordances and signifiers can be integrated within the specific product category of small household electrical appliances, a case study was conducted on the Philips series 3000 Dry electric shaver PT739, see Figure 4.

This product was selected because electric shaving devices require regular maintenance and occasional repair to ensure optimal performance and longevity. In addition, numerous online resources, such as YouTube videos, demonstrate how to disassemble Philips shavers, often highlighting recurring design limitations and repair challenges. With over 80 shaver models currently on the market, Philips represents a relevant and widely used case within this product category.

Within this case study, the specific barriers to DIY repair for the Philips shaver are analysed. Based on these insights, a redesign of the product is developed, followed by user testing to evaluate whether the proposed design interventions effectively reduce barriers throughout the DIY repair process.



**Figure 4.** Philips series 3000 Dry electric shaver PT739.



# Affordances and Signifiers in Product Design

**RQ1**

**Understanding the concept of affordances and signifiers in product design.**

**Q1.1** What are affordances and signifiers in product design theory?

**Q1.2** How do affordances and signifiers influence user perception, interpretation, and behaviour?

## 2. Affordances and Signifiers in Product Design

Affordance is a term that has been extensively studied and applied across disciplines such as perceptual psychology, human-computer interaction, and interaction design (Maier & Fadel, 2009a; Masoudi et al., 2019). The most common definition of affordances in product design tends to be Donald Norman's definition: "a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used." This definition was used in the book "The Psychology of Everyday Things": a bestseller among designers, which was first introduced in 1988, and later revised and expanded to "The Design of Everyday Things" in 2013.

However, the concept of affordances forms a complex landscape. There are different interpretations and definitions about affordances next to Norman's definition. Therefore, I will provide an theoretical background of this conceptual landscape of affordances in this chapter to explain the interpretation of affordances that I will use throughout the remainder of this project. In addition, I will explain the relevance to DIY repair and this project.

### 2.1. Theoretical background of affordances and signifiers

#### 2.1.1. Affordances

The noun affordance was made up in 1979 by the ecological psychologist James J. Gibson to explain the relation between an animal and its environment. He defined it as: "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill". He argued that "the meaning or value of a thing consists of what it affords" (Gibson, 1982, p. 407).

The cognitive scientist and usability engineer Donald A. Norman took Gibson's affordance theory in 1988, adapted the concept for design, and popularised it in the design community. He made some guidelines as to what certain objects should or should not afford. Norman argued, contrary to Gibson, that affordances are not just potential actions in the environment but perceived action possibilities that suggest actions to the agent.

Norman (2013) made a clear distinction between 'real affordances' and 'perceived affordances'. In his definition of the concept, 'real affordances' represent the actual possibilities for how an agent can interact with the object. 'Perceived affordances' are the perceived action possibilities; the actions that the agent believes are possible, whether that belief is true or false. Key here is that affordances can exist even if they are not visible or perceivable. An example Norman provides is a push-to-open cabinet door, see Figure 5.



Figure 5. Push-to-open cabinet door (Lazy\_bear, n.d.).

If you are not familiar with this mechanism, where you have to push anywhere on the door for it to jump partly open, you are not able to perceive the affordance of pushing to open. Other cabinet doors with handles or knobs have 'signifiers' (visual cues) that allow the user to perceive the affordance of pulling to open, such as a knobs and handles. A push-to-open cabinet door does not have signifiers that communicate the affordance of pushing to open. People search for clues, any sign that might help them understand the product. Therefore, Norman argues that a good design needs signifiers to communicate the purpose, structure, and operation of the device.

#### 2.1.2. Signifiers

Signifiers serve to communicate the presence of affordances. They play a key role in shaping how users understand what an object affords, which actions feel possible, desirable, or intuitive, and whether an affordance is inviting (Norman, 2013; Withagen et al., 2012). There are different types of signifiers; visual, tactile, or auditory; any mark or sound, any perceivable indicator that communicates appropriate behaviour

# “Affordances determine what actions are possible. Signifiers communicate where the action should take place. We need both.”

- Norman (2013)

to a person. For all types applies that well-designed signifiers are clear and ambiguous clues for both the proper action and its location (Norman, 2013).

## 2.2. Types of signifiers

When considering physical small household electronic products, the types of signifiers that can be implemented may be categorised into eight subgroups: visual, physical, auditory, haptic, spatial, temporal, textual/symbolic, and social/learned signifiers (Norman, 2013).

In practice, signifiers rarely operate in isolation. Instead, effective interaction design is typically achieved through the combination of multiple signifier types. For instance, temporal and auditory signifiers can reinforce one another to create a clear feedback loop, while physical and spatial signifiers can support intuitive, instruction-free interaction. Similarly, the combination of visual and haptic signifiers can enhance both clarity and engagement during product use. The strategic layering of signifiers is therefore essential in strengthening perceived affordances and reducing ambiguity in user interaction.

Figure 6 presents a Senseo coffee machine that is analysed in terms of the presence and application of these different types of signifiers. The following paragraphs provide a brief explanation of each signifier subgroup.

### 2.2.1. Visual signifiers

Visual signifiers are cues that communicate meaning purely through visual perception, without requiring physical interaction. Visual signifiers can be deliberate, such as signs, labels, and drawings placed in the world, such as the sign PUSH on a door. Others are more subtle, such as those inherent in the shape, material or texture of the affordance (Norman, 2013). Their effectiveness depends on clarity, visibility,

and the user's ability to interpret visual information correctly.

### 2.2.2. Physical signifiers

Physical signifiers are embedded in the tangible properties of a product, such as its form, materiality, and mechanical characteristics. These are cues that communicate meaning through physical interaction. Examples include indentations, texture variations, handles, knobs, sliders, and variations in weight or resistance. These signifiers often directly support perceived affordances by suggesting how a product can be manipulated.

### 2.2.3. Auditory signifiers

Auditory signifiers utilise sound to convey information about interaction or system state. Using sound as a signifier can provide information that cannot be made visible (Norman, 2013). It can serve a useful role in providing feedback about events or actions, such as the click when the toast pops up, the increase in pitch when a vacuum cleaner gets clogged, or the click when the bolt on a door slides home. It can tell us the status of a process, internal structure of objects, nature and forces of interactions (Gaver, 1991). Sound can tell us that things are working properly or that they need maintenance or repair.

### 2.2.4. Haptic (tactile) signifiers

Haptic signifiers communicate information through touch. This includes vibrations, force feedback, resistance, or tactile pulses that guide user interaction. Haptic feedback can reinforce actions and contribute to a more embodied and responsive interaction experience.

### 2.2.5. Spatial signifiers

Spatial signifiers rely on the arrangement and positioning of elements to communicate relationships and possible actions. This includes the grouping

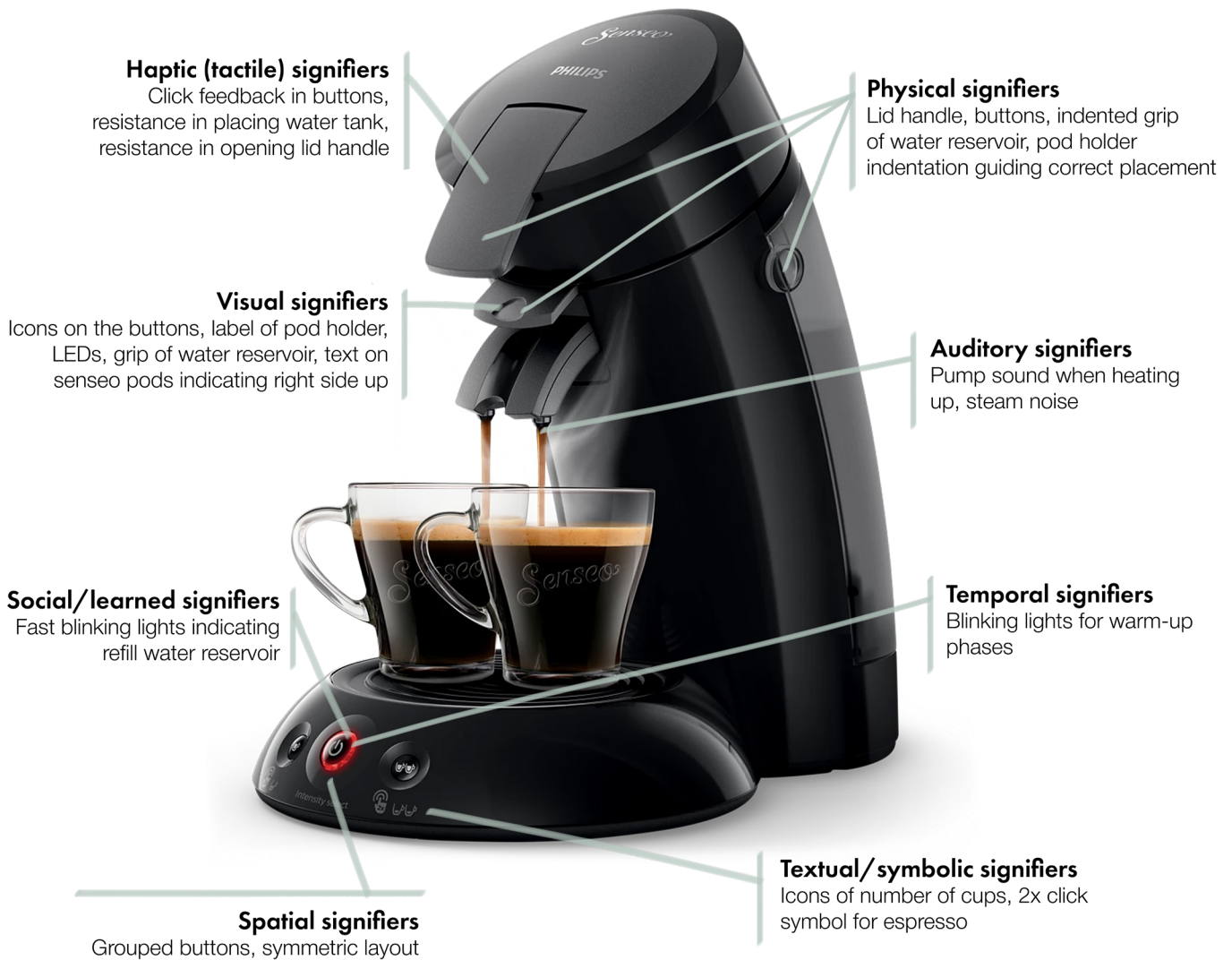


Figure 6. Signifier analysis of a Senseo coffee machine.

of related controls, hierarchical sizing, and layout structures that imply sequence or priority. Spatial organisation plays a key role in reducing cognitive load and guiding user behaviour.

### 2.2.6. Temporal signifiers

Temporal signifiers communicate information through changes over time. Examples include blinking lights, pulsing indicators, and progress representations that signal system status or ongoing processes. These signifiers help users understand when to act, wait, or anticipate a change in state.

### 2.2.7. Textual/symbolic signifiers

Textual and symbolic signifiers explicitly convey meaning through written language or standardised

symbols. Examples include instructional text, labels, numerical values, units, and widely recognised symbols such as power icons. These signifiers are particularly effective in reducing ambiguity by directly communicating function.

### 2.2.8. Social/learned signifiers

Social or learned signifiers derive their meaning from cultural conventions and prior user experience rather than inherent properties. Their interpretation depends on familiarity developed through repeated exposure. Examples include interface conventions such as play/pause icons or gesture-based interactions. While efficient for experienced users, these signifiers may be less accessible to novices or users from different cultural contexts.

## 2.3. Affordances and signifiers in product design

### 2.3.1. Inviting behaviour through affordances and signifiers

Norman conceptualises the relationship between affordances and agency by emphasising that perceived affordances indicate possible actions to a user. Withagen et al. (2012) reconsidered the relationship between affordances and agency, drawing upon industrial design, architecture, and phenomenology. They argue that perceived affordances are not mere opportunities for action, but can invite behaviours. This idea is contrary to Gibson's and Norman's, as they argue that perceived affordances do not cause behaviour, but simply make it possible. According to Withagen et al. (2012) users form affective responses to the perceived affordances when exploring a product, and their resulting behaviour is partly shaped by the action invitations, or the signifiers for these affordances. Withagen et al. (2012) define perceived affordances therefore as 'action possibilities that can invite behaviour'.

In good physical design, the same product feature often is both an affordance and signifier (Norman, 2013). I will use the term 'self-signifying affordance' for such a feature that both affords and signifies. A door

handle, for example, is a self-signifying affordance, as its shape both affords pulling and communicates this action. Similarly, the holes of a pair of scissors allow both finger insertion (affordance) and indicate where the fingers should go (signifier).

Self-signifying affordances impose a low cognitive load, as they communicate action possibilities directly through their form, allowing users to act with minimal conscious thinking. The extent to which an affordance invites behaviour depends partly on the amount of effort required to realise the action possibility (Withagen et al., 2012). When this required effort, whether physical, perceptual, or cognitive, is low, an affordance is more likely to invite action than when the required effort is high. Designs with these self-signifying affordances allow users to directly and correctly perceive what they can do with the design, and are commonly perceived considered intuitive and of high quality (Kaptelinin, 2014).

### 2.3.2. Situated perceived affordances

Because affordances describe potential interactions between two subsystems (an agent and an object) both the object's properties and the agent's capabilities determine whether, and in what way, the perceived affordance invites behaviour (Maier &



Figure 7. The same object affords different behaviours to different agents.

Fadel, 2009b; Rietveld & Kiverstein, 2014; Withagen et al., 2012). As a result, the same object can afford different behaviours to different agents. An examples of how the same object affords different behaviours to different agents is given in Figure 7.

Consider a set of stairs: stairs with low steps might invite an adult to climb them, whereas stairs with unusually high steps may not. For a small child, even “easily climbable” stairs for an adult may be difficult to climb. For a wheelchair user, the same stairs do not afford climbing at all.

This example illustrates that an agent’s capabilities fundamentally shape what an affordance invites, and that perceived affordance invitations therefore differ between agents and can change over time or from moment to moment (Withagen et al., 2012).

### **2.3.3. Signifiers for discoverability and clarification**

For objects whose usability depends on users’ cognitive capabilities and prior experience, signifiers play a crucial role in shaping perceived affordances for different agents.

Consider a water faucet. Although most people are familiar with what a faucet is, the expected mode of operation depends on prior experience. Users who have never encountered an automated faucet may search for a manual control and fail to find a physical cue. Conversely, users familiar with sensor-based faucets may instinctively place their hands underneath a faucet that lacks visible controls, expecting water to flow, only to discover that manual operation is required.

In other cases, water may activate briefly and then stop, prompting users to repeat gestures in different positions in an attempt to trigger the system again. A similar uncertainty arises with sensor-based towel dispensers: when no towel is dispensed, it is unclear whether the device is malfunctioning, empty, or simply not detecting the user’s actions. The absence of clear signifiers leaves users unsure which actions are possible or appropriate, illustrating how insufficient cues reduce discoverability and overall usability (Norman, 2013).

When designs lack effective signifiers, they lack discoverability. If products fail to communicate how they should be used, users are forced to rely on guesswork rather than understanding.

### **2.3.4. Guiding through affordances and signifiers**

The following sections outline interaction principles that guide user behaviour using affordances and signifiers.

#### **Sequential and nested affordances**

Gaver (1991) describes how affordances can be structured in relation to one another through the notions of sequential and nested affordances. Sequential affordances refer to situations in which engaging with one perceivable action possibility reveals further opportunities for action over time. Nested affordances concern affordances that are spatially organized within one another, such as a handle that is part of a door. Gaver argues that in more complex objects, such as consumer products, user attention can be effectively directed by deliberately arranging affordances in sequential and nested configurations.

Spatial signifiers play a key role in making these structures perceivable and understandable. They rely on the arrangement and positioning of elements to communicate relationships and possible actions, for example through the grouping of related components, hierarchical sizing, and layout structures that imply sequence or priority. By organising affordances spatially, designers can guide user attention and behaviour while reducing cognitive load.

By designing clear initial affordances and supporting them through spatial signifiers, users are encouraged to interact with an object in ways that gradually expose additional affordances, allowing perception and action to unfold in a coordinated manner through the structure of the product.

#### **Mappings**

Mapping refers to the relationship between a control and the effect it produces, and plays a central role in how easily users can understand and remember how a product operates. While affordances specify what actions are possible, mappings clarify how

those actions relate to their outcomes. When this relationship is clear, users can predict the results of their actions with minimal cognitive effort.

Natural mappings occur when the relationship between a control and its corresponding function is immediately understandable, often due to spatial or physical correspondence (Norman, 2013). For example, moving a control upward to raise an object aligns with embodied expectations formed through everyday interaction with the physical world. In such cases, the affordance of movement is supported by a mapping that makes its consequence self-evident.

Spatial signifiers play an important role in making mappings perceivable. Through layout, labeling, spatial arrangement, or visual grouping, designers can signal which controls correspond to which functions. By leveraging spatial correspondence and principles from Gestalt psychology, such as proximity and grouping, controls can be visually and physically associated with their effects, strengthening both the perceived affordance and the clarity of the mapping.

According to Norman (2013), mappings can be organized into three levels of effectiveness. The most direct form occurs when controls are placed directly on the element they influence. A slightly less direct, yet still effective, approach positions controls as close as possible to the controlled element. The least direct form arranges controls in a spatial configuration that mirrors the layout of the elements being controlled. As mappings become less direct, stronger signifiers are required to compensate and maintain clarity.

When affordances are clearly signified and controls follow natural mappings, interaction becomes intuitive. Users can operate the product without relying on instructions or trial-and-error. In such cases, mapping functions as a bridge between perceived affordances and actual system feedback, making the relationship between action and outcome immediately understandable.

## Constraints

Well-designed products combine clearly signified affordances with constraints that deliberately restrict the range of possible actions. Whereas affordances

specify what actions are possible, constraints define what actions are not possible or not permissible within a given context (Norman, 2013). Together, they structure the interaction space available to the user.

In product design, constraints are frequently employed to enhance safety and reduce user error by preventing hazardous or unintended interactions. A common example is a dead man's switch, which allows a system to operate only when continuous user presence or attention is maintained. Similarly, the asymmetric shape of a USB-A connector physically restricts incorrect insertion, protecting both the device and the port from damage.

Despite this, users often need to fumble to find the correct orientation of a USB-A connector, as the constraint is relatively subtle. Physical constraints are most effective when they are clearly visible and easy to interpret, allowing the range of possible actions to be limited before any action is taken. When constraints are unclear, they only prevent errors after an incorrect action has already been attempted. Many plug-in components, such as HDMI, address this effectively by using distinctive shapes, notches, and protrusions to enforce a single correct orientation (Norman, 2013).

By narrowing the range of available actions, constraints act as powerful cues that support user understanding. When thoughtfully applied, they help users identify the appropriate course of action even in unfamiliar situations, reducing reliance on trial and error (Norman, 2013).

## Feedback

Feedback is the mechanism through which the results of an action are communicated to the user. While mappings clarify how actions relate to outcomes, feedback confirms what has actually occurred. For feedback to be effective, it must be both immediate and informative (Norman, 2013).

In the absence of informative feedback, users may interpret silence as failure or assume that their action was performed incorrectly. Even negative feedback can be reassuring, as it reduces uncertainty by clearly defining system boundaries (Norman, 2013). A lack of feedback, by contrast, undermines the perceived

affordance of control and can result in frustration or repeated, unnecessary actions.

Feedback therefore plays a central role in regulating interaction. By clearly signifying the consequences of actions, it strengthens the perceived mapping between action and outcome, supports learning, and enables the development of skilled and confident behaviour.

Through visual, auditory, or tactile signifiers, feedback communicates changes in system state, while updated affordances can indicate newly available or restricted actions, guiding users toward their next appropriate step.

## 2.4. Chapter 2 Takeaways

### RO1 Understanding the concept of affordances and signifiers in product design.

#### Q1.1 What are affordances and signifiers in product design theory?

In product design theory, affordances describe the relationship between the properties of an object and the capabilities of an agent, defining the actions that are possible within a given interaction context. Following Norman's distinction, affordances may exist independently of perception, while perceived affordances determine what users believe they can do. This distinction highlights that usability depends not only on technical possibility, but on whether action possibilities are perceptible and interpretable.

Signifiers are the perceivable cues that communicate the presence and nature of affordances. They indicate where and how actions can be carried out and shape whether an affordance is discoverable, inviting, or overlooked. Affordances and signifiers therefore function together: affordances structure the possible action space, while signifiers shape how this space is perceived and understood. In combination with mappings, constraints, and feedback, they form the perceivable interaction structure through which users construct a conceptual model of a product's operation.

#### Q1.2 How can the concept of affordances and signifiers be used to influence user perception, interpretation, and behaviour?

Affordances and signifiers can be deliberately designed to shape how users perceive, interpret, and act within a product's interaction space. By making desired actions physically possible and perceptually salient, designers can invite specific behaviours while discouraging others. Self-signifying affordances reduce cognitive load by directly communicating their use, whereas constraints narrow the range of possible actions and prevent error before it occurs.

Signifiers enhance discoverability by clarifying what actions are available, how they should be performed, and what their consequences will be. Through effective mappings and informative feedback, designers can reinforce correct interpretations and strengthen users' sense of control. Importantly, the absence of action does not imply the absence of an affordance; users may fail to act when signifiers do not make possibilities visible, permissible, or worthwhile.

In this way, affordances and signifiers provide a powerful analytical and generative framework for influencing behaviour. By shaping the perceived action space, designers can guide users toward intended interactions by lowering perceptual, cognitive, and motivational barriers.



# The Context of DIY Repair

RO2

Understanding the DIY Repair Context.

Q2.1 What contextual conditions and actors must be considered when designing for DIY repair?

# 3. The Context of DIY Repair

To answer the research question “What role can signifiers and affordances play in reducing barriers within the DIY repair process?”, it is essential to first establish a clear understanding of the DIY repair process itself. Repair behaviour is a complex phenomenon influenced by a wide range of interacting factors (Terzioğlu, 2021). Each variable, whether cognitive, emotional, technical, or contextual, forms part of a broader, interconnected system that shapes how consumers approach (or avoid) repair.

DIY repair refers to the process in which consumers independently diagnose, maintain, or restore a faulty product to working condition without relying on professional repair services. Such repairs are typically carried out in informal, domestic settings, often at a kitchen table, using limited and commonly available tools, such as a basic screwdriver set, a spudger, and a multimeter, see Figure 8.

In this chapter, I further define the DIY repair context relevant to this project. First, I examine the product care practices that consumers can undertake to maintain, preserve, and extend the lifespan of their products. Next, I identify and briefly describe the key

stakeholders involved in the DIY repair ecosystem. Finally, I define consumer profiles to define the target group for whom easy DIY repair is desired.

## 3.1. Product care practices

Product care is an umbrella term that encompasses all activities initiated by the consumer to keep a product in good condition and extend its lifespan (Ackermann, 2020). DIY repair is one of these practices, alongside everyday product care, maintenance, and upgrading. Although this project focuses specifically on DIY repair, the other product care practices also shape the broader context in which repair occurs. Therefore, I will briefly introduce each of them to provide a complete understanding of the repair landscape.

### 3.1.1. Daily product care

Daily product care refers to all the preventive measures a user performs to keep a product in good condition (Ackermann, 2020). It is typically light-touch, routine, and user-initiated, like cleaning the surface of the appliance, dusting a laptop keyboard, using a protective phone case or screen protector, wiping a coffee machine after each use, or cleaning hairs out of a shaving device. The goal of daily product care

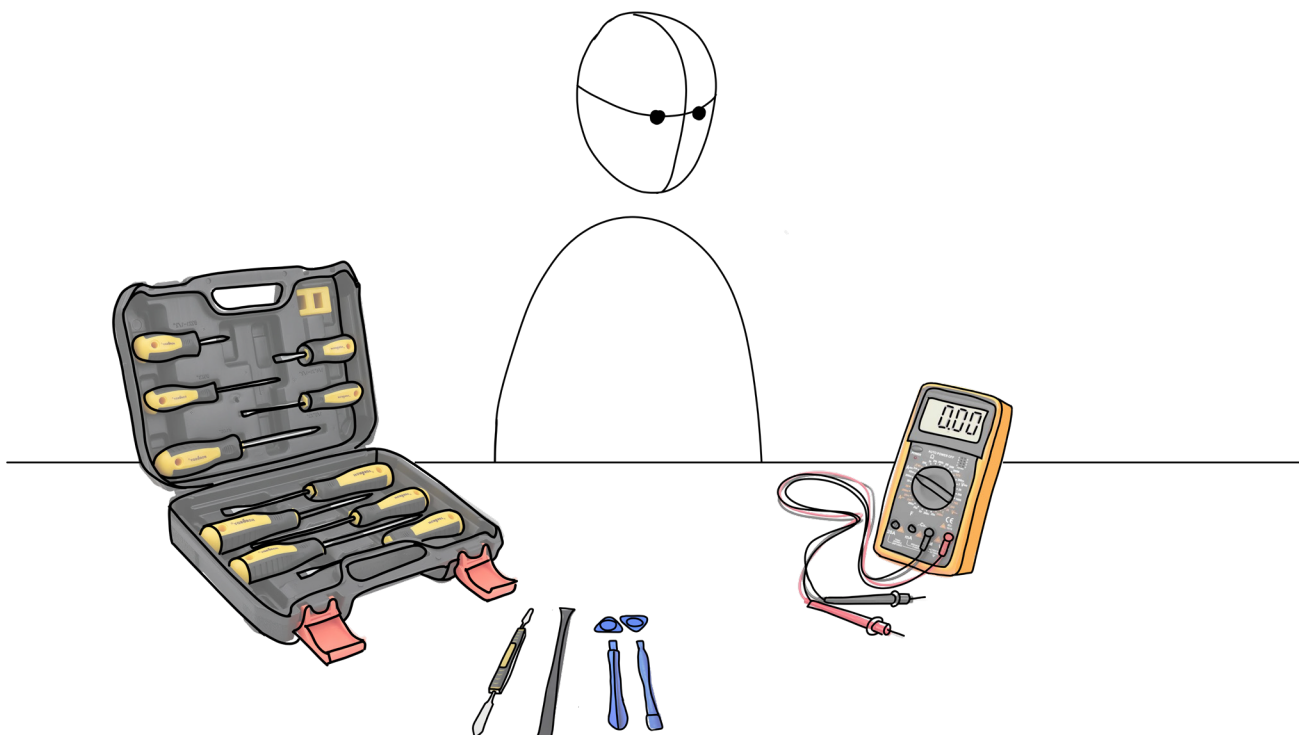


Figure 8. DIY repair context: at a kitchen table with only a basic screwdriver set, a spudger, and a multimeter.

is to prevent damage, slow down wear and prevent problems from developing.

### 3.1.2. Maintenance

Maintenance refers to technical actions required to keep a product functioning properly (Dangal et al., 2022), such as replacing the filter on a vacuum cleaner, sharpening garden tools, cleaning the inside of a coffee machine with descaling solution, changing batteries in a remote, or deep cleaning shaving device when it does not function at full capacity anymore. It is more structured than daily product care, sometimes mandatory, and may require specific knowledge, tools or parts. It is performed when signs of failure appear or at scheduled intervals. For small household electric consumer products, it is often user-performed. It involves diagnosing, adjusting, replacing, or lubricating parts and is often necessary for continued functionality of the product (Russell et al., 2023).

### 3.1.3. Repair

Repair refers to actions taken to restore a product that is no longer functioning properly or has stopped working altogether due to a mechanical failure, electrical fault, or broken component. It is not routine, but corrective. For consumers, repair typically involves identifying the faulty component, replacing broken parts such as the battery, motor, or button, or restoring malfunctioning components (Ackermann, 2018). A distinction can be made between do-it-yourself (DIY) repair and professional repair. DIY repair describes any repair activity in which the consumer plays an active role in restoring the function of their product. This may include repairing the product entirely independently while consulting online resources such as video tutorials or repair guides (self-repair), or seeking assistance from informal networks, including community repair initiatives (e.g., Repair Cafés) or skilled individuals within their social circles (Bayraktaroğlu & İdemen, 2024). Professional repair involves outsourcing the repair to an authorized service provider or trained technician (Ackermann, 2020).

Terzioglu et al. (2015) distinguish three types of DIY repair activities based on the skill level required from the individual performing them. Assembly repair involves no specialised skill or knowledge and

includes basic actions such as reattaching parts, gluing, or binding components. Medium-level repair requires some degree of technical understanding, for example knowledge of adhesives or material properties. Advanced repair encompasses tasks that demand substantial expertise, such as replacing a laptop screen.

### 3.1.4. Upgrading

Upgrading refers to the process of improving or enhancing an existing product by replacing, adding, or modifying components, features, or technologies to increase its value or better meet user needs and preferences (Pozo Arcos et al., 2018). For small household electric consumer products, upgrading is generally limited or not applicable. These products are typically designed as low-cost, tightly integrated systems with a single primary function, and introducing upgradability would increase complexity and production costs.

### 3.1.5. Scope of the project

Increasing product longevity is not only repairing the product, but also consists of the daily product care and maintenance of the product (Ackermann, 2020). Daily product care requires little technical knowledge and is often part of our routine. Therefore, it is not really necessary to design interventions for this aspect of product care. However, maintenance and repair are often not part of the consumer's routine, and are therefore often forgotten or experienced as too much trouble, resulting in products that do not function as they should anymore (Terzioglu et al., 2015). Additionally, often when a consumer thinks the product should be repaired, it should actually be maintained. Repair Café data show that vacuum cleaners with a full dustbag, or fully calcified coffee makers are often seen at Repair Cafés because consumers assume the device is broken, without realising the easy fix of performing maintenance (Postma & Stichting Repair Café International, 2025). Two examples are provided below:

During a visit to a Repair Café (see Appendix B - Visits to Repair Cafes), one visitor brought a six-year-old shaving device that he believed no longer charged, as it shut off after two seconds. A repairer immediately recognised the symptoms, opened

the product using two small screws, and cleaned out compacted hair. After reassembly, the device worked perfectly.

Similarly, a friend donated me her “broken” Epilady to analyse. She had replaced it with a new one, assuming the eight-year-old device was beyond repair. Yet after removing the epilator head and cleaning built-up hairs, the motor functioned without issues. The device had failed simply because the rotation mechanism required too much torque due to debris.

These examples illustrate a recurring pattern: Users only performing superficial maintenance in the form of daily product care (e.g., cleaning visible hair); When issues persist after some time of use, they assume the device is irreparably “broken.”; While minimal internal cleaning or basic disassembly would often solve the problem.

By designing for maintenance as well as repair, we can reduce these false ‘failures’ and empower users to keep products functioning without unnecessary replacement. In addition, repair can often be prevented by executing proper maintenance activities (Ackermann, 2020).

The overarching goal of this project is to increase product longevity through design. Since this project focuses on small household electric consumer products, which are generally not upgradeable, I consider the product care activity of ‘upgrading’ out of scope. This project is aimed at stimulating DIY repair, nevertheless, the project’s primary objective remains extending the lifetime of the products, and when DIY repair is not feasible, encouraging consumers to seek professional repair solutions is still valuable.

The analysis of product care practices shows that daily product care, maintenance, repair, and upgrading each play a role in extending product longevity, but not all are equally relevant for this project. Daily product care is already routine and requires little intervention, while upgrading is generally not applicable due to the low-cost and simplicity of small household appliances. The main opportunities lie in maintenance and DIY repair, as consumers often overlook maintenance

or misinterpret maintenance needs as product failure, leading to unnecessary repairs or premature replacement. Real-world examples from Repair Cafés illustrate that many “broken” products could be restored through simple maintenance actions such as cleaning or removing debris. Therefore, designing for better user engagement with both maintenance and repair is essential for reducing (false) failures and effectively extending product lifespan.

### 3.2. Stakeholders in the Repair journey

This project involves a wide range of stakeholders who influence, participate in, or are affected by DIY repair practices for small household electrical consumer products. Each stakeholder has distinct interests, motivations, and potential benefits from an improved self-repair journey for the consumer and the development of repair-supportive design guidelines.

Figure 9 maps the stakeholders according to their influence and interest in supporting a self-repair culture. This map highlights which stakeholders are likely to stimulate or obstruct the development of repair culture. It visualizes the social and systemic context in which DIY repair occurs, showing which actors can accelerate cultural change and which may act as barriers.

The repair culture is a complex system, that relies on the commitment of all parties in the ecosystem. Therefore, to make a shift towards a DIY repair culture, all stakeholders should take responsibility and should be motivated to make this shift. This insight was supported on the Dutch Retail2Repair 2025 event organised by Techniek Nederland and TU Delft, where all stakeholders involved in the repair culture were present to discuss the action points towards a repair culture (see Appendix B - Insights from Retail2Repair 2025 for more information and insights from Retail2Repair 2025).

Figure 10 presents a second stakeholder map that focuses on stakeholder influence and interest in the reparability of the product. This map distinguishes core, direct, and indirect stakeholders involved in the product development process. Core stakeholders are those directly responsible for the design outcomes of the product.

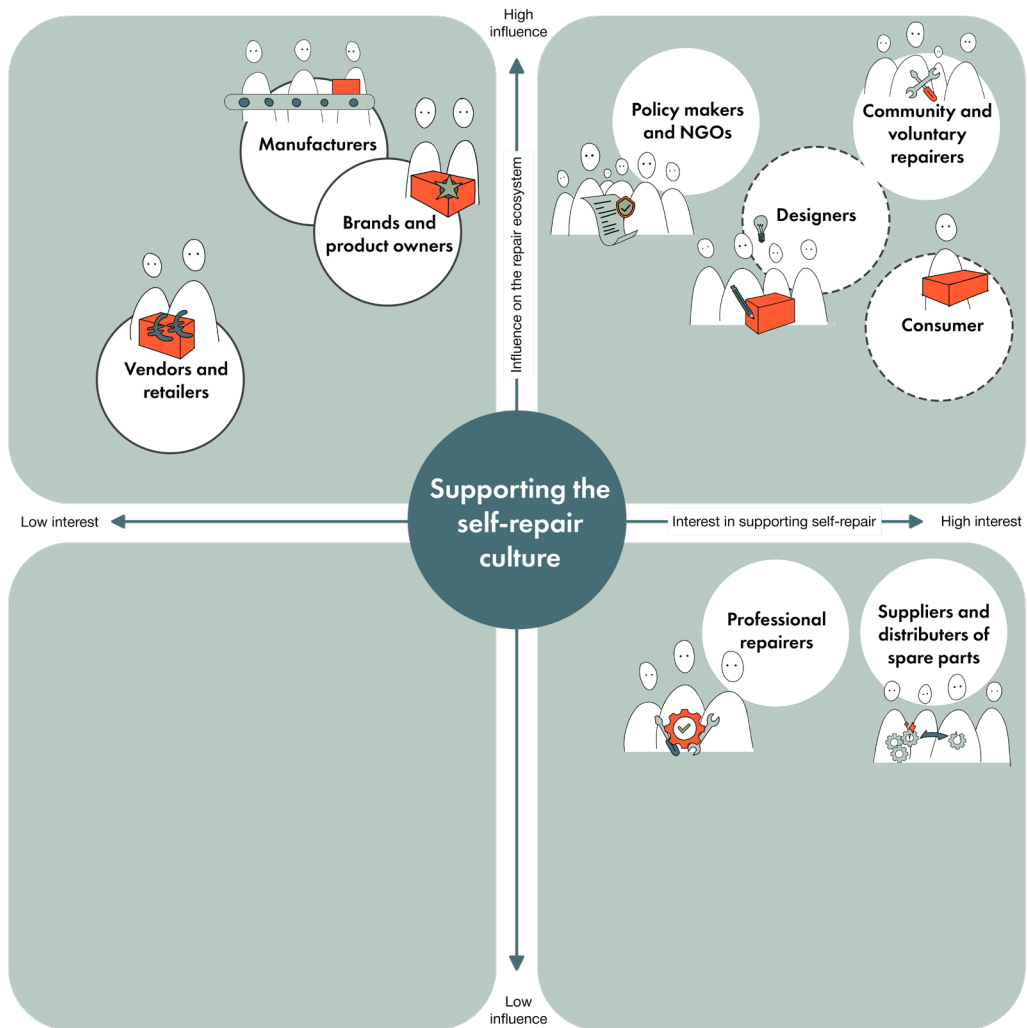


Figure 9. Stakeholder map of the self-repair ecosystem, positioning stakeholders based on their influence and interest in enabling or hindering the development of a self-repair culture.

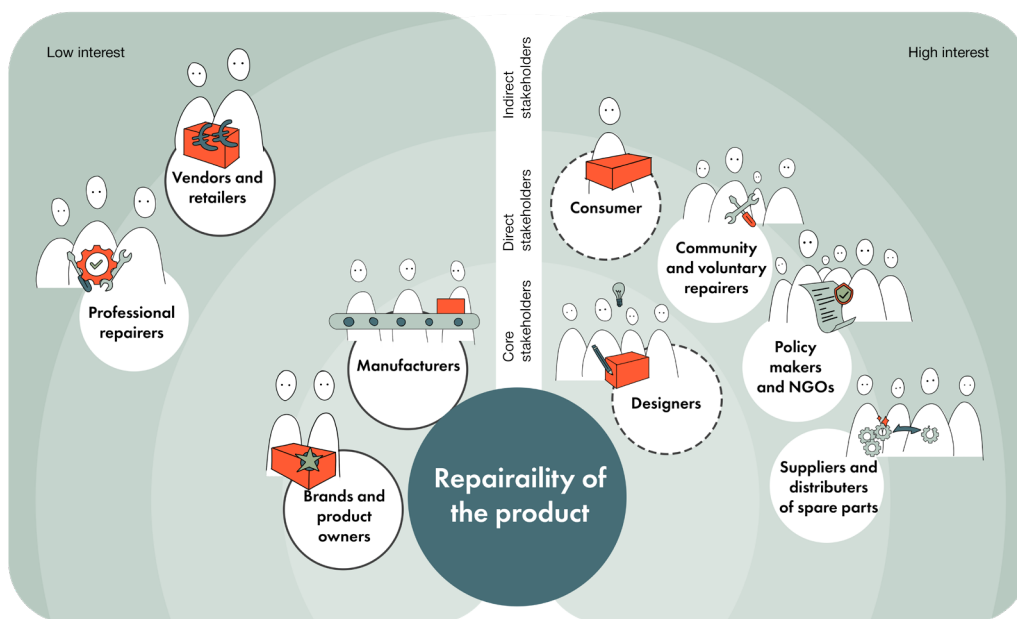


Figure 10. Stakeholder map identifying the actors who shape the reparability of small household electrical products and mapping their relative influence and interest in the product development process.

The core stakeholders designers and manufacturers strongly influence reparability through their decisions on technical features (e.g., fasteners, layout, modularity). Designers are responsible for how reparability is communicated via the product itself.

Brands and product owners, also classified as core stakeholders, determine which products are brought to market and which characteristics or features they prioritise. As a result, they have significant influence over how repairable a product is intended to be. Indirect stakeholders shape the broader conditions surrounding reparability, such as legislation, supply-chain availability of parts, and consumer perceptions during purchasing decisions. All stakeholders in the map are positioned according to their level of interest in improved reparability and their degree of influence, following the influence–interest quadrants used in Figure 9.

A distinction should be made between stakeholders that are intrinsically motivated to improve the self-repair culture, and stakeholders that are driven via external motivators, as it clarifies what type of interventions are needed to influence these stakeholders. In Figure 9 and Figure 10, the stakeholders who might have little intrinsic motivation to support the DIY repair, and therefore need external motivators, are highlighted with a grey outline. These external motivators can take the shape of legislation, market trends, or financial rewards (Roskladka et al., 2022; Wieser & Tröger, 2016). The intrinsic motivators can be feelings of pride, curiosity, moral responsibility, or brand integrity (Bergman et al., 2025; Marikyan & Papagiannidis, 2023; Wolf & McQuitty, 2013).

In the following section, all stakeholders are briefly introduced along with their motivations. This provides a foundation for identifying their needs and desires in developing a self-repair culture.



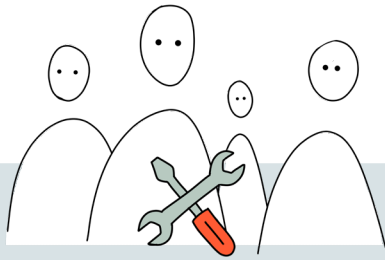
### 3.2.1. Policy makers and NGOs

The stakeholders with the greatest structural influence in stimulating a self-repair culture are policymakers and non-governmental organizations (NGOs), as well-designed legislation can drive systemic change across the entire sector, including among stakeholders who may have limited intrinsic motivation to promote repair. At the European level, the European Commission proposes legislation, while the European Parliament and the Council of the European Union jointly adopt it under the ordinary legislative procedure (EUR-Lex, 2024; European Commission, 2023). At the national level, regulatory authorities implement and enforce these frameworks. For example, the French Ministry of Ecological Transition introduced the pioneering Repairability Index (Indice de réparabilité) in 2021 as part of its Anti-Waste and Circular Economy Law, requiring manufacturers to disclose repairability scores for selected product categories (Ministère de la Transition écologique, 2022).

In addition to governmental actors, environmental NGOs play a significant agenda-setting and advocacy role. Organizations such as the European Environmental Bureau (EEB), Right to Repair Europe (R2R Europe), and iFixit campaign for stronger repair rights, increased transparency in product design, and improved access to spare parts and repair information (European Environmental Bureau, 2024; Right to Repair Europe & iFixit, 2024). Through policy advocacy, public campaigns, research reports, and coalition-building, these NGOs exert pressure on institutions and contribute to shaping the political discourse around repair.

By structurally embedding reparability legislation into the market of electrical and electronic equipment, policymakers define the regulatory framework that influences all actors in the DIY repair ecosystem. NGOs, in turn, act as intermediaries between technical

knowledge, public awareness, and political decision-making.



### 3.2.2. Community and voluntary repairers & repair knowledge platforms

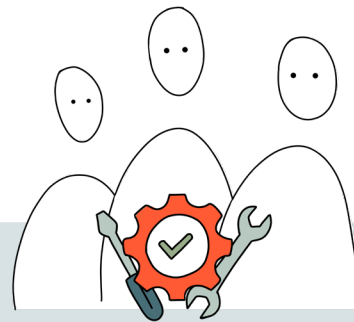
Community and voluntary repairers, along with repair knowledge platforms, also hold significant influence because they provide the safety net and primary information source for inexperienced consumers entering the world of repair. Without these stakeholders, the threshold for consumers to attempt repair would be much higher due to the absence of accessible, free, and hands-on guidance.

Community and voluntary repairers are for example Repair Cafés, maker groups, or skilled individuals in a consumer's social network. For small household electric consumer products, which are often considered too inexpensive to justify professional repair, these community initiatives represent an accessible and realistic repair pathway.

Community repairers are intrinsically motivated to share their knowledge and to help consumers overcome barriers to repair. They consistently encounter design flaws, recurring failure points, and confusing or inaccessible fasteners and layouts, which makes them a valuable source of practical insight for this project. They act as real-world testbeds for repair-friendly design and can validate whether repair affordances and signifiers work as intended. When products are easier to open, diagnose, and fix, community repairers benefit from smoother repair sessions, reduced frustration, and a more engaging experience for both the repair volunteers and participants.

Repair platforms, such as iFixit, Open Repair Data, the Repairability Database, YouTube repair channels,

and online hobbyist communities, exist to make repair knowledge accessible, support the right-to-repair movement, and build communities that help each other fix products. Many operate on volunteer effort or nonprofit funding, while others (like iFixit or YouTube creators) integrate business models that sustain their mission. Their motivations include environmental impact, consumer empowerment and advocacy for repairable products. This project shares the same general goals as these platforms.

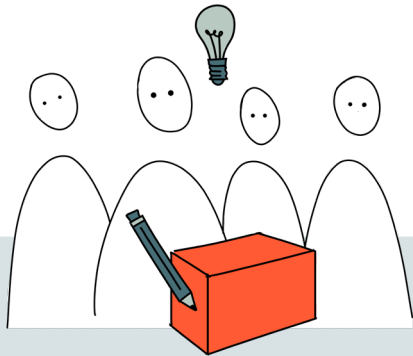


### 3.2.3. Professional repairers

Professional repairers include both brand-authorized repair services and independent technicians. At first glance, supporting consumer self-repair may seem like it would reduce the demand for professional repair. However, consumers often prefer professional repair when a product is still under warranty, as these services are typically trusted, reliable, and free of charge. After the warranty period, many small household electric consumer products are currently not considered worth repairing, meaning they rarely reach professional repair channels (D. Mous, personal communication, December 3, 2025). If self-repair becomes more visible and normalized, professional repair may actually become a more prominent and trusted option in situations where self-repair is not feasible. Thus, a decline in demand is unlikely, and an increase is plausible.

Professional repairers are motivated by efficient workflows, clear documentation, affordable spare parts, and predictable repair procedures. They benefit from products designed with accessible fasteners, modular construction, and standardized internal layouts, as these reduce repair complexity, repair time, and costs. Repair-friendly design also lowers refusal rates; situations in which

repairers decline to work on a product because it is too difficult, fragile, or risky to disassemble.

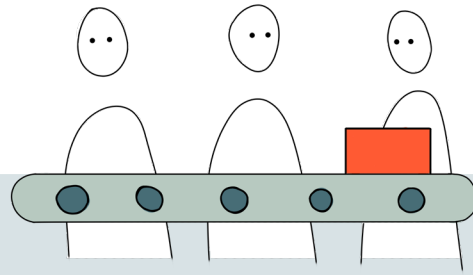


### 3.2.4. Designers

Designers play a central role in shaping the DIY repair journey. Through decisions about material choices, internal layout, fasteners, accessibility, and overall construction, they directly influence how consumers and repairers experience repair. Designers must balance aesthetics, usability, durability, cost, reparability, and brand identity within a single coherent product vision.

Motivation to design for reparability can be both intrinsic and extrinsic. Some designers are intrinsically motivated by a sense of moral responsibility and concern for a product's environmental footprint. At the same time, repair-related legislation increasingly exerts external pressure to incorporate reparability into product design. However, while such legislation often addresses technical reparability, it does not always result in the inclusion of clear signifiers that communicate repair affordances to users.

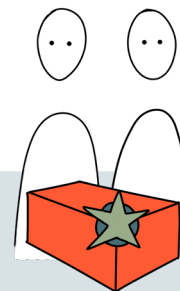
This project aims to support designers by providing actionable guidelines that make repair more intuitive and visually legible. Clearer frameworks can help designers integrate reparability into their design practice while preserving desirable aesthetics and maintaining competitive product appeal.



### 3.2.5. Product engineers and manufacturers

Product engineers and manufacturers occupy a closely connected role in translating design intent into products that can be produced at scale. While their responsibilities differ, both influence key implementation decisions, such as assembly methods, fasteners, internal layouts, and quality standards, that directly affect a product's reparability.

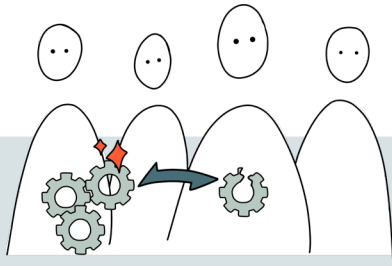
Manufacturers are primarily extrinsically motivated by factors such as low production costs, material efficiency, regulatory compliance, and the reduction of warranty claims. Within these constraints, product engineers play a key role in balancing manufacturability, robustness, and assembly efficiency. Both therefore benefit from design guidelines that support efficient assembly while also enabling future disassembly, allowing products to be repaired more easily without compromising production speed or cost control.



### 3.2.6. Brands and product owners

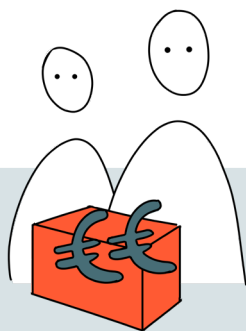
Those who place the product on the market and shape its identity care deeply about their brand reputation. This reputation is influenced by consumers' perceptions of product reliability, ease of maintenance, quality, and longevity. Brands must balance these expectations with production costs and their broader business model, which may rely on fast product cycles, after-sales services, or accessory sales. Increasing legislation, such as the Right-to-Repair, pressures brands to offer more repairable

products and to provide accessible spare parts, repair documentation, and tools. At the same time, strong repairability can enhance customer satisfaction, loyalty, and competitive differentiation, especially among sustainability-oriented consumers. Brands and product owners benefit from design guidelines that help them meet regulatory demands, reduce long-term costs, while maintaining a strong market identity and consumer trust.



### 3.2.7. Suppliers and distributors of spare parts

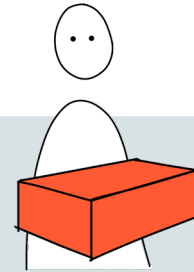
Suppliers and distributors of spare parts strongly influence whether repair is affordable and practically possible, as they determine the availability, cost, quality, and distribution of components. For consumers to engage in self-repair, they must be able to easily find these suppliers, understand which parts they need, and purchase them without unnecessary complexity. Suppliers and distributors benefit from this accessibility as it increases sales of spare components. They also gain from greater standardization of parts across product ranges, since standardized components are easier to manufacture, store, and distribute, and they create more predictable demand from professional repair services as well as community-based repair initiatives.



### 3.2.8. Vendors and retailers

Vendors and retailers influence how products are presented to consumers and whether repairability is

communicated at the point of purchase. They decide whether repairability becomes part of the product's value proposition. Vendors benefit from reduced return rates, increased customer satisfaction, and the ability to market sustainable, long-lasting products.



### 3.2.9. Consumer

Consumers are the primary stakeholders and the central target group of this project. They ultimately decide what happens when a product breaks: whether it is repaired, discarded, replaced, or sent to a professional repair service (Terzioğlu, 2021). Consumers generally seek products that are safe, functional, cost-effective, aesthetically pleasing, easy to understand, and durable. However, many experience fixophobia: a fear of failing, a lack of confidence, or the belief that repair is “not worth the effort”, especially for inexpensive small appliances (Roskladka et al., 2023).

It is likely that consumers benefit when products provide better support for DIY repair. Product features that guide users through the repair process can boost confidence, reduce feelings of anxiety around repair, and foster a sense of satisfaction, autonomy, and environmental contribution (Van den Berge et al., 2023a). Improved repairability can also lower the overall cost of ownership by helping prevent premature replacement (Jaeger-Erben et al., 2021).

## 3.3. Consumer profiles

Affordances describe the potential interactions between an agent and an object and therefore depend not only on the properties of the object, but also on the capabilities of the user (Maier & Fadel, 2009b; Rietveld & Kiverstein, 2014; Withagen et al., 2012). As a result, the same product can invite different behaviours for different consumers. In the context of repair, users vary widely in their skills, technical knowledge, access to tools, and motivation, all of

which shape how repair affordances are perceived, which barriers are encountered, and whether repair is considered a viable action at all.

Dangal et al. (2021) found that difficulties related to diagnosis and disassembly are especially challenging for users with limited repair experience, while more experienced repairers are better able to overcome such barriers. At the same time, motivation to repair also differs across consumers. Some individuals are intrinsically motivated to engage in DIY repair, experiencing it as enjoyable due to curiosity, learning, and skill mastery, while other consumers need extrinsic motivation to consider the option of repair (Wolf & McQuitty, 2013).

Because repair barriers, motivation, and affordance perception are strongly influenced by user characteristics, a one-size-fits-all approach to repair-friendly design is insufficient. To address this variation, consumer profiles are a useful tool for capturing meaningful differences between users. Based on field research in Repair Cafés and observations within my social network, six general consumer types were identified, ranging from highly inexperienced users with little interest in repair to highly experienced repairers, see Figure 11. Each profile incorporates capabilities that influence repair behaviour, including skills, technical knowledge, experience, access to tools, information access, and available resources. Because all of these factors shape perceived affordances and invitations to act, they must be considered when designing repairable products that are accessible and intuitive for everyone.

### 3.3.1. Scope of the project

Interventions aimed at facilitating DIY repair are most effective for users in the intermediate range of the motivation/experience spectrum. Consumers who rely heavily on external triggers to attempt repair are unlikely to be influenced by product-embodiment interventions alone and instead require system-level incentives. At the other end of the spectrum, experienced users already possess the skills and intrinsic motivation to repair independently. For them, technical repairability is generally sufficient, although well-designed repair affordances and signifiers can make the process more efficient and less time-consuming.

This project therefore focuses on consumers such as Ellie and Mia, for whom repair is a possible but not yet compelling option. Repair can become less intimidating when products are designed to be repaired, with inexperienced consumers in mind.

The aim is to design a product that enables advanced-level repair, as defined by Terzioglu et al. (2015), even for users with limited repair experience. By designing for this intermediate profile, the proposed interventions are also expected to support more experienced and intrinsically motivated users. The following chapter examines the specific repair barriers faced by this target group.



## Bob

*Bob has never tried repairing something, and isn't considering it either.*

### Background

Bob is a middle aged man with plenty of money and rarely considers the environmental or social impact of his choices. He sees second-hand or repaired products as less valuable and prefers to buy the newest versions, believing that this is simply the way things should be.

### Suitable design interventions

Design interventions within the product embodiment aimed at facilitating DIY repair are unlikely to influence Bob's intention to repair. Instead, Bob requires external motivators within the broader system to consider repair at all, and even then, he would most likely choose to have the repair carried out professionally.



## Kelvin

*Kelvin has never tried repairing anything, but would consider it if it were easily accessible and required little to no effort.*

### Background

Kelvin is a young man who is not intrinsically motivated to make sustainable choices but is aware of global climate issues. He believes systemic change is needed and that individual actions have little impact without it. He often makes excuses for replacing products instead of repairing them, convinced that repairs are a hassle and expensive. Most of his excuses revolve therefore around a lack of time and the effort he assumes it will take.

### Suitable design interventions

Kelvin would primarily benefit from system-level design interventions that make repair more accessible and affordable. Interventions within the product embodiment itself are unlikely to have a significant influence on him, as he lacks the intrinsic motivation to actively pursue sustainable choices.



## Ellie

*Ellie would like to repair things, but doesn't dare to do it alone or doesn't know how.*

### Background

Ellie is an elderly lady who heard from her neighbours that there's something called a repair café. She recently brought her daughter's lamp to the Repair Café to have it fixed. "My daughter never makes time for it, but I think it's important and I have all the time in the world." She brought the lamp to the repair café without having an idea on what the fault might be.

### Suitable design interventions

Ellie would benefit from products that afford safe repair and reduce the need for specialized technical expertise. At the same time, she requires support from the broader system, as she remains cautious about attempting repairs independently. She would therefore likely seek detailed repair discriptions online or continue visiting the Repair Café for guidance and reassurance.

Figure 11. Consumer profiles. (Figure continues on next page).



## Mia

*Mia has recently attempted to DIY repair her first product but lacked the knowledge and experience to complete the repair successfully.*

### Background

Mia is a student who is committed to minimizing her environmental impact and is highly aware of climate issues. She strives to make as many sustainable choices as her budget and circumstances allow. Repairing products helps her extend their lifespan and save money, but limited time and experience often lead her to procrastinate the DIY repair or to seek help at a Repair Café.

### Suitable design interventions

Products that clearly signify their repairability and afford quick, accessible repair attempts would be highly appealing to Mia, provided they are priced similarly to comparable alternatives. She would benefit from products that make the repair process understandable for users with limited technical knowledge, and that require minimal tools or tool-knowledge.



## Tom

*Tom enjoys repairing things and does so frequently. He attempts to fix his products before considering replacement.*

### Background

Tom is a middle-aged man with a workshop full of tools, who prefers older products because he believes they are built to last and easier to repair than modern ones. Confident and resourceful, he knows where to find information and how to fix most of his products, treating repairs as both a challenge and a hobby. He uses trial-and-error to get through the repair process, and is unlikely to rely on repair manuals or online instructions to guide him.

### Suitable design interventions

Tom would perceive a product that is easy to repair as a good design that he wants to explore. He would benefit from a design that is error-tolerant and provides clear feedback during the repair process, allowing him to continue using his trial-and-error approach.



## Stephan

*Stephan has extensive repair experience and enjoys helping others. He regularly volunteers at a repair café and confidently tackles even complex repairs.*

### Background

Stephan is a retired IT professional who has applied his technical skills to a wide range of repairs and enjoys sharing his knowledge with others. He volunteers at a repair café twice a month, assisting people with repairs they would not attempt on their own, and collaborates with fellow repairers on more complex products when time allows.

Confident and resourceful, he takes a hands-on approach and follows a structured, experience-based method throughout the repair process.

### Suitable design interventions

Stephan would benefit from a product that is quick and safe to repair for inexperienced users, while not limiting access or complicating the process for more experienced repairers.

Figure 10 (Continued). Consumer profiles.

## 3.4. Chapter 3 Takeaways

### RO2 Understanding the DIY Repair Context.

#### Q2.1 What contextual conditions and actors must be considered when designing for DIY repair?

Designing for DIY repair requires acknowledging that repair does not occur in isolation, but within a complex socio-technical ecosystem. The contextual conditions shaping DIY repair include the domestic setting in which repairs are typically performed, limited access to tools and technical knowledge, varying levels of user experience and motivation, and the broader cultural and legislative environment surrounding repairability. Maintenance practices, misinterpretation of product failure, and fixophobia further influence whether repair is perceived as feasible or worthwhile.

To achieve a DIY repair culture, a shift across the entire ecosystem is required. In this project, where the aim is to stimulate DIY repair through product embodiment, the most direct stakeholders are designers, product engineers, and manufacturers, as they directly determine the technical and physical repairability of products through decisions about architecture, fasteners, modularity, and accessibility. However, most designers and manufacturers work for clients and are therefore dependent on their priorities and requirements. These clients, or product owners, often require additional incentives to invest in repairable product design. Their decisions are influenced by consumer demand as well as by legislation established by policymakers, who in turn are partly guided by the propositions and advocacy of NGOs. Suppliers and spare-part distributors affect the practical feasibility and affordability of repair, while community repair initiatives and online repair platforms lower experiential barriers by providing knowledge and social support. Ultimately, consumers remain the decisive actors, as their capabilities, motivations, and perceptions determine whether repair affordances are acted upon.

Therefore, designing a product for easy DIY repair requires a broader systemic shift. In this project, the focus is on empowering designers to integrate DIY repair principles into product embodiment. By equipping designers with strategies and tools to design for repair, the project aims to lower barriers for consumers to repair their own products. However, for such design strategies to be widely adopted and effective, complementary shifts among product owners, policymakers, suppliers, and consumers are also necessary.

Because repair affordances are relational and depend on user capabilities, designing for DIY repair cannot rely solely on technical repairability. It must consider diverse consumer profiles, particularly those in the intermediate range of experience and motivation, for whom repair is possible but not yet compelling. Effective design must therefore align product-level interventions with systemic conditions, ensuring that repair is not only technically feasible but also perceivable, safe, understandable, and supported within the broader ecosystem.

Table 1 summarises the needs and wishes per stakeholder in DIY repair. This overview of needs and wishes provides a foundation for the requirements that should be considered when designing a product for easy DIY repair.

Table 1. Overview of Stakeholder Needs and Wishes for Easy DIY Repair. (Continues on next page)

## Policy makers & NGOs



Intermediaries between technical knowledge, public awareness, and political decision-making.

Drivers: Systemic change, environmental impact, and legal frameworks.

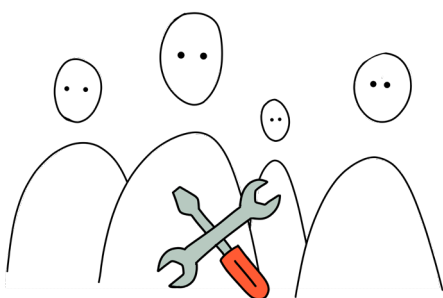
### Needs

- Regulatory Compliance: Products that adhere to current and upcoming “Right to Repair” directives and national laws (e.g., French Repairability Index).
- Transparency: Provision of clear repairability scores and public disclosure of technical data.

### Wishes

- Systemic Influence: Legislation that forces “non-intrinsically motivated” actors to adopt circular practices.

## Community and voluntary repairers & Repair knowledge platforms



Safety net and free primary information source for inexperienced consumers entering the world of repair.

Drivers: Knowledge sharing, social impact, and technical accessibility.

### Needs

- Information Accessibility: Free, high-quality repair manuals and diagnostic guides (e.g., iFixit style).
- Safety: Products must be inherently safe for non-professionals to handle during disassembly.

### Wishes

- Intuitive Layouts: Visual signifiers that indicate where to open the device or which parts are modular.
- Low Frustration: Absence of fragile clips or hidden screws that lead to accidental damage during repair.

## Professional repairers



Trusted and reliable services providers for repair where DIY repair is not feasible.

Drivers: Workflow efficiency, profitability, and reliability.

### Needs

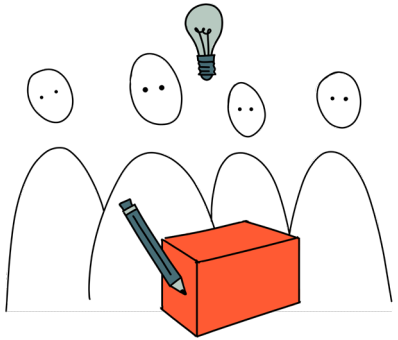
- Predictable Procedures: Logical and standardized internal layouts to minimize diagnostic time.
- Affordable Spare Parts: A supply chain that allows for profitable repair margins.

### Wishes

- Low Refusal Rates: Designs that are robust enough to be opened and closed multiple times without breaking.
- Modular Construction: Ability to replace specific sub-assemblies quickly.

Table 1 (Continued). Overview of Stakeholder Needs and Wishes for Easy DIY Repair. (Continues on next page)

## Designers



Directly influence how consumers and repairers experience repair.

Drivers: Aesthetics, usability, and brand coherence.

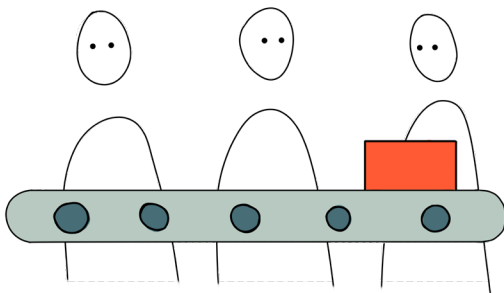
### Needs

- Actionable Guidelines: Concrete design principles that translate “repairability” into a physical form.
- Balanced Constraints: Tools to help balance repairability with aesthetics and durability.

### Wishes

- Visual Legibility: Making repair “intuitive” through the product’s physical design language.

## Product engineers and manufacturers



Directly influence key implementation decisions, such as assembly methods, fasteners, internal layouts, and quality standards, that directly affect a product’s repairability.

Drivers: Scale, cost-control, and assembly speed.

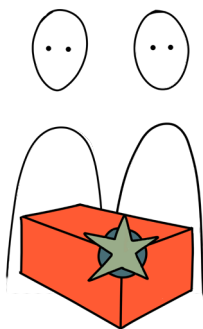
### Needs

- Efficient Production: Assembly methods that do not significantly increase “Time-to-Market” or labor costs.
- Cost Control: Maintaining low production costs while incorporating repair-friendly features.

### Wishes

- Standardization: Use of universal fasteners and standardized components to simplify inventory.
- Robustness: Ensuring that making a product “easy to open” doesn’t make it “easy to break” during normal use.

## Brands and product owners



Those who place the product on the market and shape its identity.

Drivers: Reputation, market share, and customer loyalty.

### Needs

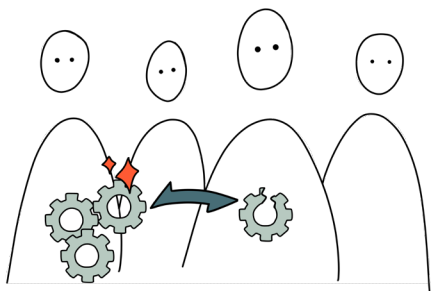
- Market Competitiveness: The product price must remain comparable to non-repairable alternatives.
- Warranty Management: Clear boundaries between what a consumer can repair safely and what requires professional service to maintain warranty.

### Wishes

- Brand Loyalty: Using “repairability” as a premium marketing feature for sustainability-minded consumers.

Table 1 (Continued). Overview of Stakeholder Needs and Wishes for Easy DIY Repair.

## Suppliers and distributors of spare parts



Determine the availability, cost, quality, and distribution of components.

Drivers: Inventory management and predictable demand.

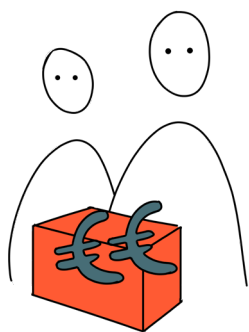
### Needs

- Findability: Clear part numbers and compatibility lists so consumers can easily identify the correct spares.

### Wishes

- Standardization of Parts: Fewer unique parts across different product lines to reduce storage costs.

## Vendors and retailers



Influence how products are presented to consumers and whether repairability is communicated at the point of purchase

Drivers: Shelf-appeal, customer trust, and operational efficiency.

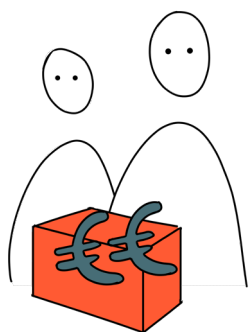
### Needs

- Price Parity: The product must remain cost-competitive compared to non-repairable alternatives.
- Regulatory Alignment: All stocked products must comply with local mandates, such as the French Repairability Index or EU labeling laws, to avoid legal friction or fines.

### Wishes

- Sustainability as a USP: The ability to use “repairability” as a Unique Selling Proposition (USP).
- Customer Loyalty: Fostering long-term trust with consumers.

## Consumers



Owners of the product

Drivers: Value for money, safety, and confidence.

### Needs

- Safety: Zero or minimal risk of electric shock or physical injury during a DIY repair.
- Support: Guidance that makes the repair process understandable for users with limited technical knowledge
- Economic Viability: The cost of the spare part and the effort must be significantly lower than buying a new product.

### Wishes

- Confidence (Overcoming ‘Fixophobia’ and other barriers in their DIY repair journey).
- “Low-Friction” Accessibility: A repair journey that is time-efficient.



# Barriers in the DIY Repair Journey

RO3

Understanding barriers within the DIY repair process.

Q3.1 What does the DIY repair process look like?

Q3.2 What psychological and practical barriers do consumers experience during the DIY repair process?

# 4. Barriers in the DIY Repair Journey

This chapter introduces the DIY repair journey as a framework to analyse where and why barriers to repair arise from the consumer’s perspective. The repair journey describes the sequence of steps a consumer goes through when attempting to repair a product, from the initial consideration of repair to the period following a completed repair (Pozo Arcos et al., 2020).

For each stage of the repair journey, this chapter first outlines the consumer’s activities, motivations, and mindset. It then identifies the barriers that arise at that particular stage. By analysing the sequence of actions involved in DIY repair, the key challenges that hinder successful repair become visible. This stage-based analysis reveals concrete opportunities for design interventions that can support, guide, and empower users throughout the DIY repair process.

## 4.1. The DIY Repair Journey

The repair journey for electrical consumer products describes the sequence of stages a consumer goes through from the moment a product breaks to the completion (or abandonment) of repair (Pozo Arcos et al., 2020). The journey is a multi-stage process shaped by both individual and external factors (Svensson-Hoglund et al., 2023). The choice to repair is therefore not a single decision, but a journey of multiple trade-offs (Jin et al., 2025).

iFixit (2025) defined a successful repair as one that includes product identification, diagnosis, part procurement, tool procurement, product disassembly,

part replacement, product reassembly, and testing. They argue that if one step in this sequence breaks down, the whole repair effort may fail.

Jin et al. (2025) define five stages of the repair journey: Repair Interest, Repair Pathfinding, Repair Arrangement, Repair Action, and Post-Repair (see Figure 12). At each stage, consumers reassess whether to continue pursuing repair or to dispose of the product. The journey therefore represents a series of decision points where repair can either progress or be abandoned.

For this project, which focuses specifically on how product design influences the DIY repair experience, a simplified and adapted version of the model by Jin et al. (2025) is used. The journey is condensed into three design-relevant stages:

1. Repair Intention
2. Repair Insight
3. Repair Action

In the Repair Intention stage, the consumer becomes aware of a malfunction and decides whether to tolerate the defect, attempt repair, or discard the product.

In the Repair Insight stage, the consumer performs a fault diagnosis to identify the problem and searches for the necessary resources for repair, such as tools, time, and spare parts.

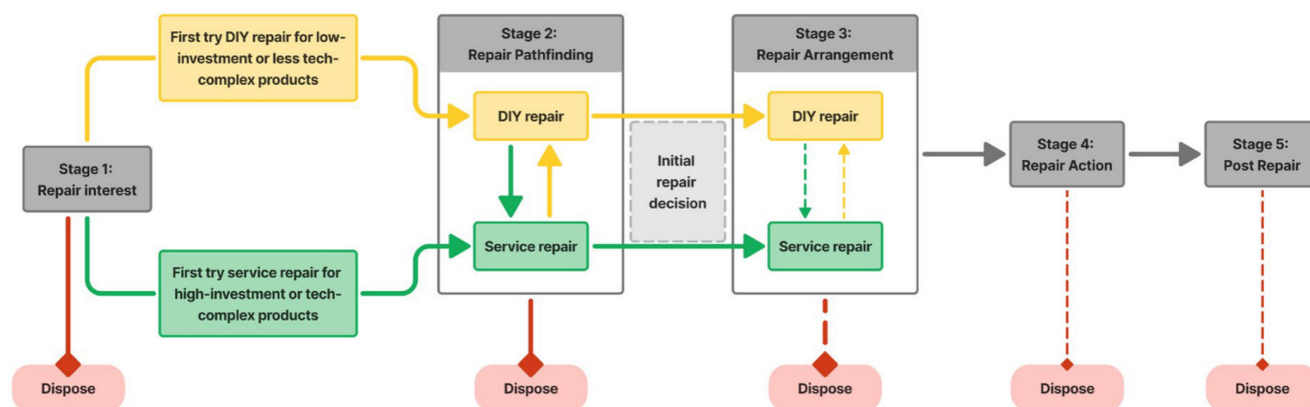


Figure 12. Overview of the DIY repair journey (Jin et al., 2025).

In the Repair Action stage, the consumer performs the practical steps required to fix the product, such as replacing the component and reassembly.

## 4.2. Stage 1 - Repair Intention

The Repair Intention stage begins when the consumer detects a failure; they notice a misalignment between the product's condition and their expectations of the product's function. This is the first time the consumer has to make the decision to either repair or dispose the product (Jin et al., 2025).

The repair barriers resulting out of the product embodiment in this stage of the repair journey are centered around the lack of signifiers that communicate that repair is possible, permissible and worth trying for inexperienced consumers.

### Difficult fault detection

Pozo Arcos et al. (2020) did research on how conventional users can detect faults in household appliances. They found that consumers detect faults by noticing five common type of symptoms in the products:

1. Product underperformance (“does not function as it should”);
2. Absence of response to user commands (“not working at all”);
3. Intermittent performance;
4. Emitting unintended signals (“louder than expected noises, smells of smoke”);
5. Emitting designed signals (e.g., a blinking light).

Davidson (2004) found that checking for symptoms often happens using ‘the three Ss’ method: sight, sound, and smell. Faults can be detected by noticing physical signs such as a burned printed circuit board, pulled wiring, the smell of smoke, abnormal component behaviour, or unexpected sounds.

Sometimes the ‘fault’ makes itself visible, making diagnosing pretty straightforward (Hielscher & Jaeger-Erben, 2019). For instance when the case of the product is partly broken, a handle comes off, or a screen is shattered. However, many contemporary small household appliances are designed as fully enclosed systems that provide few or no designed signals indicating internal failure, see Figure 13.



Figure 13. Contemporary products are designed as fully enclosed systems.

As a result, consumers are often limited to observing general performance issues (e.g., underperformance or non-response) and unintended signals, while more specific diagnostic information remains inaccessible without disassembly. The product effectively functions as a “black box”: users know that it does not operate as intended, but they cannot assess the nature or severity of the malfunction. Consequently, consumers may struggle to distinguish between minor issues (e.g., the need for cleaning) and more complex technical faults. In situations of uncertainty, people may assume the problem is severe and therefore beyond their capability to repair. However, for example underperformance is often caused by excessive dirt build-up inside the product, resulting in blockages or trouble with connectors. In these cases, standard maintenance operations are often the solution (Pozo Arcos et al., 2020).

### Perceived repair options

The need for repair typically emerges unexpectedly, at the moment a product fails. This moment constitutes a critical decision point, at which consumers choose between repair, replacement, or disposal. According to Wolf & McQuitty (2013), a key challenge in encouraging consumers to repair is ensuring that they recall, at the moment of product failure, that repair is a viable option.

Some products do communicate their maintenance options, such as the possibility of replacing a battery through visible compartments with self-signifying affordances (for example a notch to press or a space to insert a fingernail, see Figure 14). Another example of effective maintenance signifiers are the brightly coloured clips on the floor head of a Philips stick

vacuum, which indicate how to access and clean the roller brush, see Figure 15.

However, the architecture of many contemporary small household appliances does not communicate repairability. A brief survey of products currently on the market (see Appendix D - Analysis of repairability of Small Household Electric Consumer Products) shows that most products offer no visible cues suggesting they can be opened or repaired. In some cases, natural signifiers of repair, such as screws, are actively concealed through stickers, caps, or friction-fit covers, see Figure 16. As a result, the product presents itself as seamless and closed, implicitly discouraging user intervention.

When repair possibilities are not perceptually salient, repair may not even enter the consumer's immediate choice set. Instead, replacement becomes the default response. One reason for concealing opening points is aesthetic: contemporary product design norms favour sleek, uninterrupted surfaces. Yet this aesthetic preference may inadvertently communicate disposability rather than maintainability.

## Perceived safety

Consumers have safety concerns about DIY repairs (Rovira-Menaya et al., 2025). This is because during the repair process, consumers might be exposed to a number of potentially dangerous components, such as electrical parts or sharp elements (Van Nes & Cramer, 2005). The perceived risk of injury therefore influences the decision to attempt repair. Dangal et al. (2021) found that fear of injuring oneself is a significant reason for consumers to refrain from DIY repair. This barrier is particularly pronounced among users with little or no repair experience, whereas experienced users report lower levels of safety-related hesitation. This difference may be explained by increased confidence in handling potential risks as repair experience grows (Dangal et al., 2021).

Without clear indicators of what components are safe to touch, or which repair actions are safe to perform, the perceived risk often outweighs the motivation to repair (Dangal et al., 2021).



Figure 14. A remote and a mouse with signifiers for accessing the battery compartment.



**Figure 15.** The brightly coloured clips on the floor head of a Philips stick vacuum are good signifiers for maintenance action: they intuitively tell the user how to clean out the roller brush.

### Comprehension of warranty rights

Alongside concerns about physical injury, consumers also experience fear of voiding their warranty when attempting DIY repair. Many are uncertain whether repairing a product will affect their warranty status, or whether the product is still under warranty at all, as warranty rights are often poorly understood (Van den Berge et al., 2023c).

### Perceived self-efficacy

Perceived self-efficacy strongly influences a consumer's decision to attempt repair (Van den Berge et al., 2022). Self-efficacy refers to an individual's belief in their capability to successfully perform a goal-oriented behaviour. When consumers anticipate that a repair will require advanced technical knowledge, specialised tools, they may doubt their ability to complete it successfully, reducing the likelihood that they will initiate repair (Rovira-Menaya et al., 2025).



**Figure 16.** A mouse with hidden screws under stickers and in the battery compartment.

Higher levels of self-efficacy are associated with greater interest and enjoyment during the repair process, while positive and successful repair experiences, in turn, reinforce self-efficacy through mastery and positive affect (Sonogo et al., 2022). This reciprocal relationship suggests that self-efficacy influences both the initiation of repair and the likelihood of continued engagement in future repair activities.

The perceived difficulty of repair is reinforced by the way many contemporary products are designed. Products often provide no visible cues or guidance indicating that repair is possible or intended. The absence of such signals may implicitly communicate that repair is complex or reserved for professionals.

### **Perceived convenience of repair**

Convenience has been identified as an important factor in the choice to repair (Sonogo et al., 2022). When consumers compare repair to replacement, the latter is often perceived as the more convenient option, as repair requires additional time, effort, and coordination. As a result, even consumers who are positively inclined toward repair may opt for replacement if the repair process appears burdensome.

Limited access to repair information or support further reduces perceived convenience. When manuals, instructions, spare parts, or online guidance are not readily accessible, consumers must invest additional effort in searching for the necessary knowledge, which can discourage them from attempting repair (Jaeger-Erben et al., 2021; Rovira-Menaya et al., 2025).

In many current non-professional repair scenarios, including DIY repair and Repair Café settings, repairers often need to search online for instructions on how to open a product or replace a specific component, particularly when encountering a failure for the first time. Common sources include YouTube videos documenting previous repair attempts or online forums such as Reddit or iFixit, where users share personal experiences. However, this form of information gathering is unpredictable and unstructured. There is no guarantee that the required information will be available, complete, or accurate. Although platforms such as iFixit provide structured and step-by-step repair guides, their coverage does

not extend to all products. Consequently, access to reliable repair information remains uncertain and can be experienced as inconvenient, which can deter users from engaging in or even considering repair.

These observations align with the Theory of Planned Behaviour, which suggests that perceived behavioural control, the extent to which a person believes a behaviour is easy or difficult to perform, shapes behavioural intention (Van den Berge et al., 2022). When repair is perceived as inconvenient or difficult, consumers are less likely to form the intention to carry it out.

### **Perceived quality of the product**

In addition to practical considerations, perceptions of product quality play an important role in the decision to pursue repair. Rovira-Menaya et al. (2025) note that consumers are more likely to consider repairing products they perceive as high quality, as these are seen as “worth repairing.” In contrast, products perceived as low quality are often considered as disposable, reducing the likelihood that consumers will invest time and effort in repair.

Material choices strongly influence these quality perceptions. The use of fragile materials can increase the perceived risk of causing additional damage during repair, thereby discouraging users from attempting it. Beyond functional concerns, aesthetic considerations also play a significant role. Consumers may hesitate to repair a product if they expect visible repair traces to reduce its aesthetic value (Van Nes & Cramer, 2005). For example, many products rely on tight snap-fits that must be released with a spudger. Because the exact location of these snap-fits is often not clearly indicated, repairers must rely on trial and error. This frequently requires the application of considerable force, which can leave visible dents or scratches along the product’s split lines. Such traces of intervention may be difficult to avoid and can reinforce the perception that repair compromises product integrity.

Moreover, users may mistrust the durability and reliability of a repaired product. Concerns that the product will fail again shortly after repair, or that its quality has been permanently diminished, can

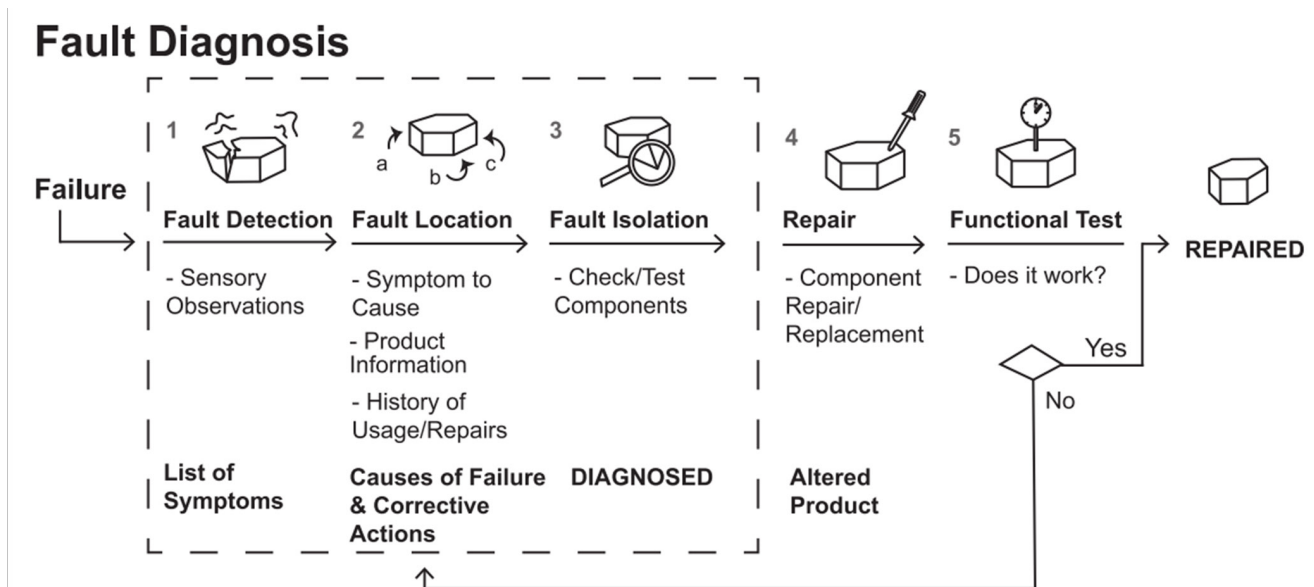


Figure 17. Conceptual framework of the process of fault diagnosis (Pozo Arcos et al., 2020).

undermine confidence in the repair outcome (Rovira-Menaya et al., 2025; Van Nes & Cramer, 2005). Such doubts reduce the perceived benefits of repair and can ultimately lead consumers to opt for replacement instead.

## 4.2 - Takeaways

In the DIY repair stage of Repair Intention, the consumer faces the overarching question: “As an inexperienced user, is repair possible, permissible, and worth attempting?” At this point, the decision is shaped not only by technical feasibility, but by how the product communicates its repairability.

## 4.3. Stage 2 - Repair Insight

When the consumer enters the repair insight stage, they have already decided that the product is worth repairing. The intention is there. The question is no longer “Should I repair this?” but “How do I repair this?”

The first step in this stage is fault diagnosis, which is the process of identifying and characterising a fault when a failure occurs. It is therefore an essential step to take before product-repair and is directly associated with the difficulty and time spent on repairs (Pozo Arcos et al., 2020). The process of fault diagnosis can be described by the subsequent actions of fault detection, fault location and fault isolation. Fault detection was achieved in the repair intention stage, and in the repair insight stage, the consumers enter

an information gathering process, including the fault location and isolation stages of fault diagnosis (Jin et al., 2025; Pozo Arcos et al., 2020). Pozo Arcos et al. (2020) provide a conceptual framework of the process of fault diagnosis, provided in Figure 17.

## Perceived self-efficacy

The repair insight stage involves an evaluation of whether a successful repair is personally feasible. Consumers assess their own skills, the availability of guidance and tools, and the perceived complexity of the task in order to determine whether repair is a realistic option (Jin et al., 2025). This evaluative process is strongly influenced by perceived self-efficacy (Van den Berge et al., 2022).

Self-efficacy plays a particularly important role during fault diagnosis (Van den Berge et al., 2023a). As previously discussed, users are often unaware of the underlying causes of electronic product failures (Pozo Arcos et al., 2021; Van den Berge et al., 2023b). When consumers are unable to interpret symptoms or identify likely fault locations, their confidence in being able to complete the repair decreases. Conversely, when individuals believe they can make sound evaluations and understand the repair process, their perceived self-efficacy increases (Van den Berge et al., 2022).

## Trial-and-error fault location

Pozo Arcos et al. (2020) did research on how

conventional users can diagnose faults in household appliances and how the design of these appliances can influence the process of fault diagnosis. In the fault location and isolation stages, the consumer has to translate the symptoms into causes. This is an accurate, quick, straightforward process that requires a low level of expertise when the symptoms are easily interpretable (Pozo Arcos et al., 2020).

When a product does not communicate explicit error codes or diagnostic information, fault location relies heavily on the user's understanding of the product's architecture and operating principles. In such cases, the number of possible failure causes is often large, and fault location becomes a process of elimination. For the repairer, this can feel like a tedious trial-and-error exercise method where actions need to be performed until the symptom disappears. The result is a time-consuming and uncertain fault diagnosis process.

The type of symptom identified during fault detection determines which fault location actions the repairer must perform. For example, if the product underperforms or emits unintended signals, a visual or manual inspection of the condition of the priority components is recommended. If the product does not respond to user commands or emits warning signals, this is often associated with failing electronic or electrical components, or problems in the circuit board. A visual inspection for cracked soldering, loose wiring or an activated safety system is recommended (Pozo Arcos et al., 2020). Experienced repairers are generally familiar with these diagnostic routines and understand the logic behind systematic fault isolation. Inexperienced repairers, however, often lack this procedural and technical knowledge. The internal structure of the product can appear complex and overwhelming. They may not understand how components function, how they relate to overall product operation, or which components are most likely to fail. Without this understanding, it becomes difficult to construct a mental model of the product or to develop a structured test plan for the next stage; fault isolation.

### **Fault isolation**

Fault diagnosis requires not only an understanding

of the product itself, but also the ability to operate diagnostic tools. During the fault isolation stage, the repairer tests the performance of components that may be defective to determine the source of the malfunction. In many cases, this process involves the use of a multimeter to perform continuity or voltage measurements in order to assess the condition of electronic components. When specialised tools are necessary to identify a malfunction, the process can become complex and intimidating, particularly for consumers who lack the required technical skills (Hielscher & Jaeger-Erben, 2019). The difficulty of tool use therefore becomes an additional barrier to repair.

While the multimeter is a versatile and effective diagnostic instrument, research by Pozo Arcos et al. (2020) shows that most users do not feel comfortable measuring electrical currents and often lack the knowledge required to operate the device correctly. As a result, even when consumers possess the appropriate tool, they may not feel capable of using it to locate a fault.

### **Technical implications of repair**

Before consumers can diagnose a fault during the repair insight stage, they must first gain physical access to the components that are most likely to have failed. Access to these priority components is therefore a prerequisite for effective fault diagnosis (Pozo Arcos et al., 2020). However, many contemporary consumer products are designed with tight snap-fit seals, hidden screws, proprietary screws, adhesive bonding, or irreversible disassembly processes. Such architectural choices restrict access to the product's interior and create an initial barrier, even before diagnostic activities can begin.

Inexperienced repairers are often unaware of how the product housing is assembled. While they are generally familiar with screws as fasteners, the absence of visible screws makes it unclear what holds the product housing together. Hidden screws and fasteners such as snap-fits provide little indication of how and where components are connected, leaving consumers uncertain about where and how to open the product housing. However, even experienced repairers frequently encounter similar uncertainty.

Observations from repair cafés and analyses of online repair videos illustrate this uncertainty in practice. Disassembly typically begins with removing all visible screws, after which the repairer must infer the next step. When no additional fasteners are apparent, experienced repairers often assume that snap-fits hold the casing together. The repairer then cautiously inserts a spudger along the product seams, unsure whether hidden screws remain, where snap-fits are located, or how much force can be applied without causing damage. This ambiguity prolongs the process and increases the perceived risk of failure. Even when the opening mechanism is relatively simple, the lack of clear guidance can lead to unnecessary casing damage and wasted time.

### 4.3 - Takeaways

The Repair Insight stage is currently a gauntlet of uncertainty due to the lack of accessibility, technical transparency, and guidance.

The main question people need answered in this stage is therefore: *“As a consumer, how do I figure out what’s broken — and what I need to do to fix it?”*

### 4.4. Stage 3 - Repair Action

Once the consumer has actually figured out why the product is not working and they decide to pursue repair, they enter the ‘repair action’ stage. This stage involves practical steps, such as the disassembly, part recovery or replacement, and reassembly of the product (Jin et al., 2025).

For a product to be considered truly repairable, it must support reversible disassembly. This means the device can be taken apart and reassembled without sustaining permanent damage. According to Park (2019), product design is the primary factor in determining this ease of dis- and reassembly.

Most repair action barriers revolve around the complexity of the actions; the amount and ease of dis- and reassembly steps, the amount and type of tools required to repair, but also the skill needed to perform a successful repair.

#### Access to tools

There are many design features that discourage or

prevent reversible disassembly, such as security (proprietary tool) fasteners, friction welded parts, sacrificial snap-fits, hidden fixings and adhesive tape bonding (Park, 2019). These non-reversible fasteners in either product disassembly steps or connection of components make the disassembly of the product difficult and time consuming, or sometimes even impossible for inexperienced repairers with limited access to tools. Those who do not have access to a heat gun or soldering iron cannot disassemble a glued battery or a cable that is connected with soldering points. In addition, they cannot reassemble these parts.

#### Lack of guidance, reassurance, and feedback

Beyond the need for specialised tools, irreversible fasteners, and unnecessarily complex disassembly sequences, the disassembly process itself is cognitively demanding and error-prone. The internal structure of many products is difficult for inexperienced repairers to interpret. Understanding how components relate to one another, in which sequence they must be removed, and how they should be reassembled imposes a high cognitive load. Experienced repairers mitigate this complexity by working cautiously and documenting each step, for example by taking photographs to track part orientation and order (Hielscher & Jaeger-Erben, 2019).

However, the product itself rarely provides guidance, overview, or structural cues to support this interpretation. As a result, both novice and experienced repairers often face uncertainty about the intended sequence of actions. It may be unclear which screws correspond to which component, or what the most efficient disassembly sequence is to access a specific part. Consequently, repairers may undo irrelevant fasteners, follow inefficient action sequences, or unintentionally complicate the process. The disassembly process becomes one of trial and error, with a constant risk of breaking components. Products typically offer no reassurance or constructive feedback during repair, leaving users to guess whether they are proceeding correctly.

#### Safety and warranty

Both consumers and manufacturers express safety concerns regarding DIY repair (Rovira-Menaya et

al., 2025). During the repair process, users may be exposed to potentially hazardous components, such as electrical parts or sharp elements (Van Nes & Cramer, 2005). Opening a product can therefore create situations in which consumers face safety risks that are normally mitigated during standard use.

In addition, most consumer products provide little to no guidance or feedback during disassembly and reassembly. As a result, insufficient skill or precision may lead to incorrect placement or connection of components. Improper reassembly can cause short circuits, mechanical failure, or further damage to the product. These risks not only discourage consumers from attempting repair, but also motivate manufacturers to restrict access to the product interior in order to limit liability and ensure user safety.

#### **4.4 - Takeaways**

The repair action stage is primarily hindered by technical complexity, limited access to appropriate tools, and product architectures that prevent reversible disassembly. In addition, the absence of structural guidance, feedback, and reassurance makes the process cognitively demanding and error-prone, particularly for inexperienced repairers. Safety risks and concerns about incorrect reassembly further discourage users, leaving them uncertain and asking: *“What steps should I take to carry out the repair safely, correctly and without errors?”*

## 4.5. Chapter 4 Takeaways

### RO3 Understanding barriers within the DIY repair process.

#### Q3.1 What does the DIY repair process look like?

The DIY repair process is a multi-stage journey rather than a single decision. It unfolds through three interconnected stages: Repair Intention, where consumers decide whether repair is possible, permissible, and worthwhile; Repair Insight, where they attempt to diagnose the fault and determine how it can be fixed; and Repair Action, where they physically disassemble, replace, and reassemble components. At each stage, consumers reassess whether to proceed or abandon repair, making the process a sequence of decision points shaped by both product design and user characteristics.

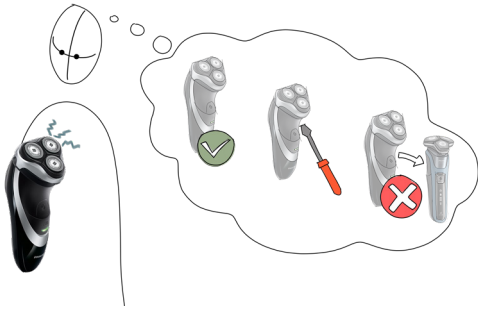
#### Q3.2 What psychological and practical barriers do consumers experience during the DIY repair process?

Across the repair journey, consumers encounter a combination of psychological and practical barriers. In the Repair Intention stage, uncertainty about fault severity, lack of visible repair cues, safety concerns, warranty fears, low self-efficacy, perceived inconvenience, and doubts about product quality discourage repair before it even begins. In the Repair Insight stage, limited technical transparency, difficulty interpreting symptoms, reliance on trial-and-error diagnosis, and challenges in using diagnostic tools create cognitive overload and reduce confidence. Finally, in the Repair Action stage, irreversible design choices, restricted access to tools, complex disassembly sequences, absence of guidance and feedback, and safety risks make the repair process technically demanding and error-prone. An overview of the barriers per stage can be seen in Table 2.

Taken together, these findings show that DIY repair is not primarily hindered by a single technical obstacle, but by accumulated uncertainty at every stage of the journey. Repair fails when products do not clearly communicate repairability, do not support fault understanding, and do not guide safe and structured action. Understanding these layered psychological and practical barriers provides a foundation for identifying where design interventions in the product embodiment can meaningfully reduce friction and support successful DIY repair.

Table 2. Overview of barriers during the 3 stages of DIY repair.

### Repair Intention



As an inexperienced consumer, is repair possible, permissible, and worth trying?

### Barriers

At the repair intention stage, barriers operate primarily through perceived feasibility and perceived risk.

- No access to clear repair instructions
- Uncertainty what type of action will actually solve the problem
- Not knowing whether repair is allowed
- Doubt about own capability of repair overall
- Fear of unsafe situations (e.g., electric shock, injury)
- Not knowing whether repair affects warranty
- Perceived excessive time and effort required

### Repair Insight



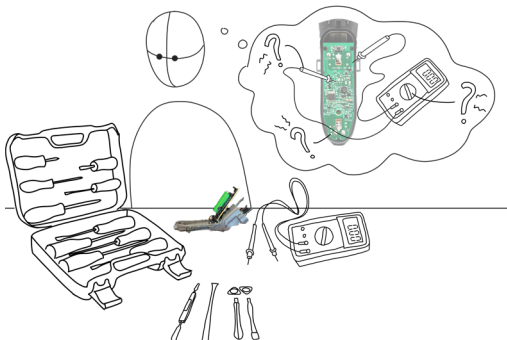
How do I figure out what's broken — and what steps do I need to take to fix it?

### Barriers

At the repair insight stage, barriers operate primarily through perceived clarity of structure and understanding of the problem.

- No access to the interior components of the product
- Specialized or proprietary tools needed to open the product
- Vulnerability of materials to damage at repair-intensive interfaces
- Fragile internal component structure
- Uncertainty about what holds the product together
- Fear of breaking the product
- Doubt about own capability of fault diagnosis
- Not understanding the function of components
- Not knowing how to operate the required tools

### Repair Action



What steps should I take to carry out the repair safely, correctly and without errors?

### Barriers

At the repair action stage, barriers operate primarily through perceived ability to execute steps correctly and safely.

- Complex (irreversible) dis- and reassembly sequences
- Specialized or proprietary tools needed to replace components
- Lack of access to spare parts
- Exposure to potentially hazardous components
- Error-prone repair process
- Unclear dis- and reassembly sequences
- Unclear orientation of components
- Lack of feedback about repair actions



# Affordances and Signifiers in the DIY Repair Journey

RO4

Exploring how affordances and signifiers can be strategically applied to reduce barriers throughout the DIY repair journey.

Q4.1 How can affordances reduce practical and functional barriers in the repair process?

Q4.2 How can signifiers reduce cognitive and psychological barriers in the repair process?

# 5. Affordances and Signifiers in the DIY Repair Journey

This chapter introduces the conceptual foundation for addressing the main research question by developing a framework that guides designers in the use of affordances and signifiers for easy-to-DIY-repair products. It establishes how affordances, as physical action possibilities, and signifiers, as cognitive cues, can be strategically designed to reduce barriers throughout the repair journey.

## 5.1. Affordances and signifiers in the DIY repair context

Synthesis of Chapter 2. Affordances and Signifiers in Product Design), Chapter 3 (The Context of DIY Repair), and Chapter 4. Barriers in the DIY Repair Journey) allows us to revisit the hypothesis stated earlier:

*'Many repairable products do contain the affordance of repairability but lack the signifiers needed to make that affordance perceivable to users. As a result, repair becomes hidden, ambiguous, or intimidating.'*

The barriers identified in Chapter 4 (Barriers in the DIY Repair Journey) support this hypothesis for inexperienced repairers. They demonstrate that technical repairability alone does not guarantee perceived repairability. Consumers encounter cognitive and psychological barriers when deciding to attempt or carry out a repair, and these barriers cannot be resolved solely by making products technically repairable. Many of the identified obstacles relate to perception: uncertainty about where to start, fear of damaging the product, lack of clarity about safe actions, and doubts about personal competence.

Chapter 2 (Affordances and Signifiers in Product Design) established that the invitation of perceived affordances depends on the capabilities of the user. Chapter 3 (The Context of DIY Repair) further showed that the DIY repair target group for this project includes consumers with widely varying levels of experience and technical knowledge. Some users lack even basic familiarity with product architecture, while others can anticipate internal structures and failure points based

on the type of product. Because affordances are relational, repair affordances must be perceivable and interpretable across this spectrum of capabilities.

Importantly, this does not mean that current repairable products lack signifiers entirely. Rather, many products communicate repairability in a “technical language” that is primarily readable by experienced repairers. Experienced users recognize standard fasteners, component layouts, or diagnostic cues and can interpret them fluently. Inexperienced users, however, may not understand these signals and therefore fail to perceive the underlying repair affordance. The issue is not the absence of signifiers, but the limited accessibility of those signifiers.

Chapter 2 (Affordances and Signifiers in Product Design) defined affordances as the action possibilities provided by a product, and signifiers as the perceivable cues that communicate those possibilities. Signifiers determine whether an affordance becomes discoverable and inviting or remains overlooked. Without effective signifiers, an affordance may exist technically but remain perceptually hidden for inexperienced consumers. In such cases, repair is not seen as a legitimate or manageable action, even if it is structurally possible.

These findings suggest that well-designed signifiers can function as a mechanism to make repair less intimidating, ambiguous, or hidden for inexperienced consumers, particularly when they translate the “repair language” into forms that are understandable without requiring extensive technical knowledge or experience.

When designing repair affordances and signifiers, they should be perceivable and interpretable by both inexperienced and experienced repairers. The existing technical language embedded in products should not be replaced, as it remains meaningful to skilled users, but rather complemented with additional signifiers that broaden accessibility. In this way, both inexperienced and experienced consumers can rely on cues that align with their respective capabilities.

## 5.2. From barriers to consumer needs

To translate the barriers to DIY repair identified in Chapter 4 into design interventions, they must first be categorized, as not all barriers operate in the same way. Some obstruct physical action, while others hinder understanding, confidence, or decision-making. Distinguishing between these mechanisms is necessary to develop targeted design responses that address root causes rather than merely treating symptoms.

The identified barriers are therefore classified into two overarching categories:

- Practical and functional barriers restrict the consumer's ability to physically perform repair actions. They relate to access, tool use, sequencing, and interaction with the product's material structure. These barriers manifest as limitations in what the product physically allows the user to do.
- Cognitive and psychological barriers restrict the consumer's ability to understand, evaluate, or feel confident about performing repair actions. They relate to uncertainty, perceived risk, legal ambiguity, and self-efficacy.

To translate these barriers into concrete design interventions, they must be reformulated as consumer needs. Barriers describe what obstructs or discourages repair behaviour, but they do not yet specify what the product should do differently. Consumer needs, in contrast, express the conditions required for repair to become feasible, understandable, and worthwhile from the user's perspective. Reformulating barriers as needs shifts the focus from problems to requirements, creating a constructive foundation for design action. This transformation enables a systematic transition from empirical findings about repair difficulties to actionable design criteria that can be addressed through affordances and signifiers in the product embodiment.

Table 3 provides an overview of the DIY repair stages, categorizing the identified barriers into practical/functional and cognitive/psychological groups, and presenting the corresponding consumer needs required for successful repair.

## 5.3. From consumer needs to design interventions

By framing needs as *repair affordances*, it becomes clear which repair actions the product should *enable* or *constrain* for the user. As such, repair affordances primarily contribute to increasing the perceived practical feasibility of repair and ensuring safety during the process, thereby reducing practical and functional barriers.

Framing the needs as *repair signifiers* clarifies which repair actions the product should *encourage* the user to take. Repair signifiers primarily increase clarity about the actions, thereby reducing the cognitive and psychological barriers.

Repair affordances are then the base of the repairability, and the repair signifiers the layer that makes sense of the repairability to the consumer. Therefore, for a strong intervention, both should be combined, and well-designed and coordinated to make a product actually easy to DIY repair.

### 5.3.1. Role and limitations of affordances and signifiers in DIY repair

While affordances and signifiers can support users, the relationship between user needs and design interventions is more complex, as multiple needs interact and are influenced by context, prior experience, and individual differences. As a result, affordances and signifiers should be understood as contributors to addressing user needs, rather than direct solutions.

A useful distinction can be made between instrumental needs and experiential needs. Instrumental needs relate to the practical and cognitive aspects of interaction, such as clarity, guidance, and reminders. These needs can be directly addressed through the use of affordances and signifiers, which structure user interaction, communicate possible actions, and reduce ambiguity.

Experiential needs, on the other hand, include aspects such as confidence, self-efficacy, trust, and perception. These are more subjective and are shaped by prior experiences, individual differences, and contextual factors. As such, they cannot be directly

**Table 3.** Overview of consumer barriers and needs across the DIY repair journey, organized by journey phase and type (practical vs. functional). (Table continues on next page.)

Repair Intention	As an inexperienced consumer, is repair possible, permissible, and worth trying?	
<b>Barriers</b>	<b>Consumer needs for successful repair</b>	
<p><b>Practical and functional barriers</b></p> <ul style="list-style-type: none"> <li>No access to clear repair instructions</li> </ul>	<p><b>Practical and functional needs</b></p> <ul style="list-style-type: none"> <li>Direct access to clear and structured repair instructions</li> </ul>	
<p><b>Cognitive and psychological barriers</b></p> <ul style="list-style-type: none"> <li>Uncertainty what type of action will actually solve the problem</li> <li>Not knowing whether repair is allowed</li> <li>Doubt about own capability of repair overall</li> <li>Fear of unsafe situations (e.g., electric shock, injury)</li> <li>Not knowing whether repair affects warranty</li> <li>Perceived excessive time and effort required</li> </ul>	<p><b>Cognitive and psychological needs</b></p> <ul style="list-style-type: none"> <li>Confidence that attempting repair can realistically solve the issue</li> <li>Reminder that repair is an option</li> <li>Perceived self-efficacy in performing the repair</li> <li>Perceived safety during repair</li> <li>Clarity about warranty rights</li> <li>Trust that repair is worth it</li> <li>Low perceived effort</li> </ul>	

Repair Insight	How do I figure out what's broken — and what steps do I need to take to fix it?	
<b>Barriers</b>	<b>Consumer needs for successful repair</b>	
<p><b>Practical and functional barriers</b></p> <ul style="list-style-type: none"> <li>No access to the interior components of the product</li> <li>Specialized or proprietary tools needed to open the product</li> <li>Vulnerability of materials to damage at repair-intensive interfaces</li> <li>Fragile internal component structure</li> </ul>	<p><b>Practical and functional needs</b></p> <ul style="list-style-type: none"> <li>Access to the interior components of the product within a few easy steps</li> <li>Only commonly available tools needed to open the product</li> <li>Robustness of components and materials subjected to repair actions.</li> <li>Forgiving component structure for fault diagnosis</li> </ul>	
<p><b>Cognitive and psychological barriers</b></p> <ul style="list-style-type: none"> <li>Uncertainty about what holds the product together</li> <li>Fear of breaking the product</li> <li>Doubt about own capability of fault diagnosis</li> <li>Not understanding the function of components</li> <li>Not knowing how to operate the required tools</li> </ul>	<p><b>Cognitive and psychological needs</b></p> <ul style="list-style-type: none"> <li>Clarity about the fasteners in the product</li> <li>Clarity about actions required to access components</li> <li>Confidence that they can find the fault</li> <li>Clarity about which components are priority components</li> <li>Feeling capable of using the required tools.</li> </ul>	

**Table 3 (Continued).** Overview of consumer barriers and needs across the DIY repair journey, organized by journey phase and type (practical vs. functional).

Repair Action	What steps should I take to carry out the repair safely, correctly and without errors?	
<b>Barriers</b>	<b>Consumer needs for successful repair</b>	
<p><b>Practical and functional barriers</b></p> <ul style="list-style-type: none"> <li>• Complex (irreversible) dis- and reassembly sequences</li> <li>• Specialized or proprietary tools needed to replace components</li> <li>• Lack of access to spare parts</li> <li>• Exposure to potentially hazardous components</li> <li>• Error-prone repair process</li> </ul>	<p><b>Practical and functional needs</b></p> <ul style="list-style-type: none"> <li>• Structured dis- and reassembly steps</li> <li>• Possible dis- and reassembly with only commonly available tools</li> <li>• Direct availability of spare parts</li> <li>• Protection from hazardous components during repair</li> <li>• Protection from user-errors during repair</li> </ul>	
<p><b>Cognitive and psychological barriers</b></p> <ul style="list-style-type: none"> <li>• Unclear dis- and reassembly sequences</li> <li>• Unclear orientation of components</li> <li>• Lack of feedback about repair actions</li> </ul>	<p><b>Cognitive and psychological needs</b></p> <ul style="list-style-type: none"> <li>• Clarity about repair process sequences</li> <li>• Clarity on correct orientation of components</li> <li>• Progressive validation</li> </ul>	

designed for through isolated product features.

Importantly, these two categories of needs are closely interrelated. By addressing instrumental needs, designers can indirectly influence experiential needs. For example, when a product clearly communicates how it should be opened or handled, users are more likely to feel capable and confident in their actions.

### 5.3.2. Affordances as enablers of physical repair action

Dangal et al. (2022) present design principles for physical durability, diagnosis, maintenance, and repair, identifying key design aspects that influence product repairability. Table 4 below presents the design principles they identified for the repairability of electrical and electronic equipment (EEE), together with their definitions and relevance to repair. These principles have been adapted to the context of small household consumer electronics and DIY repair, and filtered to align with the practical and functional needs identified previously.

The identified design principles describe structural properties that make repair technically possible. At the interaction level, these structural properties manifest as repair affordances; action possibilities

that the product offers, such as opening the enclosure, separating modules, replacing components, or reassembling the product to its original configuration. In this framing, affordances refer to the physical opportunities for repair embedded in the product’s material and architectural configuration.

### 5.3.3. Signifiers as reducers of cognitive uncertainty

Where repair affordances define the physical action possibilities embedded in a product’s architecture, repair signifiers reduce cognitive barriers by signalling how those possibilities can be actualized. Repair signifiers are perceivable cues, such as markings, visual contrasts, labels, alignment indicators, or instructional prompts, that communicate the presence, location, and sequence of repair actions. They function as reducers of cognitive uncertainty, supporting users in understanding how to access, manipulate, and restore components. In this way, signifiers mediate between technical repairability and user comprehension, enabling the effective enactment of repair affordances.

## **5.4. Extending repair design principles to cognitive and psychological needs**

The design principles proposed by Dangal et al. (2022) primarily address the structural and technical conditions that make repair possible. However, they do not explicitly account for how users comprehend the repair opportunities. While structural repairability is necessary, it is not sufficient to ensure that consumers are able or willing to perform repair actions. The cognitive and psychological needs identified previously therefore require explicit translation into complementary design principles.

To address this gap, the following chapter introduces a set of design principles aimed at supporting user comprehension, reducing uncertainty, and strengthening self-efficacy during repair. These principles build upon structural repairability by focusing on how repair actions are communicated, guided, and cognitively supported within the product-user interaction.

**Table 4.** Design principles for reparability of electrical and electronic equipment (EEE), adapted from Dangal et al. (2022) to the context of small household consumer electronics and DIY repair.

Design Principles	Definition and how it relates to repair
<b>Disassembly</b>	The product is taken apart such that it could subsequently be reassembled and made operational. Required to access components for most repairs.
<b>Reassembly</b>	Assembling a product after disassembly, to its original configuration. Required to return a product to operation.
<b>Modularity</b>	Modularity refers to the way in which a product design is decomposed into different modules. A module can consist of one or more components. Modules can be separated from the rest of the product; they can be isolated as self-contained, semi-autonomous chunks; and they can be recombined with other components. The degree of modularity needs to be balanced for product reparability; big modules (bundling) could decrease disassembly time, however would make spare parts expensive and vice versa.
<b>Ease of Handling</b>	Features such as small size, low centre of gravity, & handle promote handling of the product. Facilitates disassembly process during product manipulation.
<b>Interchangeability</b>	Assuring components can be replaced in the field with no physical rework required for achieving a physical fit. Allows for component testing & facilitates component replacement. Interchangeability of components is required for the replacement of the component.
<b>Robustness</b>	Selecting designs that are robust. Assures products do not break during repair, increases confidence during disassembly.
<b>Redundancy*</b>	Providing an excess of functionality and/or material in products or parts. Allows removal of material as part of a recovery intervention. Functional redundancy assists fault location and isolation.
<b>Keying</b>	Providing “keyed” slots so that parts could only fit in one direction. Assists in correct reassembly of the product. Increases reassembly time and decreases post-repair safety hazards.
<b>Standard parts and interface</b>	Enforcing “the conformance of commonly used parts and assemblies to generally accepted design standards for configuration, dimensional tolerances, performance ratings and other functional design attributes”. Standardization reduces spare part costs, tooling, component identification complexity, and skill level required, and increases interchangeability of components during maintenance and repair.
<b>Accessibility of Information</b>	Accessibility of Information to the user and repairers. Whilst this is not directly a design element, manuals and labels are provided with the product. Guides repair process.
<b>Health and Safety</b>	Health and Safety risk to the user during and after repair. Features minimizing safety risks also increases confidence in product disassembly and reassembly.

\* Redundancy = the inclusion of extra components which are not strictly necessary for normal operations, but act as backups.

## 5.5. Chapter 5 Takeaways

**RO4 Exploring how affordances and signifiers can be strategically applied to reduce barriers throughout the DIY repair journey.**

### Q4.1 How can affordances reduce practical and functional barriers in the repair process?

Affordances reduce practical and functional barriers by embedding physical repair possibilities and safety constraints directly into the product's architecture. When a product affords reversible disassembly, modular separation, accessible fasteners, standardized components, non-destructive reassembly, and safe repair, it makes DIY repair technically possible. In this sense, repair affordances address barriers related to access, tool compatibility, sequencing complexity, perceived safety, and material constraints by structurally enabling feasible repair actions and constraining unsafe actions.

Repair affordances should address specific consumer needs, such as enabling enclosure opening through intuitive actions recognizable from everyday practice, isolating hazardous components from direct contact, or making component orientation error-proof. These affordances reduce the practical and effort-related threshold of repair by minimizing required force, lowering cognitive load, and supporting safe operation.

Affordances therefore form the structural foundation of repairability: without them, repair remains technically impossible, or unnecessarily effortful, regardless of how clearly it is communicated.

### Q4.2 How can signifiers reduce cognitive and psychological barriers in the repair process?

Signifiers reduce cognitive and psychological barriers by making repair affordances perceivable, interpretable, and trustworthy. While affordances define what can be done, signifiers communicate where, how, and in which sequence actions should be performed. Through markings, visual hierarchies, alignment cues, labels, colour contrasts, or tactile indicators, signifiers reduce uncertainty and guide attention toward relevant components.

Cognitive barriers such as confusion, ambiguity, and high mental load are reduced when products clearly indicate opening points, tool types, disassembly order, and safe handling zones. Psychological barriers such as fear of damage, perceived risk, and low self-efficacy are reduced when repair actions are visibly framed as legitimate, structured, and supported. By clarifying which actions are intended and safe, signifiers transform repair from an intimidating exploration into a guided process.

Crucially, signifiers mediate between structural repairability and user comprehension. A technically repairable product may still appear sealed, complex, or risky if its repair affordances are not perceptually accessible. Well-designed repair signifiers translate the embedded "technical language" of the product into cues that can be understood across varying levels of experience. In doing so, they reduce ambiguity, strengthen confidence, and increase the likelihood that users will act upon the available repair affordances.

This suggests that affordances and signifiers play an indirect yet crucial role in reducing psychological barriers to repair: while they primarily address instrumental needs, they help create the conditions under which positive experiential outcomes, such as confidence and trust, can emerge.



# Design Principles for Easy DIY Repair

RO4

Exploring how affordances and signifiers can be strategically applied to reduce barriers throughout the DIY repair journey.

Q4.3 How can affordances and signifiers be integrated within product embodiment to guide, reassure, and structure the repair journey?

# 6. Design Principles for Easy DIY Repair

This chapter approaches repairability as an integrated design challenge, translating insights from stakeholder needs and consumer barriers to DIY repair into concrete product design requirements. These requirements establish a foundation for creating products that not only can be repaired, but actively support and guide users throughout the repair process. Building on this foundation, they are further translated into design principles that focus on the use of affordances and signifiers to shape DIY repair interactions, providing designers with a practical framework for designing repairable products.

it is also important to consider the needs and wishes of the other stakeholders and the context of DIY repair. After all, designing for repairability involves navigating a fundamental trade-off between ease of repair, cost, feasibility, and sustainability.

Drawing from the stakeholder needs and wishes defined in Chapter 3 (The Context of DIY Repair), and the additional consumer needs defined in Chapter 5 (Affordances and Signifiers in the DIY Repair Journey), the requirements for easy DIY repair are listed in Table 5.

## 6.1. Product design requirements for easy DIY repair

In defining the design requirements for easy DIY repair, it is important to take the consumer into account, but

These requirements are further elaborated on in Appendix E - Design Requirements for Easy DIY Repair.

Table 5. Requirements for Easy DIY Repair. (Table continues on next page)

### 1. Technical & Structural Requirements

Focus: How the product is physically built.

	Requirement Description	Stakeholder link
TR-01	<b>Standardized Fasteners:</b> All internal fasteners must be reachable with standard tools. Use a maximum of 2 unique, non-proprietary screw types (e.g., Phillips #2 or Torx T10). No permanent adhesives/welding for access.	Engineers, Consumers, Professional & Community Repairers
TR-02	<b>Priority Components:</b> Organize modules so the repair sequence is logical; components that fail most often should be accessible first.	Designer, Professional Repairers, Suppliers, Consumers
TR-03	<b>Modular Architecture:</b> Critical failure components (motors, fuses, batteries) must be separate modules.	Designer, Professional Repairers, Suppliers, Consumers
TR-04	<b>Diagnostic Hierarchy:</b> The internal layout should reflect a diagnostic hierarchy. Components that are easy to test (like fuses) should have a high visual hierarchy upon opening, allowing for a 'quick win' that builds the user's confidence early in the process.	Designer, Professional Repairers, Suppliers, Consumers

Table 5 (Continued). Requirements for Easy DIY Repair. (Table continues on next page)

TR-05	<b>Standardized Components:</b> Use “off-the-shelf” parts (O-rings, bearings, switches) that are common across the industry to ensure long-term availability.	Suppliers, Engineers, Professional & Community Repairers
TR-06	<b>Ergonomic Clearance:</b> Provide enough physical clearance around fasteners so that the user’s hand and tool have a clear line of sight and room to move. This ensures the user feels physically capable and in control.	Suppliers, Engineers, Professional & Community Repairers

## 2. Human-Centric & Educational Requirements

Focus: Combatting “fixophobia” and ensuring user safety.

	Requirement Description	Stakeholder link
HR-01	<b>Visual Signifiers:</b> The product must use signifiers such as icons or colour-coding (e.g., “blue means unscrew”) to guide the user through the opening process.	Designers, Consumers
HR-02	<b>Fail-Safe Disassembly:</b> The design must prevent “unintentional damage” during opening (e.g., no hidden plastic clips that snap if pulled the wrong way).	Community Repairers, Consumers
HR-03	<b>Fail-Safe Reassembly:</b> The design must prevent incorrect reassembly by using physical constraints (e.g., asymmetrical geometry, keyed connections) and must communicate the intended assembly actions through intuitive physical affordances.	Community Repairers, Consumers
HR-04	<b>Inherent Safety:</b> High-voltage areas must be shielded or automatically discharged upon opening the outer casing to prevent shock.	Policy Makers, Consumers
HR-05	<b>On-Device Documentation:</b> A permanent link (QR code, NFC chip) must be visible on the product, linking directly to free, interactive, multi-language repair guides.	NGOs, Repair Platforms
HR-06	<b>Intended repair:</b> The aesthetic design should signal that opening the device is an intended, legitimate behaviour, removing the visual ‘fear’ of tampering.	Manufacturers, Brands
HR-07	<b>Feedback:</b> The design should incorporate ‘active feedback’ (e.g., an audible ‘click’ or a visible alignment tab) that confirms a component is correctly seated.	Community Repairers, Consumers

Table 5 (Continued). Requirements for Easy DIY Repair.

### 3. Economic & Manufacturing Requirements

Focus: Keeping the product viable for the brand and the buyer.

	Requirement Description	Stakeholder link
ER-01	<b>Production Efficiency:</b> The product architecture must prioritise reversible fastening methods that are compatible with high-speed automated assembly lines.	Engineers, Manufacturers, Consumers
ER-02	<b>Recycling :</b> The product architecture must prioritize reversible fastening methods that comply with design for recycling.	Engineers, Manufacturers
ER-03	<b>Cost-to-Repair Ratio:</b> The retail price of common spare parts must not exceed 20% of the original product’s MSRP to ensure repair is “worth it” (Right to Repair Europe, 2024).	Consumers, Professional & Community Repairers, Suppliers
ER-04	<b>BOM Impact:</b> Design interventions for repairability must not increase the Bill of Materials (BOM) cost by more than 5% compared to the baseline.	Manufacturers, Brands

### 4. Regulatory & Brand Requirements

Focus: Compliance and market positioning.

	Requirement Description	Stakeholder link
RR-01	<b>Repair score:</b> The design must meet or exceed the minimum repairability score required by EU/national legislation for its category, and display it on the product.	Policy Makers, Manufacturers, Vendors
RR-02	<b>Warranty Transparency:</b> The product must clearly define “user-serviceable” zones that do not void the overall warranty if opened.	Consumers, Vendors
RR-03	<b>Brand Aesthetic Integrity:</b> Repair features (screws, seams) must be integrated into the visual language so they don’t compromise the “premium” feel.	Manufacturers, Brands

## 6.2. Product design principles for easy DIY repair

While the requirements define what a repairable product must achieve, they do not specify how designers can realise these qualities in practice. The following design principles on page 64 translate these requirements into actionable strategies, focusing on the use of affordances and signifiers to shape DIY repair interactions. These principles for Easy DIY Repair are additional to the design principles for repairability of EEE that Dungal et al. (2022) proposed (Table 4 on page 54).

Because products differ in function, architecture, aesthetics, and design intent, the way repairability is implemented will vary. Rather than prescribing fixed solutions, these principles provide a flexible framework that can be interpreted and applied by designers across different contexts.

In Chapter 2 (Affordances and Signifiers in Product Design), eight types of signifiers were defined: visual, physical, auditory, haptic, spatial, temporal, textual/symbolic, and social/learned. To support application in practice, each principle is illustrated with examples of how specific affordances and signifiers can be used to shape the product. Each principle highlights the signifier types that are most relevant to its implementation, indicated through the accompanying icons.

The principles are further contextualised through three case studies: an electric shaver, a hairdryer, and a coffee machine. These products were selected to represent a range of product architectures and use contexts within small household electrical appliances. The shaver is battery-powered, whereas the hairdryer and coffee machine operate via a power cord. In addition, the coffee machine includes surfaces that are not visible during regular use (back and bottom sides), unlike the other two products. Together, these differences provide a broad basis for demonstrating

how the principles can be operationalised across varying design conditions.

Together, the principles and examples provide designers with both a conceptual framework and practical guidance for designing products for easy DIY repair.

## 6.3. Concepts used in the design principles

In the proposed principles, several new and existing concepts are introduced that may require clarification.

The following paragraphs provide a more detailed explanation of these concepts.

### 6.3.1. Easy-to-Repair Score

In 2021, the French government introduced a mandatory repairability scoring system for ten categories of electrical products: wired vacuum cleaners, cordless vacuum cleaners, robot vacuum cleaners, household dishwashers, high-pressure cleaners, multifunction mobile phones (smartphones), corded electric lawnmowers, battery-powered electric lawnmowers, robotic electric mowers, and laptops.

French sellers within these product categories are required to display the repairability score of the device either on their website or on the product label in-store. The French Repairability Index defines five categories of criteria on which the score is based:

- Length of time documentation is available;
- Dismountability of the equipment;
- Availability period of spare parts;
- Relationship between the selling price of spare parts and the sale price of the equipment;
- Product category-specific criteria.

For each sub-criterion, the score is calculated as follows:



Figure 18. French Repairability Index scores (iFixit, 2025).

Score for the sub-criterion = (number of points obtained / maximum number of points for that criterion) × 10.

The overall repairability index is calculated by summing all sub-scores and dividing the total by 10.

If we examine the categories of corded and cordless vacuum cleaners (arguably the closest category to small household consumer electronics), we see that the product category-specific criterion (criterion 5) is “free remote assistance.” This criterion is subdivided into “up-to-date information available on-site” for repairers, and “remote information,” “remote diagnostic assistance,” and “remote repair assistance” for consumers.

Notably, there is no specific criterion addressing how the product itself communicates its repairability to the user.

The French Repairability Index could be extended to incorporate the ease of repair for consumers based on these principles. In addition to the existing criteria, an additional sub-criterion could be introduced under “product assistance,” in which the product is evaluated on the presence of six principles that support easy DIY repair.

However, even if the general repairability score were



**Figure 19.** Easy-to-repair score, based on the quality of repair related signifiers integrated into the product.

placed on a component, this would not directly indicate how easy the DIY repair process is for inexperienced consumers, since this aspect would represent only a small portion of the overall score.

Therefore, introducing a separate “ease-of-repair” score, based specifically on the quality of repair-related signifiers integrated into the product, could help inexperienced consumers better align their perceived self-efficacy with the actual ease of performing a repair, see Figure 19.

### 6.3.2. The Digital Product Passport

The Digital Product Passport (DPP) is an initiative of the Ecodesign for Sustainable Products Regulation of the European Union. By providing comprehensive information about each product’s origin, environmental impact, materials, and disposal recommendations, it aims to enhance transparency across the product value chains. The DPP will include essential details for repair such as a unique product identifier, user manuals, and safety instructions (Publications Office of the European Union, 2024).

The DPP has the opportunity to also play an important role in DIY repair. The DPP can be found by scanning the QR code displayed on the product. The DPP includes specific repair information for that product, such as replacement steps for each component, information on spare parts availability, and details of the product’s warranty coverage, including any applicable terms and conditions, see Figure 20.

By providing a direct link to the DPP on the product in the form of a QR code or NFC chip, the user does not have to search for the manual in a cupboard or on an online platform. The QR code or NFC chip should be visible within the maintenance range of the product, meaning the consumer should be able to easily spot the link during regular maintenance tasks.

### 6.3.3. Repair Layers

Safety concerns and warranty control are significant obstacles for companies when designing product interiors to be accessible. To find a balance between accessibility, safety, and warranty protection, products could be designed with distinct repair layers.

These repair layers can be understood as separate interaction spaces within the product, physically divided by barriers. As the repair layer increases, the repair actions become more complex and potentially more hazardous. For example:

#### R1 – Repair Layer 1

This layer is intended for inexperienced repairers. It provides guided access to testing and replacing priority components. All hazardous components are shielded from direct contact.

#### R2 – Repair Layer 2

This layer is intended for more experienced repairers. It provides direct access to the PCB and other non-priority components. In this layer, the repairer assumes greater responsibility and risk, as there is less guidance and reduced protection from potentially dangerous components.

The barriers between repair layers function as deliberate affordances: they require an intentional action to open but do not require specialised tools or professional skills. In principle, the entire product remains accessible. However, the separation into layers allows consumers to operate within the layer they feel comfortable with, while still maintaining the possibility of deeper access.

Designing with repair layers also enables companies to retain partial control over warranty conditions. For example, a warranty policy could state:

- Accessing R1 does not void the warranty.
- Accessing R2 voids the warranty for consumers.
- R2 may be accessed by certified professional repairers without affecting warranty validity.



Figure 20. Digital Product Passport.

Consumers can find detailed information about repair layers and warranty conditions in the Digital Product Passport (DPP).

Warranty coverage is often voided when consumers open or modify a product because manufacturers can no longer verify whether a defect results from a manufacturing fault or from consumer interference. To address this issue, an optional digital repair check could be introduced.

#### 6.3.4. Digital Repair Check

The digital repair check would allow the manufacturer to verify:

- Which repair layer has been accessed;
- Whether the performed actions fall within warranty conditions;
- Whether components are correctly installed.

If the repair is successfully validated through the digital check, the consumer can demonstrate in the event of a future malfunction that the defect was not caused by improper repair. In this way, warranty coverage can be preserved.

The repair check is optional; however, warranty preservation after self-repair is conditional upon completing the repair check.

To maintain warranty validity, the manufacturer would require the following verification through the digital repair check:

- Confirmation that warranty-sensitive repair layers were not accessed;
- Confirmation that approved spare parts (as specified in the DPP) were used;
- Confirmation that components are correctly installed;
- Confirmation that all safety mechanisms (e.g., fuses) remain intact;
- Confirmation that uploaded images correspond to the specific product and were taken in real time.

To determine which repair layer has been accessed, the fasteners separating the layers could include visual and tamper-evident markers. Opening these fasteners would provide visible indication that a

higher repair layer has been entered, see Figure 21. These tamper-evident markers are not replaceable by consumers but could be replaced by certified professional repairers. In this way, warranty coverage can remain valid after repair, provided that the intervention was carried out by a certified professional. If a consumer opens a higher repair layer and cannot restore the tamper-evident markers, this serves as verifiable evidence that the product has been accessed beyond the warranty-permitted layer.

In addition, components that remain covered under warranty should include indicators that allow verification of correct placement and installation.

The digital repair check could be integrated into the DPP and partially supported by Artificial Intelligence (AI). After completing a repair, but before fully reassembling the product, the consumer could initiate the repair check via the DPP. As part of the process, real-time photographs would be taken as verification. The AI system would guide the user in taking appropriate images and perform an initial assessment to determine whether the repair appears to have been completed correctly.

Once validated, the repairer can reassemble the product and continue using it while retaining warranty coverage.

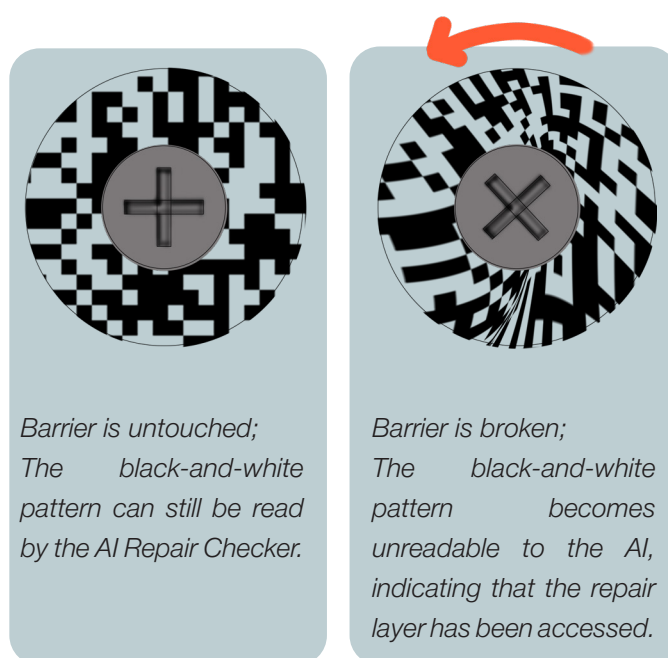



Figure 21. Barrier markers.

# Design for Easy DIY Repair

Six principles for empowering consumers to repair their own products

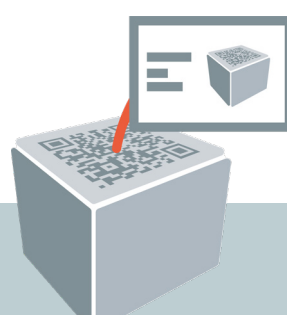
**01**



### Make Repairability Explicit

Use visual, physical, textual, and symbolic signifiers to clearly communicate that the product is intended to be opened and repaired, legitimising repair as a visible and supported action.

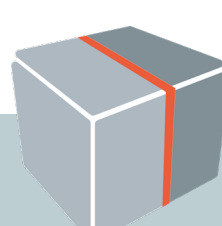
**02**



### Bridge to Digital Support

Place contextual visual and spatial signifiers at key interaction points to seamlessly connect physical actions to relevant digital repair guidance.

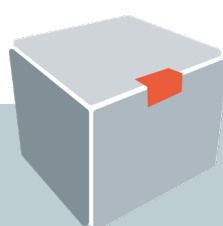
**03**



### Define Repair Boundaries

Use visual, spatial, and physical signifiers to clearly distinguish between user-serviceable and restricted areas, reducing ambiguity and guiding safe interaction.

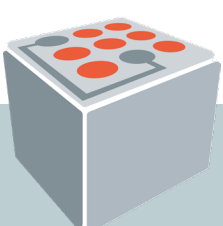
**04**



### Speak the Intended Action

Design physical affordances supported by visual and haptic signifiers so the intended action is immediately understandable through form, geometry, and touch.

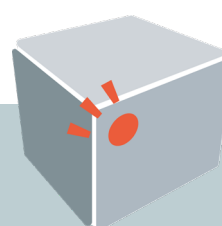
**05**



### Structure the Product Architecture








Use spatial signifiers to organize components and fasteners in a way that communicates hierarchy, relationships, and repair sequence at a glance.

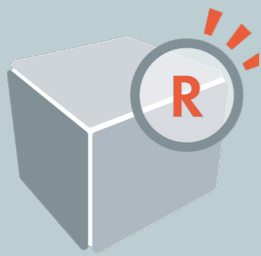
**06**



### Constrain Incorrect and Unsafe Actions

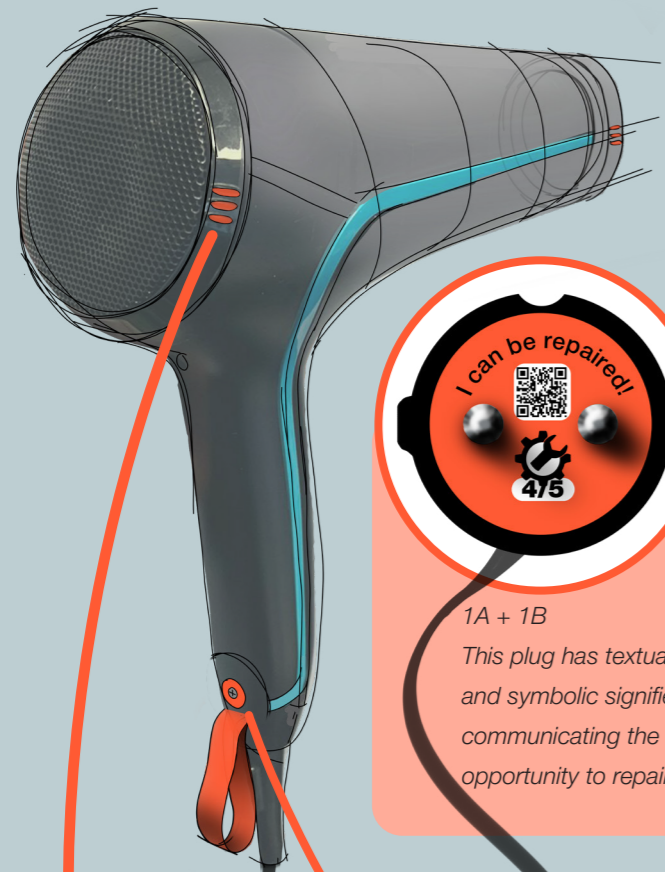
Constrain incorrect interaction through physical affordances and use haptic and auditory feedback to prevent errors and ensure safe repairs.

Types of signifiers applied:  Visual  Physical  Auditory  Textual/symbolic  Spatial  Haptic  Temporal

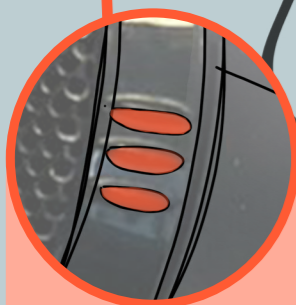


# 1. Make Repairability Explicit

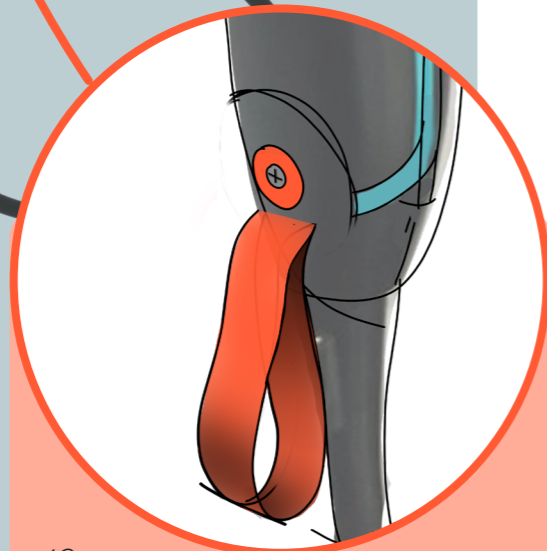
Use visual, physical, textual, and symbolic signifiers to clearly communicate that the product is intended to be opened and repaired, legitimising repair as a visible and supported action.



**1A + 1B**  
This plug has textual and symbolic signifiers communicating the opportunity to repair.



**1C**  
This affordance of turning the protective cover to remove it is highlighted with colour coding and colour contrast signifiers, in addition to the physical signifiers for grip.



**1C**  
This entry point is highlighted by the screw marker and the pull tab. All affordances for repair have the same colour coding.

**Aa**

## 1A - Repair Reminder

Display a subtle but explicit cue (e.g., "Repair me" or a repair icon) on the product in a location visible during routine use or maintenance.

**Aa**

## 1B - Easy-to-Repair Score\*

Include the ease-of-repair score in a frequently visible area, such as near the plug or maintenance access point.



## 1C - Visible Entry Point

Visually highlight entry points to the product interior using the same visual language and hierarchy as primary controls (e.g., power button, maintenance lid), signaling that opening is intentional and supported.

\* The Easy-to-Repair Score is an indication of how easy it is for a consumer to repair the product. More information on page 60.



**1A + 1B**

These subtle repair reminder and easy-to-repair score are visible during product use, without drawing attention away from the product's overall aesthetic.



**1A + 1B**

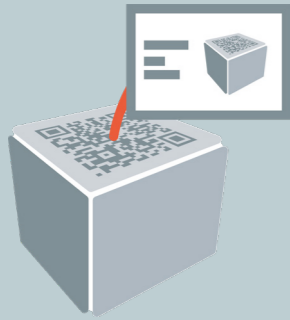
On products, such as a coffee machine, the back sides can display extra repair information, such as a component list or deliberate repair instructions.



**1C**

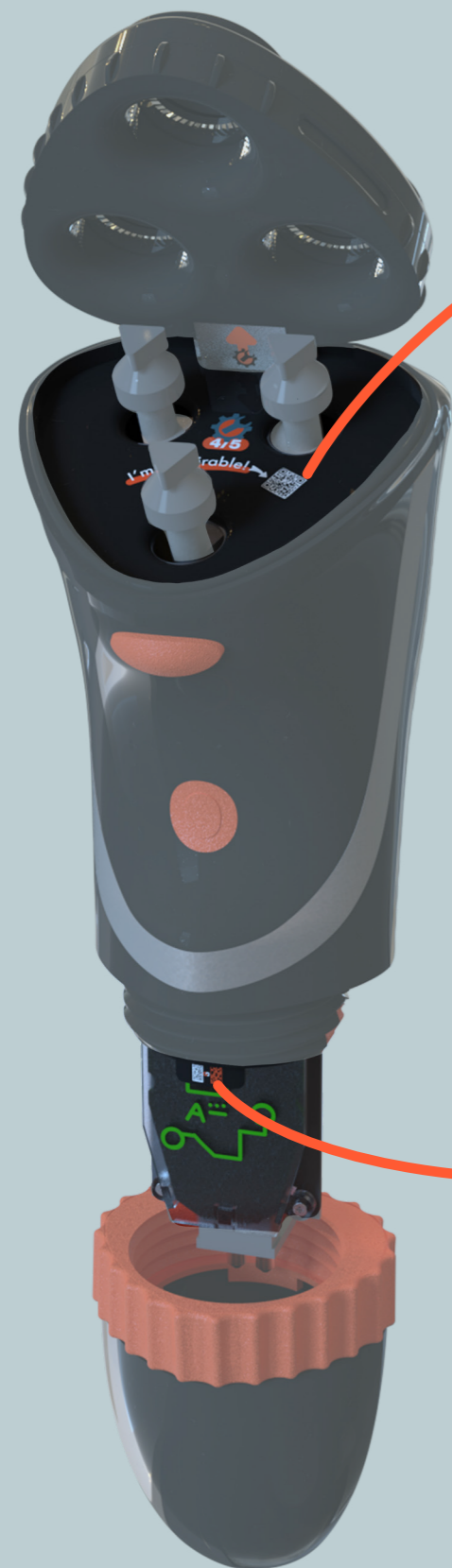
These screw markers highlight the screws and therefore communicate the disassembly potential.





## 2. Bridge to Digital Support

Place contextual visual and spatial signifiers at key interaction points to seamlessly connect physical actions to relevant digital repair guidance.



**2A + 2C**  
The QR code linking to the DPP and DRC is placed under the blades; a place that user see when cleaning the product after each use.



**2B**  
The QR code linking to the fault diagnosis steps is revealed when fault diagnosis is possible, providing access to more information at the right time.



### 2A - Digital Product Passport\* (DPP) Access

Integrate clearly visible scannable markers (QR codes/NFC tags) that link directly to the DPP, positioned in locations naturally accessed during routine use or maintenance.



### 2B- Component-Specific Links

Place scannable markers (QR codes/NFC tags) near priority components that link directly to relevant spare parts, diagnostic steps, and replacement instructions.

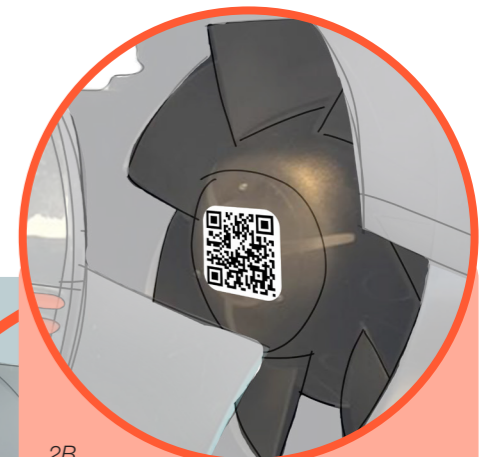
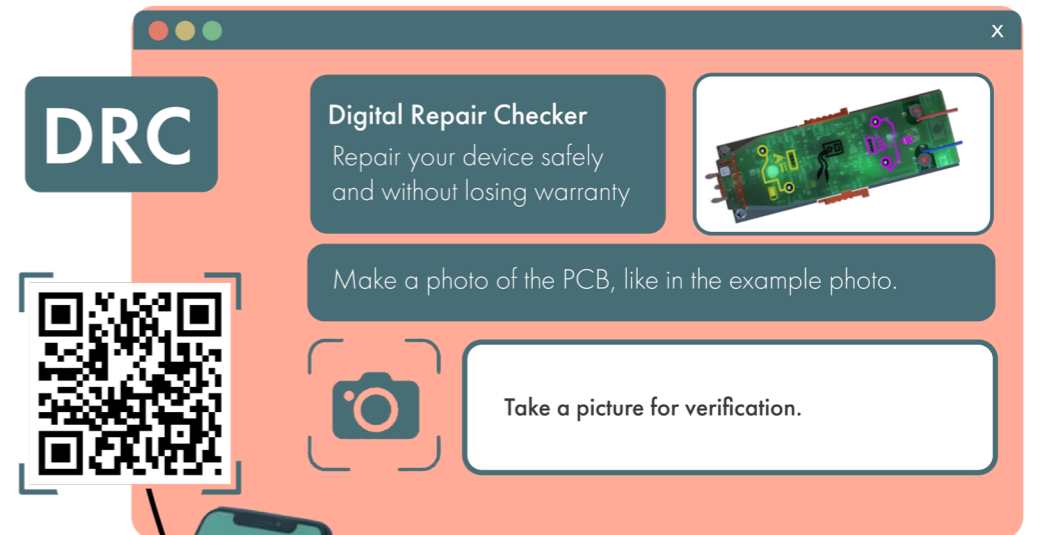


### 2C - Digital Repair Checker (DRC) \*\*

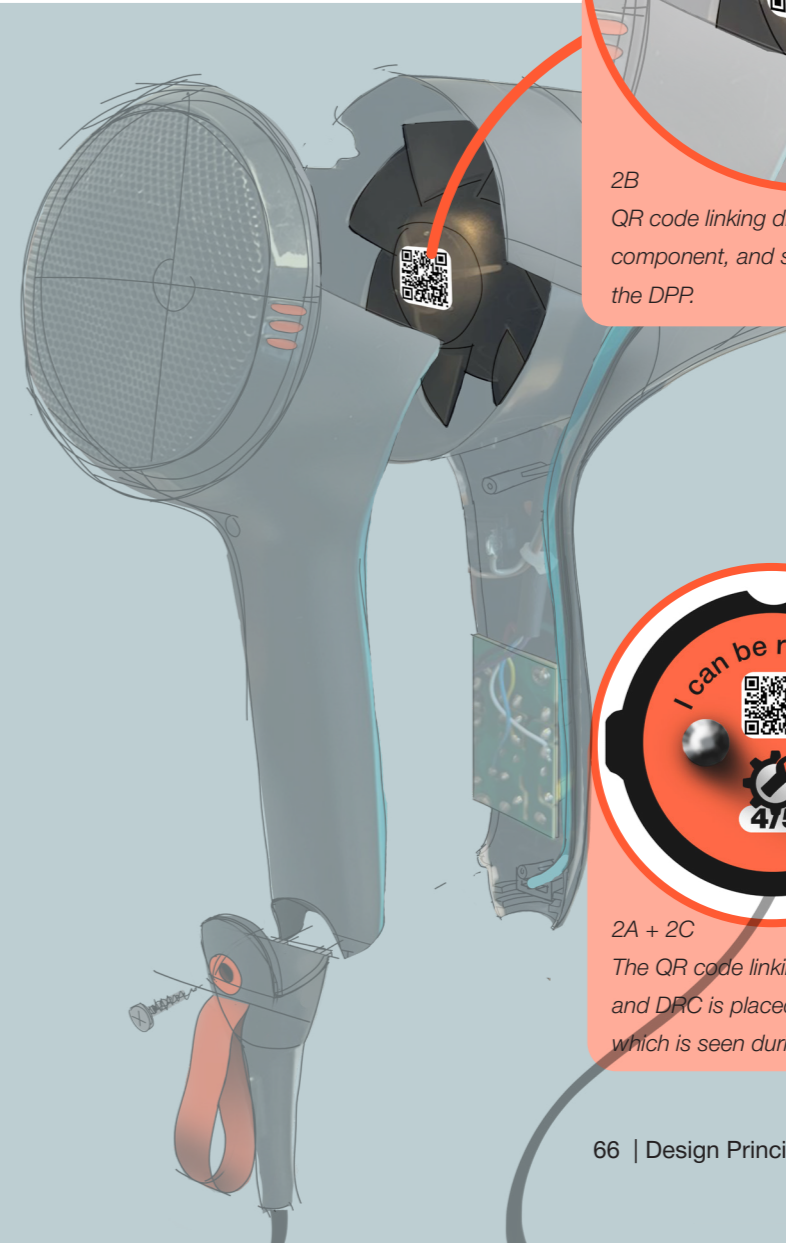
Integrate a link to the optional digital repair checker within the DPP that guides users in validating correct repair execution, verifies the accessed repair layer, and confirms the resulting warranty status.

\* The DPP is an online page with information about the product, see page 61.

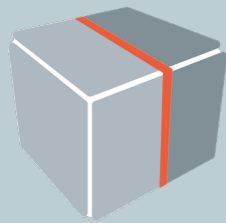
\*\* The DRC is an online tool to check the process during repair, see page 63.



**2B**  
QR code linking directly to the spare component, and specific repair steps in the DPP.



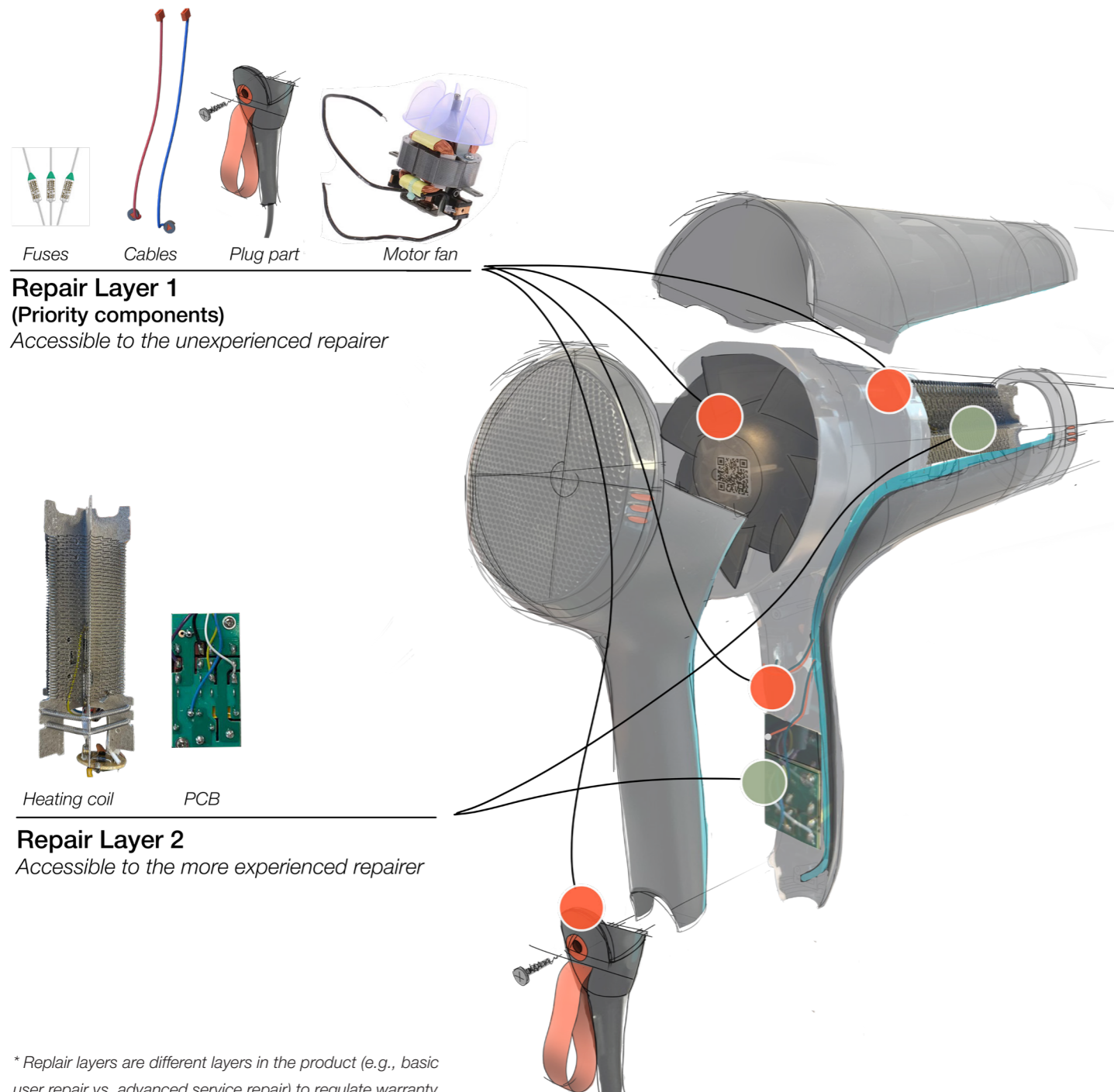
**2A + 2C**  
The QR code linking to the DPP and DRC is placed on the plug, which is seen during every use.



### 3. Define Repair Boundaries

Use visual, spatial, and physical signifiers to clearly distinguish between user-serviceable and restricted areas, reducing ambiguity and guiding safe interaction.

In a hairdryer, the components that most commonly fail are the plug connection, the motor fan, and the fuses. This hairdryer is therefore redesigned to place these components in repair layer 1. Repair layer 2 contains components that are too complex or fragile to be repaired using standard tools available to a typical consumer.



\* Repair layers are different layers in the product (e.g., basic user repair vs. advanced service repair) to regulate warranty and safety conditions. More information about repair layers on page 61.



#### Indicate Repair Layers\*

Indicate the presence of repair layers and the consequences of entering a new repair layer at the beginning of the repair journey.

[Link to more information about the repair layers in the DPP.](#)

Repairers must unscrew the large red ring before accessing the next repair layer. Unlike the orange repair signifiers in repair layer 1, this ring is coloured bright red to signal the transition to a new repair layer. In addition, textual and symbolic signifiers explicitly warn the user about entering a new repair layer and the potential consequences. The repairer can access more direct information via the QR code.



#### Barrier Markers

Use visual and tamper-evident markers on fasteners or access points to indicate the transition to a higher repair layer. These markers should visibly deform when opened, signalling increased responsibility or risk to the repairer and allowing the manufacturer to verify which repair layer has been accessed.

Before repair layer 2 is reached, the barrier marker on top of the red ring displays a distinct black-and-white pattern that can be scanned and verified by an AI system to confirm that it is still intact.

Once repair layer 2 is accessed, the act of turning the red ring deforms the barrier marker due to mechanical strain. As a result, the black-and-white pattern becomes unreadable to the AI, indicating that repair layer 2 has been accessed.

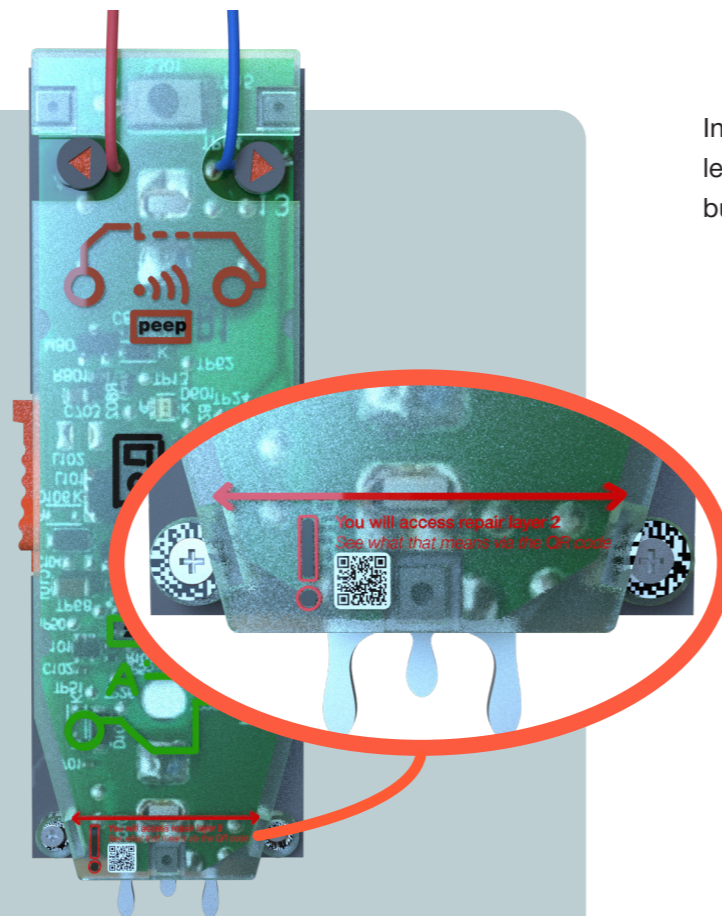




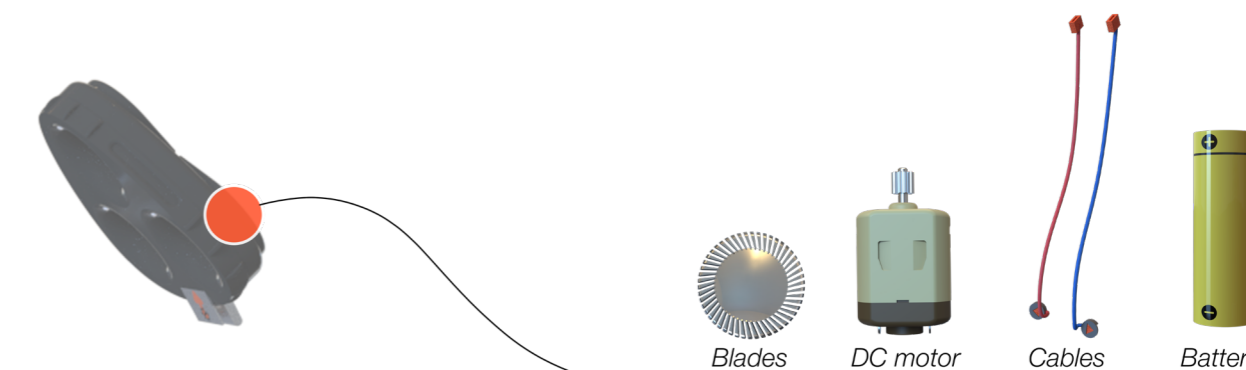
### Indicate Repair Layers

Indicate the presence of repair layers and the consequences of entering a new repair layer near the barrier between the levels, and at the beginning of the repair journey.

Right next to the access point of repair layer 2, there is an additional warning informing the repairer about entry into the next repair layer. It includes a QR code that links directly to more information about how the repair levels work and the consequences for the warranty of this specific product.



In a product without much complex components, such as this electric shaver, most components can be in repair level 1. The PCB, in this specific example, is placed in level 2, as there is not enough space in this product to build a consumer-friendly repair base around the pcb.



### Repair Layer 1 (Priority components)

Accessible to the unexperienced repairer



PCB

### Repair Layer 2

Accessible to the more experienced repairer

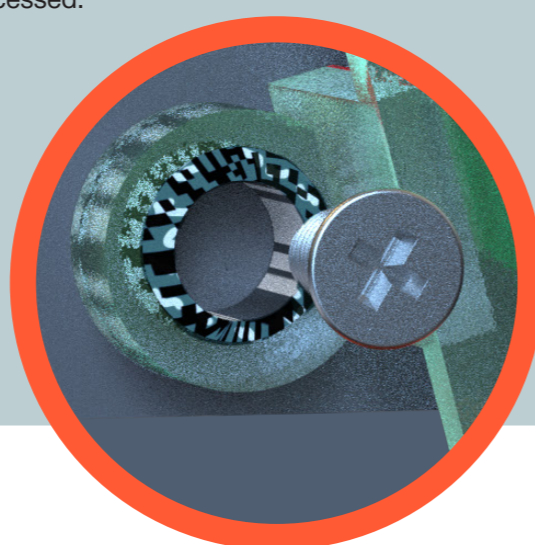
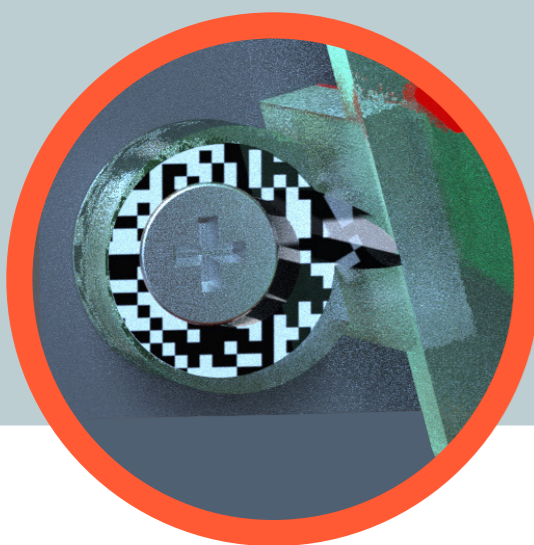


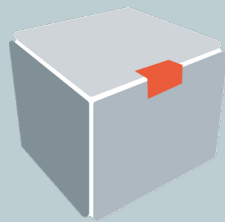
### Barrier Markers

Use visual and tamper-evident markers on fasteners or access points to indicate the transition to a higher repair layer. These markers should visibly deform when opened, signalling increased responsibility or risk to the repairer and allowing the manufacturer to verify which repair layer has been accessed.

Before repair layer 2 is reached, the barrier marker displays a distinct black-and-white pattern that can be scanned and verified by an AI system to confirm that it is still intact.

Once repair layer 2 is accessed, the act of turning the screws deforms the barrier marker due to mechanical strain. As a result, the black-and-white pattern becomes unreadable to the AI, indicating that repair layer 2 has been accessed.





## 4. Speak the Intended Action

Design physical affordances supported by visual and haptic signifiers so that the intended action is immediately understandable through form, geometry, and touch.



### 4A - Haptic Guidance

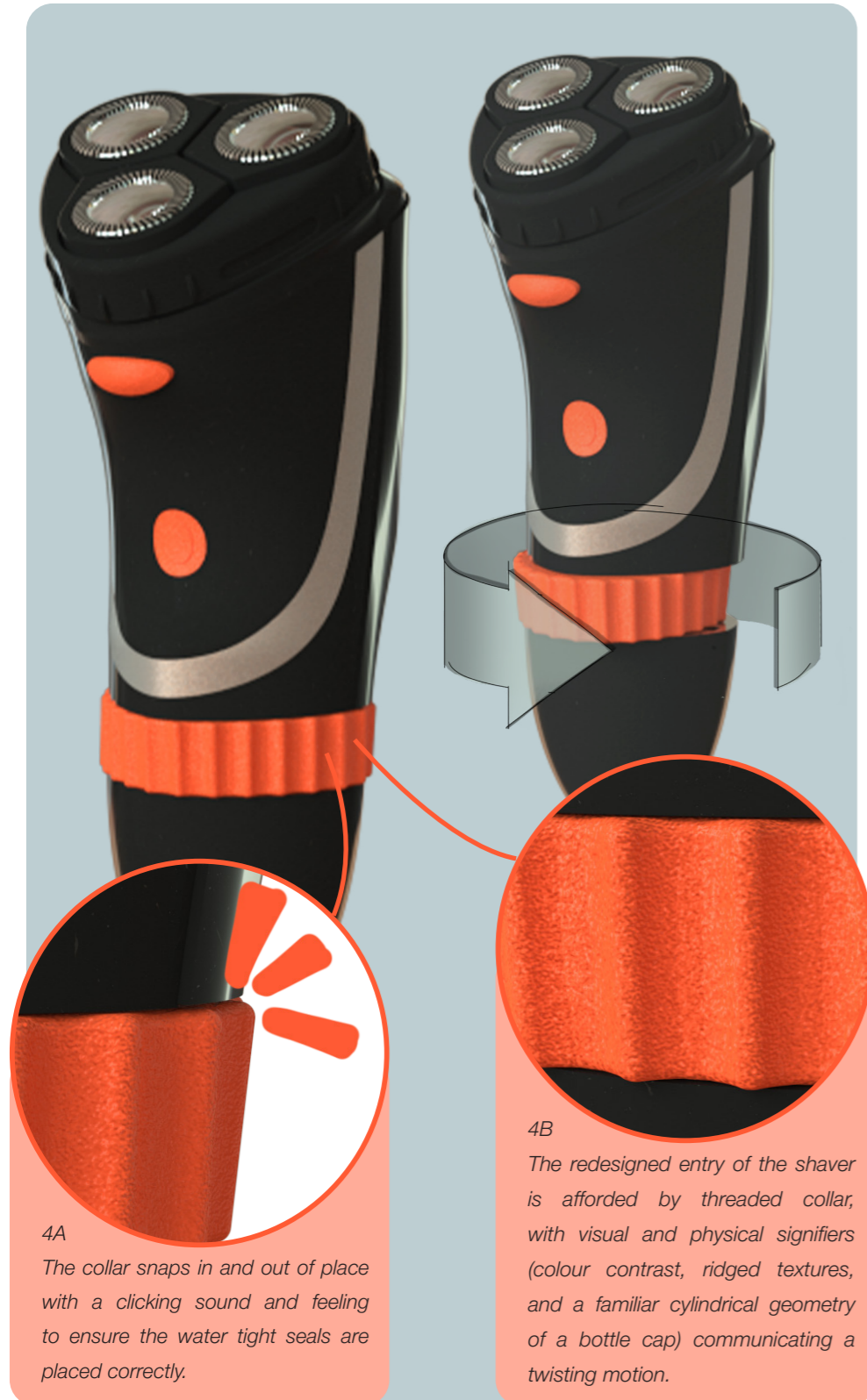
Use auditory and haptic signifiers (e.g., a click at the final turn of a twist, a snap when a component is correctly inserted, or a change in resistance when tightening) to suggest correct mode of operation during an action.



### 4B - Self-Signifying Forms with Familiar Interaction

Use self-signifying affordances with visual and physical signifiers (e.g., textured grip surfaces, recessed finger-pulls, or contoured edges), that suggest their mode of operation, correct hand placement and the mechanical actions required to initiate the action.

Leverage familiar geometries (e.g., radial ridges for twisting, tabs for pulling) that draw on everyday interaction patterns.

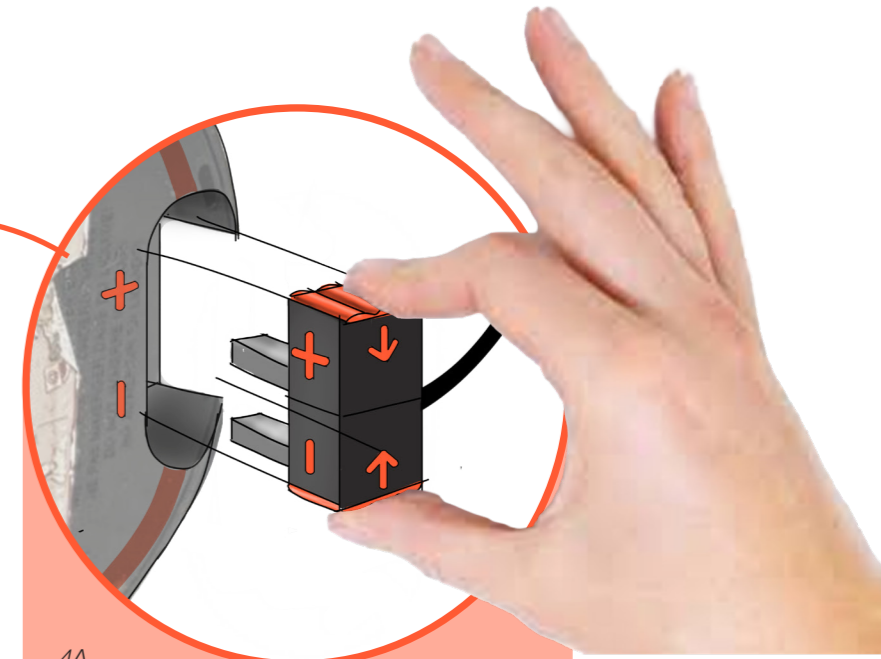


4A  
The collar snaps in and out of place with a clicking sound and feeling to ensure the water tight seals are placed correctly.

4B  
The redesigned entry of the shaver is afforded by threaded collar, with visual and physical signifiers (colour contrast, ridged textures, and a familiar cylindrical geometry of a bottle cap) communicating a twisting motion.

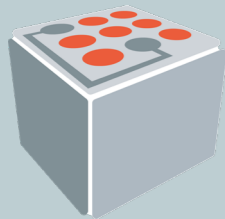


4B  
The affordance of removing the power source is communicated through physical affordances, such as ridges and an ergonomic casing shape that provides just enough space for finger placement. These features act as physical signifiers, suggesting the intended finger placement. Additionally, symbolic signifiers, such as arrows, reinforce that the user should pinch to disassemble the component.



4A  
The part has two clips that click back in place when reassembling.





## 5. Structure the Product Architecture

Use spatial signifiers to organize components and fasteners in a way that communicates hierarchy, relationships, and repair sequence at a glance.



### 5A - Visible Flow Lines

Use spatial signifiers in combination with visual signifiers to indicate functional relationships and flow paths between components.



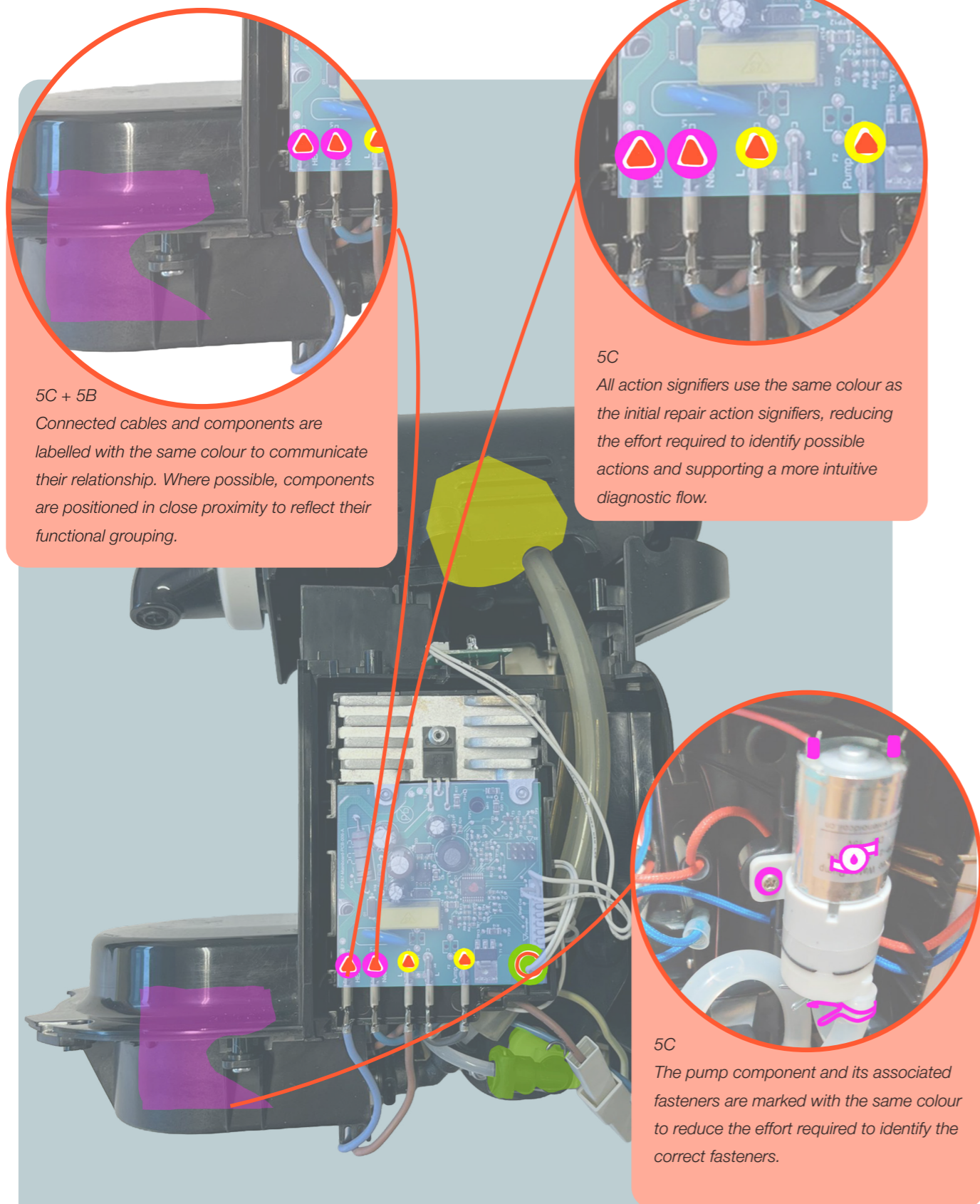
### 5B - Functional Grouping

Group related components and fasteners using visual similarity, proximity, or consistent colour coding, applying Gestalt principles to support intuitive understanding of the product structure.



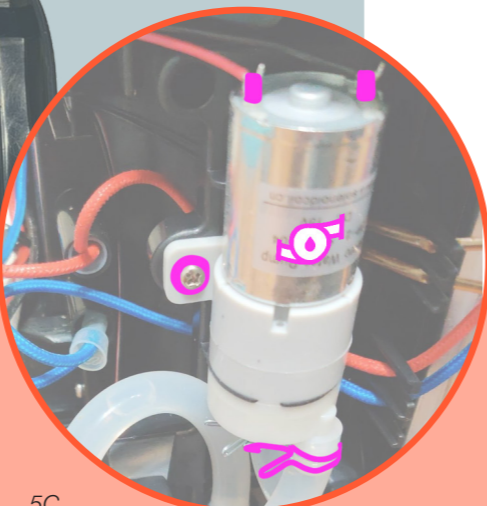
### 5C - Diagnostic Flow

Prioritize components with the highest likelihood of failure early in the disassembly sequence. Structure the product architecture with clear visual and spatial signifiers to support efficient fault diagnosis, ensuring that critical components are easily accessed, tested, and replaced in a logical manner. Complement this with textual or symbolic signifiers that communicate component function and priority, guiding users or technicians toward effective fault identification and intervention.

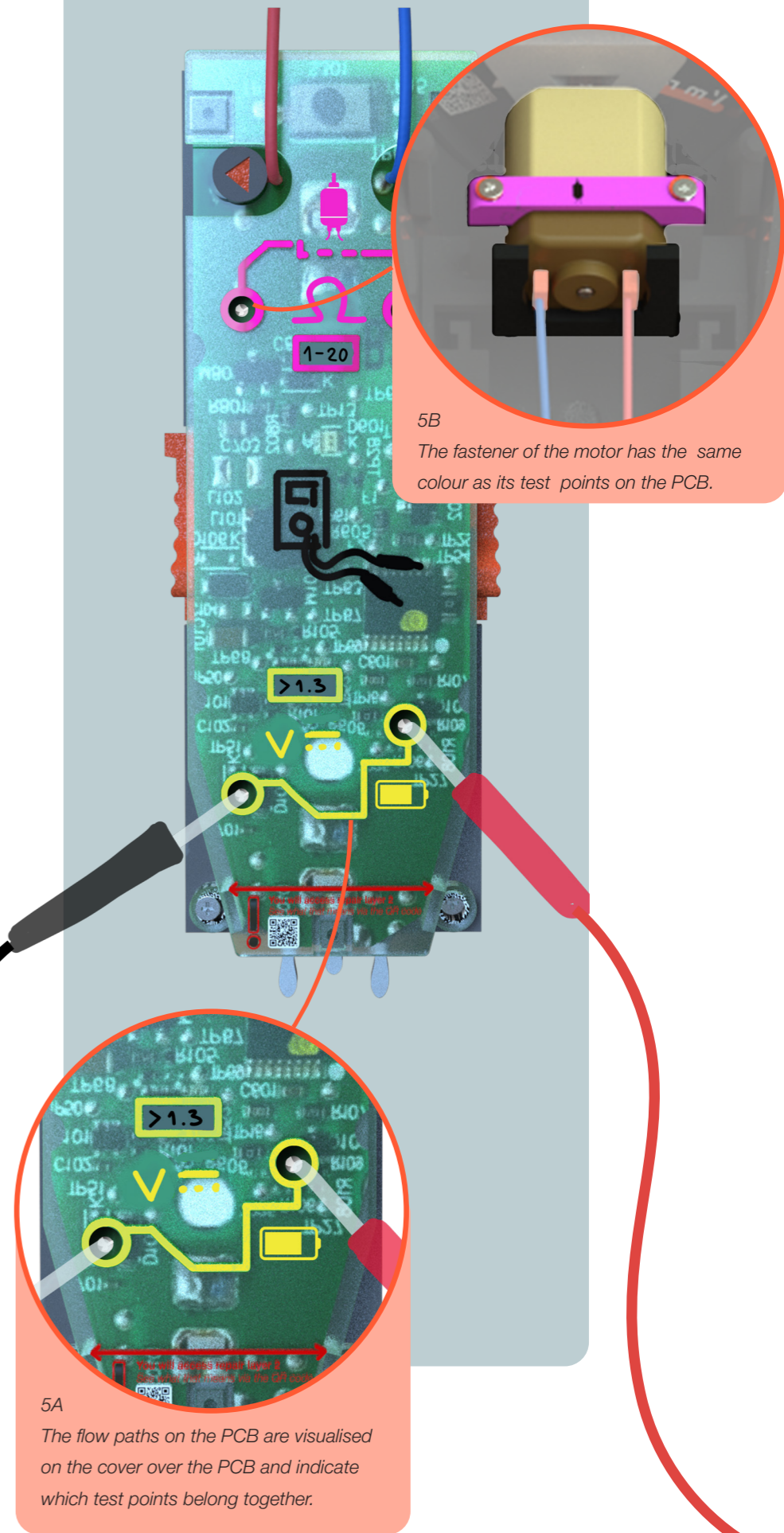


**5C + 5B**  
Connected cables and components are labelled with the same colour to communicate their relationship. Where possible, components are positioned in close proximity to reflect their functional grouping.

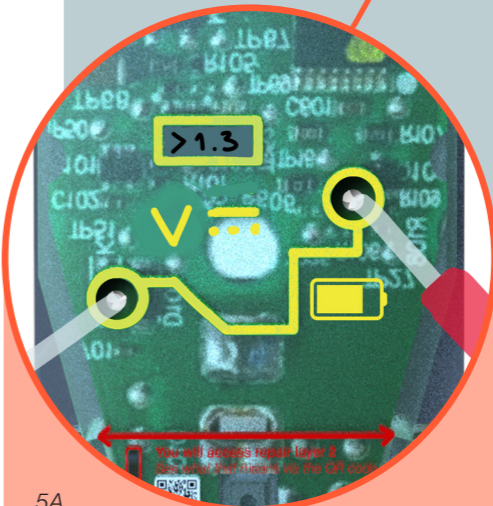
**5C**  
All action signifiers use the same colour as the initial repair action signifiers, reducing the effort required to identify possible actions and supporting a more intuitive diagnostic flow.



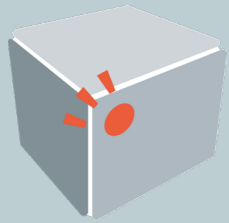
**5C**  
The pump component and its associated fasteners are marked with the same colour to reduce the effort required to identify the correct fasteners.



**5B**  
The fastener of the motor has the same colour as its test points on the PCB.



**5A**  
The flow paths on the PCB are visualised on the cover over the PCB and indicate which test points belong together.



## 6. Prevent Incorrect and Unsafe Actions

Constrain interaction through physical affordances and reinforce correct behaviour with haptic and auditory feedback to prevent errors and ensure safe use.



### 6A - Shield Hazardous Components

Restrict direct access to hazardous components, but enable deliberate access and clearly communicate it through visual signifiers, optionally supported by textual or symbolic signifiers.



### 6B - Error-Preventing Interfaces

Integrate constraining affordances, such as asymmetric geometries and keyed connectors (poka-yoke), together with auditory (e.g., a rattle when turning the wrong way) and temporal signifiers (e.g., a light blinking faster) around standard replaceable components to prevent incorrect placement.

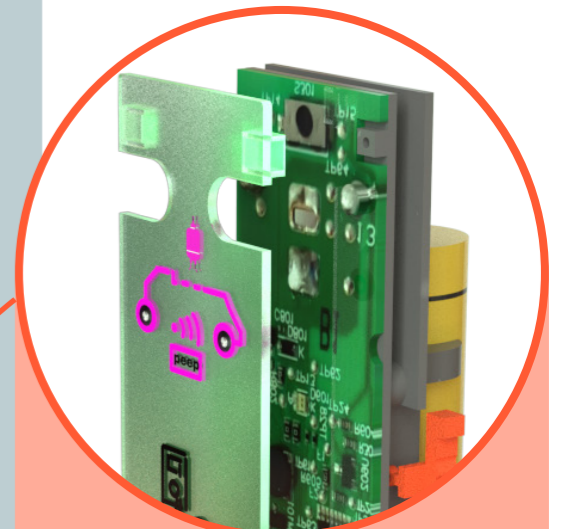


### 6C - Enforced Power-off

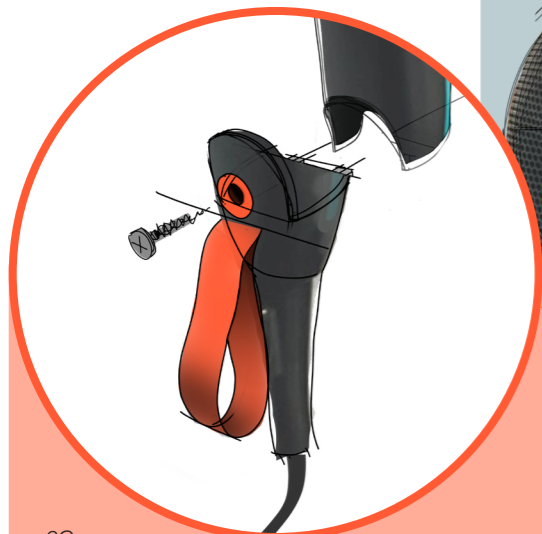
Integrate constraints that prevent access while the product is powered (e.g., forced unplugging), and clearly indicate how to disable these constraints using physical and visual signifiers.



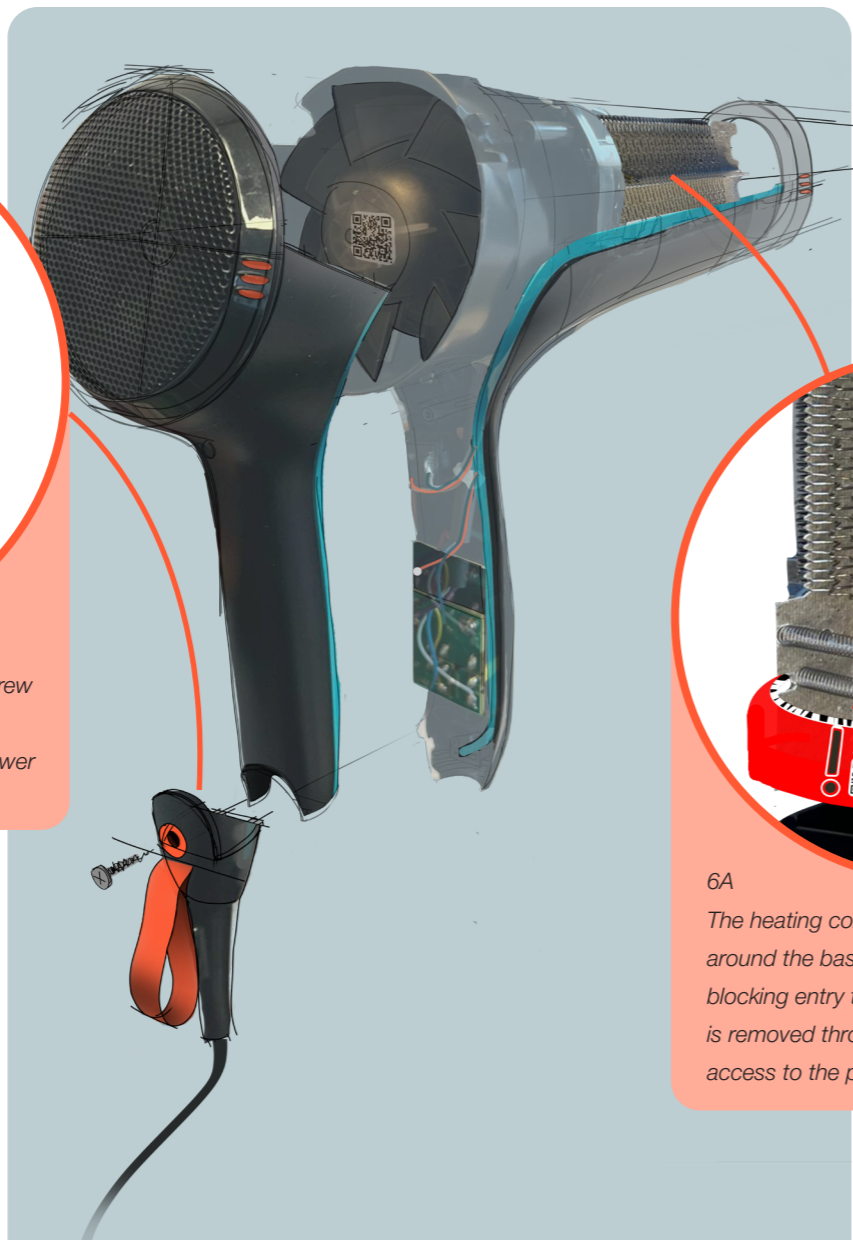
**6B**  
The PCB and battery module can only be inserted in the slider of the upper casing in one way, ensuring correct alignment with the other components. The symbolic signifiers on the upper casing where the module must slide in, communicate the correct placement.



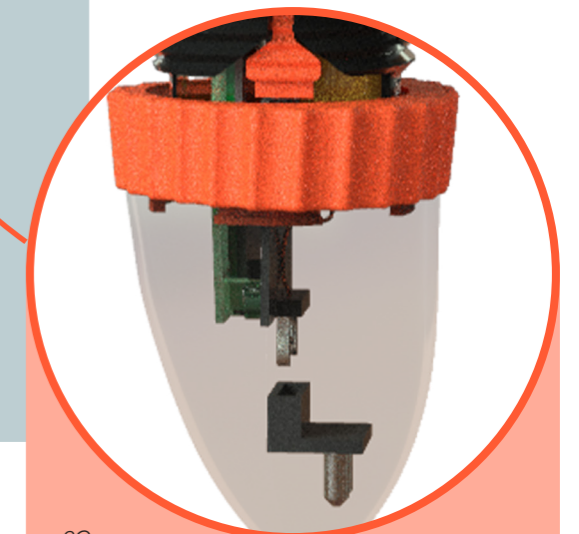
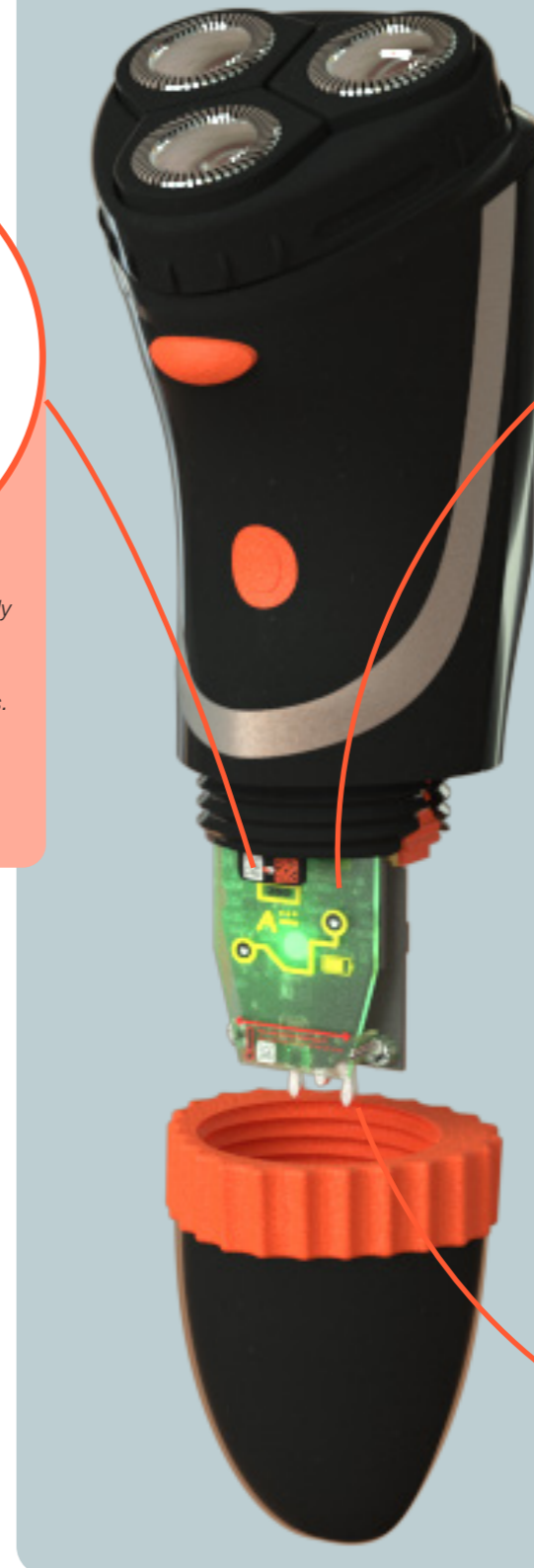
**6A**  
The repairer is shielded from direct touch of the PCB, due to the transparent cover over it. The cover can be removed with a screwdriver.



**6C**  
The first disassembly step (removing the screw component) automatically disconnects the power cord from the device and cuts off power at the plug contacts.



**6A**  
The heating coil is protected by a red ring around the base, that restricts touch by blocking entry to the part. Once the red ring is removed through turning it, the repairer has access to the part.



**6C**  
The first disassembly step (removing the bottom part of the shaver) automatically disconnects the battery from one of its poles, before any other components can be touched.

## 6.4. Chapter 6 Takeaways

**RO4 Exploring how affordances and signifiers can be strategically applied to reduce barriers throughout the DIY repair journey.**

### **Q4.3 How can affordances and signifiers be integrated within product embodiment to guide, reassure, and structure the repair journey?**

Designing for repairability requires navigating a fundamental balance between ease of repair, cost, feasibility, and sustainability. Rather than treating repairability as an isolated objective, it can be approached as an integrated design strategy in which these factors are aligned within the product's embodiment. Within this context, affordances and signifiers play a central role in enabling consumers, particularly inexperienced repairers, to engage with repair in a guided, safe, and structured way.

At a structural level, repair affordances can be embedded into the product architecture to make repair actions technically possible and practically achievable. By enabling reversible disassembly, accessible fastening, non-destructive opening, and clear component separation, affordances reduce functional and effort-related barriers. They support safe interaction, minimize required force, and help prevent incorrect assembly, thereby lowering the practical threshold for engaging in repair.

Building upon this foundation, repair signifiers can be integrated as a perceptual and communicative layer that makes these affordances visible and interpretable. Through visual, tactile, or material cues, such as markings, alignment guides, colour contrasts, or surface differentiation, signifiers indicate where and how actions should be performed, in which sequence, and with what level of care. In doing so, they guide user attention, structure the repair process, and reduce cognitive load.

Beyond guidance, signifiers also play a critical role in reassurance. By clearly framing which interactions are intended and safe, they reduce uncertainty, perceived risk, and fear of damaging the product. This strengthens user confidence and increases the likelihood that available repair affordances are actually acted upon.

Affordances and signifiers therefore operate as a hierarchical yet interdependent system within product embodiment. Affordances establish the possibility of repair, while signifiers make this possibility perceivable, understandable, and actionable. When effectively integrated, they transform repair from a technically feasible but potentially intimidating task into a guided and approachable process.

At the same time, this integration must be balanced with considerations of manufacturability, cost, and environmental impact. Strategies such as component standardization, selective modularity, and material efficiency can support repair without introducing unnecessary complexity or waste. In this way, repairability becomes not only a question of technical feasibility, but of designing products that actively guide, reassure, and structure the repair journey while remaining viable within real-world constraints.



# Case study

- Applying the Principles in Product Design to validate

# 7. Case study

In this chapter, the Design for Easy DIY Repair principles are applied in a case study to validate their usefulness in design practice.

The Philips Shaver Series 3000 PT739 was selected for redesign due to its relatively simple product architecture, which makes it feasible to address all physical aspects of the shaver within the project timeframe. The product is positioned in the mid-range price segment and lacks non-visible surfaces during regular use (such as a back or bottom), increasing the challenge of implementing the principles without compromising its aesthetic value. Furthermore, numerous online repair videos reveal user frustrations with the product's repairability, offering valuable insights into existing barriers.

## 7.1. Redesign process

This section outlines the redesign process of the Philips Shaver Series 3000 PT739. It describes how the Design for Easy DIY Repair principles were applied throughout the different stages of the project, from the initial analysis of repair barriers to the development and evaluation of design concepts.

### 7.1.1. Barrier Analysis

The design process began with an analysis of the repair process of the shaver. This was conducted by disassembling the product, reviewing repair videos, and identifying DIY repair barriers throughout the process. Appendix D - Analysis of repairability of Small Household Electric Consumer Products) presents the full analysis, while Figure 22 summarises the main barriers across the DIY repair journey.

### 7.1.2. Design requirements

After identifying the main DIY repair barriers for this specific product, the previously developed DIY repair requirements were analysed and adapted for this specific project. Three additional requirements were defined for this project:

#### Requirement Description

AR-01

**Use the same components and basic structure as the original shaver**

The original components and overall structure were retained to evaluate whether the principles can be applied to existing designs without fundamentally altering the product architecture.

AR-02

**Maintain the aesthetic character of the shaver**

The original aesthetic appearance, look, and feel of the product were preserved to respect the brand identity. This serves as a test of whether the principles are applicable across different design languages.

AR-03

**Integrate multiple fastener types, including at least one tool-less fastener**

Although using a single type of fastener is generally preferable for clarity, multiple fastener types were intentionally explored to test whether the principles can support intuitive understanding across varied fastening methods.

### 7.1.3. Brainstorming

With the design requirements defined, brainstorming was conducted for each step of the repair journey. For each identified barrier, relevant principles were applied to determine suitable signifiers that could resolve the issue. This resulted in a wide range of sketches exploring different solution directions.

To integrate these solutions into a single product, a morphological chart was created, organizing the sketches by type of design intervention (see Appendix F - Morphological Chart Redesign Electric Shaver). Using this chart, solutions were filtered and combined into several redesign directions.

## Barriers concerning product architecture

Lack of trust in materials due to low quality (seals, snapfits)

Unsafe exposure to electrical components before battery can be removed

The battery, a priority component, is the last component to reach

Snapfits bend non-elastically when opened, leading to uncertainty about water tightness after opening

## Barriers concerning clarity

Unclear that the product can be repaired

Unclear what to look for to find the fault

Only 3 screws, but not grouped together and therefore unclear connection (2 under blades, and one in the back)

Unclear which fasteners hold the part together

Unclear how to continue the disassembly process in multiple stages

Once found that the fastener must be a snapfit, it is unclear where it is located

Unclear what components there are and how they are connected

Unclear what the user is 'allowed' to do without harming the product, themselves or the warranty

Unclear whether warranty is still valid (when opening the product)



**Figure 22.** Main barriers across the DIY repair journey of a Philips shaver, with on the left all barriers concerning product architecture, and on the right all barriers concerning clarity.

### 7.1.4. Conceptualising

Concept development began by selecting solution options with the highest impact on the overall product architecture. These were used as a starting point, after which additional design interventions from the morphological chart were incrementally integrated.

As the redesign of the opening mechanism was expected to have the greatest influence on the product architecture, this aspect was addressed first. Figure 23 shows a lineup of shavers with different opening affordances.

Subsequently, the repair journey was mapped for each opening concept and used as a guiding

framework for further development. By systematically progressing through the steps of the envisioned repair process, gaps in interaction and understanding were identified. These were addressed through the iterative application of design interventions, ensuring that each stage of the repair journey was adequately supported.

### 7.1.5. Prototyping

After identifying the most promising configuration of solutions through a harris profile, prototyping of the redesign was carried out using 3D printing. Initial prototypes focused on refining the physical signifiers, the movement, and the shape of self-signifying affordances.

Before each next iteration, the prototype was

evaluated based on:

- visual and tactile quality,
- ease and intuitiveness of disassembly,
- compatibility with existing components,
- alignment with the design principles.

An overview of the prototypes made and the iterations explained can be found in Appendix G - Prototype Overview.

Through multiple iterations and adjustments to the product architecture, a concept emerged in which all affordances were sequential (each action reveals the next possible action) and nested (affordances are spatially organized within one another), allowing them to function cohesively.

Once the affordances were sufficiently refined, additional signifiers, such as colour coding, text, symbols, and confirming haptic or auditory feedback, were introduced where necessary. These enhancements further improved the clarity of the repair process and increased user confidence.

## 7.2. Redesign Result

The final redesign of the Philips Shaver Series 3000 PT739 is presented in Figures 24-30. The redesign transforms the repair process into a guided, step-by-step experience, in which physical and digital signifiers support the user throughout the repair journey.

The design is structured as a sequence of nested and sequential affordances, where each action reveals the next possible step. This creates a coherent interaction flow that reduces uncertainty and increases user confidence during repair.

This section presents the redesign from the perspective of the user's repair journey. For each stage, the implemented design interventions are explained, highlighting how they embody the Design for Easy DIY Repair principles and support the user in overcoming repair barriers.

### 7.2.1. Perceived Repair Options & Digital Support

Figure 24 shows how repairability is made visible and how the design connects the user to digital support.

All repair-related information, including a repair reminder, a QR code linking to the Digital Product Passport (DPP) and Digital Repair Check (DRC), and the ease-to-repair score, are integrated beneath the blades on the shaving head. As users routinely open this part of the shaver for cleaning after each use, these elements become naturally visible during regular use, which is in line with Principle 1 (Make Repairability Explicit).

This placement embeds repairability into everyday interaction with the product, reinforcing repair as a normal and accessible option. Following Principle 2 (Bridge to Digital Support), the QR code provides immediate access to additional guidance, enabling a seamless transition between physical interaction and digital support.

Applied principles:

1. Make Repairability Explicit
2. Bridge to Digital Support

### 7.2.2. Visible Entry Point & Fault Detection

illustrates the redesigned entry point of the shaver.

The product is opened through a clearly identifiable, brightly coloured ring located at the separation between the upper and lower housing. The ring incorporates visual and physical signifiers, such as colour contrast, ridged textures, and a familiar cylindrical geometry, that suggest a twisting motion.

In line with Principle 1 (Make Repairability Explicit), the entry point uses the same colour coding as other action signifiers on the product, reinforcing its affordance.

Additionally, following Principle 4 (Speak the Intended Action), the geometry and tactile qualities of the ring draw on a familiar interaction pattern, similar to opening a water bottle cap, reducing the cognitive effort required to understand how to access the interior. Once the ring is unscrewed, the top and bottom housing can be easily separated, exposing part of the PCB. This accessible entry point lowers the threshold for initiating repair and enables users to perform a first inspection of the product. Visible



Figure 23. Shaver line-up with each a different point of entry affordance

components, such as the PCB, wiring, and charging port, can be quickly checked for evident signs of failure (e.g., water damage or loose connections).

By clearly signalling how to open the product and by reducing perceived risk, the design increases perceived safety, convenience, and self-efficacy, making the first repair step less intimidating.

Applied principles:

1. Make Repairability Explicit
4. Speak the Intended Action

### 7.2.3. Fault Location & Fault Isolation

Figure 27, Figure 28, and Figure 29 provide an overview of the battery and PCB module. This module can be removed as a single unit during the second step of the disassembly sequence, see Figure 30-3

These figures also provide an overview of the features that support fault location and isolation.

To assist users in diagnosing faults, and to prevent users from unsafe behaviour, a protective cover is placed over the PCB that integrates visual and physical signifiers. These signifiers guide the user in identifying and testing priority components, specifically the motor and battery.

Small openings in the cover align with designated test points on the PCB, allowing users to perform measurements with a multimeter without directly interacting with the complex and potentially hazardous electronics on the PCB. A symbolic signifier of a multimeter marks where testing is required.

Color coding, connecting lines, and simplified component symbols visually link test points to their corresponding components. These signifiers also communicate:

- which points belong together,
- which measurement setting to use,
- and what outcome to expect.

Given the inherent complexity of fault diagnosis, the physical guidance of the product is complemented by digital support, accessed through the integrated QR code linking to a step-by-step troubleshooting guide by iFixit (see Figure 25). Although AI-assisted guidance has the potential to further improve fault diagnosis by offering adaptive and personalized support, this project deliberately focuses on low-complexity and accessible solutions. The integration of AI is therefore considered beyond scope and proposed as a direction for future development.

This structured guidance reduces the need for prior technical knowledge and helps users translate observed symptoms of failure into targeted diagnostic actions. As a result, the user is supported in developing a clear and manageable fault-finding process.

Applied principles:

2. Bridge to Digital Support
5. Structure the Product Architecture
6. Constrain Incorrect and Unsafe Actions

#### **7.2.4. Guided Disassembly**

Figure 30 shows the disassembly steps of the shaver, with the intended actions and the signifiers for these actions highlighted.

The disassembly process is designed as a sequence of clearly guided steps, in which each action naturally reveals the next, following Principle 5 (Structure the Product Architecture). Affordances are organized both sequentially (each action leads to the next step) and nested (components are spatially arranged within one another), creating a logical and intuitive progression through the product.

Following Principle 6 (Constrain Incorrect and Unsafe Actions), the battery is automatically disconnected in the first disassembly step. The PCB, in this product the only potentially hazardous component, is shielded off from direct touch, and is placed in repair layer 2 (see Figure 26).

Following Principle 4 (Speak the Intended Action), visual and physical signifiers indicate where and how

to interact with the product at each stage. These include colour-coded interaction points, directional cues, and form-based guidance that suggests appropriate handling. Where relevant, such as with the closing of the collar, or with the connection of the cables, feedback mechanisms, such as haptic or auditory clicks, confirm correct actions, increasing user confidence and reducing uncertainty.

By structuring the disassembly process in this way, the design minimizes the likelihood of errors and ensures that users can proceed through the repair process in a controlled and predictable manner.

Applied principles:

3. Define Repair Boundaries
4. Speak the Intended Action
5. Structure the Product Architecture
6. Constrain Incorrect and Unsafe Actions



Figure 24. Repairability made visible and link to digital repair support through textual and symbolic signifiers.

Troubleshooting guide



## Philips Shaver 3000 Series

Student-Contributed Wiki  
An awesome team of students from our education program made this wiki.

### Shaver Will Not Start

*Shaver doesn't respond when power button has been pressed.*

- Defective Adapter**  
Check if the power adapter is plugged in and the charge light is on. If not then your charging adapter might be faulty.
- Low Battery**  
Check if your battery is charged by plugging in the charger and making sure the indicator light is green and not red.
- Replace the Battery**  
If the battery won't charge at all then the battery might be faulty and you might need a replacement for that, follow [this guide](#) to replace the battery.

### Shaver Wont Charge or Hold Charge

*Your battery might be faulty.*

- Replace Battery**  
Your battery might be the reason why the shaver is not working, so replace the battery with a new one by following [this guide](#).

### Check the Indicator Light

The indicator light on the shaver can tell you if the battery has faulty wiring. If you see any light, then the wiring is not faulty and it's the battery that needs to be replaced.

### Pop Up trimmer Comes Apart

*While opening the trimmer the springs might come loose.*

- Replace the Trimmer**  
Sometimes when you open the pop up trimmer the spring that retracts the trimmer might also come apart with it. You can follow [this guide](#) to replace the spring and the trimmer.

### Replacing the Casing

The pop up trimmer may be coming apart due to a defective casing. In this case, follow [this guide](#) for dismantling and reassembling the shaver casing.

PHILIPS NORELCO  
SHAVER 2100  
TROUBLESHOOTING

- Shaver Will Not Start**
  - Defective Adapter
  - Low Battery
  - Replace the Battery
- Shaver Wont Charge or Hold Charge**
  - Replace Battery
  - Check the Indicator Light
- Pop Up trimmer Comes Apart**
  - Replace the Trimmer
  - Replacing the Casing
- Shaver Blades Do Not Cut Properly**
  - You Might Have to Remove Hair Build Up from the Blades
  - Replacing the Shaver Heads
- Trimmer Stops Suddenly After Turning On**
  - Replacing the Shaver Head Seat
  - Shaver May Be Overheating

Figure 25. Example of structured troubleshooting guidance, as provided on platforms such as iFixit.

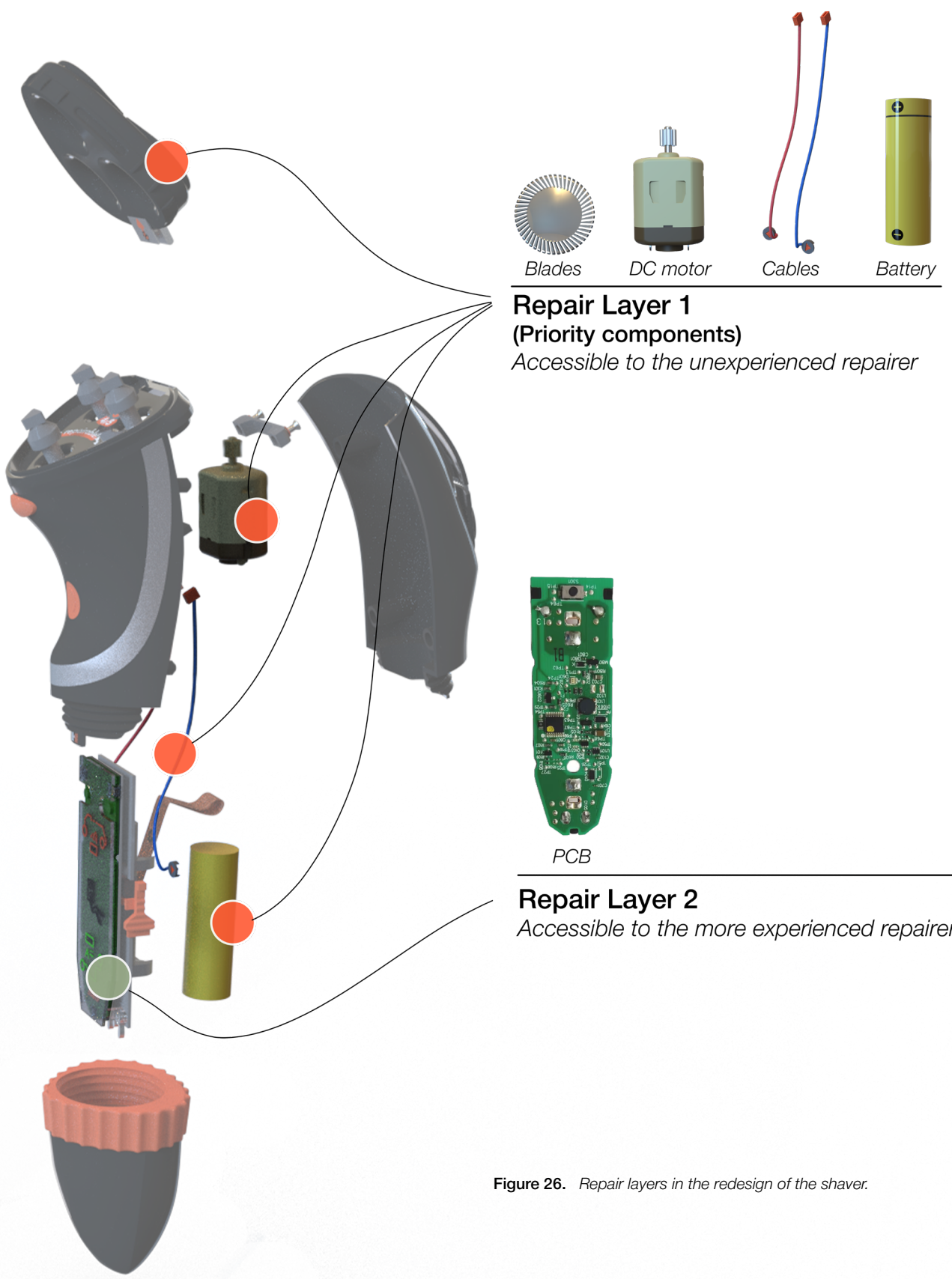


Figure 26. Repair layers in the redesign of the shaver.

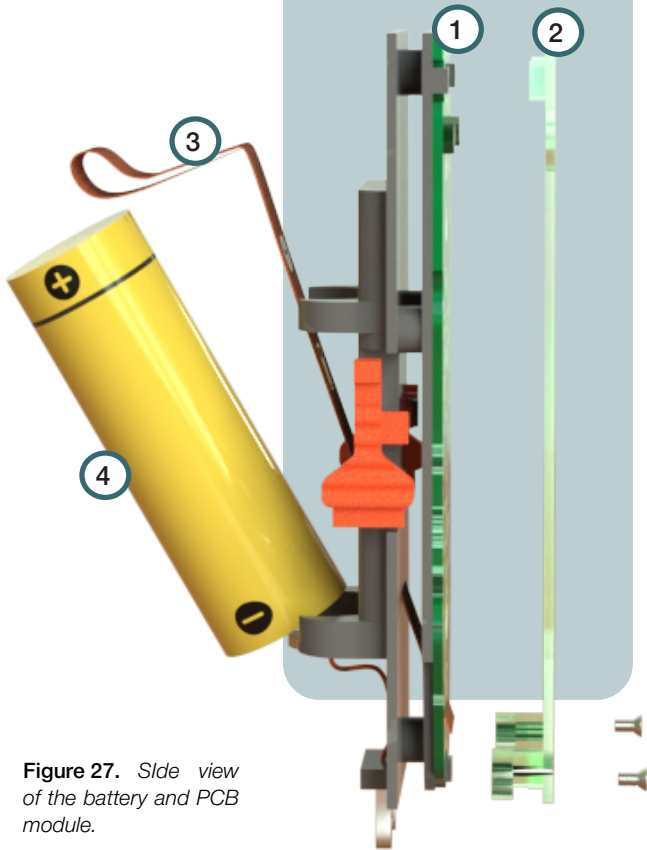


Figure 27. Side view of the battery and PCB module.

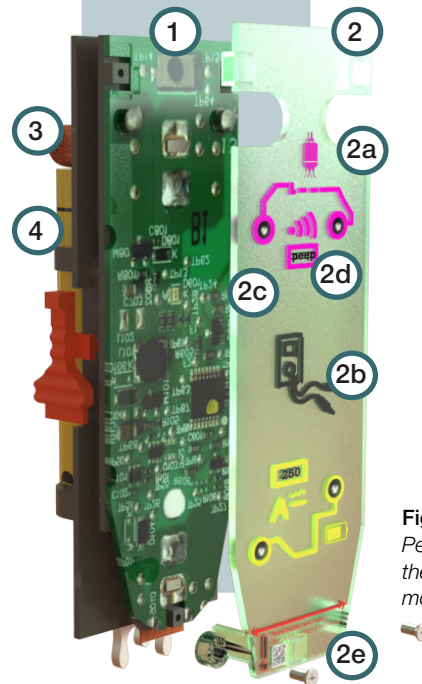


Figure 28. Perspective view of the battery and PCB module.

**1. Printed Circuit Board (PCB)**

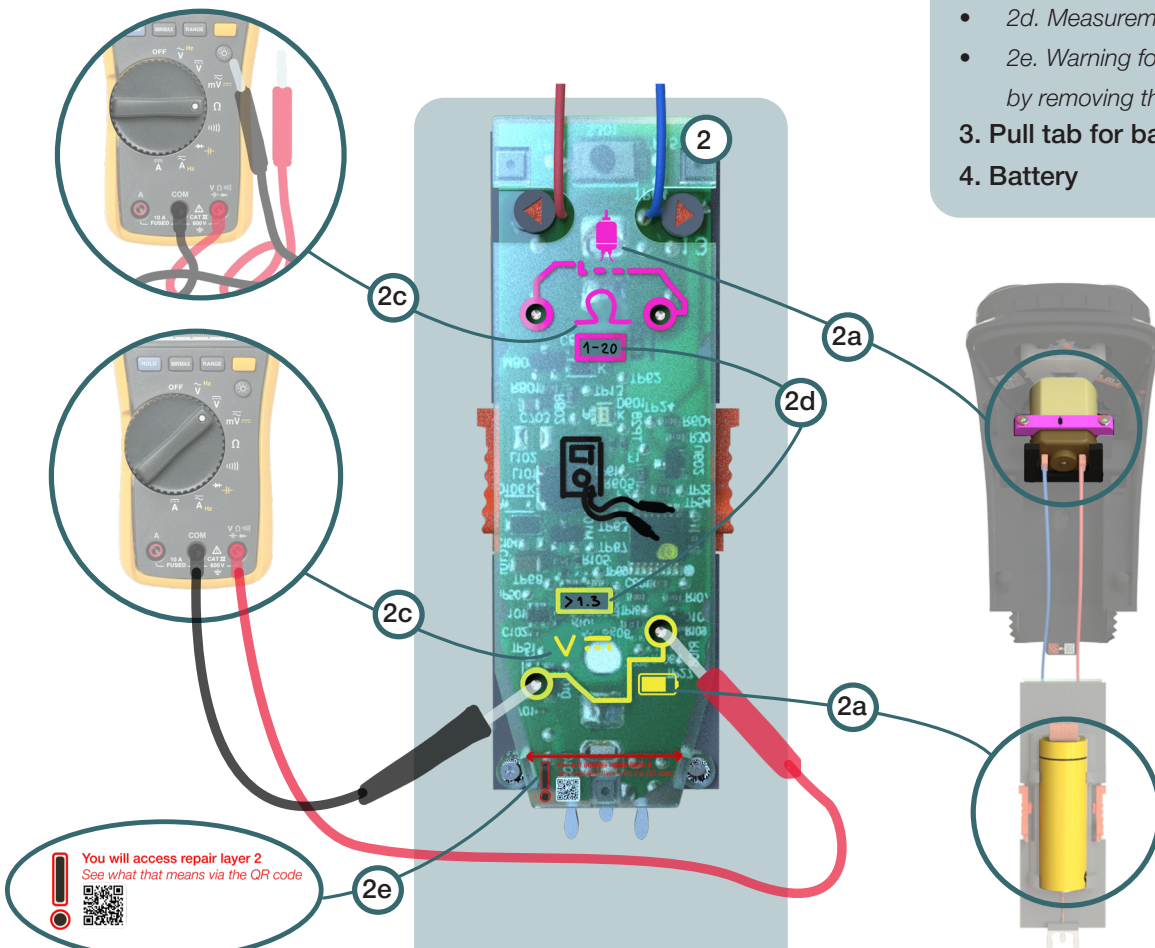
**2. PCB cover**

With symbolic signifiers that refer to:

- 2a. Corresponding components
- 2b. Tool needed (multimeter)
- 2c. Correct measurement setting
- 2d. Measurement outcome to expect
- 2e. Warning for entering repair layer 2 by removing the PCB cover

**3. Pull tab for battery removal**

**4. Battery**



**!** You will access repair layer 2  
See what that means via the QR code

Figure 29. Front view of the battery and PCB module.

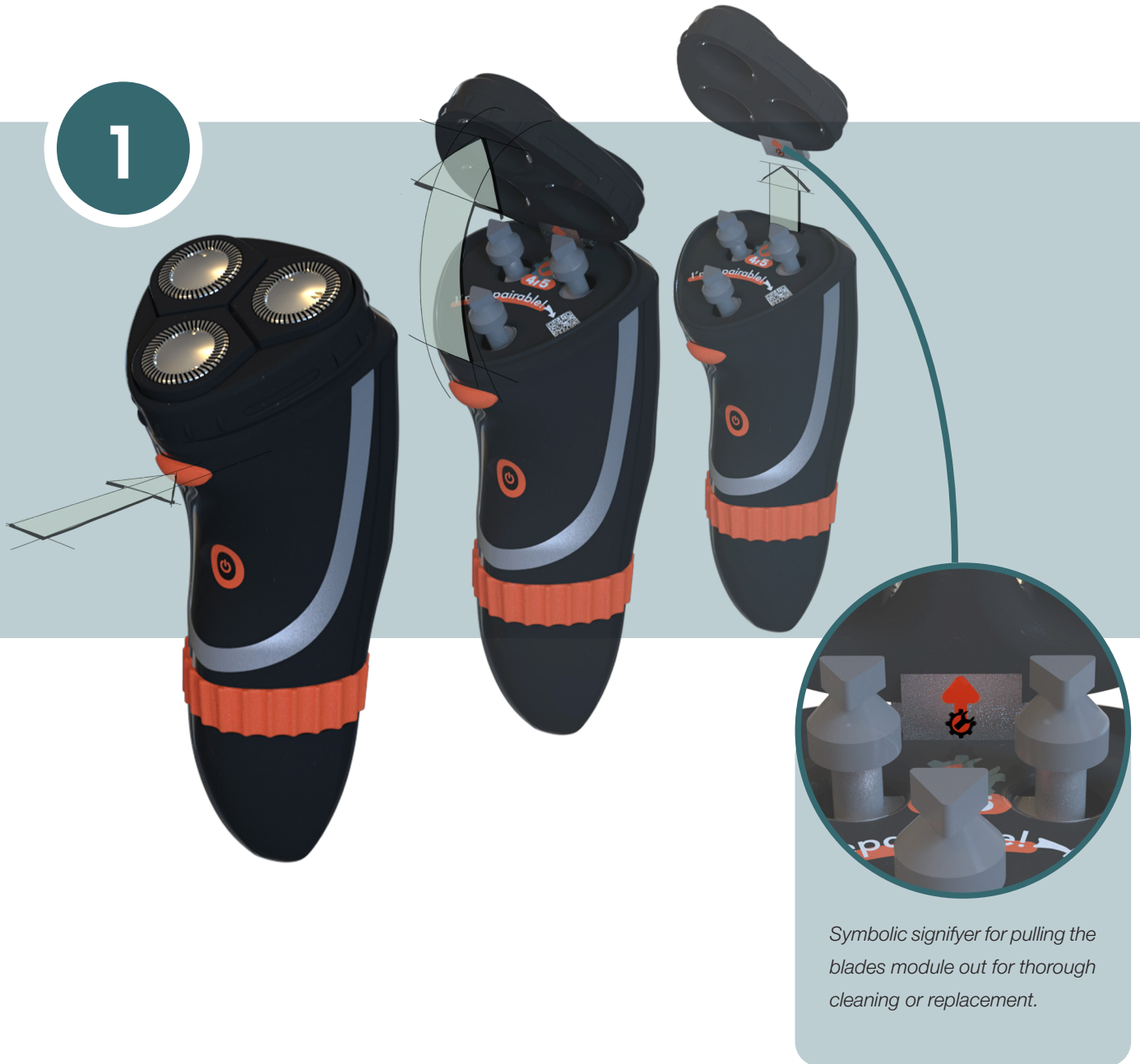
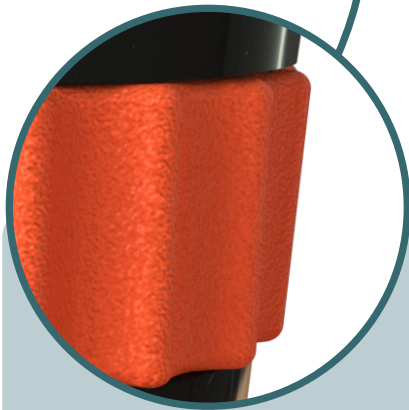
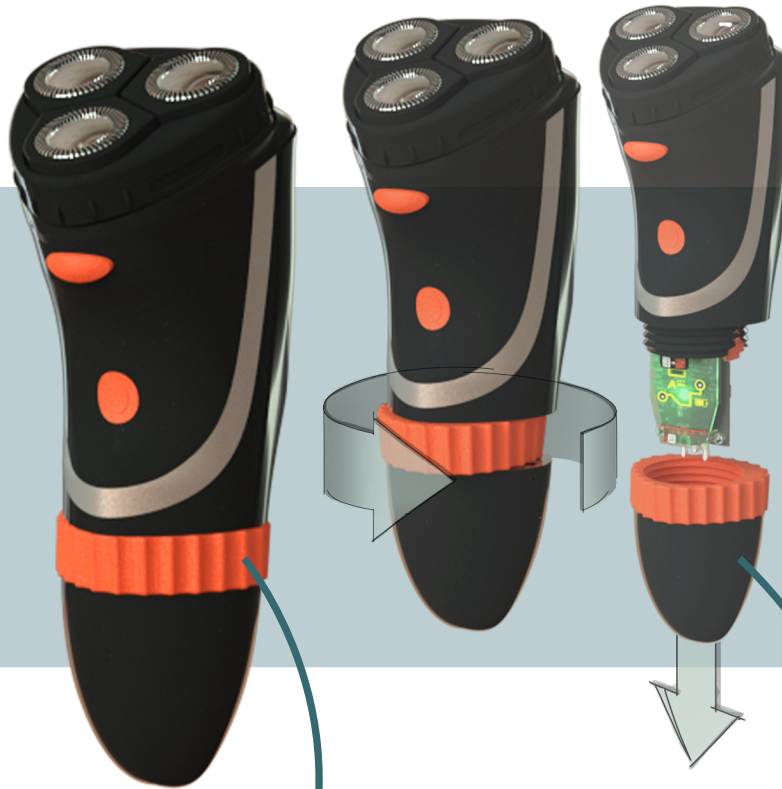
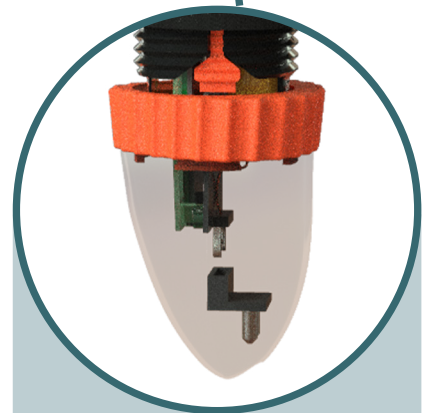


Figure 30. Disassembly steps of the redesign. (Figure continues for 8 pages)

2

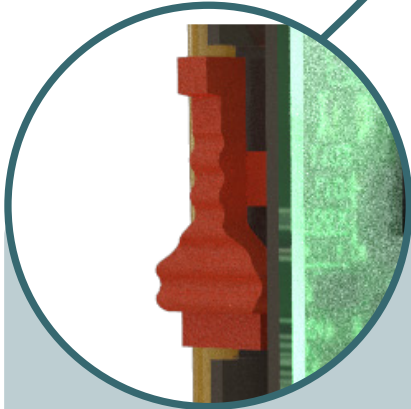
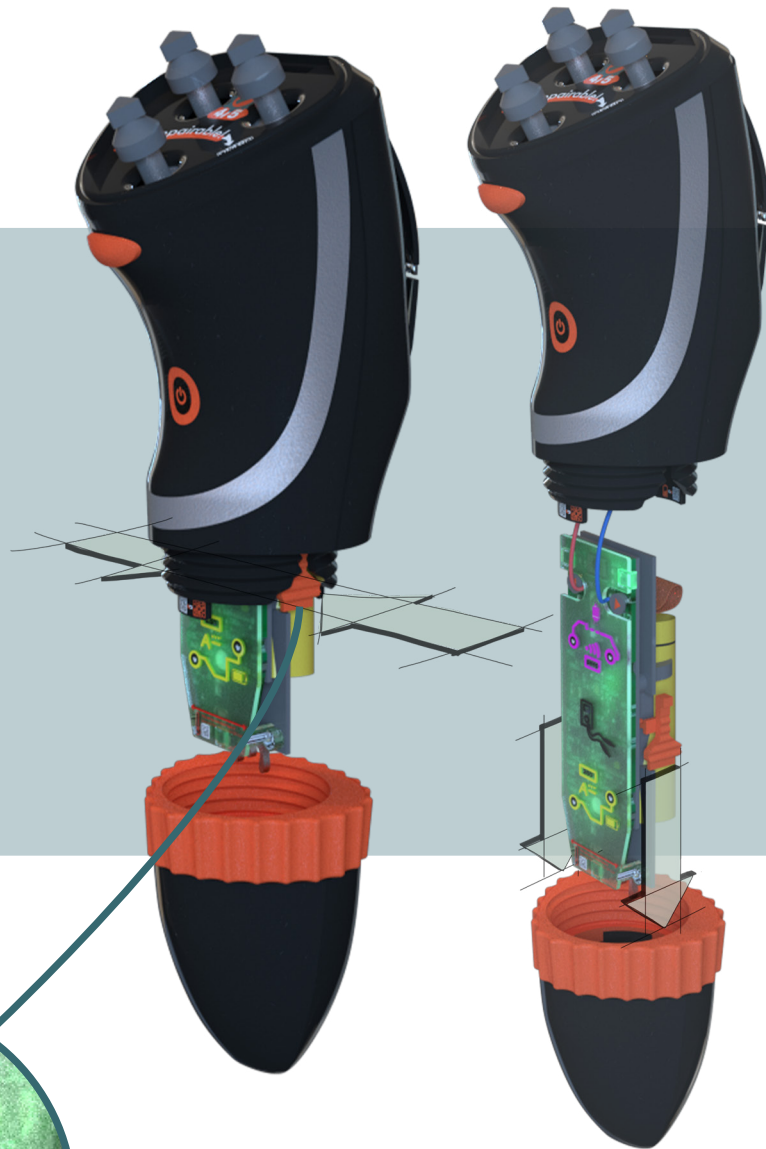


*The redesigned entry of the shaver is afforded by threaded collar, with visual and physical signifiers (colour contrast, ridged textures, and a familiar cylindrical geometry) communicating a twisting motion.*



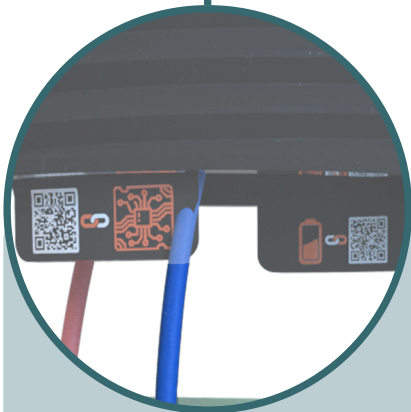
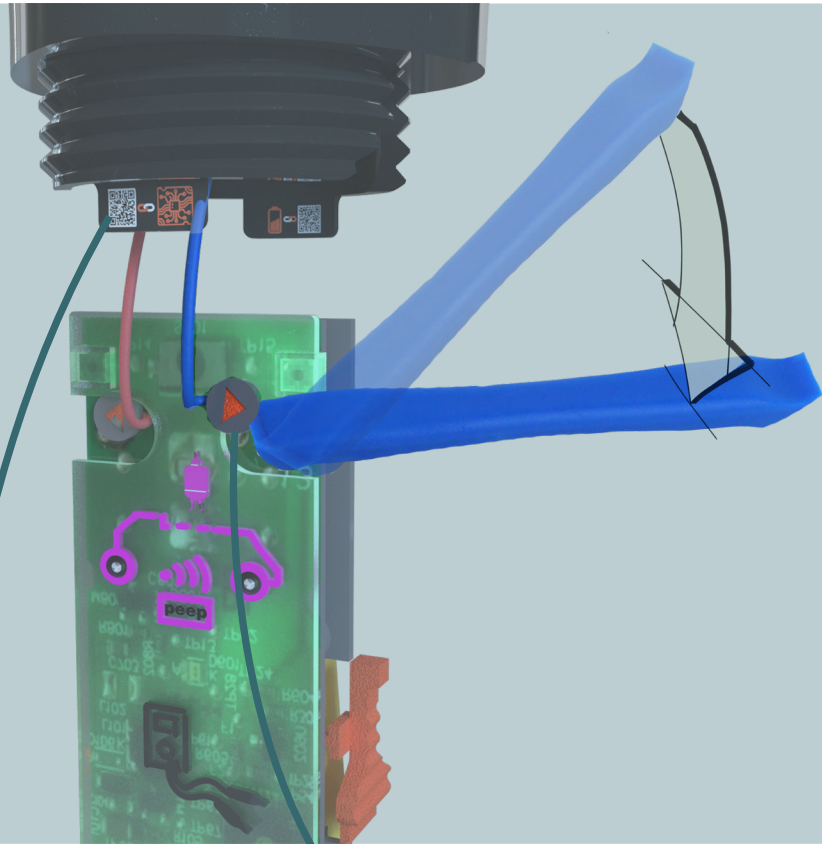
*In the first disassembly step (removing the bottom part of the shaver) automatically disconnects the battery from one of its poles.*

3

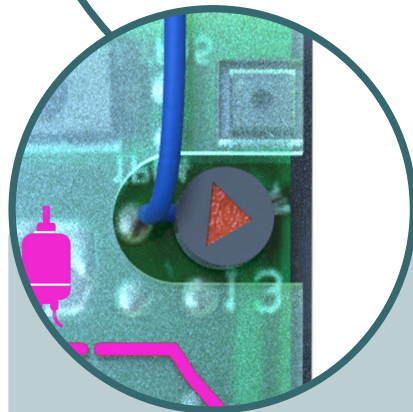


*Removing the PCB and battery module is afforded by the extra space for the finger to push the snapfits out of their frame. The visual signifiers 'colour contrast' and 'colour coding' communicate the action possibility, and physical signifier 'ridged texture' communicates the intended motion.*

# 4

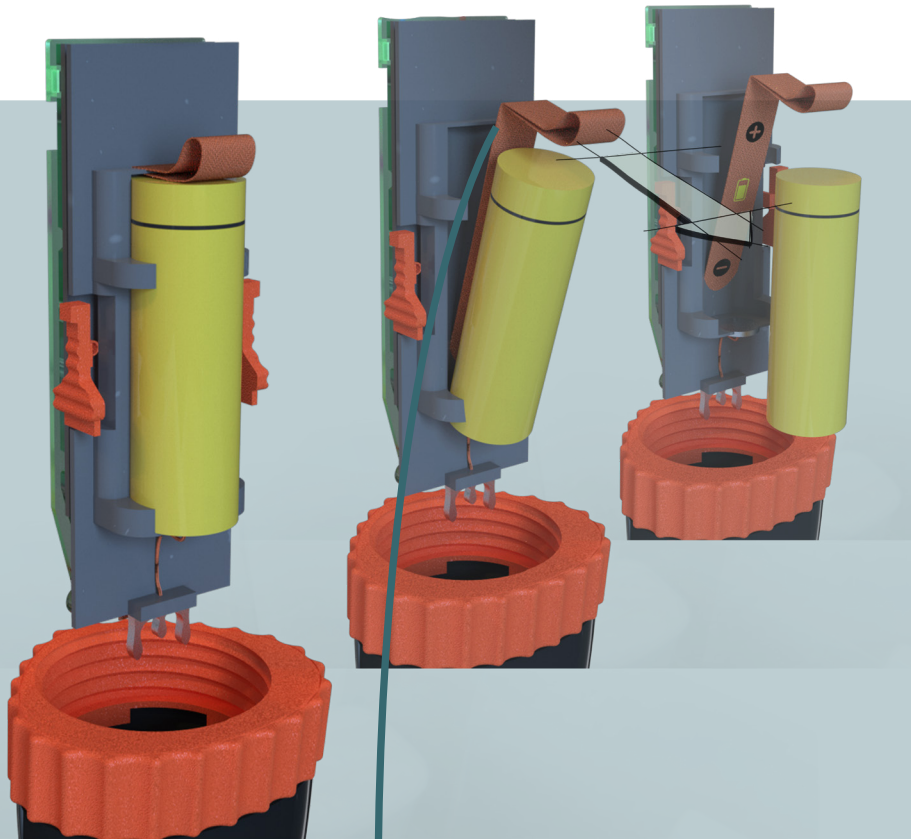


*These symbolic signifiers are twofold: they communicate the correct way to place the PCB and battery module back into the casing, and they are component-specific links that link directly to the repair steps of the component.*



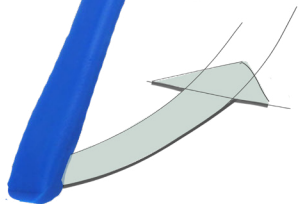
*The cables can be disconnected with either a fingernail or a spudger. The symbolic signifier points to where the little gap to put the spudger is located.*

5



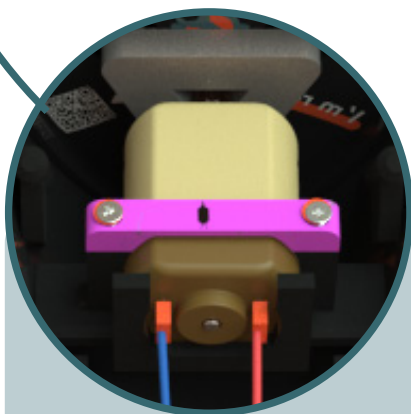
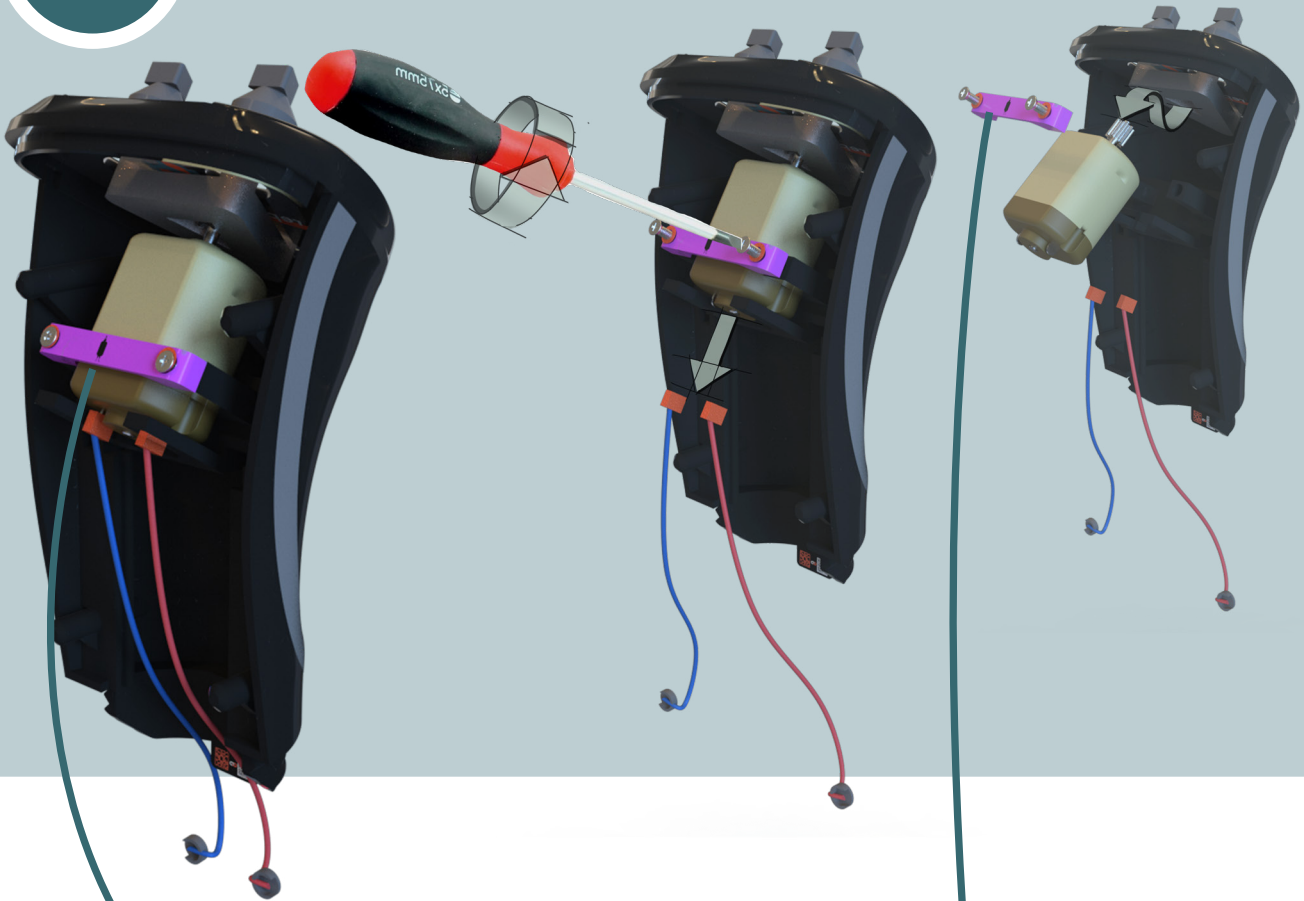
*This pull tab affords easy replacement of the battery. The visual signifier of colour coding, the physical signifier of a tab that can be pulled, and the symbolic signifiers on the tab make replacement of the battery intuitive.*

6

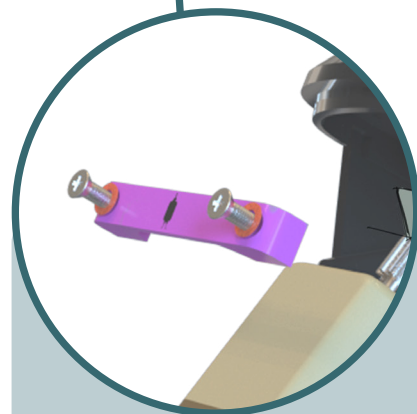


*The gap between the front and back casing affords opening with a spudger. The visual signifier colour coding attracts attention to the affordance.*

7



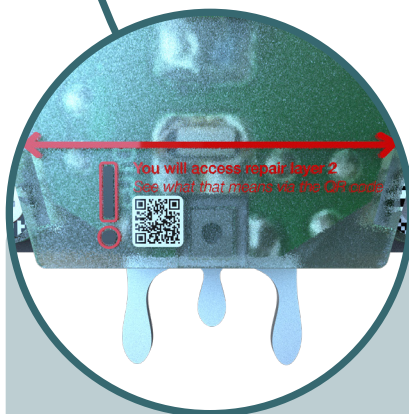
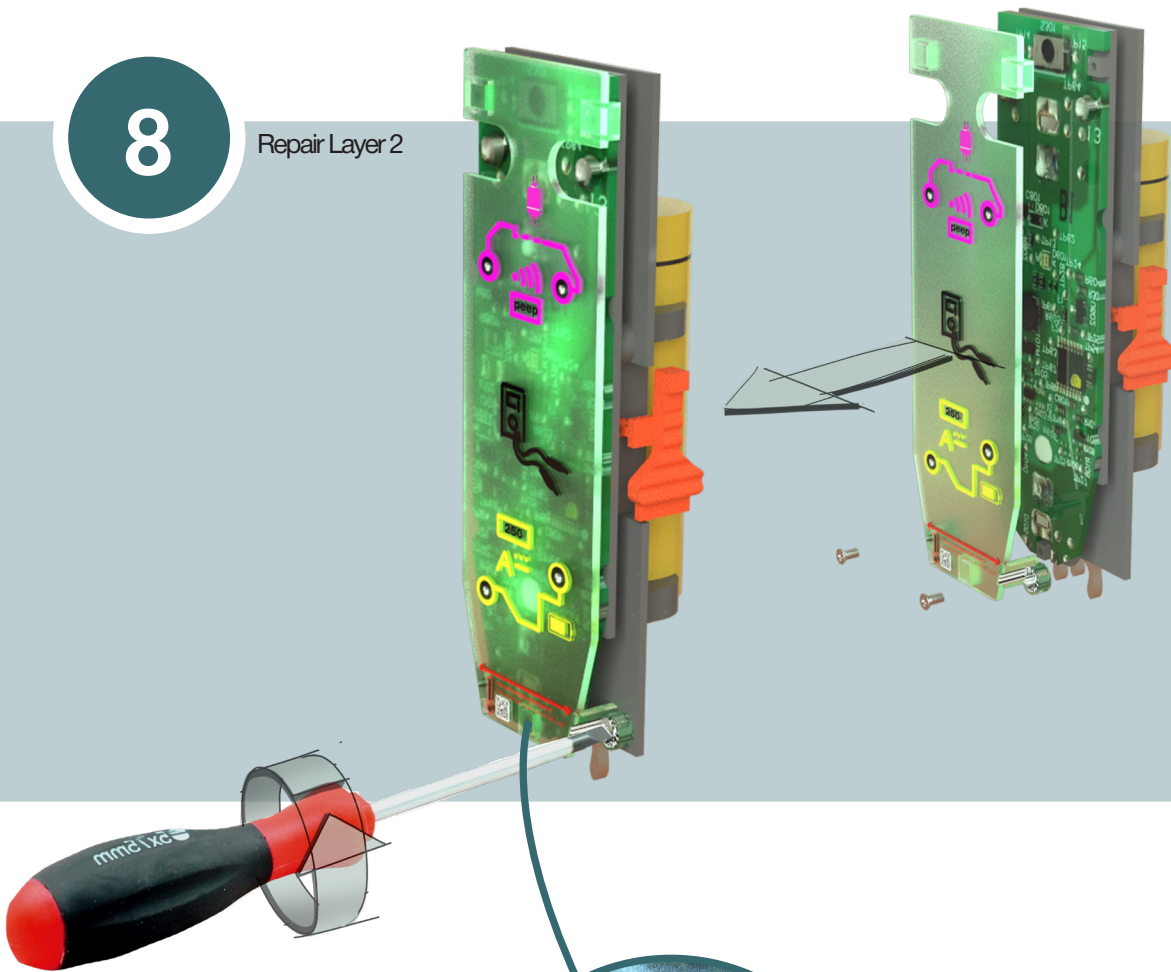
*The affordance 'motor replacement' is communicated through the visual signifiers 'colour coding' and visible screws. The accessibility of the screws is very high.*



*The replacement action is more convenient because of the captive screws.*

# 8

## Repair Layer 2



The textual and symbolic signifiers next to the barrier to repair layer 2 warn the consumer about the change in layer, and refer to more information via the QR code.

However, the easily accessible screws afford the consumer to easily access the pcb when they desire to.



# Validation

# 8. Validation

The validation of the design principles and case study is carried out against the general design requirements defined in Chapter 6 (Design Principles for Easy DIY Repair), and the additional design requirements specific to the shaver in Chapter 7 (Case Study). References to specific requirements (e.g., TR, HR, ER, RR, AR) are used to indicate how the results support or challenge these criteria.

## 8.1. Prototypes

Through multiple iterations of prototypes, the feasibility of the product architecture was explored and refined. These iterations demonstrate that the redesign supports reversible disassembly and structured access to components, aligning with requirements such as TR-01 (Standardized Fasteners) and TR-03 (Modular Architecture).

The redesign also reflects TR-06 (Ergonomic Clearance), as components and fasteners are positioned to allow clear access and controlled interaction during disassembly.

Access to the motor (identified as a priority component in the shaver) occurs relatively late in the disassembly sequence. This challenges TR-02 (Priority Components) and TR-04 (Diagnostic Hierarchy), which emphasize early access to frequently failing components.

While an alternative design solution could improve direct access to the motor, this would conflict with HR-04 (Inherent Safety) and HR-02 (Fail-Safe Disassembly), as it would allow access to internal components before disconnecting the battery.

This finding highlights a critical trade-off between accessibility and safety, indicating that not all requirements can be optimized simultaneously.

The redesign meets AR-01 (Use the same components and basic structure), as the original architecture was largely retained, demonstrating that the principles can be applied without fundamentally altering the product.

AR-03 (Integrate multiple fastener types) is also met.

Screws are used to secure the motor, snap-fits for the main casing, and tool-less fasteners such as the collar and the clamping system of the PCB and battery unit in the upper casing were implemented, while maintaining a clear and understandable disassembly process.

The requirement AR-02 (Maintain the aesthetic character of the shaver) is partially met. While the main shape, product features, and overall visual identity of the shaver were preserved, the addition of a collar introduces a noticeable change to the product's appearance. This reflects a deliberate design choice to support Principle 1 (make repairability explicit) and Principle 4 (speak the intended action) by clearly signalling the entry point for repair.

An alternative approach could involve embedding these signifiers within a maintenance region of the product, allowing users to encounter them during use without significantly altering the external appearance. However, in this case, a more explicit and visible intervention was chosen to emphasize repairability as a core aspect of the product architecture.

This finding highlights a key design trade-off between aesthetic integration and the visibility of repair cues, suggesting that making repairability explicit may, in some cases, require a shift in traditional product aesthetics. At the same time, when entry affordances are designed to be self-signifying, they can be integrated as a meaningful part of the product's aesthetic rather than a disruption.

The original shaver design is highly water-resistant, featuring a double-casing system. In the redesign, water resistance is maintained through a sealed outer casing while enabling easier access. However, this introduces a trade-off between repairability and robustness, indicating tension between technical requirements and long-term durability.

## 8.2. User tests

User tests were conducted to evaluate the ease of repair and, in particular, the understandability of the repair process, addressing requirements such as HR-

01 (Visual Signifiers), HR-03 (Fail-Safe Reassembly), and HR-06 (Intended Repair).

The user test was conducted with three participants without technical knowledge or prior repair experience.

Participants were tested individually and were presented with the prototype of the redesigned shaver, along with a render showing the same redesign with all signifiers applied. They were first asked to list all actions that came to mind when interacting with the product, in order to evaluate HR-06 (Intended Repair).

The results showed that activities such as “repair” or “disassembly” were mentioned as the 4th,

6th, and 7th actions, following activities such as shaving, trimming, cleaning, charging, and playful interpretations (e.g., “using it as a microphone”). Two participants mentioned “turning the orange ring” as an early action, indicating that the component successfully signified an interaction possibility, even if it was not immediately interpreted as a repair step.

This suggests that, while repair is not the primary perceived function, the design does invite exploratory interaction, which may lead users toward repair through engagement.

Next, an iFixit repair kit and a multimeter were introduced, and participants were asked to explain



Figure 31. Main barriers accross the DIY repair journey of a Philips shaver, tested against the redesign of the shaver.

how they would approach diagnosing a fault. One participant indicated they would rely on someone else to fix the product, while the other two began interacting with the prototype.

The results indicate that users were able to follow the disassembly process with relatively low confusion, suggesting that the applied signifiers effectively reduced cognitive barriers (HR-01) and supported user confidence (HR-07 – Feedback, partially).

Some hesitation remained during the fault diagnosis phase. However, after scanning the QR code and receiving guidance (guidance was verbally provided to the participants, simulating how instructions would be presented through the Digital Product Passport), participants were able to follow the steps successfully. This highlights the limitations of affordances and signifiers alone, and the need for additional guidance through external tools.

Based on these results, Figure 30 was created to visualize which repair barriers were resolved, partially resolved, or remained unaddressed.

### 8.3. Reflection on signifiers

The individual signifiers applied in the case study were not fully optimized. While their function and placement align with HR-01 (Visual Signifiers), further refinement and detailed design is required in terms of clarity, consistency, and effectiveness.

Additionally, the influence of prior knowledge suggests that some signifiers rely on learned conventions. This partially challenges the goal of intuitive interaction and relates to HR-05 (On-Device Documentation), as additional guidance may still be required for inexperienced users.

These findings indicate that signifiers can reduce cognitive barriers, but their effectiveness depends on both design quality and user context.

### 8.4. Expert discussions

Expert discussions highlighted uncertainties related to safety and warranty, particularly in relation to RR-02 (Warranty Transparency) and HR-04 (Inherent Safety).

A discussion with an employee of Action confirmed the interest of larger companies in adapting repair levels within products to better manage safety and warranty conditions.

Additionally, discussions with experts during repair events, such as the Council of Repair\*, provided insight into regulatory considerations in the Netherlands.

These discussions indicate that while the principles provide a strong conceptual foundation for facilitating DIY repair, further validation is needed to ensure compliance with regulatory and commercial constraints.

### 8.5. Conclusion of validation

The validation demonstrates that the proposed design principles effectively support key requirements related to repairability, particularly in reducing cognitive barriers (HR-01, HR-06) and enabling structured disassembly (TR-01, TR-03).

At the same time, the results reveal important trade-offs between requirements, especially between accessibility (TR-02, TR-04) and safety (HR-02, HR-04).

Additionally, aspects related to regulation and warranty (RR-02) require further development.

Overall, the principles provide a strong foundation for enabling DIY repair, but require further refinement and validation across different contexts and stakeholders.

\* The Council of Repair is an initiative of the repair lab of LDE Thesis labs, where discussions are held around repair in name of the products.



## Discussion

## 9. Discussion

This study set out to explore the role of signifiers and affordances in reducing psychological and practical barriers in the DIY repair process of small household electrical products. The findings demonstrate that both design elements play a complementary role in supporting repair, with affordances primarily addressing practical feasibility and signifiers shaping user understanding, confidence, and engagement.

However, these results also highlight that enabling repair through product design is not a singular or fully resolved challenge. While signifiers and affordances can significantly lower barriers related to access, comprehension, and perceived risk, the DIY repair process remains inherently complex, particularly in stages that require diagnostic reasoning. This discussion therefore reflects on the implications, limitations, and broader relevance of these findings.

### 9.1. Role of signifiers and affordances

The results of this study show that affordances and signifiers should be understood as an interdependent system within the product embodiment. Affordances create the structural conditions that make repair actions possible, while signifiers translate these possibilities into perceivable and understandable cues for the user. Together, they bridge the gap between technical repairability and user capability.

Affordances reduce practical and functional barriers by embedding repair possibilities into the product architecture. Features such as reversible disassembly, accessible fasteners, and modular organization lower the physical and procedural effort required for repair. Signifiers reduce cognitive and psychological barriers by guiding interpretation and action, structuring the repair process, and reducing uncertainty and perceived risk.

At the same time, the findings reveal that the effectiveness of signifiers and affordances is not uniform across the entire repair journey. Their contribution is strongest in stages such as disassembly, reassembly, and navigation within the product, where physical interaction and guidance are central.

In contrast, more cognitively demanding stages, particularly fault diagnosis, are less effectively supported. While certain principles, such as structuring product architecture and clearly communicating intended actions, can assist in navigating components and understanding system logic, they do not fully address the challenges of identifying faults.

This highlights an important boundary of signifiers and affordances: while they can make repair actions accessible and understandable, they are less suited to supporting complex diagnostic reasoning. As such, they should be seen as foundational, but not comprehensive, solutions within the broader repair process.

### 9.2. Limitations

Several limitations should be considered when interpreting the results of this study.

This research was conducted in a context where repairability is a prominent and actively discussed topic. Although efforts were made to ground the work in user insights outside of this context, this may have introduced bias in assumptions about what users understand, expect, or find intuitive.

Additionally, the development of the Design for Easy DIY Repair principles and the redesign of the shaver took place in parallel. This may have introduced bias in the evaluation of the principles, as insights from the design process could have influenced the formulation and validation of the principles. While this iterative approach strengthened the alignment between theory and practice, it limits the independence of the validation.

Furthermore, the principles have primarily been validated through the redesign of an existing product. Their applicability to design-from-scratch processes and across different product categories remains to be tested, and may require further adaptation depending on context.

The empirical validation of the design was also limited. The prototype used in user testing had

restricted functionality, which may have influenced how participants interacted with the product and approached repair tasks. In addition, the sample size of the user tests was relatively small, limiting the generalizability of the findings. While the results provide valuable qualitative insights, they should be interpreted with caution when extrapolating to broader user populations.

Another limitation lies in the scope of the repair journey explored through the exploratory repair activities conducted during the project. Many of these activities focused on opening and understanding products, rather than fully diagnosing and repairing faults, and in some cases involved products that were not actually broken. As a result, the study provides deeper insight into barriers related to accessing and navigating products than into the challenges associated with identifying and resolving faults. While this focus was justified (these stages form the entry point to repair and were experienced as key barriers during the exploratory phase), it may have reinforced an imbalance in the findings. In particular, aspects related to fault diagnosis were less extensively investigated.

Finally, the redesign of the shaver itself should be interpreted as a conceptual case study. While efforts were made to balance repairability with product requirements such as water resistance, these requirements were simplified in favor of focusing on DIY repair. For real-world implementation, further validation by experienced designers and engineers would be required to ensure feasibility, performance, and compliance with industry standards.

### 9.3. Implications for design practice

The findings of this study have several implications for design practice. They suggest that repairability should be approached as an integrated and user-centered design challenge, rather than a purely technical feature.

First, the results highlight the importance of designing for both enabling repair action and understanding. While affordances enable interaction, their effectiveness depends on the presence of signifiers that make these interactions perceivable and

interpretable. This indicates that designers should consider not only whether a repair action is possible, but also whether it is clearly communicated to users.

Second, the study emphasizes the role of user confidence in enabling repair behaviour. The reduction of psychological barriers appears to be closely linked to how clearly products communicate safe and intended interactions.

Finally, the study underscores that the effectiveness of signifiers is highly dependent on their execution. While their functional role can be defined conceptually, their impact relies on careful refinement in terms of visual clarity, consistency, and placement. This highlights the importance of iterative testing and detailing in the design process.

At the same time, it is important to consider the broader system-level effects of these design interventions. While improving repairability through affordances and signifiers aims to extend product lifetimes and reduce electronic waste, lowering the barriers to repair may also lead to unintended user behaviours. For example, increased accessibility could encourage unnecessary disassembly, premature replacement of components, or a perception that products are easily fixable, potentially influencing consumption patterns. Although these effects are likely limited in comparison to the benefits of improved repairability, they highlight that design interventions do not operate in isolation and should be considered within a broader system of use and behaviour.

### 9.4. Future opportunities

This research highlights several directions for future work.

A key opportunity lies in the integration of AI-assisted repair support, as explored in prior research (e.g., Jin et al., 2025). While signifiers and affordances provide static, embedded guidance, AI systems could offer dynamic, context-aware support, particularly in complex stages such as fault diagnosis and troubleshooting. A combination of physical design interventions and digital guidance may provide the most effective repair experience.

Further opportunities include testing the developed principles across different product categories to evaluate their applicability and effectiveness in varied contexts, as well as conducting longitudinal user studies to understand how repair skills and confidence develop over time. Such studies could also explore the potential didactic role of repair affordances and signifiers, investigating whether they support inexperienced users in learning how to repair through interaction with the product itself.

Additionally, future research could explore how product design can better connect to the broader repair ecosystem, including access to spare parts, repair information, and community-based repair initiatives.

## **9.5. Conclusion of discussion**

In conclusion, signifiers and affordances play a crucial role in reducing both practical and psychological barriers in DIY repair by enabling action, guiding behaviour, and building user confidence. At the same time, their limitations reveal that repairability extends beyond product design alone. Addressing the full complexity of the repair process requires a combination of well-integrated design strategies and complementary support systems, opening up new directions for both research and practice.

# 10.

## **Conclusion & Recommendations**

# 10. Conclusion & Recommendations

This thesis set out to explore the role of signifiers and affordances in reducing psychological and practical barriers in the DIY repair process of small household electrical products. The rapid growth of electrical and electronic equipment (EEE) has led to increasing levels of electronic waste, highlighting the need for more sustainable product lifecycles. Although repair is a key strategy within the circular economy, consumers often replace products even when repair is feasible. This research therefore aims to understand how product design can better support consumers in engaging with repair.

The findings of this research demonstrate that signifiers and affordances play a complementary and interdependent role in enabling DIY repair. Affordances reduce practical and functional barriers by embedding repair possibilities directly into the product's structure, making repair actions technically feasible and physically achievable. Signifiers, in turn, reduce cognitive and psychological barriers by making these possibilities perceivable, understandable, and trustworthy. Together, they bridge the gap between technical repairability and user capability, transforming repair from a potentially intimidating task into a more guided and approachable experience.

At the same time, the results show that the impact of signifiers and affordances is not uniform across the entire repair journey. Their contribution is strongest in interaction-focused stages such as disassembly, reassembly, and navigation within the product. In contrast, more complex stages, particularly fault diagnosis, remain less effectively supported. This indicates that while signifiers and affordances form a foundational layer in reducing barriers to repair, they are not sufficient to fully address the complexity of the DIY repair process on their own.

This research contributes to the field of design

for repair by translating the roles of signifiers and affordances into a set of design principles for Easy DIY repair, and by demonstrating how these principles can be integrated within product embodiment through a case study redesign. In doing so, it highlights that reducing barriers to repair is not only a matter of technical feasibility, but also of designing products that communicate clearly, guide user interaction, and build confidence.

Based on these findings, several recommendations can be made for design practice. Designers should approach repairability as an integrated and user-centered design challenge, ensuring that repair actions are structurally enabled, safe, and clearly communicated. This requires the alignment of affordances and signifiers within the product to achieve well as an explicit focus on supporting user understanding through clear guidance and safe interaction cues. In addition, designers can benefit from anticipating common failure points and designing products in a way that allows for efficient testing and access to these components.

To support the practical implementation of the developed principles, further validation is recommended. This includes testing the principles across different product categories, applying them within design-from-scratch processes, and conducting longitudinal user studies to assess their impact on user behaviour, skill development, and confidence over time.

Ultimately, this research shows that making products repairable is not only a technical challenge, but also an interaction design challenge. By aligning what a product allows with what a user perceives and understands, signifiers and affordances can play a key role in making DIY repair more accessible, approachable, and widely adopted.

# Personal Reflection

At the start of this project, I set out with a few clear personal goals: to work more efficiently towards what truly moves the project forward, to become more confident in making design decisions, to become better at presenting my projects, and to better understand what consumers need of products in order to feel confident repairing products. Looking back, this project has been a valuable process in working towards those goals, while also revealing where I still have room to grow.

This project was the first design project in which I took on a wide range of roles simultaneously, including design lead, academic researcher, UX researcher, product designer, UI designer, interaction designer, content strategist, and project manager. Taking on these multiple roles at once pushed me to explore what kind of designer I am. What stood out most is that I confirmed my passion and motivation driven by topics related to sustainability and user behaviour. Working on design for repair felt meaningful, and that intrinsic motivation helped me stay engaged throughout the entire project.

In terms of efficiency, I learned that I can structure my work well in theory, but struggle to maintain that structure in practice. I tend to get absorbed in tasks and continue iterating, which sometimes makes it hard to keep track of priorities. Over time, I found that working with a small set of clearly defined, short-term goals, with timers to limit the time per task, helped me stay focused. This showed me that efficiency, for me, is less about strict planning and more about creating simple, tangible focus points during the process.

Furthermore, I pushed myself to present my work more frequently during this project. I delivered two presentations to a group of repair experts: one at the Retail2Repair Marktmeesters event and another at an LDE thesis repair lab event. I also practiced by discussing my project with various stakeholders in the repair industry. Engaging with experts and consumers helped me gain confidence in my expertise, learn to articulate my ideas clearly regarding the topic, and adopt the correct technical terminology.

When it comes to decision-making, I noticed that I often hesitate by keeping options open for too long. This was especially visible in the transition from research to design. While I felt confident and engaged during the research phase, particularly when interacting with users and exploring real-life repair situations, I found it difficult to narrow down insights into a clear design direction. As a result, I stayed quite conceptual and delayed making concrete design choices. This made me realise that building confidence in design decisions is not just about mindset, but also about creating the right conditions, such as defining clear design requirements and principles early on and allowing myself to commit to them.

One of the project's greatest strengths was the deep dive into user needs, where I found a perfect synergy between user research and product design. My exploratory approach, ranging from direct observation to personal experimentation, revealed the deep-seated emotional and practical barriers that often prevent people from repairing products. A core insight I will carry forward is the power of 'default' sustainability: the idea that through intuitive design cues, we can make sustainable actions feel automatic rather than a difficult decision. Ultimately, this work reaffirmed my passion for user-centric roles, proving that I enjoy designing most when I can directly interact with and understand the people I am designing for.

At the same time, the project highlighted how much I rely on external input to move forward. I noticed that I worked most effectively when approaching feedback moments, as they forced me to structure my thoughts and make decisions. This helped me realize that I have a social learning style and thrive in agile feedback loops. The lesson for me is not just that I benefit from working in a team, but that I need to proactively organize structures, such as peer reviews, to maintain momentum. I also realised that I missed collaboration during the design phase, and that involving perspectives of other designers earlier in the project would have helped me overcome uncertainty. This is something I want to actively incorporate in future projects.

Finally, I struggled with defining the appropriate level of detail and determining when a design could be considered “finished” within an exploratory context. While continuous iteration helped to evolve the design, it also made it difficult to finalize outcomes and present results. This uncertainty occasionally slowed down my progress and decision-making.

At the same time, this relatively unstructured design process was partly intentional. I chose to give myself the freedom to explore and develop my identity as a designer, without being overly constrained by predefined methods or rigid processes. Through this, I discovered that I thrive particularly in the early, generative phases and the engineering aspects of a project. I enjoy engaging with the broader problem space and taking an integrated approach that considers multiple aspects simultaneously to arrive at

a cohesive design. However, I found the final stages of the project more challenging, particularly in translating my ideas into clear and understandable visuals.

Moving forward, I aim to define clearer expectations for the level of resolution earlier in the design process, in order to better balance exploration with timely decision-making and project completion.

Overall, this project helped me take important steps towards my initial goals. I have become more aware of how I work, what motivates me, and where my strengths lie: particularly in research, ideation, and iteration. At the same time, I recognise that I need to keep developing my ability to make decisions, structure my process, and confidently move from exploration to execution.

# References

- Ackermann, L. (2018). Design for Product Care: Enhancing Consumers' Repair and Maintenance Activities. *The Design Journal*, 21(4), 543–551. <https://doi.org/10.1080/14606925.2018.1469331>
- Ackermann, L. (2020). Design for Product Care [TU Delft]. <https://doi.org/10.4233/uuid:9fe0a3cd-a7f7-4d29-bb44-6dc78575a2e8>
- Ackermann, L., Mugge, R., & Schoormans, J. (2018). Consumers' perspective on product care: An exploratory study of motivators, ability factors, and triggers. *Journal of Cleaner Production*, 183, 380–391. <https://doi.org/10.1016/J.JCLEPRO.2018.02.099>
- Andeobu, L., Wibowo, S., & Grandhi, S. (2021). An assessment of e-waste generation and environmental management of selected countries in Africa, Europe and North America: A systematic review. *Science of The Total Environment*, 792, 148078. <https://doi.org/10.1016/J.SCITOTENV.2021.148078>
- Baldé, C. P., Kuehr, R., Yamamoto, T., McDonald, R., Althaf, S., Bel, G., Deubzer, O., Fernandez-Cubillo, E., Forti, V., Gray, V., Herat, S., Honda, S., Iattoni, G., Khetriwal, D. S., Luda di Cortemiglia, V., Lobuntsova, Y., Nnorom, I., Pralat, N., & Wagner, M. (2024). *The Global E-waste Monitor 2024* (United Nations Institute for Training and Research (UNITAR), Ed.; 2nd ed.). International Telecommunication Union (ITU). <https://www.itu.int/itu-d/sites/environment>.
- Bayraktaroğlu, S., & İdemen, E. (2024). Redefining Repair as a Value Co-Creation Process for Circular Economy: Facilitated Do-It-Yourself Repair. *International Journal of Design*, 18(1), 1–22. <https://doi.org/10.57698/V18I1.01>
- Bergman, M., Apostolova, V., Simeone, L., & Laursen, L. N. (2025). Service Design for Repair Practices in the Circular Economy: A Systematic Review Approach. *World 2025*, Vol. 6, Page 154, 6(4), 154. <https://doi.org/10.3390/world6040154>
- Chakraborty, S. C., Qamruzzaman, M., Zaman, M. W. U., Alam, M. M., Hossain, M. D., Pramanik, B. K., Nguyen, L. N., Nghiem, L. D., Ahmed, M. F., Zhou, J. L., Mondal, M. I. H., Hossain, M. A., Johir, M. A. H., Ahmed, M. B., Sithi, J. A., Zargar, M., & Moni, M. A. (2022). Metals in e-waste: Occurrence, fate, impacts and remediation technologies. *Process Safety and Environmental Protection*, 162, 230–252. <https://doi.org/10.1016/J.PSEP.2022.04.011>
- Dangal, S., Balkenende, R., Faludi, J., Den Berge, V., & Arcos, P. (2021). Perceived Capabilities and Barriers for Do-It-Yourself Repair. <https://www.researchgate.net/publication/361074098>
- Dangal, S., Balkenende, R., Faludi, J., Eisenriegler, S., Reichl, H., Haas, J., Neumerkel, A., Wild, J., Depypere, M., & Opsomer, T. (2022). Design for physical durability, diagnosis, maintenance, and repair.

- Davidson, H. L. (2004). *Troubleshooting and Repairing Consumer Electronics without a schematic* (3rd ed.). McGraw-Hill.
- Elkington, T. (2021). Right to Repair: 6 Design for Repairability Principles | LinkedIn. <https://www.linkedin.com/pulse/right-repair-6-design-repairability-principles-tony-elkington/>
- Ellen MacArthur Foundation. (2023, February 10). What is the linear economy? <https://www.ellenmacarthurfoundation.org/what-is-the-linear-economy>
- EUR-Lex. (2024). Common rules promoting the repair of goods and amending related EU legislation. <https://eur-lex.europa.eu/EN/legal-content/summary/common-rules-promoting-the-repair-of-goods-and-amending-related-eu-legislation.html>
- European Commission. (2023, March 22). Right to repair: Making repair easier for consumers. [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_23\\_1794](https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1794)
- European Environmental Bureau. (2024). Right to Repair - EEB - The European Environmental Bureau. <https://eeb.org/en/work-areas/circular-economy/right-to-repair/>
- Fairphone. (2025). We are Fairphone. Our journey so far. <https://shop.fairphone.com/about-us>
- Fathy, A. T. M., Ghareeb, S. El, & Shaban, Y. (2024). Digital Transformation and Design for Maintainability in Industrial Design. *Journal of Art, Design and Music*, 3(1). <https://doi.org/10.55554/2785-9649.1031>
- Flipsen, B. (2023, January). HotSpot Mapping user guide: Analysis of the circular readiness of your product. BrightSpace TU Delft. <https://brightspace.tudelft.nl/d2l/le/content/681549/viewContent/4037076/View>
- Framework. (2025). Framework. <https://frame.work/nl/en/about#what-we-re-fixing>
- Gaur, T. S., Yadav, V., Mittal, S., & Sharma, M. K. (2024). A systematic review on sustainable E-waste management: challenges, circular economy practices, and a conceptual framework. *Management of Environmental Quality: An International Journal*, 35(4), 858–884. <https://doi.org/10.1108/MEQ-05-2023-0139>
- Gaver, W. W. (1991). Technology affordances. *Conference on Human Factors in Computing Systems - Proceedings*, 79–84. <https://doi.org/10.1145/108844.108856>
- Gibson, J. J. (1979). The theory of affordances. *The Ecological Approach to Visual Perception.*, 127–143.
- Gibson, J. J. (1982). Notes on affordances. In E. Reed & R. Jones (Eds.), *Reasons for Realism: The selected essays of James J. Gibson* (pp. 401–418). Lawrence Erlbaum Associates.
- Guo, C., Lyu, C., Chen, J., & Zhou, D. (2018). A design approach based on a correlative relationship between maintainability and functional construction. *Eksploracja i Niezawodnosc*, 20(1), 115–124. <https://doi.org/10.17531/ein.2018.1.15>
- Hielscher, S., & Jaeger-Erben, M. (2019, September). Resisting Obsolescence? The Role of a “Culture of Repair” for Product Longevity. *PLATE Conference - Product Lifetimes and the Environment*. <https://doi.org/10.14279/depositonce-9253>

- iFixit. (2025a). Repairability - iFixit. <https://www.ifixit.com/repairability>
- iFixit. (2025b, June 18). Tough, Tiny, and Totally Repairable: Inside the Framework 12. [https://nl.ifixit.com/News/111201/tough-tiny-and-totally-repairable-inside-the-framework-12?utm\\_source=chatgpt.com](https://nl.ifixit.com/News/111201/tough-tiny-and-totally-repairable-inside-the-framework-12?utm_source=chatgpt.com)
- Interaction Design Foundation. (n.d.). What are design guidelines? | IxDF. Retrieved January 15, 2026, from <https://www.interaction-design.org/literature/topics/design-guidelines?srsItd=AfmBOorHnMGzA7ScY5D0yqZwYCajJy8pjoHIHq9GNP0EnYQmWGSuacJX>
- Islam, M. T., Huda, N., Baumber, A., Shumon, R., Zaman, A., Ali, F., Hossain, R., & Sahajwalla, V. (2021). A global review of consumer behaviour towards e-waste and implications for the circular economy. *Journal of Cleaner Production*, 316, 128297. <https://doi.org/10.1016/J.JCLEPRO.2021.128297>
- Jaeger-Erben, M., Frick, V., & Hipp, T. (2021). Why do users (not) repair their devices? A study of the predictors of repair practices. *Journal of Cleaner Production*, 286. <https://doi.org/10.1016/J.JCLEPRO.2020.125382>
- Jin, Y., Mugge, R., Balkenende, R., & De Hooge, I. (2025). The Value of Emerging Technologies for Enhancing Consumer Trust and Adoption of Repair Electronics. *Proceedings of the 6th Product Lifetimes and the Environment Conference (PLATE2025)*, (6), 10323. <https://doi.org/10.54337/PLATE2025-10323>
- Lefebvre, M. (2019). To repair or not to repair: an investigation of the factors influencing prosumer repair propensity. <https://doi.org/10.26174/THESIS.LBORO.11365325.V1>
- Luo, X., Ge, Z., Guan, F., & Yang, Y. (2016). A method for the maintainability assessment at design stage based on maintainability attributes. *International Conference on Prognostics and Health Management*.
- Luo, X., Ge, Z., Zhang, S. G., & Yang, Y. (2021). A method for the maintainability evaluation at design stage using maintainability design attributes. *Reliability Engineering and System Safety*, 210. <https://doi.org/10.1016/j.res.2021.107535>
- Maier, J. R. A., & Fadel, G. M. (2009a). Affordance based design: A relational theory for design. *Research in Engineering Design*, 20(1), 13–27. <https://doi.org/10.1007/S00163-008-0060-3>
- Maier, J. R. A., & Fadel, G. M. (2009b). Affordance-based design methods for innovative design, redesign and reverse engineering. *Research in Engineering Design*, 20(4), 225–239. <https://doi.org/10.1007/S00163-009-0064-7/FIGURES/11>
- Marikyan, D., & Papagiannidis, S. (2023). Exercising the “Right to Repair”: A Customer’s Perspective. *Journal of Business Ethics* 2023 193:1, 193(1), 35–61. <https://doi.org/10.1007/s10551-023-05569-9>
- Masoudi, N., Fadel, G. M., Pagano, C. C., & Elena, M. V. (2019). A Review of Affordances and Affordance-Based Design to Address Usability. *Proceedings of the Design Society: International Conference on Engineering Design*, 1(1), 1353–1362. <https://doi.org/10.1017/DSI.2019.141>
- Ministère de la Transition écologique. (2022). Instructions manual for the display and the calculation of the repairability index of electrical and electronic equipments.
- Norman, D. (2013). *The design of everyday things (Revised & Expanded)*. Basic Books.

- Paasch, R. K., & Ruff, O. N. (1997). Evaluation of Failure Diagnosis in Conceptual Design of Mechanical Systems. *Journal of Mechanical Design*, 119(1), 57–64. <https://doi.org/10.1115/1.2828789>
- Parajuly, K., Green, J., Richter, J., Johnson, M., Rückschloss, J., Peeters, J., Kuehr, R., & Fitzpatrick, C. (2024). Product repair in a circular economy: Exploring public repair behaviour from a systems perspective. *Journal of Industrial Ecology*, 28(1), 74–86. <https://doi.org/10.1111/JIEC.13451>
- Park, M. (2019). Closed for repair: design affordances for product disassembly. Nissen, Nils F.; Jaeger-Erben, Melanie (Eds.): PLATE – Product Lifetimes And The Environment: 3rd PLATE CONFERENCE, BERLIN, GERMANY, 633–638. <https://doi.org/10.14279/depositonce-9253>
- Postma, M., & Stichting Repair Café International. (2025). Jaarverslag 2024 - Stichting Repair Café International. [www.repaircafe.org](http://www.repaircafe.org)
- Pouyamanesh, S., Kowsari, E., Ramakrishna, S., & Chinnappan, A. (2023). A review of various strategies in e-waste management in line with circular economics. *Environmental Science and Pollution Research* 2023 30:41, 30(41), 93462–93490. <https://doi.org/10.1007/S11356-023-29224-Y>
- Pozo Arcos, B. (n.d.). Corales Studio | Experts in Circular Design & Strategy. Retrieved November 22, 2025, from <https://corales.studio/hello/>
- Pozo Arcos, B. (2022). Fault Diagnosis in Household Appliances: A Design Perspective [TU Delft]. <https://doi.org/10.4233/uuid:b9fef4c4-c52d-4155-875c-bda9bc985f0d>
- Pozo Arcos, B., Bakker, C., Flipsen, B., & Balkenende, R. (2020). Practices of fault diagnosis in household appliances: Insights for design. *Journal of Cleaner Production*, 265, 121812. <https://doi.org/10.1016/J.JCLEPRO.2020.121812>
- Pozo Arcos, B., Balkenende, A. R., Bakker, C. A., & Sundin, E. (2018). Product design for a circular economy: Functional recovery on focus. *Proceedings of International Design Conference, DESIGN*, 6, 2727–2738. <https://doi.org/10.21278/IDC.2018.0214>
- Pozo Arcos, B., Dungal, S., Bakker, C., Faludi, J., & Balkenende, R. (2021). Faults in consumer products are difficult to diagnose, and design is to blame: A user observation study. *Journal of Cleaner Production*, 319, 128741. <https://doi.org/10.1016/J.JCLEPRO.2021.128741>
- Publications Office of the European Union. (2024, September 27). EU's Digital Product Passport: Advancing transparency and sustainability | [data.europa.eu](https://data.europa.eu). <https://data.europa.eu/en/news-events/news/eus-digital-product-passport-advancing-transparency-and-sustainability>
- Rietveld, E., & Kiverstein, J. (2014). A Rich Landscape of Affordances. *Ecological Psychology*, 26(4), 325–352. <https://doi.org/10.1080/10407413.2014.958035>
- Right to Repair Europe, & iFixit. (2024). Current State of EU Right to Repair. <https://www.repair.org/know-your-rights>.
- Roskladka, N., Bressanelli, G., Sacconi, N., & Miragliotta, G. (2025). Repairable electronic products for the circular economy: a review of design for repair features, practices and measures to contrast obsolescence.

Discover Sustainability, 6(1). <https://doi.org/10.1007/S43621-024-00753-X>

Roskladka, N., Jaegler, A., & Miragliotta, G. (2023). From “right to repair” to “willingness to repair”: Exploring consumer’s perspective to product lifecycle extension. *Journal of Cleaner Production*, 432, 139705. <https://doi.org/10.1016/J.JCLEPRO.2023.139705>

Roskladka, N., Miragliotta, G., Bressanelli, G., & Saccani, N. (2022). Exploiting the Right to Repair towards a sustainable future: a systematic literature review. 1–10. <https://re.public.polimi.it/handle/11311/1230486>

Rovira-Menaya, P., Pina, C., & Sierra-Pérez, J. (2025). Existing barriers to consumer repair of small household appliances from a product design approach: A scoping review. *Proceedings of the 6th Product Lifetimes and the Environment Conference (PLATE2025)*, (6). <https://doi.org/10.54337/PLATE2025-10288>

Russell, J. D., Svensson-Hoglund, S., Richter, J. L., Dalhammar, C., & Milios, L. (2023). A matter of timing: System requirements for repair and their temporal dimensions. *Journal of Industrial Ecology*, 27(3), 845–855. <https://doi.org/10.1111/JIEC.13280>

Sandez, S., Ibáñez-Forés, V., Pérez-Belis, V., Juan, P., & Bovea, M. D. (2023). Consumer practices regarding the purchase, use, willingness to repair, and disposal of small electric and electronic equipment: A Spanish survey on kettles. *Journal of Industrial Ecology*, 27(6), 1613–1625. <https://doi.org/10.1111/JIEC.13444>

Sandez, S., Pérez-Belis, V., Juan, P., & Bovea, M. D. (2023). Do users have the ability to self-repair non-complex electrical appliances? Design and development of a self-guided workshop with repair documentation in different formats. *Sustainable Production and Consumption*, 39, 244–256. <https://doi.org/10.1016/J.SPC.2023.05.007>

Shahabuddin, M., Uddin, M. N., Chowdhury, J. I., Ahmed, S. F., Uddin, M. N., Mofijur, M., & Uddin, M. A. (2022). A review of the recent development, challenges, and opportunities of electronic waste (e-waste). *International Journal of Environmental Science and Technology*, 20(4), 4513–4520. <https://doi.org/10.1007/S13762-022-04274-W/TABLES/1>

Sonego, M., Echeveste, M. E. S., & Debarba, H. G. (2022). Repair of electronic products: Consumer practices and institutional initiatives. *Sustainable Production and Consumption*, 30, 556–565. <https://doi.org/10.1016/J.SPC.2021.12.031>

Svensson-Hoglund, S., Russell, J. D., & Richter, J. L. (2023). A Process Approach to Product Repair from the Perspective of the Individual. *Circular Economy and Sustainability*, 3(3), 1327–1359. <https://doi.org/10.1007/S43615-022-00226-1>

Tackling Fixophobia. (2024). *Het Groene Brein*. <https://hetgroenebrein.nl/tackling-fixophobia/about-tackling-fixophob/>

Terzioğlu, N. (2021). Repair motivation and barriers model: Investigating user perspectives related to product repair towards a circular economy. *Journal of Cleaner Production*, 289, 125644. <https://doi.org/10.1016/J.JCLEPRO.2020.125644>

Terzioglu, N., Lockton, D., & Brass, C. (2015). Understanding User Motivations and Drawbacks Related to Product Repair. 9–10. <https://www.researchgate.net/publication/294256488>

- Tjiparuro, Z., & Thompson, G. (n.d.). Review of maintainability design principles and their application to conceptual design.
- Torca-Adell, L., Ceschin, F., & Bovea, M. D. (2025). The need for incorporating user perception into the reparability indices: Insights from an observational study on small electrical devices. *Sustainable Production and Consumption*, 57, 413–427. <https://doi.org/10.1016/J.SPC.2025.05.024>
- Van den Berge, R., Magnier, L. B. M., & Mugge, R. (2022). Enhancing consumers' willingness to repair electronic products: How design can nudge sustainable behaviour. <https://doi.org/10.21606/DRS2022.335>
- Van den Berge, R., Magnier, L., & Mugge, R. (2023a). Sparking the Repair “Can-Do” Attitude: Enhancing Users' Willingness to Repair through Design Support in Fault Diagnostics. *International Journal of Design*, 17(3), 25–39. <https://doi.org/10.57698/v17i3.02>
- Van den Berge, R., Magnier, L., & Mugge, R. (2023b). Until death do us part? In-depth insights into Dutch consumers' considerations about product lifetimes and lifetime extension. *Journal of Industrial Ecology*, 27(3), 908–922. <https://doi.org/10.1111/JIEC.13372>
- Van Nes, N., & Cramer, J. (2005). Influencing product lifetime through product design. *Business Strategy and the Environment*, 14(5), 286–299. <https://doi.org/10.1002/bse.491>
- Waalboer, M., & Stichting Repair Café International. (2024, October 23). 15 years of Repair Café exuberantly celebrated in The Hague - Repaircafe. <https://www.repaircafe.org/en/15-years-of-repair-cafe-exuberantly-celebrated-in-the-hague/>
- Wieser, H., & Tröger, N. (2016). Exploring the inner loops of the circular economy: Replacement, repair, and reuse of mobile phones in Austria. *Journal of Cleaner Production*, 172, 3042–3055. <https://doi.org/10.1016/j.jclepro.2017.11.106>
- Withagen, R., de Poel, H. J., Araújo, D., & Pepping, G. J. (2012). Affordances can invite behaviour: Reconsidering the relationship between affordances and agency. *New Ideas in Psychology*, 30(2), 250–258. <https://doi.org/10.1016/J.NEUIDEAPSYCH.2011.12.003>
- Wolf, M., & McQuitty, S. (2013). Circumventing traditional markets: An empirical study of the marketplace motivations and outcomes of consumers' do-it-yourself behaviours. *Journal of Marketing Theory and Practice*, 21(2), 195–210. <https://doi.org/10.2753/MTP1069-6679210205>
- Xavier, L. H., Giese, E. C., Ribeiro-Duthie, A. C., & Lins, F. A. F. (2021). Sustainability and the circular economy: A theoretical approach focused on e-waste urban mining. *Resources Policy*, 74, 101467. <https://doi.org/10.1016/J.RESOURPOL.2019.101467>



Name student Finn Kasse

Student number 5,060,834

## PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Tackling Fixophobia: Exploring how product embodiment influences consumer perceptions of repairability

*Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.*

### Introduction

*Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)*

The waste stream of electrical and electronic equipment (WEEE), or e-waste, is growing rapidly due to current production and consumption patterns of consumer electronics (Shahabuddin et al., 2022). E-waste severely impacts the environment through CO<sub>2</sub> emissions and the use of toxic heavy metals and harmful plastics in production (Mary & Meenambal, 2016). The principles of the circular economy (CE) promote a closed-loop system aimed at minimizing waste streams and reducing environmental harm. Within the circular economy, repair plays a central role in reducing waste by prolonging product use and value (Rogers et al., 2021).

Despite growing legislative and industrial efforts to improve product repairability, many consumer electronics are still discarded rather than repaired. Especially for lower-investment electronic products, such as coffee makers, buying new is considered low-risk and more convenient compared to repair. This tendency is reinforced by “fixophobia”: the reluctance to attempt repair due to perceived complexity or low self-efficacy, that is, a lack of confidence in one's ability to successfully complete the task (Van den Berge et al., 2023).

This project explores whether design practitioners can influence consumers' perception of repairability and enhance their self-efficacy by integrating repair affordances into product embodiment and interaction cues. Features such as visible fasteners, color coding, transparent housings, and modular components may make repair more intuitive and help reduce fixophobia.

Key stakeholders include policymakers seeking to reduce e-waste through right-to-repair legislation; Manufacturers and design practitioners balancing regulations, cost, brand reputation, and aesthetics; Consumers seeking safe, aesthetic, functional and understandable products; and Repair cafés and independent repairers, who demonstrate the value of hands-on repair while also exposing how current designs can frustrate or discourage users.

→ space available for images / figures on next page

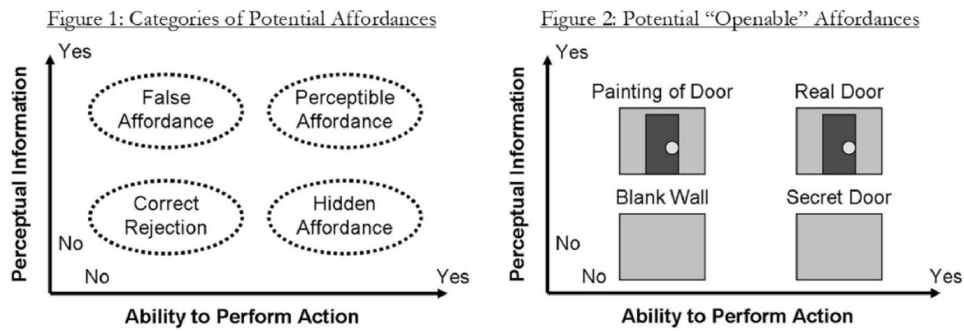


Fig 1: Relationship between affordances and an agent's perceptual information.

Fig 2: Examples that fit these categories.

Repair affordances are now hidden affordances. How can we make them perceptible Affordances?

image / figure 1 Relationship between affordances and an agent's perceptual information (Nye & Silverman, 2012).

image / figure 2

## Problem Definition

*What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.*

*(max 200 words)*

The consumer perspective on repair affordances remains underexplored, and there are no clear guidelines for design practitioners on how to effectively communicate a product's reparability through design to encourage repair behaviour. Many products that are technically repairable lack perceptual cues indicating how a repair can be performed. Their repair affordances are often hidden (Figure 1), providing little support for consumers' sense of self-efficacy; the belief in one's own ability to successfully perform a task.

This project investigates whether making repair affordances more perceptible can empower consumers in their repair practices. It aims to identify how designers and manufacturers can better support repair through product embodiment and interaction cues. To make the research more concrete, a selection of 3-5 fitting product categories will be chosen as case examples. Research within these categories will serve to explore and apply the developed framework and findings in context. Potential opportunities include introducing repair nudges or triggers (such as visible fasteners, color coding, or transparent housings) to make repair more intuitive and approachable while strengthening consumers' confidence and perceived self-efficacy. Ultimately, the project seeks to demonstrate how design features can empower consumers to repair, extend product lifespans, and contribute to a more circular approach to (lower-investment) consumer electronics.

## Assignment

*This is the most important part of the project brief because it will give a clear direction of what you are heading for.*

*Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence)*

*As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:*

*Deliver design guidelines and validated product prototypes that demonstrate how design interventions via embodiment and interaction cues can reduce consumer fixophobia and increase willingness to repair (lower-investment) consumer electronics.*

*Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)*

Week 1: Kick-off - Further define project brief and potentially reframe

Week 2-4: Research - Conduct a literature review and background analysis on fixophobia, consumer perception/behaviour, and repair affordances

Week 5-6: Ideate - Brainstorm concept directions, low-fi prototyping and testing

Week 7-8: Define - Midterm evaluation, define concept direction

Week 9-11: Develop - Develop prototypes to verify and validate concept viability and feasibility (relook and redefine concept, if needed)

Week 12-15: Test - Hi-fidelity prototype development, validate concept through user-testing

Week 16: Deliver - Greenlight meeting, 80% of report finished

Week 17-18: Synthesis - Combine user-test results, propose design guidelines

Week 19: Report - Finalize graduation deliverables

Week 20: Presentation

## Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting, mid-term evaluation meeting, green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).

Make sure to attach the full plan to this project brief.  
The four key moment dates must be filled in below

Kick off meeting	<u>7 okt 2025</u>
Mid-term evaluation	<u>1 dec 2025</u>
Green light meeting	<u>13 feb 2026</u>
Graduation ceremony	<u>20 mrt 2026</u>

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	<input type="checkbox"/>
For how many project weeks	
Number of project days per week	

Comments:

## Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.

(200 words max)

I am an Industrial Designer with a strong focus on human-product interaction and a passion for sustainable design. My ambition is to merge these dimensions to create user-centered solutions that are both meaningful and environmentally responsible.

For my graduation project, I chose to focus on repairability and consumer behaviour, as I believe this intersection is still underexplored yet increasingly relevant, particularly with the rise of right-to-repair legislation. This project allows me to investigate how design can encourage repair while also engaging with product embodiment and prototyping.

On a personal level, I aim to work efficiently towards the project's end goal; focusing on what I genuinely believe will move the project forward, rather than doing things just because I think they are expected of me. In addition, I aim to strengthen my confidence in making design decisions. I tend to hesitate by considering too many options, and I want to challenge myself to dive in, experiment, and trust my process. Through this project, I also want to gain a clear understanding of what consumers need from a product in order to feel confident enough to repair it. Ultimately, I hope this will help me better define my qualities as a designer and reflect on them in a constructive and stimulating way.

I also want to work on my presentation skills, particularly on my posture and finding a sense of calm while presenting.

In the early weeks of the project, several visits were made to Repair Cafés in and around Delft\* to explore repair culture and its barriers in practice. In addition, Repair Café de Esch in Rotterdam was visited on four occasions. This Repair Café operates with two volunteers who repair products brought in by customers, which are collected once the repair is completed.

During these visits, the repair process was observed in detail, including interactions between volunteers and customers. Conversations with both repairers and users provided insights into common product failures, repair strategies, required tools, and the types of products most frequently brought in for repair.

One of the most valuable insights was the systematic workflow used by experienced repairers. Eventhough the process seems unstructured and chaotic, see Figure I, there is an efficient workflow that resulted out of experience. Regardless of the product category, they follow a consistent diagnostic sequence: first testing the power source, followed by checking fuses, cables, individual components, and finally the PCB.

A similarly structured approach was observed in disassembly. Repairers typically begin by identifying visible screws, then look for other fastening mechanisms. If no fasteners are detected, they assume the product is assembled using snap-fit connections.

\* *Repair Café De Esch, Rotterdam*  
*Repair Café Delft-Papsouwselaan*  
*Repair Café Schipluiden*  
*Repair Café BlueDot TU Delft (unofficial)*

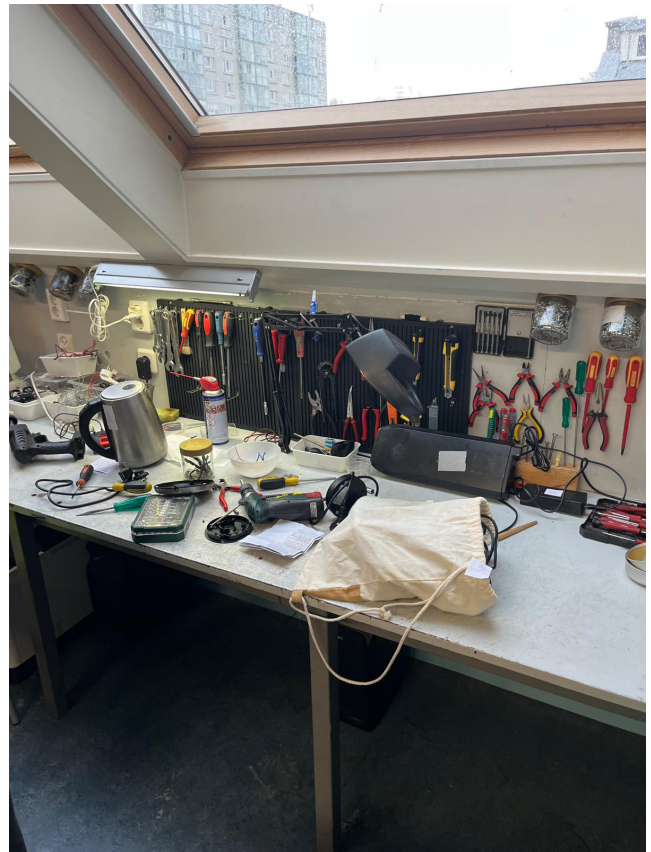


Figure 1. Photos made at Repair Café de Esch, Rotterdam.



Retail2Repair is an event focused on innovation, practical insights, and networking for professionals in the electrical retail and repair industry. It is hosted by Techniek Nederland and Delft University of Technology. Retail2Repair 2025 was held on 3 November at the Faculty of Industrial Design Engineering at Delft University of Technology. The event featured keynote speakers, interactive breakout sessions, the NK Mobile Repair competition, MarktMeesters student pitches, and an information square.

I applied for MarktMeesters and was invited to pitch my thesis research at the event, see Figure III.

In my pitch, I presented the focus of my thesis and the problem I aim to address: repair affordances are often hidden, and designers should incorporate signifiers to make these affordances visible, thereby encouraging consumers to repair their devices.

I presented to a panel of judges and an audience of professionals from the repair industry. Afterwards, I received feedback both verbally and through contact forms submitted by attendees, see Figure IV.

This feedback provided valuable insights into existing interventions in the market related to my topic, as well as important considerations for developing design guidelines, particularly regarding safety and regulatory constraints. It also helped identify which product categories are most suitable for further exploration within my research.

One of the respondents, a professor from the Hogeschool van Amsterdam, invited me to follow up for further discussion and examples of repairable products. During an online meeting, we exchanged ideas and explored how signifiers influence the perception of repairability, as well as which types of products are most suitable for implementing repair signifiers.

Together, we concluded that there is a gradation in the conspicuousness and explicitness of signifiers. Additionally, we observed that some products are better suited to “obvious” signifiers, such as those with a back or bottom plate (see Figure II), while others require more subtle or aesthetic signifiers due to the absence of hidden surfaces, such as shaving devices.

Takeaways:

- The concept of repair affordances and signifiers, as well as embedded repair cues, is not yet widely recognized within the Dutch repair sector.
- There is a gradation in the conspicuousness of signifiers, and their interpretation depends on the user’s knowledge and experience.
- Safety and regulatory compliance are primary concerns for companies in the context of DIY repair.



Figure II. Example of an obvious signifier for repair on the bottom plate of a coffee machine.



Figure III. Photos of my presentation at Retail2Repair 2025.

Welkom bij de Marktmeesters!

Je gaat zo luisteren naar studenten die midden in hun onderzoek zitten. Je krijgt een uniek kijkje in de onderwerpen waar studenten vandaag de dag mee bezig zijn en welke inzichten ze al hebben opgedaan. Maar ze kunnen jouw hulp goed gebruiken!

Help jij deze studenten op weg door hen in contact te brengen met de juiste bedrijven of personen? Of misschien kun je zelf op een andere manier iets voor ze betekenen? Vul dan dit formulier in en stop het na afloop van deze sessie in de wasmachine trommel bij de uitgang van de zaal en Techniek Nederland zorgt ervoor dat je in contact met ze komt.

Deelnemer: A - B - C - D

Naam bezoeker: \_\_\_\_\_

Organisatie: \_\_\_\_\_

Telefoonnummer: \_\_\_\_\_

E-mailadres: \_\_\_\_\_

Wat zou je voor de deelnemer kunnen betekenen?

*finw: kijkt naar "flawless e-commerce"  
→ Reparatie POEN = dan de conversie*

Welkom bij de Marktmeesters!

Je gaat zo luisteren naar studenten die midden in hun onderzoek zitten. Je krijgt een uniek kijkje in de onderwerpen waar studenten vandaag de dag mee bezig zijn en welke inzichten ze al hebben opgedaan. Maar ze kunnen jouw hulp goed gebruiken!

Help jij deze studenten op weg door hen in contact te brengen met de juiste bedrijven of personen? Of misschien kun je zelf op een andere manier iets voor ze betekenen? Vul dan dit formulier in en stop het na afloop van deze sessie in de wasmachine trommel bij de uitgang van de zaal en Techniek Nederland zorgt ervoor dat je in contact met ze komt.

Deelnemer: A - B - C - D

Naam bezoeker: \_\_\_\_\_

Organisatie: *Hogeschool v Amsterdam*

Telefoonnummer: \_\_\_\_\_

E-mailadres: *j...@HVA.NL*

Wat zou je voor de deelnemer kunnen betekenen? *INTERESSANT ONDERZOEK!*

*Mail mij voor voorbeeldproducten en een goed gesprek*

Welkom bij de Marktmeesters!

Je gaat zo luisteren naar studenten die midden in hun onderzoek zitten. Je krijg een uniek kijkje in de onderwerpen waar studenten vandaag de dag mee bezig zijn en welke inzichten ze al hebben opgedaan. Maar ze kunnen jouw hulp goed gebruiken!

Help jij deze studenten op weg door hen in contact te brengen met de juiste bedrijven of personen? Of misschien kun je zelf op een andere manier iets voor ze betekenen? Vul dan dit formulier in en stop het na afloop van deze sessie in de brievenbus bij de uitgang van de zaal en Techniek Nederland zorgt ervoor dat je in contact met ze komt.

Deelnemer: A - B - C - D

Naam bezoeker: \_\_\_\_\_

Organisatie: *HVA*

Telefoonnummer: \_\_\_\_\_

E-mailadres: \_\_\_\_\_ @ HVA.NL

Wat zou je voor de deelnemer kunnen betekenen?

*Maybe it makes your project too broad, but it might be interesting to look at business-models and not only line of production. I don't recollect any product that promotes repair, but companies that do that because of their business-model - they make profit of it or need it to decrease costs - such as phoneblocks or lease services such as Swappies. So far, it has to create value for the company or be imposed by law.  
( Sorry for the English, but faster for me :)*

Figure IV. Contact forms handed in after my presentation at Retail2Repair.

# Appendix D - Analysis of repairability of Small Household Electric Consumer Products



To get a more practical insight into the repairability of small household electric consumer products in the market, I analysed a range of products in these product categories:

- 2x Handheld vacuum cleaner
- 4x Philips Shaver
- 3x Hairdryer
- 2x Coffee machine
- 1x Electric heater
- 1x Gourmet hot plate
- 1x Styling iron

The analysis was twofold. I analysed videos of some products being repaired on Youtube, and I did some practical analysis myself. The practical analysis consisted of disassembling the product, finding the fault if there was any, and reassembling the product again.

I had no prior experience with repairing products before this project started. However, as I am an Industrial Design student, I did have prior technical knowledge and some insight in how products are designed and their architecture.

During the analysis proces, I took some notes and photos of the repair steps. Below, some of these notes and photo's can be seen. Some are restructured using ChatGPT.

## Insights

For almost every product I disassembled myself or had someone else disassemble, there were one or more moments of confusion and uncertainty about how to open the product. This often occurred because users started by removing the screws, but were then unable to proceed further. Consumers did not know what the next step was and began probing randomly with a spudger and pulling on the casing.

Hidden screws that still held the casing in place, or very strong snap-fits, led consumers to believe that the casing would break if they continued.

It was also unclear which casing components were actually connected. Some components appear to consist of two separate parts but are in fact a single piece for aesthetic purposes. Conversely, some components appear to be one piece but can actually be disassembled.

## Challenges in Disassembly

- How to open the product
- Where to start
- Uncertainty about whether the process is being done correctly
- Fear of breaking the casing
- Excessive effort required to open the product
- Lack of appropriate tools

## Minimum Requirements for Disassembly

- Product
- Screwdriver set
- Spudger

## Implications for Product Design

The product should clearly communicate:

- Where to begin disassembly
- That disassembly is possible
- Where snap-fits are located
- That visible screws actually provide access
- All while maintaining an attractive product appearance.

It is important that consumers have access to additional online support, particularly in cases of:

- Uncertainty
- First-time product disassembly

- Lack of appropriate tools

What consumers need:

- A clear step-by-step guide
- Additional explanation of specific actions
- Guidance on tool usage
- A nearby support point where they can receive assistance

# Philips Shaver Series 3000

## Video Observation 1

This analysis is based on a video in which an experienced repairer disassembles and diagnoses a faulty Philips AquaTouch Shaver (Jonny Fix, 2016). The video provides insight into the repair process, including fault diagnosis, iterative exploration, and interaction with product architecture.

### 1. Initial Diagnosis and Approach

The repair process begins with a hypothesis-driven diagnosis. Based on the symptoms (an unreliable power button) the repairer initially suspects water damage. This assumption guides the early stages of exploration.

The repairer starts by removing external “maintenance-level” components (e.g., shaving head), which are designed for regular user interaction. These components are easily accessible and clearly communicate their removability through visible affordances.

### 2. Exploration of Disassembly Path

After removing the maintenance components, the repairer begins searching for entry points into the internal structure:

- **Screws as signifiers:** The repairer identifies and removes visible screws, which serve as clear indicators of disassembly.
- **Uncertainty in product architecture:** At this stage, the repairer does not yet understand how the product opens. The process becomes exploratory and iterative.
- **Trial-and-error interaction:** The repairer attempts to gently pull apart components to test whether they are connected via clips or friction fits. When this fails, he switches to using a spudger.
- **Use of experience-based reasoning:** The repairer states that “it can’t be a great deal that holds this together,” indicating reliance on prior experience to justify applying more force.
- **Audible Feedback:** Upon applying torque with the spudger, audible “clicks” confirm the presence of snap-fit connections.
- **Delayed recognition of a visible screw:** After approximately one minute of attempting

to separate the casing, the repairer notices an additional, clearly visible screw on the back of the device. This suggests that even explicit signifiers can be overlooked when the overall product architecture is unclear.

### 3. Layered Product Architecture

Once opened, the repairer discovers a multi-layered internal structure:

- **Outer casing vs. inner sealed unit:** The product consists of an outer shell and a secondary, more tightly sealed inner casing.
- **Hidden clips and unclear separation logic:** The repairer initially struggles to separate these layers, again searching for clips and testing edges. A clip that was already visible is only recognised after further inspection, highlighting limitations in the clarity of signifiers.
- **Force-dependent disassembly:** Some clips require increased force or specific angles to disengage, which are not communicated by the product itself.

### 4. Access to Internal Components

Upon reaching the inner casing:

- **Perceived sealing and expectations:** The repairer observes that the internal components are well sealed, which leads him to reconsider the likelihood of water damage.
- **Transparent casing as a diagnostic aid:** A transparent enclosure reveals the PCB, providing visual access without immediate disassembly. The casing includes visible clips, clearly indicating how it can be opened.
- **Seal integrity concerns:** When opening the sealed casing, the repairer notes a “pop,” suggesting a loss of sealing integrity and reduced confidence in the product’s water resistance after reassembly.

### 5. Fault Diagnosis Process

The repairer proceeds with diagnosing the fault:

- **Initial assumption challenged:** Based on the button’s binary function (on/off), the repairer initially assumes the button is unlikely to be the issue, an assessment requiring prior technical knowledge.
- **Iterative diagnosis:** After inspecting electronic components (e.g., capacitors, transistors), the

- repairer returns to the button as a potential cause.
- Component-level repair: The button is desoldered and tested for electrical continuity. The repairer identifies internal resistance issues, likely caused by minor water damage or mechanical sticking.
- Micro-disassembly: The button itself is opened using tools (pliers), revealing an additional layer of complexity not intended for typical repair scenarios.

### 6. Reassembly Process

The repairer mentions that the reassembly includes several critical but implicit requirements:

- Ensuring proper alignment and engagement of the charging port (“must click properly”)
- Correct placement of seals to maintain water resistance
- Re-engagement of snap-fit connections, often requiring manual adjustment of deformed clips
- Application of force to close the casing, again guided by experience rather than explicit cues

Notably, the repairer does not strictly follow the reverse order of disassembly, indicating flexibility in assembly sequencing.

### Key Observations

- Repair as an iterative and interpretive process: The repairer continuously forms and revises hypotheses based on feedback from the product.

- Dependence on tacit knowledge: Many actions (e.g., where to apply force, how clips behave) rely on prior experience rather than explicit product communication.
- Limited effectiveness of signifiers: While screws and some clips are visible, their role in the overall disassembly sequence is not always clear, leading to inefficiencies.
- Hidden complexity: The layered architecture and sealed components increase repair difficulty and reduce accessibility for non-expert users.
- Mismatch between maintenance and repair design: While maintenance components are clearly accessible, deeper repair actions are not supported by adequate affordances or signifiers.

### Implications for Design

This case highlights several opportunities for improving repairability through design:

- Clearer communication of disassembly sequences and hierarchy
- Improved visibility and consistency of signifiers (e.g., screws, clips)
- Reduction of unnecessary concealment of functional elements
- Consideration of force requirements and how they are communicated
- Differentiation between maintenance access and repair access



Figure V. Screenshot from the Youtube video of Jonny Fix (2016) repairing a Philips aquatouch shaver.

Jonny Fix. (2016, 19 januari). Philips aquatouch shaver repair [Video]. YouTube. [https://www.youtube.com/watch?v=752F5QHsS\\_A](https://www.youtube.com/watch?v=752F5QHsS_A)

## Video Observation 2

This analysis is based on a video documenting a consumer attempting to diagnose and repair a faulty Philips electric shaver. The case provides insight into how non-expert users interact with product architecture, interpret faults, and navigate disassembly without prior repair experience.

### 1. User Context and Problem Framing

The user begins from a position of frustration. The device has stopped functioning despite being fully charged, and this is the second unit of the same model to fail within a relatively short period. This prior negative experience shapes the user's expectations and trust in the product.

The user reports:

- The shaver does not turn on despite being charged
- It does not function even when plugged in
- The on/off button is suspected to be faulty

The user explicitly questions product quality, attributing the issue to a "poor-quality button." This indicates an initial diagnosis based on observable interaction (button failure) rather than internal system understanding.

### 2. Initial Maintenance Actions

Before attempting full disassembly, the user performs surface-level maintenance:

- Cleaning the shaving head using compressed air
- Opening the accessible "lid" and removing visible debris

These actions reflect an understanding of routine maintenance affordances. However, when these do not resolve the issue, the user transitions to exploratory repair.

### 3. Disassembly Process

The disassembly process is largely exploratory and driven by visible cues:

- Screws as primary signifiers: The user identifies two screws beneath the shaving head and one on the back of the device. These are removed using a drill, indicating reliance on familiar fastening mechanisms.
- Uncertainty after initial access: After removing the

screws, the user pauses and explicitly questions how to proceed ("Can it come apart now?"). This highlights a lack of guidance in the product's disassembly logic.

- Transition to force-based exploration: The user attempts to pull apart the casing. When unsuccessful, a spudger is introduced to probe seams, revealing snap-fit connections.
- Discovery of clips through iteration: The user works around the perimeter of the device, locating clips incrementally. This process is time-consuming and dependent on trial-and-error rather than clear signifiers.

### 4. Access to Internal Components

Once the outer casing is removed:

- The user searches for additional fasteners and identifies internal clips securing the inner housing
- A screwdriver is used to disengage these clips
- The inner casing is removed only after applying force and slight manipulation ("wiggling"), indicating unclear detachment conditions

This stage demonstrates that internal layers are not intuitively separable and require persistence and improvisation.

### 5. Interaction with Fragile Components

At the next layer, the user encounters a transparent plastic cover with visible clips:

- Attempts to open the clips manually result in breakage
- The user attributes this to material degradation ("brittle" plastic)
- Further opening is achieved using a screwdriver, applying prying force

This highlights a critical barrier: even when affordances are visible, material properties and force requirements are not communicated, leading to damage during disassembly.

### 6. Fault Diagnosis Process

The user proceeds with diagnosing the issue:

- Initial hypothesis: faulty button
- The button is identified as a simple switch, and the user attempts to bypass it by shorting the contacts

- When this yields no result, the user shifts focus to the battery

During measurement with a multimeter:

- The device unexpectedly turns on when contact is made with the battery
- This leads to a revised hypothesis: a loose or unstable electrical connection

The user tests the button again and finds it functional, contradicting the initial assumption. This illustrates an iterative and non-linear diagnostic process.

### 7. Uncertain Fault Resolution

Further observations include:

- The battery voltage appears within expected range (~3.6–3.7 V), causing confusion
- The device begins functioning intermittently without a clear intervention
- The user speculates on possible causes (e.g., motor brushes, loose connections) but cannot confirm

Ultimately, no definitive fault is identified. The device appears operational, but reliability remains uncertain.

### 8. Reassembly Process

During reassembly:

- The user repeatedly tests the device after partial reassembly, indicating uncertainty about the repair outcome
- Snap-fit connections prove difficult to re-engage, requiring multiple attempts and increased force
- Component orientation (e.g., button placement) is unclear, suggesting a lack of reassembly guidance
- Screws are only reinserted after full reassembly, reflecting a non-systematic approach

### 9. User Experience and Perception

The user remains dissatisfied despite partial success:

- The repair is not perceived as successful due to the absence of a clear diagnosis
- Trust in the product is further reduced
- The user expresses disappointment with the brand, referencing prior positive experiences and contrasting them with recent failures



Figure VI. Screenshot from the Youtube video of aaanton11 (2018) repairing a Philips aquatouch shaver.

aaanton11. (2018, 23 oktober). Philips Shaver Faulty, “How to Repair” [Video]. YouTube. <https://www.youtube.com/watch?v=5pqES502-TE>

This case illustrates how unclear repair processes can negatively impact both product perception and brand trust.

### **10. Key Observations**

Exploratory repair behaviour:

- The user relies heavily on trial-and-error due to a lack of clear repair signifiers and guidance.
- Over-reliance on screws as entry cues: Once screws are removed, the next steps are not communicated, leading to uncertainty.
- Hidden or ambiguous snap-fit connections: Clips are only discovered through probing, increasing effort and risk of damage.
- Material degradation as a barrier: Brittle components hinder repair and reduce perceived product quality.
- Iterative and uncertain diagnosis: The user repeatedly revises hypotheses without reaching a

definitive conclusion.

- Low perceived repair success: Even when functionality is restored, the absence of clear causality reduces confidence in the repair.

### **11. Implications for Design**

This case highlights several design opportunities:

- Provide clearer signifiers for disassembly sequences beyond initial screws
- Improve communication of snap-fit locations and required force
- Design components and materials to withstand multiple disassembly cycles
- Support intuitive reassembly through clearer orientation cues
- Facilitate fault diagnosis by making system behaviour more interpretable

## Own observation disassembly

After analysing the two videos of the somewhat experienced repairers attempting the repair of the Philips Aquatouch Wet&Dry on Youtube, I got my own product secondhand, and attempted the disassembly process myself.

I was biased and informed about the barriers to repair for this specific shaver model because of the Youtube clips, but I still wanted to experience the barriers myself.

I report only the most important additional findings in Figure VII, and divided all the findings over the repair stages, and identifying first need for signifiers

and affordances in Figure VIII, Figure IX, and Figure X. As I knew where the initial 3 screws were located, I started by removing those, allowing for the top to come off, see Figure VII. With the top removed, the small hair trimmer on the back of the shaver shot off unexpectedly.

For the next step, I knew that there were snapfits holding the front and back of the casing together. Even though I had analysed two prior repair videos of this product, I still found it hard to navigate the spudger in the casing, as there were three different product lines that could be slightly opened with the spudger.

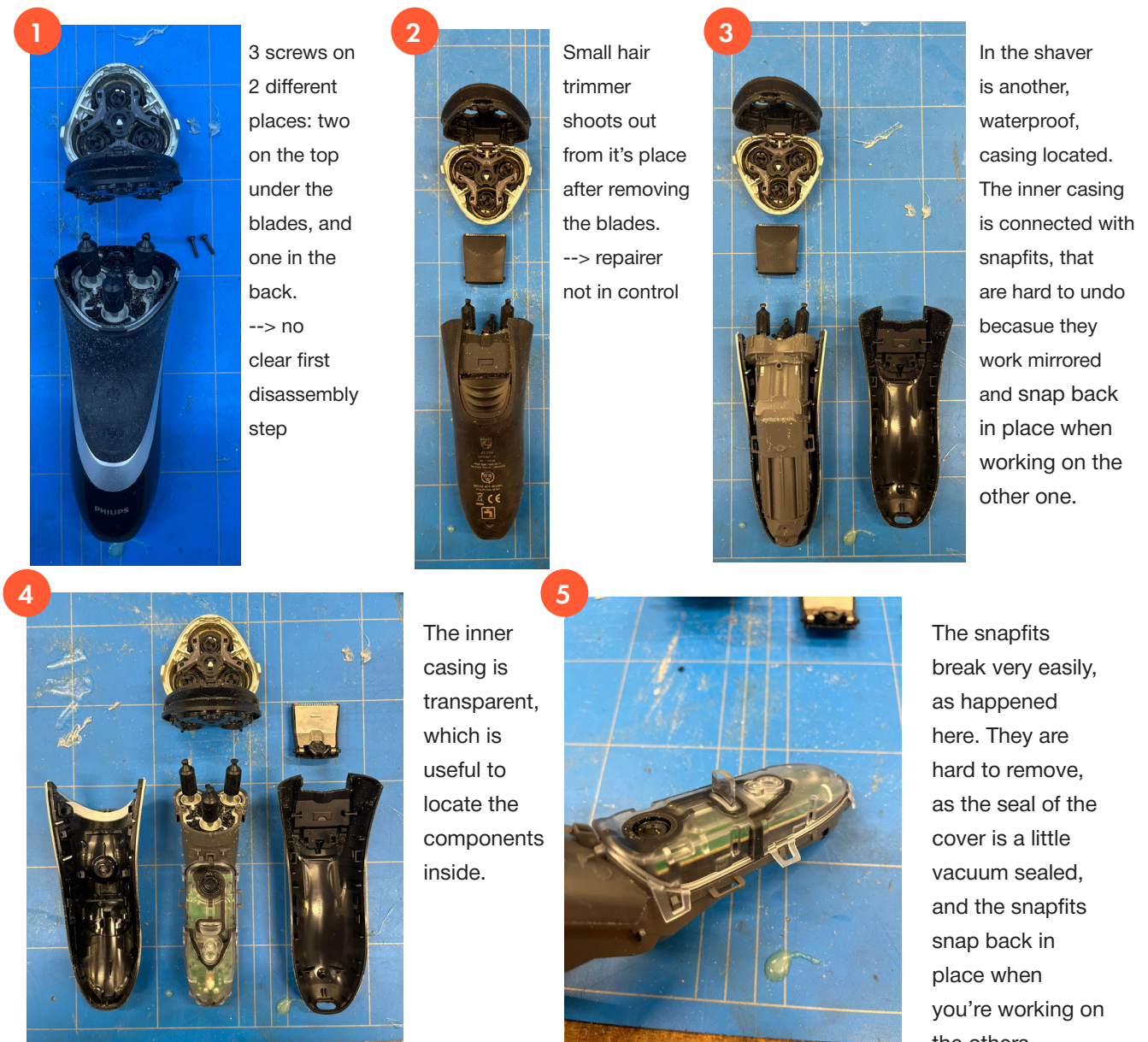


Figure VII. Shaver disassembly analysis.

# Repair-intention

As an inexperienced consumer, is repair possible, permissible, and worth trying?



Unclear that product can be repaired

Unclear whether warranty is still valid (when opening product)

Unclear what the user is 'allowed' to do without harming the product, themselves or the warranty

- ↳ signifier
  - ↳ communicate that product can be repaired
  - ↳ communicate warranty rules
  - ↳ communicate where user can find more information
- ↳ self-signifying affordance
  - ↳ show our ability through sturdy materials and shapes
  - ↳ show first step in the disassembly process

Figure VIII. Barriers shaver during the repair-intention stage.

# Repair-insight

As a consumer, how can I find out what is faulty and what steps are needed to repair the product?



Unclear what components there are and how they are connected for an inexperienced repairer

Unclear what to look for to find the fault

- ↳ signifier
  - ↳ communicate/guide the user through the fault diagnosis
  - ↳ communicate which components should be tested
  - ↳ communicate where to place multimeter probes
  - ↳ communicate which result is expected
- ↳ affordance
  - ↳ make the fault diagnosis fool-proof



Battery, a priority component is the last component to reach

Unsafe exposure to electrical components before battery can be removed

- ↳ affordance
  - ↳ make the priority components easy to reach



Unclear what the user is 'allowed' to do without harming the product, themselves or the warranty

- ↳ signifier
  - ↳ communicate warranty rules
  - ↳ communicate where user can find more information

Figure IX. Barriers shaver during the repair-insight stage.

## Repair-action

What steps should I take to carry out the repair safely, correctly and without errors?



3 screws, but not grouped together and therefore unclear connection; 2 under blades, and one in the back

Unclear which fasteners hold the part together

↳ mapping  
↳ map fasteners that have relevance to each other together



Unclear what to do after screws are removed and upper part has come off

Unclear where to continue the disassembly process

↳ signifier/self-signifying affordance  
↳ communicate the next possible disassembly actions



Once found that it must be a snapfit, it is unclear where the snapfit is located

↳ signifier/self-signifying affordance  
↳ communicate where the snapfit can be opened



Unclear what the next disassembly step is once the outer case is off

↳ signifier  
↳ mark the fasteners that need to be removed with colour or icons



Snapfits bend non-elastically when opened, leading to uncertainty about water tightness after opening

Lack of trust in materials (seals, opened snapfits)

↳ affordance  
↳ each step is reversible  
↳ materials and shape communicate durability

Figure X. Barriers shaver during the repair-action stage.

## Black+Decker handheld vacuum cleaner

This round handheld vacuum cleaner was the first product I disassembled for this project. The experience did not start well, as I was initially unable to open the device. I explored the product from all sides, searching for entry points, but without success. The visible screws did not release any part of the casing, and attempts to insert a spudger at various seams were unsuccessful.

I then asked a couple peers to attempt opening the product without damaging it, but they encountered the same difficulties.

During a visit to the Repair Café in Schipluiden, I presented the product to two volunteer repairers and challenged them to open it. They also searched for cues indicating how the product could be opened, but were unable to find any. Additionally, no relevant information on disassembling this specific vacuum cleaner could be found online.

They pulled and applied force to various parts,

taking turns in their attempts to open the product, see Figure XI. Eventually, they applied significant force with a spudger between the casing parts and managed to open the device after approximately 15 minutes (see Figure XII). After opening it, the repairers discovered that screws enabling disassembly were present, but hidden beneath a friction-fit, ring-shaped cover (see Figure XIII).

Had the location of these concealed screws been apparent, the product could likely have been opened within two minutes.

Takeaways:

- Visible screws should correspond to actual disassembly functions; otherwise, they are deceptive.
- Successful repair often requires confidence and a willingness to apply force, particularly when products lack clear opening cues.



Figure XI. Applying force to various parts on the product.





Figure XII. Prying the handheld vacuum open with a spudger and a lot of force.



Figure XIII. Realising that there were screws that could open the casing, but hidden under a friction fit ring-shaped cover.

## Power drill (Repair Cafe Schipluiden)

This observation is based on a repair session at the Repair Café in Schipluiden, where two volunteer repairers collaboratively worked on a faulty power drill.

The product was relatively easy to disassemble. The housing was secured with clearly visible screws, which acted as effective signifiers for disassembly. Additionally, the product architecture was straightforward, consisting of a limited number of components, which reduced overall complexity during opening.

However, despite the visibility of the screws, access was not fully straightforward. The screws were deeply recessed within the casing, requiring a specific type of screwdriver to reach them. This created a dependency on specialized tools, forming a barrier to repair for users without access to such equipment.

Once opened, the repairers encountered difficulties in understanding the internal component layout. In particular, they were uncertain about how different

components were connected to the PCB and how the wiring was structured. This lack of clarity made it challenging to determine how to measure and assess the functionality of individual components.

Takeaways:

- Visible screws function as effective signifiers for disassembly and lower the threshold for opening a product.
- Accessibility of fasteners is as important as their visibility; recessed screws can create practical barriers by requiring specialized tools.
- A low number of components and a simple product architecture support ease of disassembly.
- Internal layouts that are not clearly structured or labeled hinder fault diagnosis, even for experienced repairers.
- Repairability depends not only on the ability to open a product, but also on the clarity of internal organization and component relationships.

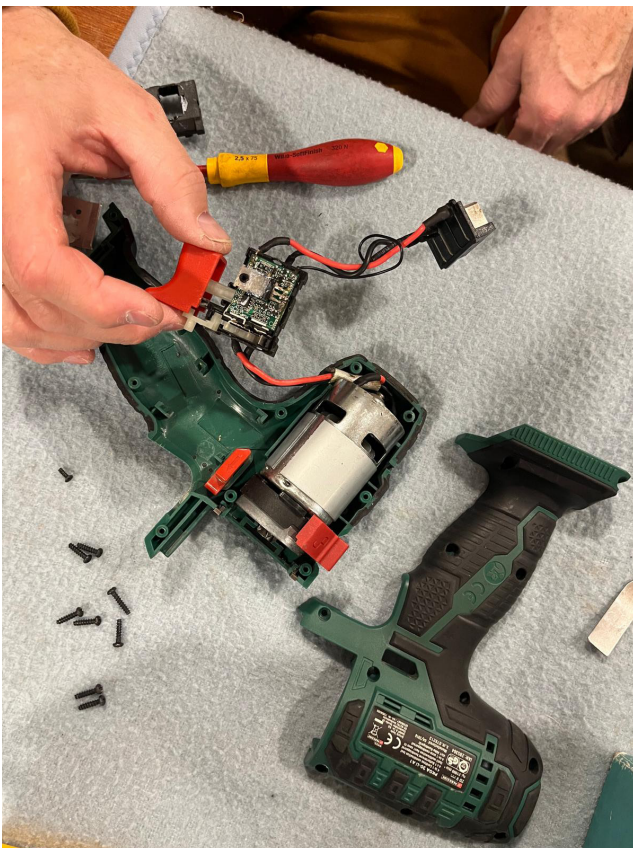


Figure XIV. Repair of a power drill during Repair Café Schipluiden.



## Electric heater

This case describes the disassembly and analysis of an electric heater, carried out with support from technicians at the Product Modelling & Building (PMB) facility at the Faculty of Industrial Design Engineering.

The device was straightforward to open, as the housing was secured with visible screws. These screws acted as clear signifiers for disassembly and allowed relatively easy access to the internal components.

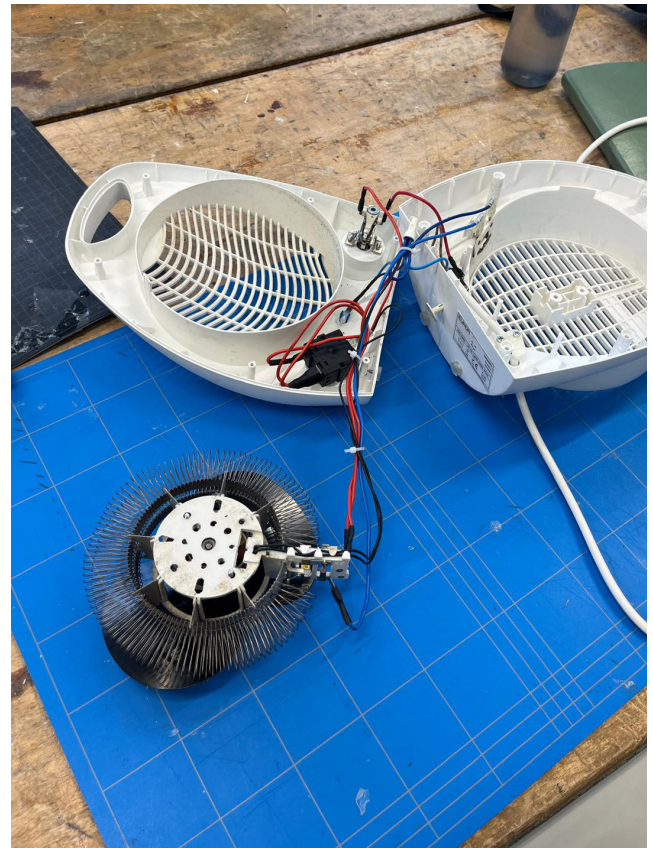
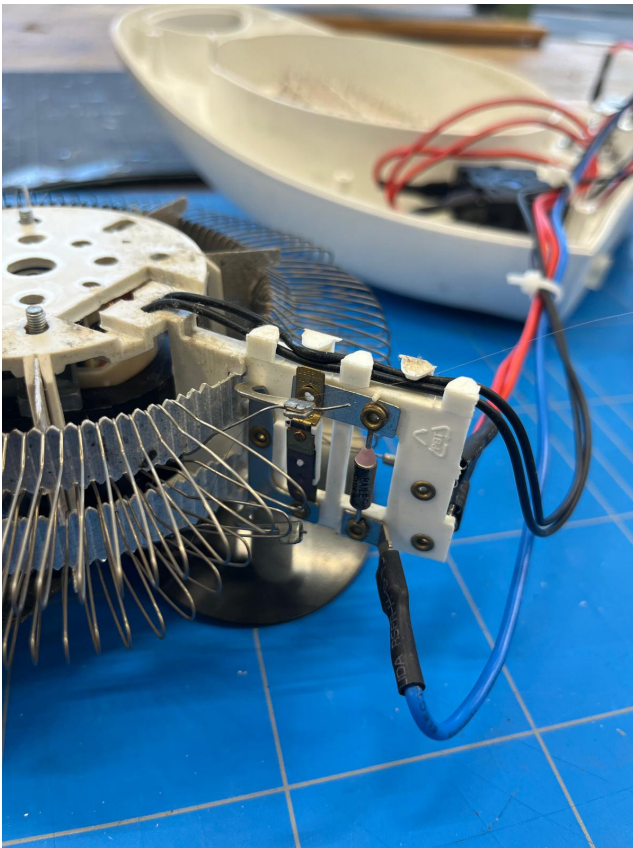
However, once opened, the internal structure proved difficult to interpret. The heater contained a dense arrangement of wires, small components, and multiple fuses. For an inexperienced repairer, the relationships between components and their respective functions were not immediately clear, making it challenging to understand how the system operated as a whole.

Based on the observed symptoms (specifically, that the fan was functioning while no heat was produced), it was initially hypothesised that a thermal fuse had failed. This assumption aligns with common repair heuristics, as fuses are often designed to fail first in order to protect the system.

With the assistance of experienced technicians, the internal functioning of the device was gradually mapped. This process revealed that, while identifying a broken fuse may be relatively straightforward, determining the underlying cause of failure is significantly more complex. A blown fuse is typically a consequence of another issue within the system, and diagnosing that root cause requires a deeper understanding of the product's internal architecture.

Takeaways:

- Visible screws provide clear and effective entry points for disassembly.
- Ease of opening does not guarantee ease of understanding; internal complexity can still form a significant barrier.
- Dense wiring and lack of clear organization or labeling make it difficult for inexperienced users to interpret product architecture.
- Fuses are commonly the first components to fail, but they indicate a symptom rather than the root cause of a problem.
- Diagnosing underlying faults requires system-level understanding, which is often not supported by the product's design.



# Nespresso Delonghi Magimix M100 NM

I got a broken nespresso machine from a teammate. She told me there was probably something wrong with one of the buttons.

I attempted the repair in the Bluedot Repair Café.

I tried to get as far as I could without help, and when I didn't know how to proceed, I could ask for help from the experienced repair volunteers.

I had watched videos of repairs of similar Nespresso machines previous to the repair attempt.

Symptoms: It doesn't respond at all when plugged in. No lights visible, and no noise.



I started by removing the water tank and cup holder.

Then I noticed the special oval screws, that I expected because I saw Youtube videos previous to this repair.



My own toolkit didn't have the oval screwdriver bits, so I asked around. The iFixit kit does have an oval bit that fitted the screw.

I unscrewed all screws at the bottom of the device and those visible.

Once I removed the screws, I could remove the bottom case of the device



I had seen online that the sides of the device were only connected with snapfits once the first screws were removed, so I pried between the parts and got the first couple snapfits loose.

I used quite some force, as I had seen online that it were snapfits holding that part together.

However, once I had the parts removed, I noticed I broke the same part on both sides of the device without noticing it in the moment.

Once I had the side covers removed, I observed whether I could see loose cables or other visible cues indicating a fault.

There were no visible faults.



Since the buttons didn't respond, I assumed something was wrong with either the PCB or the button connections.

I wanted to take a closer look at both the PCB and the button boards to look for faults.



The button boards were not yet accessible, as I had to remove the top case to get there.



I found that the PCB was covered with a plastic case. This case was held by two screws that I removed.

Once these screws were removed, I noticed that the PCB and the case were still connected together with snapfits, but that the subassembly had come loose by removing the screws.



I inspected the board for loose cables/connections or burn marks, but there were no visible faults.



It was harder to undo the snapfits because the whole subassembly was loose, but I managed to undo the snapfits with a flathead screwdriver.



I tried removing the top case, and I managed to loosen the snapfits of the base of this part. However, there was still something holding it in place. I couldn't figure out what it was for some time, so I started working on other parts. After some time of not understanding what the next step was, I only saw the screw at the bottom holding that case in place. It was visible, but I didn't expect it to be there and to hold the case, so I didn't notice it.



Once I removed the top case, I could see the button boards. However, there were also no visible faults here.



After removing this screw, the case could easily be lifted off.

I then didn't know how to further proceed, as I didn't know how to operate or effectively use a multimeter.

I asked one of the repair volunteers to help. They took a multimeter and explained and demonstrated me how to use it to check the connection of the cables and connectors.



We checked the power cable, the cables to the main board, and the cables to the button boards.

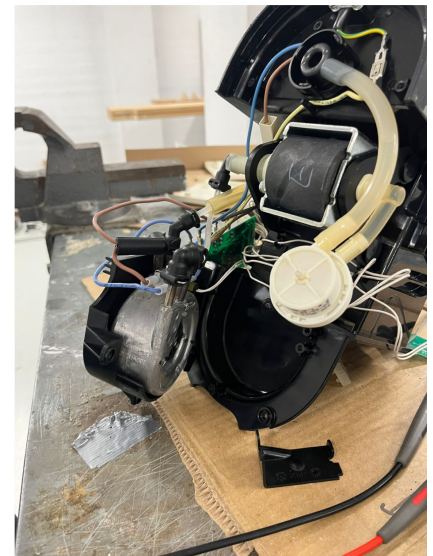
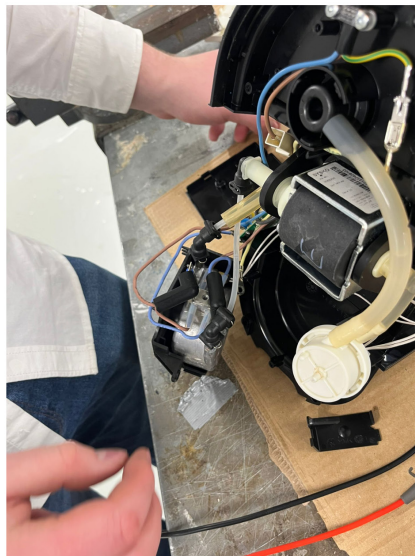
All connections seemed intact.

The repair volunteer blamed the fault on the PCB and told me that I should give up the repair.

Since I was also just interested in how the device looked like inside, I kept it open and explored.

Another volunteer repairer came looking. I explained that we checked all cables and found no faults.

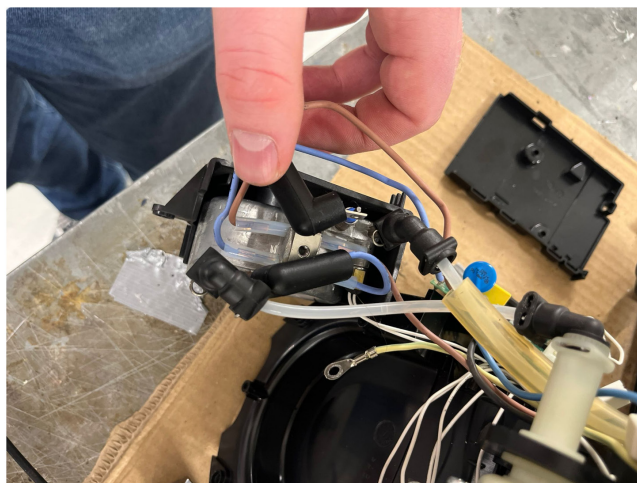
He told me that sometimes it is the thermal fuses that blow up.



We opened the device further by unscrewing 3 screws of the cover of the pump or heater.

We found the thermal fuses, and measured again the connection with the multimeter. The multimeter showed that the fuses were still intact.

We didn't have to have removed the case of the heater, since we already measured the same cables before and they showed no faults.



The volunteer repairer told me to check the manual online again to see if there was some information on what to do if there are no light indicators.

I found the manual online and found a 'troubleshooting' page, which told me to call the Nespresso Club.

On the next page, I found that to the contact details of the Nespresso Club could be found on the machine box or on nespresso.com

I visited nespresso.com because I didn't have the machine box.

I called the number on the Nespresso website.

They asked for the type of machine. I told them the machine is a 'Nespresso Magimix M100 auto NM', which is exactly what it says on the sticker at the bottom of the machine.

They could not find the machine in their system and asked me to look for the machine name on the purchase receipt.

I told them that I didn't have the purchase receipt anymore.

They could not help me further.

# TROUBLESHOOTING

No light indicator.	→ <b>Check</b> the mains, plug, voltage, and fuse. In case of problems, <b>call</b> the Nespresso Club.
No coffee, no water.	→ Water tank empty – fill water tank with potable water. → Descale, if necessary. → Fill up the water pump*
Coffee comes out very slowly.	→ Flow speed depends on the coffee variety. → <b>Descal</b> if necessary; see Descaling section.
Coffee is not hot enough.	→ <b>Preheat</b> cup. → <b>Descal</b> if necessary.
Capsule area is leaking (water in capsule container).	→ <b>Position</b> capsule correctly. If leakages occur, <b>call</b> the Nespresso Club.
Irregular blinking.	→ <b>Send</b> appliance to repair or call the Nespresso Club.
No coffee, just water runs out (despite inserted capsule).	→ In case of problems, call the Nespresso Club.
Both LEDs blink during ready mode.	→ Proceed to descaling.



# CONTACT THE NESPRESSO CLUB

As we may not have foreseen all uses of your appliance, should you need any additional information, in case of problems or simply to seek advice, call the Nespresso Club or your Nespresso authorized representative. Contact details for your nearest Nespresso Club or your Nespresso authorized representative can be found in the «Welcome to Nespresso» folder in your machine box or at nespresso.com

I looked at the FAQ, to see if the problems I experienced with the machine were maybe frequently asked. I found a question about a defect machine and the repair costs.

I cannot directly find the model 'magimix' in the types, but after searching online, I think the magimix is part of the essenza or inissia type. Therefore, Nespresso asks consumers to pay €75, without even knowing what is wrong what the machine or whether it is a problem that can be fixed.

**Mijn machine is defect. Hoeveel bedragen de reparatiekosten?**

Wij geven 2 jaar garantie op onze machines. Op machines met ingebouwde melkfunctie geven wij 1 jaar extra garantie. Op vertoon van het aankoopbewijs heb je, onder de voorwaarden van desbetreffende garantie, recht op een reparatie onder de garantie. Reparatie is in dit geval gratis. De kosten van transport, reparatie en onderdelen worden niet in rekening gebracht. Wanneer blijkt dat jouw toestel niet onder de garantie hersteld kan worden, word je hiervan op de hoogte gebracht.

Indien je geen aanspraak meer kunt maken op garantie, betaal je de kosten van de reparatie. De kosten verschillen per type machine en zijn een vast bedrag, ongeacht wat er mis is met jouw machine, zodat jij van te voren weet waar je aan toe bent.

Type	Kosten (Incl. transport, reparatie en onderdelen, excl. leenmachine)
Barista, Citiz, Essenza, Expert, Inissia, Pixie	€75
Citiz & Milk, Expert & Milk, Lattissima (behalve Lattissima Pro), Atelier	€115,-
Lattissima Pro, Creatista (Alle modellen)	€145,-
Vertuo Pop	€89,-
Vertuo Plus Vertuo Plus Deluxe Vertuo Next Vertuo Next Deluxe Vertuo Next Premium	€115,-

## Observation hair removal devices

During a visit to a Repair Café, I spoke with repairers and observed interactions with visitors to better understand their motivations and knowledge when dealing with broken products. One visitor brought in a six-year-old shaving device. He believed the device was no longer charging properly, as it would turn on for only two seconds before shutting off again.

The repairer was sceptical of this diagnosis, recognising the issue from prior experience. He began by removing the component beneath the blades by unscrewing two screws, after which he cleaned out the accumulated hairs inside the device. Once reassembled, the device functioned normally again.

At the beginning of my project, I also asked people in my social circle if they had broken products I could analyse. A friend showed me her “broken” epilator (Epilady), describing symptoms very similar to those observed at the Repair Café: the device would turn on briefly and then shut off. She had already purchased a replacement, assuming the original device (approximately eight years old) was beyond repair.

When I tested the device, I confirmed the same issue. However, after removing the epilator head and

turning it on again, the motor operated without any problems. This indicated that the device itself was not defective. Instead, the hair-catching mechanism was obstructed by built-up debris, which increased resistance and prevented proper operation. A thorough cleaning would likely have resolved the issue.

Takeaways:

- Shaving devices, particularly electric shavers and epilators, require periodic deep cleaning in addition to regular surface maintenance to ensure proper functioning and longevity.
- While many users are aware of routine maintenance (e.g., removing visible hairs after use), they often overlook the need for deeper internal cleaning over time.
- When a device stops functioning and routine maintenance does not resolve the issue, users tend to assume the product is broken and irreparable.
- In many cases, simple internal access and cleaning are sufficient to diagnose and resolve the problem.
- Even when products are technically repairable, a lack of visible repair affordances and signifiers prevents users from attempting repair in the first place.



## 1. Technical & Structural Requirements

Focus: How the product is physically built.

	Requirement Description	Stakeholder link
<p><b>TR-01</b></p>	<p><b>Standardized Fasteners:</b> All internal fasteners must be reachable with standard tools. Use a maximum of 2 unique, non-proprietary screw types (e.g., Phillips #2 or Torx T10). No permanent adhesives/welding for access.</p>	<p>Engineers, Consumers, Professional &amp; Community Repairers</p>
	<p>Reducing tool complexity is the first step in lowering the barrier to entry. If a consumer encounters “security screws” or glue, the repair journey usually ends immediately. Standardizing to 1–2 common types (like Phillips #2) ensures that a single, household screwdriver is all that is needed to service the entire device.</p>	
<p><b>TR-02</b></p>	<p><b>Priority Components:</b> Organize modules so the repair sequence is logical; components that fail most often should be accessible first.</p>	<p>Designer, Professional Repairers, Suppliers, Consumers</p>
	<p>Placing priority components at the start of the disassembly path, the design ensures that the most common repairs require the least effort, significantly increasing the likelihood of a successful DIY outcome and reducing the total repair time.</p>	
<p><b>TR-03</b></p>	<p><b>Modular Architecture:</b> Critical failure components (motors, fuses, batteries) must be separate modules.</p>	<p>Designer, Professional Repairers, Suppliers, Consumers</p>
	<p>This prevents “component-to-system” failure. When a 50-cent fuse is soldered directly onto a \$50 mainboard, the entire board becomes e-waste when the fuse blows. Modularity ensures that only the faulty part is replaced, keeping repair costs low and material efficiency high.</p>	
<p><b>TR-04</b></p>	<p><b>Diagnostic Hierarchy:</b> The internal layout should reflect a diagnostic hierarchy. Components that are easy to test (like fuses) should have a high visual hierarchy upon opening, allowing for a ‘quick win’ that builds the user’s confidence early in the process.</p>	<p>Designer, Professional Repairers, Suppliers, Consumers</p>
	<p>By layering the product architecture so that the most common and easily verifiable failure points are the “first-touch” components, the design facilitates a rapid diagnosis. This provides the user with an early success that validates their decision to attempt the repair and provides the psychological momentum needed to proceed with more complex steps. It also mirrors the way a professional technician thinks: “Check the power source first, then the fuse, then the switch.” By baking this into the physical layout, the product “thinks” for the consumer.</p>	

<b>TR-05</b>	<b>Standardized Components:</b> Use “off-the-shelf” parts (O-rings, bearings, switches) that are common across the industry to ensure long-term availability.	Suppliers, Engineers, Professional & Community Repairers
<p>Proprietary parts are the “bottleneck” of repair; if the manufacturer stops producing them, the product cannot be repaired as intended. Using industry-standard components ensures that spare parts remain available from third-party suppliers for decades, long after the original brand has moved on to newer models. Furthermore, this strategy provides a significant economic advantage to the manufacturer by eliminating the R&amp;D and tooling costs associated with specialized parts.</p>		
<b>TR-06</b>	<b>Ergonomic Clearance:</b> Provide enough physical clearance around fasteners so that the user’s hand and tool have a clear line of sight and room to move. This ensures the user feels physically capable and in control.	Suppliers, Engineers, Professional & Community Repairers
<p>For the DIY repairer, the ability to clearly see a fastener and comfortably maneuver a tool is directly linked to their perceived self-efficacy. This requirement ensures the user feels physically capable and in command of the process.</p>		

## 2. Human-Centric & Educational Requirements

Focus: Combatting “fixophobia” and ensuring user safety.

Requirement Description	Stakeholder link	
<b>HR-01</b>	<b>Visual Signifiers:</b> The product must use signifiers such as icons or colour-coding (e.g., “blue means unscrew”) to guide the user through the opening process.	Designers, Consumers
<p>This provides “on-product” guidance that reduces “fixophobia.” By using signifiers for repair actions, the product effectively explains its own assembly logic. This reduces cognitive load and the need for the user to constantly refer back to a manual.</p>		
<b>HR-02</b>	<b>Fail-Safe Disassembly:</b> The design must prevent “unintentional damage” during opening (e.g., no hidden plastic clips that snap if pulled the wrong way).	Community Repairers, Consumers
<p>Plastic tabs that snap during prying are a major source of user frustration. Designing for “non-destructive” entry ensures that the product remains aesthetically pleasing and structurally sound after it has been closed back up, encouraging the user to try again in the future.</p>		
<b>HR-03</b>	<b>Fail-Safe Reassembly:</b> The design must prevent incorrect reassembly by using physical constraints (e.g., asymmetrical geometry, keyed connections) and must communicate the intended assembly actions through intuitive physical affordances.	Community Repairers, Consumers
<p>By incorporating “Poka-yoke” (mistake-proofing) features like asymmetrical connectors or unique keyed housings, the product physically rejects incorrect assembly attempts. This “silent guidance” ensures the device remains safe and functional upon completion, reinforcing the consumer’s sense of autonomy and preventing “repair-induced” damage that would otherwise lead to total product replacement or complex warranty claims.</p>		

HR-04

**Inherent Safety:** High-voltage areas must be shielded or automatically discharged upon opening the outer casing to prevent shock.

Policy Makers,  
Consumers

Safety is a non-negotiable requirement for DIY repair. Physical shielding (Zone-based design) allows a consumer to safely access low-voltage components (like a fan or switch) without the risk of accidental electric shock from a capacitor or power supply.

HR-05

**On-Device Documentation:** A permanent link (QR code, NFC chip) must be visible on the product, linking directly to free, interactive, multi-language repair guides.

NGOs, Repair Platforms

Paper manuals are almost always lost by the time a product breaks (usually 3–5 years later). A permanent QR code provides a “Bridge to Digital Support,” ensuring the user always has access to the most up-to-date, multi-language repair instructions exactly when they need them.

HR-06

**Intended repair:** The aesthetic design should signal that opening the device is an intended, legitimate behaviour, removing the visual ‘fear’ of tampering.

Manufacturers, Brands

Signaling that a device is meant to be opened reduces psychological barriers and reframes repair from risky tampering to normal use. When users perceive disassembly as intentional, they are more likely to attempt repairs.

HR-07

**Feedback:** The design should incorporate ‘active feedback’ (e.g., an audible ‘click’ or a visible alignment tab) that confirms a component is correctly seated.

Community Repairers,  
Consumers

By incorporating multisensory feedback, the product provides progressive validation. This significantly reduces cognitive load and anxiety, as the user no longer has to wonder if a part is correctly placed or aligned. Beyond the psychological benefit, active feedback prevents common post-repair failures such as loose electrical connections, rattling components, or air leaks, ensuring the product returns to its original performance and safety.

### 3. Economic & Manufacturing Requirements

Focus: Keeping the product viable for the brand and the buyer.

#### Requirement Description

#### Stakeholder link

ER-01

**Production Efficiency:** The product architecture must prioritise reversible fastening methods that are compatible with high-speed automated assembly lines.

Engineers,  
Manufacturers,  
Consumers

In a high-speed automated environment, every second of cycle time matters. This requirement ensures that a product designed for DIY repair can still be produced for a reasonable price. It moves repairability out of the “niche/artisanal” category and into the mainstream mass market, which is essential for achieving systemic change.

ER-02

**Recycling** : The product architecture must prioritize reversible fastening methods that comply with design for recycling.

Engineers,  
Manufacturers

This requirement ensures that the choice to make a product repairable does not accidentally make it harder to recycle. While the priority is reversibility (for the DIY repairer), this requirement pushes the designer to think about the chemical compatibility of those fasteners. If a fastener can be made of the same material family as the component it holds (monomateriality), the entire assembly can sometimes be recycled as a single unit, further reducing industrial energy consumption.

ER-03

**Cost-to-Repair Ratio**: The retail price of common spare parts must not exceed 20% of the original product’s MSRP to ensure repair is “worth it” (Right to Repair Europe, 2024).

Consumers, Professional  
& Community Repairers,  
Suppliers

While current EU Right to Repair legislation does not mandate specific price caps, the European Commission’s Impact Assessment identifies 20% of the original purchase price as the upper limit for consumer acceptance of repair costs (Right to Repair Europe, 2024). Furthermore, the French Repairability Index penalizes products where spare part costs exceed 30%, categorizing them as economically unviable for the mass market. Consequently, this project adopts a 20% cost-to-repair ratio as a core economic requirement for DIY feasibility.

ER-04

**BOM Impact**: Design interventions for repairability must not increase the Bill of Materials (BOM) cost by more than 5% compared to the baseline.

Manufacturers, Brands

In alignment with the European Commission’s Principle of Proportionality used in Ecodesign preparatory studies (European Commission, 2018), this project adopts a 5% BOM cost-increase ceiling. This ensures that repairability features remain ‘cost-neutral’ enough for mass-market adoption without triggering significant retail price inflation that would alienate budget-conscious consumers.

## 4. Regulatory & Brand Requirements

Focus: Compliance and market positioning.

### Requirement Description

### Stakeholder link

RR-01

**Repair score**: The design must meet or exceed the minimum repairability score required by EU/national legislation for its category, and display it on the product.

Policy Makers,  
Manufacturers, Vendors

In the 2026 regulatory landscape, a repair score (ranging from 1–10 or A–G) acts as the “Energy Label of the Circular Economy.” By displaying this score prominently, the brand provides immediate, standardized transparency that allows consumers to compare the longevity of products at the point of purchase.

RR-02

**Warranty Transparency:** The product must clearly define “user-serviceable” zones that do not void the overall warranty if opened.

Consumers, Vendors

Uncertainty about what is legally permitted often discourages people from attempting DIY repairs. By clearly indicating which actions are acceptable, the brand builds trust and reassures users that they are not violating any rules. This clarity empowers consumers to maintain their own products with confidence.

RR-03

**Brand Aesthetic Integrity:** Repair features (screws, seams) must be integrated into the visual language so they don’t compromise the “premium” feel.

Manufacturers, Brands

Repairability should not look “clunky” or “industrial.” By treating fasteners and seams as intentional design elements, the brand maintains its “premium” feel while signaling to the customer that the product is a high-quality, long-lasting investment.

Right to Repair Europe. (2024). Towards a threshold for “reasonable price” of spare parts. [https://www.ecologie.gouv.fr/sites/default/files/documents/Notice\\_indice\\_reparabilite\\_](https://www.ecologie.gouv.fr/sites/default/files/documents/Notice_indice_reparabilite_)

European Commission. (2018). Behavioural Study on Consumers’ Engagement in the Circular Economy.



## Shaving device

<p>1.1.1 The design must explicitly communicate that DIY repair is possible, permitted, and supported.</p>	
<p>1.1.2 Communicate transparently about safety and warranty rules.</p>	
<p>2.1 Group actions into logically recognisable sets</p>	<p>Kleur sets          Rituel, labels, afbeeldingen, pictogrammen, voor de gebruiker</p> <p>Groneping door tegelijkertijd zichtbaar maken          "Kleur" "Rituel" "Labels" "Afbeeldingen" "Pictogrammen" "Voor de gebruiker"</p>
<p>2.1.2 Clearly indicate the first step in the repair process</p>	
<p>2.1.3 Clearly indicate the next step in the repair process</p>	
<p>2.2.1 Provide components with recognisable and consistent labels</p>	
<p>2.2.2 Label components and associated fasteners consistently</p>	
<p>2.3.1 Provide components or their immediate housing with clearly visible references to component-specific support</p>	
<p>2.3.2 Provide clearly visible references to general repair information and support on the product housing</p>	
<p>2.4.1 Support diagnosis by structuring the system in an understandable way</p>	
<p>2.4.2 Support diagnosis without reliance on measuring equipment</p>	
<p>2.4.3 When measurement is required, provide explicit and error-proof guidance</p>	
<p>3.1.1 Design components that only fit into the product in one way</p>	
<p>3.1.2 Visually indicate directions of movement and</p>	

<p>2.3.2 Provide clearly visible references to general repair information and support on the product housing</p>	
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<p>2.4.2 Support diagnosis without reliance on measuring equipment</p>	
<p>2.4.3 When measurement is required, provide explicit and error-proof guidance</p>	
<p>3.1.1 Design components that only fit into the product in one way</p>	
<p>3.1.2 Visually indicate directions of movement and alignment</p>	
<p>3.1.3 Use icons, colour coding, chamfers or magnetic guidance to indicate the correct placement</p>	
<p>3.1.4 Connectors can be detached and reattached with a limited number of actions</p>	
<p>3.1.5 Use design to make the intended user action (pull, push, pinch, turn) clear and intuitive</p>	
<p>3.2.1 Make hazardous components clearly identifiable</p>	
<p>3.2.2 Integrate automatic or guided discharge and blocking of hazardous components</p>	
<p>3.2.3 Force disconnection from power before the product can be opened</p>	



To evaluate whether the ideated concepts would function in a real product, I developed a series of 3D-printed prototypes to test the product architecture. Using CAD models created in Onshape, I produced these prototypes with the Bambu Lab printers available in the PMB at the Faculty of Industrial Design Engineering at TU Delft.

Following each prototype, I conducted iterative refinements based on observed issues and insights. In the photos below, I highlight the key shortcomings of each iteration, along with the corresponding improvements that were implemented.

After iteration 8, the fundamental product architecture proved to be successful. The prototype validated that all components fit within the redesigned product and that the proposed repair steps were feasible.

However, several improvements are still required to fully evaluate the user experience of the repair process. These include aspects such as refining interaction smoothness (introducing resistance in the entry-point collar of the redesign), and ensuring that the release button mechanism of the PCB unit functions properly within the casing. Due to inherent limitations of 3D printing, such as limited precision and material constraints, further development of fine details proved challenging with this prototyping method. As a result, additional iterations using this method were not suitable for achieving the desired level of refinement.

Therefore, this prototype primarily served to validate functional aspects and overall product architecture, while detailed refinement and finishing were further developed in the rendering software KeyShot.

## Prototype #1



*Basis shape of the shaver, copied from the original shaver design, with a threaded collar inserted to see whether turning a not-round shape as a collar would work, whether the action was intuitive, and whether it was logical to attach the collar to the bottom part or the upper part of the casing.*

*Improvements needed:*

- Thicker casing
- Something to hold the collar and bottom part of the casing together
- Snapfits that hold the two upper parts of the casing together

## Prototype #2



*Added snapfits to the upper part of the casing to simulate the original design of the shaver, and to see whether the pcb would fit in this redesign of the shaver.*

*Improvements needed:*

- Something sturdier to hold the collar and bottom part of the casing together
- Something to hold the PCB in place
- Sturdier snapfits

### Prototype #3



Made a module where both the PCB and battery can be attached to. Added sturdier snapfits to the upper part of the casing, and inserted a slider for the PCB module on the back part of the upper casing. Added hooks under the collar that could snap into the bottom part.

Improvements needed:

- More intuitive and stand-out shape of the collar
- Resistance when closing the collar

### Prototype #4



Added a rubber at the end of the ring to stimulate the feeling of a water tight seal. Added ribs/waves to the collar to signify the turning affordance. Added more detail to the upper casing to resemble the shaver better

Improvements needed:

- Moving the collar up in the architecture for aesthetic reasons

## Prototype #5



Moved the PCB slider from the back upper casing to the front upper casing. Altered the PCB and battery module to be a stack of layers, with a locking mechanism of the module to the bottom part in between them.

Improvements needed:

- Sturdier sliders
- Sturdier locking mechanism
- Better fit for the PCB and battery module

## Prototype #6



Moved the collar up in the product architecture. Made the PCB slider sturdier. Added part of the PCB slider in the bottom part. Added a split in the bottom part, with snapfits between them.

Improvements needed:

- Something to be able to add the razor blades part on top
- Better fit for the PCB and battery module, and hooks for locking in the bottom part

## Prototype #7



*Made the locking mechanism sturdier, and added a spring. Added a part on top that can connect the blades part on the upper casing.*

*Improvements needed:*

- *New idea for the locking mechanism, as the space in the shaver is too small to make this one work as desired*

## Prototype #8



*Subbed the locking mechanism with another locking mechanism, that instead of locking the pcb and battery module in the bottom part, locks it in the upper casing. I tried prototyping this mechanism in the 3D printer, but this prototyping method was not fitted for this mechanism.*