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The need for incorporating user perception into the repairability indices: Insights from an observational study on small electrical devices

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ABSTRACT

Repair is a key strategy in advancing a circular economy, as it extends product lifespan and reduces electronic waste. Existing Repairability Indeces assess the potential for repair, although they often focus on professional repairs, often overlooking end-user repair activities. This creates a research gap in understanding how non-professional users experience and perceive repairability. Small household electrical appliances, due to their relatively simple architecture, are sometimes repaired by users themselves rather than taken to a professional repair service. This study contributes to closing this gap by exploring users' perceptions of repairability in small electrical and electronic equipment and examining their alignment with calculated repairability indices. A user observation study (n = 26) was conducted to evaluate three critical stages of the repair process: (1) initial interaction with the fully assembled appliance, (2) the opening process, and (3) interaction with internal components once accessed. The observational study design included a protocol designed to standardise procedures across participants, and structured rubrics to ensure consistency in response interpretation. This rigorous methodological approach ensured reproducibility and enabled a detailed exploration of user behaviour. The results reveal a misalignment between users' perceptions and repairability indices, with perceived repairability scores decreasing by around 35.9 % and 58.8 % compared to the calculated ones, for two specific appliances. In addition, during the observational study, the following key barriers were identified: limited accessibility to internal components, particularly the difficulty of opening the product, and the complexity of fault identification. These findings highlight how user-centered barriers, such as design-related challenges (i.e. opening the appliance) and perceived complexity, differ significantly from the criteria considered in current repairability indices. Furthermore, findings emphasise the need to address user-centred repair challenges through design improvements that enhance accessibility and simplify disassembly, ultimately fostering greater consumer engagement in repair activities.

1. Introduction

Since the adoption of the New Circular Economy Action Plan (European Commission, 2022) and the European Green Deal (European Commission, 2019), the need to establish specific requirements for product durability, reusability, upgradability and repairability has grown. In this context, repairability has become a key factor in extending product lifespans. As Cooper et al. (2020) argue, it holds a particular relevance in the context of sustainable consumption, especially concerning Energy-Related Products (European Commission, 2022). This approach not only extends product lifecycles but also helps mitigate one of the fastest-growing waste streams globally—electronic waste—(Dhir et al., 2021; Koshta et al., 2022), which is projected to reach around 120 million metric tonnes annually by 2050 if current trends continue (Forti et al., 2020). Enhancing product repairability is also closely aligned with the objectives of the United Nations Sustainable Development Goals (SDGs), particularly SDG 12, which promotes sustainable consumption and production patterns by encouraging practices such as product longevity, waste prevention, and resource efficiency (United Nations, 2025).

Although recent EU regulations emphasise repairability, they remain primarily focused on professional repairers, offering limited guidance or resources for end-users attempting self-repair. Regulation such as Directive 2024/1781/EU (European Commission, 2024a) and Directive

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2024/1799/EU (European Commission, 2024b) grant professionals access to spare parts and technical documentation, but fails to address the practical challenges they face when attempting repairs. Similarly, Directive 2024/825/EU (European Commission, 2024c) focuses on informing consumers about repairability at the point of sale but fail to address the practical challenges they face when attempting repairs. This professional-oriented approach highlights a significant gap in current legislation, underscoring the need to better understand and support consumer repair efforts.

In addition to regulatory gaps, existing reparability indices, such as AsMeR (Bracquené et al., 2018), Repair Score System (RSS) (Cordella et al., 2019), French Repairability Index (FRI) (Ministère de la Transition Écologique, 2021), iFixit (Suovanen, 2023) or Repair Matrix (RM) (Blanco-Espeleta et al., 2024), tend to focus on professional contexts. These indices often fail to account for factors critical to consumers, such as ease of disassembly or the availability and clarity of repair instructions for end-users. As Barros and Dimla (2023) note, the lack of distinction between repairs by professionals and end-users creates a disconnect that undermines the practical usability of these indices for consumers.

Consumer decisions play a crucial role in sustainable consumption. Studies emphasise how awareness and motivation influence repair choices (Sonego et al., 2022) and how reluctance to repair can hinder environmental policies (Roskladka et al., 2023). Factors like accessible repair information and user-friendly designs have been identified as key enablers for repairability (Sandez et al., 2023a). Yet, barriers such as difficulty in opening devices (van den Berge et al., 2021; Pozo Arcos et al., 2021; Terzioğlu, 2021; van der Velden et al., 2023), in identifying faults (Pozo Arcos et al., 2021; Sandez et al., 2023b) or in reassembling the product (Cuthbert et al., 2016; Pozo Arcos et al., 2018) persist. However, none of the existing repairability assessment methods have been evaluated from the perspective of non-professional users. Existing indices focus primarily on professional repair scenarios and fail to address the practical barriers consumers face when attempting self-repair, such as disassembly complexity or unclear fault identification.

To date, no empirical study has analysed the relationship between calculated repairability scores and how users perceive the repairability of products during self-repair attempts. This gap is particularly relevant given the growing emphasis on consumer involvement in circular practices.

To address this gap, this research investigates three key aspects: (1) the alignment between users' perceptions and calculated repairability indices; (2) the impact of opening difficulty on perceived repairability; and (3) how user perceptions of priority parts can inform improvements in product design and repair methods. Through a user-centred observational study, this paper contributes to the development of more accurate, inclusive, and actionable repairability frameworks and aims to answer the following research questions (RQ):

- RQ1 - Do calculated Repairability Index scores align with users' perceptions of repairability?
- RQ2 - Can the difficulty of opening the product be a factor that casts doubt on the aspects evaluated in the Repairability Index?
- RQ3 - How could the perception of the reparability of priority parts influence the improvement of repair methods?

The paper is structured as follows: Section 2 provides a literature review on workshops and observational studies related to repairability. Section 3 describes the methodology adopted to address the research questions. Section 4 analyses the obtained results. Section 5 discusses how the findings address the research questions. Section 6 presents the conclusions, the limitations of the study, and recommendations for future research.

2. Literature review

The literature on product repair has addressed a wide variety of aspects, including consumer barriers and motivations to engage in repair, as highlighted by Ackermann et al. (2018), who emphasise the lack of effective triggers despite positive attitudes. Similarly, Dangal et al. (2021) underline how perceived capabilities and access to tools shape consumers' ability to engage in DIY repair (do-it-yourself repair). Along these lines, Terzioğlu (2021) expands this view by proposing a model that captures the complex mix of motivations and barriers influencing repair decisions. Regarding the socioeconomic characteristics of consumers who repair or choose not to repair, Sandez et al. (2023a) show that factors like price and energy efficiency outweigh repairability in purchase decisions, while Torca-Adell et al. (2025) point to the influence of income and education on repair practices. Comparisons of repair methods were also explored: Barros and Dimla (2023) link repairability scores to design features and policy tools; Pozo Arcos et al. (2023) examine how design decisions impact user repair behaviour; and Wandji et al. (2023) assess various standards for evaluating repairability across product types. The advantages of repair have also been analysed from both environmental and economic perspectives: Korsunova et al. (2023) highlight the role of social initiatives in promoting sustainable practices, Niskanen et al. (2021) frame repair as a political and justice-oriented act within a circular economy, while Svensson-Hoglund et al. (2023) conceptualize it as a user-centred, multi-stage process shaped by personal and contextual factors.

These studies provide a broad understanding of the repair ecosystem, highlighting key factors that influence repairability and consumer engagement. While previous research has addressed diverse aspects of repair behaviour, motivations and barriers, the relationship between calculated repairability indices and user perception during self-repair remains unexplored. This study builds on these foundations by employing an observational, workshop-based approach to bridge that gap.

Table 1 provides a comprehensive review of studies that investigate repair activities. For each study, key aspects have been identified, including the type of study, differentiating between: workshop, which are structured sessions where participants actively engage in acquiring knowledge and collaboratively solving repair problems with guidance or facilitation; observational studies, where researchers document participants' natural behaviour encountering repair challenges, without providing assistance or intervening in the process; and interviews and questionnaires, which capture individual or group perceptions, motivations, and knowledge related to repair.

The review also considers whether pilot studies were conducted prior to the final version, the sample size, and the type of participants. Two main categories of participant groups are defined: Mixed Experience Groups (MEG), composed of individuals with deliberately diverse backgrounds and varying levels of repair-related experience in order to capture a broad spectrum of perspectives; and Representative Samples of the Population (RSP), statistically constructed to reflect the demographic composition of the general population. In addition to these criteria, the review examines the types of resources participants used during repair activities—such as prior personal experience, visual guides, user manuals, and information from the internet— as well as the country where the study was conducted and the level of experience required for participation.

Lastly, the review outlines the specific aspects addressed by each study (aim), the type of analysis employed, and the category of products analysed.

The analysed studies are grouped into three main methods. A total of 41.2 % (7 out of 17 studies) used workshops. Observational methods were employed in 23.5 % (4 out of 17 studies). Finally, 64.7 % (11 out of 17 studies) used interviews or surveys, either as the main method or in combination with others. This strong reliance on interviews and surveys indicates a preference for self-reported data over actual user behaviour.

Table 1
Literature review of studies on product repairability: research designs, methods and focus areas.

	Type of study	Pilot study	Type of participants	Sample size	Skill levels	Data analysis	Addressed aspects								Support source	Products	Country
							Reuse	Self-repair	Barriers	Motivation	Fault diagnosis	Product lifetime	Repair information	Ease of disassembly			
Julsari et al. (2025)	Interviews and Workshop	✗	MEG	-	I	Descriptive analysis	✓		✓	✓		✓			Prior experience	Electronic equipment	Indonesia
Bakare & Rotimi (2024)	Interviews and workshops	✗	MEG	100	E	Quantitative analysis – statistical descriptive	✓	✓	✓		✓		✓		Prior experience	Electronic equipment	Nigeria
(Sandez et al. 2023b)	Self-guided workshop and interviews and observation	✓	RSP	60	M	Statistical analysis		✓			✓		✓		YouTube videos, user manual, and visual guide provided	Water kettles	Spain
Sandez et al. (2023a)	Surveys	✓	RSP	78	M	Quantitative analysis	✓	✓	✓			✓	✓		Not applicable	Electronic equipment	Spain
Masclet et al. (2023)	Interviews and observation in repair cafes	✗	MEG	25	I + E	Qualitative analysis			✓						Prior experience, external support or volunteer help, and occasional use of the internet	Household appliances, electrical appliances, clothes, Toys and bicycles	Belgium
Güsser-Fachbach et al. (2023)	Interviews	✓	RSP	40	E	Qualitative analysis	✓		✓	✓			✓		Prior experience, external support or volunteer help, and occasional use of the internet	Household appliances, bicycle, IT, cameras, smartphone	Austria
Talens Peiró et al. (2022)	Workshop	✗	MEG	500	I + E	Quantitative analysis	✓				✓	✓	✓	✓	Prior experience	Washing machines	Spain
Magnier & Mugge (2022)	Online survey	✗	MEG	617	B	Quantitative analysis	✓	✓	✓	✓		✓	✓		Not applicable	Smartphones, televisions, washing machines, vacuum cleaners	Netherlands
(Pozo Arcos et al. 2021)	Thinking out loud, observation and interviews	✗	MEG	24	M	Content analysis			✓	✓	✓			✓	Prior experience and product manual	Vacuum cleaner, kitchen blender, radio CD player, and coffee maker	Netherlands
Hielscher and Jaeger-Erben, (2021)	Participatory workshops and open interviews	✗	MEG	8	M	Statistical analysis		✓		✓		✓			Prior experience and product manual	Electronic devices, furniture, textile	Germany
Terzioğlu, (2021)	Interviews and workshops	✓	MEG	52	M	Content analysis			✓	✓					Prior experience and visual documentation	Textiles, furniture, electrical household appliances, toys	UK and Sweden
Gobert et al. (2021)	Semi-structured interviews, direct observation	✗	MEG	31	M	Qualitative analysis	✓			✓					Prior experience	Clothes, small household appliances, furniture	France
Laitala et al. (2021)	Semi-structured interviews and questionaries	✗	MEG	15 interviews 1196 questionaries	M	Qualitative and quantitative analysis	✓	✓	✓	✓		✓	✓		Not applicable	Electronic equipment	Norway
Bovea et al. (2018)	Telephone interview	✓	RSP	384	M	Statistical analysis	✓		✓	✓		✓			Not applicable	Household appliances	Spain
Pérez-Belis et al. (2017)	Telephone survey	✓	RSP	400	M	Quantitative descriptive analysis	✓			✓		✓			Not applicable	Household appliances	Spain
Terzioğlu (2017)	Interviews	✓	MEG	52	M	Affinity diagrams			✓	✓					Prior experience, technical documentation, and online resources	Household goods	United Kingdom (UK)
Chou et al. (2015)	Participatory workshops	✗	-	-	E	Conceptual model	✓					✓		✓	Not applicable	Electronic equipment	Taiwan

RSP: representative sample of population; MEG: mixed experience group.
Skill levels: B = beginner, I = intermediate, E = expert, M = mixed.
(Bakare and Rotimi, 2024; Bovea et al., 2018; Chou et al., 2015; Gobert et al., 2021; Güsser-Fachbach et al., 2023; Hielscher and Jaeger-Erben, 2021; Julsari et al., 2025; Laitala et al., 2021a; Magnier and Mugge, 2022; Masclet et al., 2023; Pérez-Belis et al., 2017; Pozo Arcos et al., 2021; Sandez et al., 2023a, 2023b; Talens Peiró et al., 2022; Terzioğlu, 2017, 2021).

Only a few studies employ observational approaches, which are essential for capturing real-life repair experiences and design-user interaction.

Regarding the addressed aspects, there is a clear emphasis on barriers and motivations related to repair, discussed in 61.1 % and 50 % of the studies, respectively. In contrast, other relevant factors—such as ease of disassembly, fault diagnosis, self-repair, and reuse, received significantly less attention, each appearing in only 22.2 % of the cases. Similarly, aspects like the availability of repair information and product lifetime extension were mentioned in 33.3 % and 38.9 % of the studies, respectively, indicating a comparatively lower level of focus than that given to barriers and motivations.

As for pilot testing, only 6 out of the 17 studies (35 %) reported conducting a pilot phase before the main research. To ensure methodological reliability and user adaptation, this study incorporated a dedicated pilot phase to validate and refine the tools used in the observational scenario.

In terms of sample types, 35 % of the studies (6 out of 17) used a representative sample of the population (RSP), while 59 % (10 out of 17) involved participants with mixed experience profiles (MEP), reflecting a more exploratory and contextual approach. One study did not specify the type of sample. Sample sizes varied considerably, ranging from 8 to 1196 participants, depending largely on the methodological design. Studies that used online or telephone surveys, such as those by Bovea et al. (2018), Laitala et al. (2021b), Magnier and Mugge (2022) and Victoria Pérez-Belis et al. (2017), typically achieved large-scale samples (between 384 and 1196 participants), enabling the collection of representative and quantifiable data.

Conversely, observational studies, including interviews, participatory workshops, direct observation, or "thinking aloud" sessions, worked with smaller samples ranging from 8 to 60 participants. For instance, Masclet et al. (2023), through observations at repair cafés, involved 25 participants; Gobert et al. (2021), using direct observation and semi-structured interviews, included 31; and Pozo Arcos et al. (2021), combining observation and interviews, had 24 participants. While these methods are more limited in scale, they offer valuable interpretive depth and help capture behavioural nuances that are often missed in survey-based approaches.

For data analysis, 47.1 % (8 out of 17) of the studies employed qualitative methods, such as content analysis and interviews. Quantitative approaches were used in 41.2 % (7 out of 17), primarily involving statistical analysis. The remaining 11.8 % (2 out of 17) adopted mixed-methods designs, combining both qualitative and quantitative techniques.

The literature review also reveals notable patterns in the sources of support used during repairs, the types of products considered, and the geographic contexts studied. Prior user experience emerged as the most frequently cited support mechanism, appearing in 66.7 % of the studies. This was followed by user manuals or technical documentation (27.8 %), visual guides and digital resources such as videos (22.2 %), and external or volunteer assistance (16.7 %). Another 16.7 % of the studies did not specify any source of support.

Geographically, 77.8 % of the studies were conducted in European countries, with a notable concentration in Spain (22.2 %), followed by nations such as the Netherlands, Germany, Norway, Belgium, Austria, France, the United Kingdom, and Sweden. This strong European presence reflects the continent's institutional, academic, and regulatory emphasis on circular economy principles and product reparability. However, it is important to highlight a recent trend towards the inclusion of non-European contexts: 22.2 % of the studies were conducted in Asia and Africa, including countries like Indonesia, Taiwan, and Nigeria. This expansion marks a significant step toward a more diverse and global understanding of repairability.

Finally, regarding the type of products, the analysis reveals a predominant focus on electronic devices, such as computers, mobile phones, general household items like washing machines, with 70.6 % (12 out of 17) of studies examining these categories. However, there is limited attention (33.3 %) to small household electrical appliances. Despite their widespread use and potential for repair, these products are often overlooked. Their relatively simple architecture and frequent disposal due to perceived irreparability make them an ideal category for investigating the alignment between design, repairability indices, and consumer experiences. For this reason, hairdryers were selected as the object of study. They are small electrical and electronic devices that have not been specifically analysed to date, generate a significant amount of waste—being disposed of in 62 % of cases without being repaired (Torca-Adell et al., 2025), and are present in more than half of households, according to Pérez-Belis et al. (2017).

Previous approaches have provided valuable insights into consumer behaviours, barriers, and motivations regarding repair. However, the present review identifies a crucial shortcoming: none of the reviewed studies examine the relationship between calculated repairability indices and user perceptions, particularly in self-repair contexts. Without understanding how users interpret and respond to repairability scores or design features, the practical usefulness of these indices remains uncertain.

This gap underscores the need for research focused on how users interact with repairability-related attributes, especially when attempting to repair devices independently. By addressing these limitations, the present study aims to contribute to a more user-centred approach to repairability assessment, offering actionable insights to improve product design and ensure that repairability scores better reflect real-world user experiences.

3. Material and methods

To address the three research questions, a three-stage methodology (Fig. 1) is proposed: (I) product category selection, (II) design of the observational study, and (III) implementation of the observational study.

3.1. Stage I. Product category and models selection

The category of electrical and electronic equipment (EEE) is prioritised in the EU Circular Economy Action Plan (European Commission, 2020) due to its rapid growth and significant resource consumption. EEE represents one of the fastest-growing waste streams in the EU (Neves et al., 2024; Parajuly et al., 2019) driven by increasing consumer demand and technological obsolescence. In it, the subcategory of small household electrical appliances is relevant due to their high production volume, short lifespan, and current low repair rates.

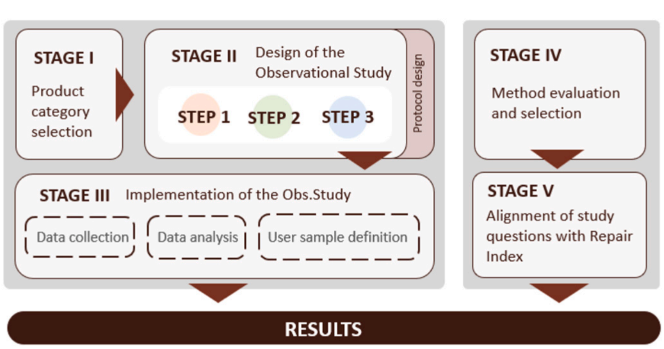

Fig. 1. Methodology.

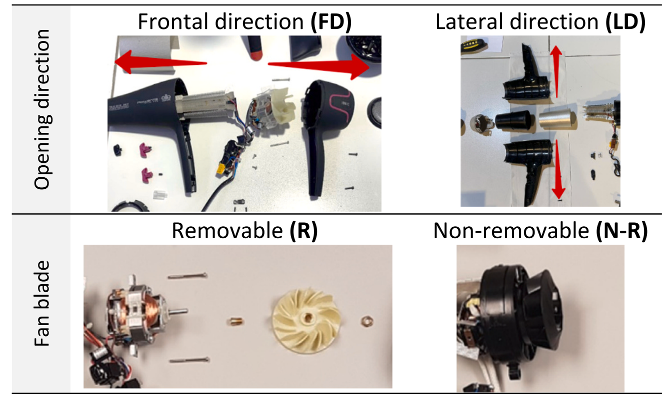

Fig. 2. Main differences between selected appliances, according to the opening direction and the type of fan blade.

As a case study for the development of this methodology, the appliance 'hairdryer' is selected, since it has a high prevalence in households and high frequent occurrence of malfunctions (European Commission, 2022), and since it is typically repaired by users rather than being taken to repair centres, as they are not complex devices (Sandez et al., 2023b). Moreover, they are non-fashion items, where new models often maintain similar aesthetics and functionalities (Cox et al., 2013). According to the Open Repair Alliance (2024), 96 % of the electrical and electronic products reviewed at repair events do not have a right to repair. Furthermore, these products, including the category of hair dryers, are reported to have a significant repair potential.

For the selection of the hairdryer models to be used in the study, an extensive search of models available on the market was conducted, taking into account a range of factors such as price, power, brand, and exterior and interior design. From this search, an initial sample of eight hairdryers was selected, disassembled, and analysed in terms of aspects such as accessibility, architecture, etc. It was observed that the characteristics that most influenced the hairdryer's opening and disassembly the hairdryer were the direction of opening and the type of fan blade (Torca Adell and Bovea, 2022), as shown in Fig. 2. Taking this into account, the two following hairdryers were chosen as a case study, since they are representative of the market and of the two most common product architectures identified:

- HD-A. Opens laterally | Fan blade is removable | High-quality internal components | Screws are hidden | 2400 W | 2 speeds and 3 temperatures | 24 × 11.6 × 30 cm | Brand 02 | Price: 80€.
- HD-B. Opens frontally | Fan blade is non-removable | Medium-low quality internal components | Screws are visible | 1200 W | 2 modes | 29 × 21 × 9 cm | Brand 08 | Price: 25€.

3.2. Stage II. Design of the observational study: protocol design

A protocol was designed to establish the steps to follow during the observational study. It ensured standardisation and consistency in data collection, reduce bias, and guarantee in its replicability. It included information related to the location, the duration, the equipment to be examined and the tools available for that. The pilot protocol was tested with two people in order to check the timing, the comprehensibility of the tasks and rubrics, etc. The improvement proposals were incorporated into the protocol, leading to the final version described below. The final version of the protocol was approved by the Brunel University of

London Ethics Committee (reference 47877-LR-May/2024-50860-2).

The observational study was designed to allow two people to participate simultaneously. Each participant was provided with the following material:

- Informed consent and Information sheet, according to the Ethics Committee, that should be signed to confirm their participation or, if not, to withdraw from the study (see Supplementary Materials S1 and S2).
- Two hairdryers corresponding to each of the models reported in Fig. 2, HD-A and HD-B. The selection of two hairdryer models made it possible to conduct the study with two participants in the same session. Each participant started with one model and, upon finishing, exchanged it with the other participant's model. This approach ensured that participants did not consistently rate the same model first, reducing any potential bias arising from the order of evaluation.
- A set of common tools (screwdrivers, spudgers, opening tools, etc.).
- Assessment guide, that enables participants to assess the reparability of devices during the observational study (see Table 2 and Supplementary Material S3: Guided Form). It included questions, scoring guides for each question and open fields for comments.

To ensure a clear understanding and proper conduction of the observational study, a 5-min presentation was made in which participants were given instructions on the steps to follow based on the material provided. The tasks to be done by each participant were divided into three steps:

Table 2
The evaluation questions used in the three steps.

STEP 1	DESIGN	D1	How accessible/easy is it to **open** this device, in case repair is needed?
		D2	How easy is it to locate the **connections**, **screws** or **access points** for disassembly?
		D3	How easy is **maintenance**, such as cleaning the blade?
		D4	How clear do you find the **device design** for identifying **potential faults**?
		D5	How intuitive is the **disassembly and assembly process** of the device?
		D6	How **confident and safe** would you feel to **repair the device** based on its external design?
		D7	How likely are you to choose to repair this device instead of replacing it in case of a failure, based on its design and perceived repairability?
	INFO.	I1	How do you rate the **access** to repair/disassembly **documentation** on the device?
		I2	How **useful** is the repair or disassembly **documentation** for the device?
		I3	How **clear** is the **documentation in identifying potential** device **issues?**
	SERVICE	S1	How **easy** would it be to request and/or purchase **spare parts** for this device?
		S2	How **varied** do you find the **range of spare parts** they offer?
		S3	How **suitable** do you find the **spare parts prices** compared to the device price?
		S4	How would you rate the **support** they provide for **product returns or repairs**?
STEP 2		A	Were you able to **open it**?
		B	Evaluate the difficulty you have encountered
			Mark which tools you have used. You will find the tools, their names and their references.
		A1	Flathead, Phillips, or star screwdriver
		B1	Special screwdriver (different from the previous ones)
		A2	Lever / Spudger (metal or plastic)

STEP 3

GENERAL QUESTIONS
G1 - Easy of identifying **screws inside**
G2 - Ease of identifying **components** *(e.g., motor, resistance, cables, fan blade)*
G3 - Ease of **accessing to components**
G4 - Ease of **replacing components without special tools**
G5 - Easy of **replacing components without removing other**
G6 - Ease of **disconnecting cables and connectors**
G8 - Component marking that helps with identification *(code or something similar to know which is which)*
G9 - Presence of components with **permanent fixings** *(non-reusable fastenings once removed)*
G10 - Kind of **tools**
G11 - Component design planned for **removal**
G12 - Compatibility of spare parts with **standard connectors** *(regarding interconnections between them)*
G13 - **Compatibility of spare parts** with other in the market *(in terms of size)*
G14 - Level of permanent **soldered joints** and components

	PRIORITY PARTS QUESTIONS
Motor	**M1** - How easy is to access the **motor** once the device is disassembled?
	M2 - How clearly can the motor and its connections be identified?
	M3 - How available and accessible are the spare parts for the motor?
	M4 - How well is the motor protected against dirt and fragments entry?
	M5 - How easy the motor connectors easy to handle and disconnect?
	M6 - How easy is it for you to repair the motor?
Heating element	**R1** - How easy is to access the **heating element** once the device is disassembled?
	R2 - How clearly can the heating element be distinguished from other components?
	R3 - How easy would it be to find and obtain a replacement resistance if it were damaged?
	R4 - How easy the resistance designed for easy removal and installation?
	R5 - How easy is it for you to repair the resistance?
Inter. cables	**IC1**- How easy is to access the **internal cables** once the device is disassembled?
	IC2 - How clearly can the internal cables and their connections be identified?
	IC3 - Are the cables color-coded for easier identification?
	IC4 - How easy would it be repair or replace the internal cables?
Fan blade	**FB1** - How easy is to access the **fan blade** once the device is disassembled?
	FB2 - How clearly is it evident which is the fan blade and how it is connected to the motor?
	FB3 - How available and accessible are the replacement fan blades for this device model?
	FB4 - How easy is it for you to repair the fan blade?
Power cable	**PW1** - How easy is it to access the **power cable** once the device is disassembled?
	PW2 - How clearly can the power cable and its connections be identified?
	PW3 - How easy is it for you to repair the power cable?

- Step 1 — Perception of repairability when the device is fully assembled. Participants rate their perception of the repairability of the devices while they were assembled, considering aspects such as the external design, information and service. To evaluate the design, in this step, participants were allowed to handle the appliance without trying to open it, focusing exclusively on its external design. For information and service, participants consulted the user manual and the manufacturer's website, which were provided to them in physical format and via a QR code. They then answered the corresponding questions reported in Table 2 and Supplementary Material S3.
- Step 2 — Evaluation of repairability when opening the device. Participants opened the device to assess its difficulty, determined whether it was possible to open it, what tools were used and what difficulties were encountered. At the end of this stage, participants had to answer the corresponding questions reported in Table 2.
- Step 3 — Perception of repairability once the device is open. In this stage, participants assessed the repairability of the device with its interior exposed. Those who were unable to open the appliance in step 2 were provided with an already opened hairdryer of the same model, so that all participants could take part in this third step, regardless of their success in the previous step. Participants answered general questions about the device's interior, including aspects such as the number of screws and component identification. In addition, more specific questions are asked about the priority parts identified in the Torca-Adell et al. (2024) study. Participants were asked if they could detect a fault in the hairdryer after analysing the priority parts.

The questions for each step (Table 2) were formulated based on the analysis of the EN 45554 (2020) standard. Each question was assessed on a Likert scale ranging from 1 (lowest score) to 5 (highest score), with a detailed scoring guide for each question (see Supplementary Material S3). Participants were also encouraged to provide comments related to each question.

The duration of each stage was established based on the following criteria:

- Pilot studies: the time it took participants to complete each step was observed during the pilot study.
- Theoretical disassembly times: times were estimated using the eDIM (Ease of Disassembly Method) (Vanegas et al., 2018), applying the disassembly sequence based on the disassembly map of De Fazio et al. (2021).
- Range of time from previous studies on the repair of small appliances:
  - Pozo Arcos et al. (2021) reported a time of 40 min (vacuum cleaner, kitchen blender, radio CD player, coffee maker).
  - Matarin et al. (2022) reported times between 15 and 30 min (coffee machine).
  - Sandez et al. (2023a) reported a range of 20 to 35 min (kettle).

Based on this information, the following time periods were defined for the steps of the observational study: 15 min for the first step, and 20 min for the second and third steps. Since each participant evaluates two hairdryers during the study, the total evaluation time was 2 h.

A facilitator was present throughout each observational study to provide assistance or answer questions as needed, ensuring that the study ran smoothly. The facilitator minimised interaction with participants to avoid influencing their perceptions, following the recommendations of Pozo Arcos et al. (2021). A video recording of each session was made in case additional information needed to be extracted later.

The collection of qualitative responses was intentional, as the aim was to capture users' perceptions of repairability rather than conduct a purely technical evaluation. This approach aligns with common practices in user-centred design and behavioural research, where perception is essential to understanding real-world experience. To reduce interpretive variability, a structured rubric was used to code responses consistently. These data were then analysed descriptively to identify common patterns across participant profiles.

3.3. Stage III. Implementation of the observational study

Data collection was conducted between May and July 2024. Recruitment posters with a QR code were hung in some public areas of the city (London) to recruit participants (see Supplementary Material S4 — Document to recruit participants). The QR code directed potential participants to a brief description of the observational study, including its objectives and procedures. If interested, they were asked basic sociodemographic information (gender, age and professional field) and their experience in repair, indicating whether they had previously repaired or disassembled an electrical or electronic appliance. Finally, they selected a preferred day and time for participating in the study.

The observations were carried at Brunel University of London. At the beginning of the session, each of the two participants found the required material already arranged on the table and proceeded to make their observations individually and simultaneously. Participant were positioned in the room so that they could not see one another, thereby reducing any potential bias in their responses. Also, they were assigned letters A and B according to their registration order, which indicated the hairdryer they would analyse first. The setup of the participants is showed in Fig. 3.

The "thinking aloud" method (Whalley and Kasto, 2014) was used, where participants were asked to freely express their thoughts and opinions while performing the repair tasks. This technique allowed for a broader and more detailed perspective on the difficulties and perceptions that arose during the process.

To define the sample size for this observational study, the saturation method (Morse, 2015) was applied. This method involves continuing the data collection process until the obtained information no longer contributes to new significant differences. At this point, saturation was considered achieved, and the inclusion of new participants ceased. According to the study by Hennink and Kaiser (2022) the sample size to achieve saturation in qualitative studies varies between 5 and 24 participants. In this study, saturation was achieved with 26 participants, evenly distributed by gender and repair experience, with age considered non-determinant in repair-related terms. Reaching saturation was a simultaneous process of data collection and analysis, as recommended by Braun and Clarke (2019) allowing for ongoing adjustments and refinements to the analysis.

At the end of each step, the response to each question in Table 2, for steps 1, 2 and 3, was obtained. To analyse the collected data, a preliminary descriptive analysis was conducted for each step of the study. Although the data was qualitative, the standardised responses in the forms allowed for the quantification of certain aspects, providing an overview of each step. This initial descriptive analysis enabled a general understanding of the perceptions and experiences of participants in each phase of the observational study and allowed for the identification and grouping of each theme from each step, which later helped to address the research questions.

3.4. Stage IV. Selection of the method to calculate repairability indices

Since one of the objectives of the study was to determine whether the perceptions assessed in the observational study aligned with the repairability indices, existing methods were analysed to select the appropriate one. Several methods have been developed in recent years to calculate the Repairability Index, as shown in Table 3.

All these methods evaluate three common aspects: design, information and service, though they do so associating different weighting factors. Table 3 details the weighting factors for the three previously mentioned aspects, while also separately considering whether the time for disassembly and priority parts are considered. Among the five

Fig. 3. Participant disposition in the study.

Table 3
Comparison of existing methods for calculating the reparability index.

Method for calculating Repairability Index	Reference	Design	Information	Service	Disassembly time	Priority parts
RM	Blanco-Espeleta et al. (2024)	35 %	37 %	29 %	✓	✓
iFixit	Flipsen et al., 2016, 2019; Suovanen, 2023	80 %	10 %	10 %	✘	✘
FRI	Ministère de la Transition Écologique, 2021	40 %	20 %	40 %	✘	✘
RSS	Cordella et al., 2019	55 %	30 %	15 %	✓	✓
AsMeR	Bracquené et al., 2018	38 %	29 %	34 %	✓	✘

Table 4
Calculated reparability index.

Hair dryer	Repairability Index of priority parts					Overall Repairability Index
	Motor	Heating element	Internal cables	Fan blade	Power cable	
HD-A	3.57	5.55	6.03	2.98	5.34	**5.89**
HD-B	3.53	5.50	6.00	2.58	5.34	**4.60**

Overall Repairability Index, result of the sum of the row values.

methods analysed, three (RM, RSS and AsMer) consider disassembly time, while only two (RM and RSS) take into account priority parts. For this reason, and due to its ease of application through a matrix-based scoring system, the RM method was selected as a tool to assess whether user perception aligns with the Repairability Index.

Torca-Adell et al. (2024) adapted the RM for the case of hair dryers, which was applied to HD-A and HD-B, obtaining indeces reported in Table 4. These indices are presented in detail in Supplementary Material S5.

3.5. Stage V. Alignment of study questions and the Repairability Index: review of the correspondence for subsequent comparison

In this section, an assessment was conducted to analyse whether questions formulated in the observational study (user perception) were aligned with the aspects evaluated in the calculated Reparability Index with RM method.

The evaluation was performed through an analysis that assessed the coherence and alignment of each question answered during the observational study in relation to the corresponding criteria in the reparability index. The results are presented in Table 5.

As can be observed, the first part of the table corresponded to the study conducted (observational study), while the second referred to the reparability index. Both sections were aligned and directly related: the questions from the study were linked to the aspects evaluated in the index. Additionally, in the study section, a mark indicated whether each question belongs to the first or third step of the process.

It is important to note that Step 2 of the observational study is not included in the table, as it represents an aspect not considered in any of the reparability methods analysed. However, and according to the literature review, it was introduced as an intermediate stage in the study to evaluate the difficulty and success rate of opening the appliance.

4. Results

This section presents the results from each stage of the observational study. The results are organised according to Step 1, Step 2 and Step 3.

4.1. Step 1. Perception of repairability when the device is fully assembled

In this step, the participants assessed the perceived repairability of two hair dryer models, HD-A and HD-B, with the devices fully assembled. The evaluation focused on aspects related to the external design (D), as well as, the information (I) and services (S) provided by the manufacturer. Fig. 4 shows the results, presenting the averages of findings obteined from the 26 participants.

The results reveal a marked difference among the three evaluated dimensions. Exterior design (D) received the highest ratings, particularly in the HD-B model, suggesting that certain formal elements of the device allow users to perceive its structure as more accessible and easier to handle. This difference was especially evident in items related to the perception of openness and disassembly (D1, D2, D5).

These findings suggest that while a more accessible design can enhance the perception of repairability, it does not necessarily translate into greater confidence in the ability to repair, as reflected in the low D6 scores for both models. This highlights the importance of designs that not only convey accessibility but also reinforce users' confidence in their ability to repair the product.

In contrast, the information (I) and service (S) dimensions received significantly lower ratings. In the I dimension, scores indicate a lack of clear and accessible resources to guide users through diagnostic and repair processes, aside from a slight advantage in fault identification (I3). In the S dimension, responses suggest a general perception of limited support when attempting repairs, particularly regarding access to spare parts (S2) and technical assistance (S3). These findings underscore a notable absence of accessible repair resources, which may discourage users from attempting to fix issues on their own. They also suggest that users lack clear, step-by-step guidance necessary to successfully carry out repairs, further reducing the perceived feasibility of self-repair.

4.2. Step 2. Evaluation of repairability when opening the device

In Step 2, participants were tasked to attempt to open the device, evaluating factors such as the difficulty of opening it, the tools used,

Table 5
Correspondence between study questions and Repairability Index criteria (RM method).

	OBSERVATIONAL STUDY			REPAIR MATRIX (RM)
	Study questions	**Step 1***	**Step 3***	**Parameter**
DESIGN	D1 How accessible/easy is it to open this hairdryer, in case repair is needed?	♦		#1: Depth of disassembly sequence
	D2 How easy is it to locate the connections, screws or access points for disassembly?	♦		#2: Type of connection
	D3 How easy is maintenance, such as cleaning the blade?	♦		#3: Tools required
	D4 How clear do you find the hairdryer design for identifying potential faults?	♦		#5: Skill level
	D5 How intuitive is the disassembly and assembly process of the hairdryer?	♦		#1: Depth of disassembly sequence
	D6 How confident and safe would you feel to repair the hairdryer based on its external design?	♦		#4: Working environment #5: Skill level
	G1 Easy of identifying screws inside		♦	#1: Depth of disassembly sequence
	G2 Ease of identifying components (e.g., motor, resistance, cables, fan blade)		♦	#5: Skill level
	G3 Ease of accessing to components		♦	#1: Depth of disassembly sequence
	G4 Ease of replacing components without special tools		♦	#2: Type of connection #3: Tools required #8: Spare parts interface
	G5 Easy of replacing components without removing other		♦	#2: Type of connection
	G6 Ease of disconnecting cables and connectors		♦	#2: Type of connection
	G8 Component marking that helps with identification		♦	#8: Spare parts interface
	G9 Presence of components with permanent fixings		♦	#2: Type of connection
	G10 Type of tools		♦	#3: Tools required
	G11 Component design planned for removal		♦	#2: Type of connection
	G12 Compatibility of spare parts with standard connectors		♦	#8: Spare parts interface
	G13 Compatibility of spare parts with other in the market		♦	#8: Spare parts interface
	G14 Level of permanent soldered joints and components		♦	#1: Depth of disassembly sequence #2: Type of connection
	X1 How easy is to access the *XXX* once the hairdryer is disassembled? X2 How clearly can the *XXX* and its connections be identified? X3 How available and accessible are the spare parts for the *XXX*? X4 How well is the *XXX* protected against dirt and fragments entry? X5 How easy the *XXX* connectors easy to handle and disconnect? X6 How easy is it for you to repair the *XXX*? **XXX is the priority part*		♦	$pp_{1:}$ Priority parts
INFO.	I1 How do you rate the access to repair/disassembly documentation on the hairdryer?	♦		#12: Availability of information
	I2 How useful is the repair or disassembly documentation for the hairdryer?	♦		#11: Type of information
	I3 How clear is the documentation in identifying potential hairdryer issues?	♦		#11: Type of information
SERIVCE	S1 How easy would it be to request and/or purchase spare parts for this hairdryer?	♦		#7: Availability of spare parts #14: Data management
	S2 How varied do you find the range of spare parts they offer?	♦		#9: Spare parts availability
	S3 How suitable do you find the spare parts prices compared to the hairdryer price?	♦		#10: Spare parts Price
	S4 How would you rate the support they provide for product returns or repairs?	♦		#6: Diagnostic support and interfaces #13: Return options

*Note: Refers to the steps followed by participants during the study, detailed in Stage II.

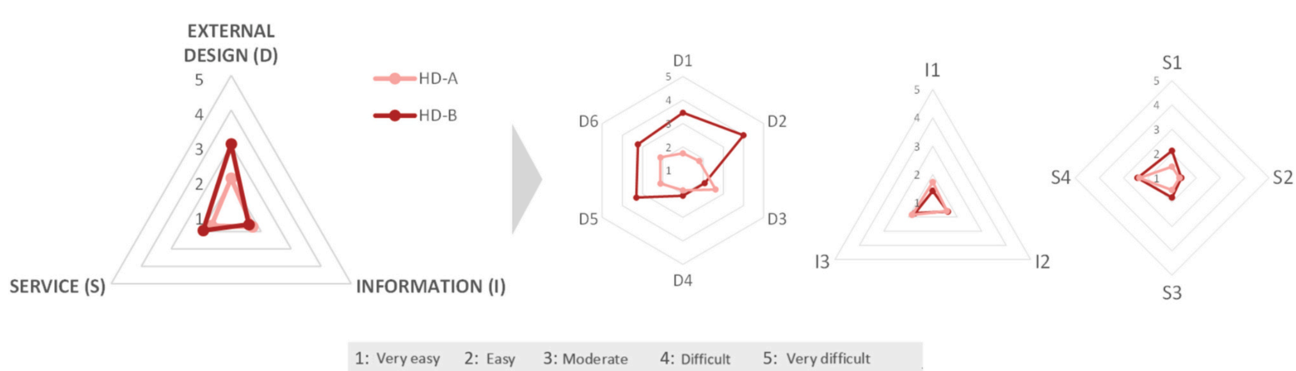

Fig. 4. Assessment of the perception for the external design, information and service (Step 1).

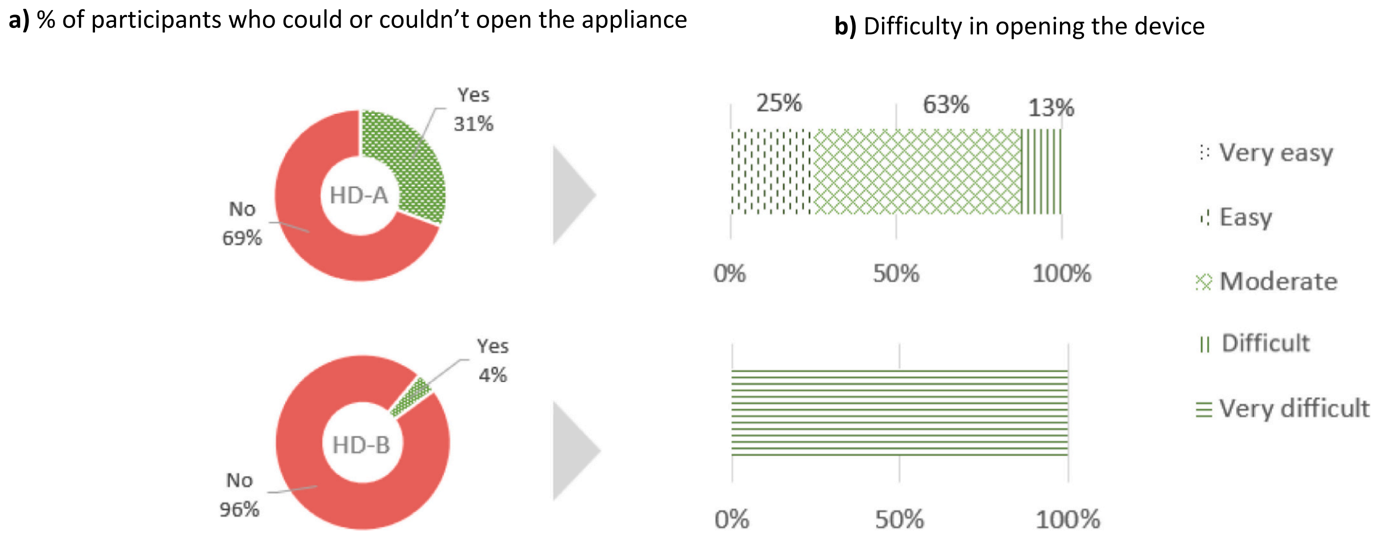

Fig. 5. Answer analysis for step 2.

whether they had them at home and any complications encountered.

As showed in Fig. 5a, the vast majority of participants could not open either of the devices. The HD-B device was particularly problematic, with 96 % of participants unable to open it. In contrast, HD-A device was opened more frequently, though just over 30 % of attempts were successful. Fig. 5b shows the evaluation of the difficulty experienced by participants who managed to open the device. Of those who opened the HD-A, 13 % found it difficult, while all of those who managed to open the HD-B rated it as very difficult.

These results suggest that the design of both devices does not appear to consider the user as an active agent in the repair process. While the difficulty in opening the devices could be due to protective design measures, such as ensuring durability during transportation, it is important to highlight that product integrity does not necessarily have to come at the expense of accessibility. Design alternatives exist that can allow safe and easy access to internal components without increasing the risk of damage or structural failure. Limited accessibility, as observed here, may hinder the user's ability to identify components and perform basic maintenance or part replacement.

In Fig. 6, additional details are presented regarding the profile of participants who successfully opened the hairdryers (in green) and those who did not (in red). Aspects such as their willingness to open it beforehand, their experience repairing small electrical appliances, and gender were analysed. The data showed that neither experience nor gender had a significant impact on the success of opening the product (see Fig. 6a and b). On the other hand, the willingness to repair was closely related to success (see Fig. 6c): those who expressed a positive attitude toward repair succeeded in opening the hairdryer, while those with an indifferent attitude were less successful.

The results showed that prior experience in repairing small appliances was not related to the ability to open the device, regardless of the hairdryer model evaluated. However, regarding gender, a higher percentage of men successfully opened the hairdryers compared to women. In terms of prior willingness to repair, it was observed that for the HD-A hairdryer, participants with a positive attitude toward repair were more likely to succeed in opening the device, while those with an indifferent attitude were less successful. For the HD-B hairdryer, this pattern was not observed. Nonetheless, for both hairdryers, participants with an indifferent attitude were consistently the least successful in opening the device.

Fig. 6. Relationship between participant profile and success in opening the HD-A hairdryer.

Table 6
Priority parts in the HD-A and HD-B devices.

Priority part	Device									
	HD-A					HD-B				
	M	HE	IC	FB	PW	M	HE	IC	FB	PW
Accessibility	3.3	3.3	3.8	4.1	4.2	1.6	3.7	3.6	3.2	4.0
Identification	3.0	3.8	3.8	–	3.9	2.4	3.9	3.7	–	3.9
Spare parts	2.1	2.6	–	2.6	–	2.0	2.5	–	1.9	–
Design for disassembly	2.4	2.3	2.5	4.5	–	2.1	2.2	3.7	2.7	–
Easy repair	**2.4**	**2.2**	**2.5**	**3.4**	**3.0**	**1.6**	**1.9**	**2.3**	**2.0**	**3.3**

M — motor; HE — heating element; IC — internal cables; FB — fan blade; PW — power cable.

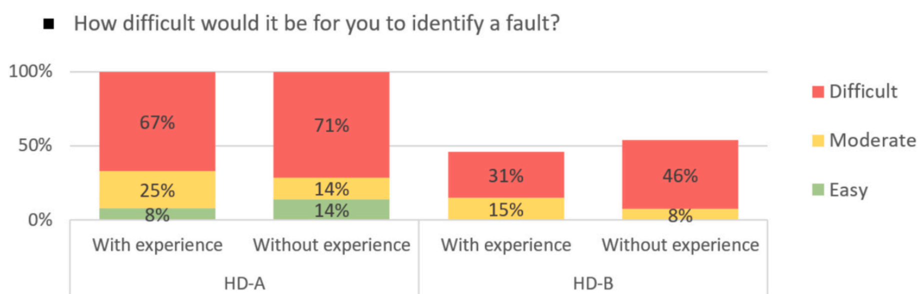

Fig. 7. Results for step 3.

4.3. *Step 3. Perception of repairability once the device is open*

In Step 3 of the study, various data related to the priority parts and their perception of their repairability were collected. This included the ability to diagnose potential failures and the methods used for that purpose.

Participants were asked to identify the components most likely to fail and, for each one, to evaluate their perception of how easy it would be to repair. Each component was analysed based on four main criteria: accessibility, identification, availability of spare parts, and design for disassembly. Additionally, a general criterion called "ease of repair" was considered. Scores were assigned on a scale from 1 to 5, with 5 representing the best performance.

Table 6 provides a detailed evaluation of the two analysed devices (HD-A and HD-B) based on their priority parts: M (motor), HE (heating element), IC (internal cables), FB (fan blade), and PW (power cord).

It was observed that the hairdryer HD-A received higher ratings in terms of accessibility and ease of repair, particularly for components like the fan blade. In general, the most significant differences were found in accessibility and design for disassembly, while differences in identification and availability of spare parts were less pronounced. However, both devices exhibited areas in need of improvement, particularly regarding the availability of spare parts. Users considered the HD-A device easier to repair overall.

After evaluating the perception of the priority parts, participants were asked about the ease of identifying a fault in the device if one occurred. The results showed fairly similar percentages for both types of hair dryers: 12 % of participants considered it easy to identify faults in the HD-A, while 8 % reported the same for the HD-B. On the other hand, 70 % and 50 % of participants rated fault identification as difficult for the HD-A and HD-B, respectively. The remaining participants indicated that they could partially identify the fault.

This question was posed hypothetically, not in the context of an actual fault, as it was not feasible to simulate multiple failures under controlled conditions. It was included after participants had evaluated the priority parts, those most commonly associated with malfunctions. By first observing the device and answering the preceding questions (see Supplementary Material S3), participants were in a better position to judge whether they would be able to detect a potential fault in any of the five key components.

Table 7
Some of the collected comments.

Could you identify a faulty component?	How would you identify a fault in a component?
Yes	Depends on what is broken, sometimes you can see, smell or hear the problem
	I would test each switch to see if everything on the hairdryer is working
	I would assess function with a multimeter open and look for obvious burn marks or broken solder
No	I don't think I have the expertise to define
	Using multimeter, but risky because you need to plug it in
	Watching a tutorial on YouTube
Partially	I can figure out where is the problem if I turn on it
	See what is broken or burned
	If something blocks the fan blade, I can easily observe

Given the similarity in results between the two devices, an analysis was conducted to explore potential differences between participants with experience and those without experience, the details of which are presented in Fig. 7.

Additionally, comments on how they would identify the fault (question C in step 3) were collected, providing a space for written responses. Table 7 presents some of the collected comments. For each comment, the option selected in the first questions, shown in Fig. 7, is specified.

5. Discussion

This section addresses the discussion of the research questions formulated in the introduction. Fig. 8 illustrates how the steps of the observational study help to answer the formulated research questions.

5.1. *Alignment of the Repairability Index with users' perceptions (RQ1)*

While the Repairability Index provides a technical assessment of repair ease, it does not always align with users' practical experiences. To ensure a proper comparison, it was essential that the same aspects were considered in both cases. Therefore, the criteria of the RM method were aligned with the different aspects addressed in each of the stages of the

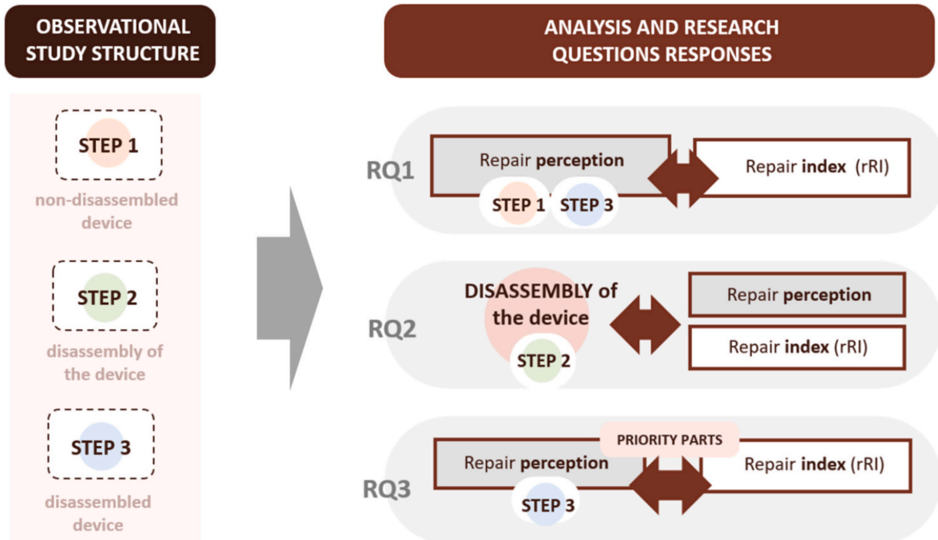

Fig. 8. Relationship between observational study structure and presentation of results.

Table 8
User perception and Repairability Index according to the Repair Matrix for the HD-A and HD-B devices.

	HD-A		HD-B	
	RM	User perception	RM	User perception
Design	7.0	4.9	5.8	5.5
Information	5.5	1.8	2.7	1.9
Service	3.0	2.3	3.3	2.5
GLOBAL	**5.9**	**3.9**	**4.6**	**4.3**

study. This is shown in Table 5, which displays the relationship between the questions asked during the observational study (Steps 1 and 3), reported with more detail in Table 5 and supplementary material S3, and the aspects of the selected method (RM). In this analysis, both questions regarding exterior design (Step 1) and interior design (Step 3) were considered, since the questions related to the Repairability Index refer to both the internal and external structures.

Below, Table 8 presents the results of user perception related to the Repairability Index calculated using the RM for the HD-A and HD-B devices, measured on scale from 0 to 10. The repairability indices for both devices were derived from calculations performed in prior studies by Torca-Adell et al. (2024). The calculation process involved the identification of priority parts according to their failure probability, the assignment of relative weights to these components, and the evaluation of fifteen parameters related to design, information, and service aspects. These parameters were weighted based on their perceived relevance, using data collected from an international sample of Repair Café organizations. Each parameter was rated on a scale from 0 to 10, with scoring adapted to the number of evaluation levels for each criterion. The final Repairability Index was obtained by aggregating the weighted scores of the parameters, considering the relative importance of each component. Further details on the calculation method and the adapted matrix used can be consulted in the supplementary material S5 and the referenced previous study.

The data are categorized by design, information and service aspects, as well as a global index for each device.

- **Design**. For the HD-A device, the Repairability Index for design was 7.0, whereas user perception was 4.9, showing a difference of 2.1 points. This indicates that, despite positive evaluation of the HD-A design in terms of repairability, uses perception was significantly lower. In contrast, the HD-B device had a Repairability Index of 5.8 for design and a user perception of 5.5 showing a smaller difference. This suggest that user perception was a somewhat more aligned with the Repairability Index for the HD-B, though still lower. During the observational study, user comments and observations revealed that the HD-A device was rated more negatively compared to the HD-B, mainly due to the fact that participants were unable to open the device. Also, in relation to the presence of hidden screws, participants indicated that this feature complicated repair and led to greater user dissatisfaction, impacting their perception of the device's repairability. This aligns with the findings of De Fazio et al. (2021) which indicate that hidden connectors hinder disassembly. It is also consistent with conclusions drawn from studies such as Barros and Dimla (2023), Pozo Arcos et al. (2023) and van der Velden et al. (2023) which highlight the difficulty of opening a product as a barrier to repair and lead to the research question RQ2.
- **Information**. The analysis of information related to the repairability of devices reveals significant discrepancies between the method score and users' perceptions. For the HD-A device, the method score was 5.5, while user perception was only 1.8, reflecting a significant difference. For the HD-B, the difference was smaller, with an index of 2.7 compared to a user perception of 1.9. However, in both cases, user perception remained lower compared to the method's index. According to the Green Alliance (Peake and Vallauri, 2021), the legislation does not address the information barrier for consumers or cost-related issues, which are two key obstacles to repairing products. As noted by Barros and Dimla (2023), "The result does not disclose whether the information is for professional repairers or if it is meant for end users to repair their phones."
- **Service**. Concerning service, a trend similar to that observed for information is noted. The HD-A device was rated lower by both the method and users, with user perception again being lower than the Repairability Index score. In this case, grater discrepancy was observed in the HD-A hairdryer.

Overall, although the HD-A device had a higher reparability index compared to the HD-B, user perception was higher for the HD-B. In both cases, however, user perception was lower than the reparability index.

In response to the research question: RQ1 — Does the Repairability Index align with users' perceptions of repairability? it is found that the Repairability Index is not directly aligned with consumer perception, as in all evaluated aspects, users provided lower scores. The largest discrepancies were observed in scores related to design compared to those related to information and service. This suggest that design is a more decisive factor in establishing differences between two products of the same category, as most manufacturers offer similar services and information to users.

This divergence between user perception and calculated Repairability Index underscores the need for multidimensional approaches in evaluating repairability. While the RM method captures technical design features, it lacks sensitivity to contextual and user-experience aspects, such as visual cues and repair confidence. As Barros and Dimla (2023) point out in the context of smartphones, high index scores may not reflect actual ease of repair if the design remains opaque or intimidating to non-experts. Similarly, Dangal et al. (2025) emphasise that current scoring systems often lack validity in distinguishing between repairable and unrepairable products. These findings align with the results of this study and highlight the necessity of complementing technical indices with user-informed assessments to more accurately predict real-world repair outcomes.

5.2. Difficulty to open the device as a consideration in repairability assessment (RQ2)

In this study, participants were asked to evaluate the repairability of the products after attempting to open them, with the aim of incorporating a criterion that, although previously mentioned in the literature, has not been empirically assessed or analysed from the user's perspective: the difficulty of opening the device. Several studies have theoretically identified opening as a critical initial barrier in the repair process (Roskladka et al., 2023; van der Velden, 2021). However, this aspect has not been addressed through direct observation or evaluated based on actual user experience. Its inclusion in this research responds to the need to capture real-world conditions that directly affect the feasibility of repair, especially in non-professional or domestic settings. If a product cannot be easily opened, access to internal components, and consequently any attempt to diagnose or repair a fault, is severely hindered or rendered impossible.

Two main aspects were highlighted in the results:

- **Difficulty in opening the devices.** Most participants encountered challenges in opening the devices. Specifically, 69 % of participants were unable to open the HD-A device, while 96 % failed to open the HD-B device (see Section 4.2).
- **Impact on perceived repairability.** The difficulty of opening was reflected in the repairability scores. The results of this evaluation are presented in Fig. 9, which compares information for the HD-A and HD-B hairdryers. For each device, three columns are displayed. The first two columns (marked in red) exclude the difficulty of opening the device, reflecting results from the previous analysis (Section 5.1 and Table 9). The third column (marked in grey) includes the perception of repairability considering the difficulty of opening the device. It was observed that the perceived repairability score for the HD-A hairdryer decreased from 5.9 to 2.8 when the difficulty of opening was considered, compared to the previous Repairability Index. For the HD-B hairdryer, the perceived score dropped from 4.61 to 1.79 (on a 10-point scale). Both values fell below 3, indicating minimal repairability.

Table 9
Difficulties encountered for opening the hairdryers.

Difficulties in opening the device	Difficulties encountered once the device is open
Unable to access screws	No repair instructions
Even after removing screws, the casings don't separate	Internal components not marked for unfamiliar users
Hidden internal connections	Welded joins
No indicators for where to open	Requirement for special tools
Requirement for special tools	

The results of the study show that the difficulty of opening significantly influences the users' perception of repairability. Therefore, including this variable in the analysis makes it possible to enrich the assessment of reparability by incorporating a practical and experiential dimension, which contributes to a more complete and realistic understanding of the concept.

In response to RQ2, the results indicate that the difficulty of opening significantly reduces the perception of repairability for the devices, with scores notably lower than those obtained without considering this factor. This decrease suggests that if a device cannot be opened, repairing it becomes unfeasible, which undermines the relevance of previously established repairability criteria.

The difficulties encountered and reported by participants in the comment section are summarized in Table 9. It includes general difficulties experienced by participants, categorized into issues related to opening the device and those concerning the device's interior.

These findings reinforce the growing consensus that ease of disassembly is a cornerstone of repairability. Roskladka et al. (2025) emphasise that intuitive and tool-accessible entry points significantly increase the likelihood of repair, especially for non-professional users. If the first step of a repair—opening the device—cannot be achieved, subsequent actions such as identifying and replacing a faulty component become irrelevant. The participant feedback in this study highlights this clearly: when disassembly is obstructed by hidden fasteners, welded joints, or non-obvious seams, users tend to abandon the repair attempt altogether. This validates the argument that opening difficulty is not a peripheral factor, but a threshold barrier that must be addressed in both design and regulation frameworks.

Moreover, the results confirm that repairability cannot be assessed solely through observable technical parameters. The act of attempting to repair, which in practice begins with opening the product, fundamentally reshapes the user's perception. This experience not only influences

Fig. 9. Repairability according to opening difficulty, Repairability Index and perception.

their evaluation but can also determine whether the repair attempt is pursued or abandoned altogether.

5.3. Influence of perceived repairability of priority parts on the improvement of repair methods (RQ3)

To analyse user perception of priority parts, data collected in Step 3 were examined, when participants had access to the internal components of the devices. During this step, specific questions about **priority parts** were asked, designed to be answered by both **experienced and inexperienced users**, applying the same evaluation criteria.

Fig. 10, shows the repairability indices assigned to each component according to the method on the left, and the scores assigned by participants based on their perceptions on the right. The following observations can be made:

– The RM method assigned nearly identical repairability scores to different priority parts for both hairdryers, whereas user evaluations showed greater variability. This suggests that the method may not be precise enough to reflect significant architectural differences between devices.
– The RM method rated the fan blade (FB) as the least repairable part, whereas participants identified the motor (M) as the most difficult part to repair.
– There was a direct relationship between user perceptions and product design, but this was not reflected in the Repairability Index. For example, participants rated the fan blade in HD-B less favourably than in HD-A, even though HD-B featured a replaceable joint, whereas HD-A had a fully integrated motor and fan blade, making it impossible to separate. The RM method failed to capture this critical distinction, indicating that current repairability indices do not sufficiently account for modularity and ease of replacement.
– The ability to separate and replace components, as observed in HD-B's design, was perceived as an essential factor for improving product repairability. Previous studies, such as Matarin et al. (2022) and Van den Berge et al. (2023), has emphasised the importance of modular designs that allow for easy part replacement, promoting durability and reducing waste EEE.

Answering the research question, the following conclusions can be extracted:

– **Inaccuracy of the reparability index in assessing differences between components of different devices.** The Repairability Index based on the method does not accurately reflect the major design and architectural differences between components of different devices. As the results show, although the HD-A and HD-B hairdryers had significantly different design features, the index did not show significant differences in their ratings. However, users noted significant differences, such as the replaceability of the fan blade on the HD-B model compared to the integrated design of the HD-A. This suggests that the index used may not capture important aspects related to modularity and ease of repair as perceived by users. This underlines the importance of considering replaceability as a critical factor that directly influences the decision to repair a product or not.
– **Modular design as a strategy to improve reparability.** The ability to replace components, as observed in the modular design of the HD-B, was perceived as an essential feature for a better assessment of repairability. This result is in line with previous research findings that emphasise the benefits of designs that allow easy replacement of parts and promote product sustainability and durability. Therefore, modular design should be a priority in the development of future devices to improve repairability and align with user expectations.

The observed discrepancies in user perception regarding the repairability of internal components point to the limitations of applying generic scoring to diverse device architectures. Boix Rodríguez et al. (2024) advocate for the inclusion of component-specific parameters—such as time to access, depth of disassembly, and reversibility of joints—in scoring frameworks. Doing so improves the granularity and precision of assessments. This study's results support that recommendation: although both devices were scored similarly using the RM method, participants noted critical differences, particularly regarding modularity. The integrated motor-fan assembly in HD-A was perceived as a major barrier, in contrast with the more serviceable design of HD-B. These perceptions align with the argument that modular design not only facilitates repair but also contributes to product longevity and user empowerment (Bayraktaroğlu and İdemen, 2024).

6. Conclusions

This study provides insights into how users perceive product repairability and whether these perceptions align with existing repairability indices. A qualitative analysis based on user observation studies and guided rubrics was used to evaluate two different devices. This approach reveals several key aspects regarding the relationship between repairability indices and user perceptions, as well as the influence of the difficulty of opening devices on the overall perception of their repairability.

Regarding the relationship between the Repairability Index and user perception (RQ1), significant discrepancies were found when comparing the two factors. Although one device had a higher Repairability Index, user perception was lower for both devices. This discrepancy suggests that although the Repairability Index is useful, it does not fully capture users' experiences and perceptions.

In relation to the impact of opening difficulty on reparability

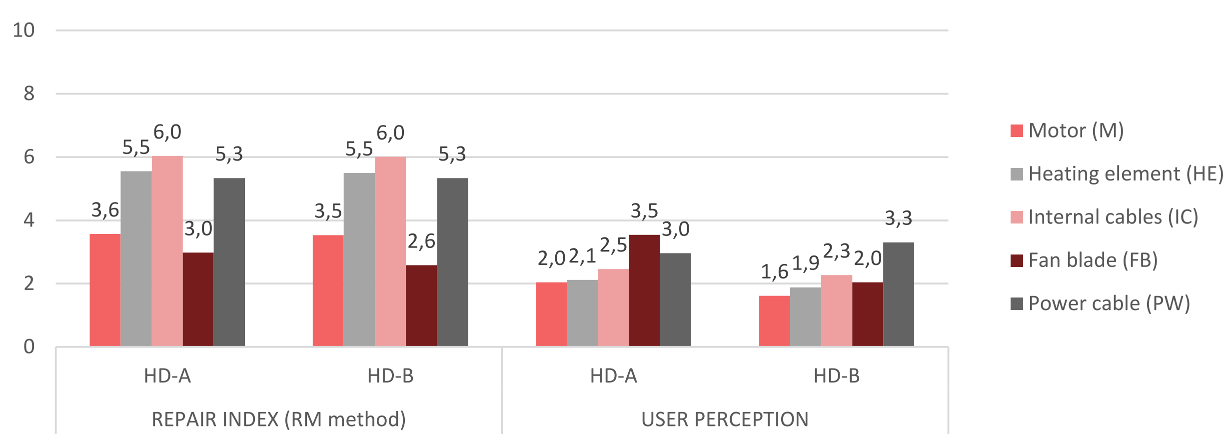

Fig. 10. Repairability scores of priority parts: method vs. user perception.

perception (RQ2), it was found that the challenges participants faced when trying to open the devices significantly influenced their repairability evaluation. For device HD-A 96 % of participants were unable to open it, while 69 % had the same problem with device HD-B. When this difficulty was taken into account when assessing repairability, the scores dropped dramatically: for device HD-A, the perception of repairability dropped from 5.9 to 2.8 and for device HD-B from 4.6 to 1.8. This underlines the fact that the ease with which a device can be opened is a decisive factor in its repairability.

Finally, regarding RQ3 about the perception of the priority parts in relation to the calculated Repairability Index, some differences were identified. For example, while the Repairability Index indicated that the motor and fan were difficult to repair for both devices, users observed differences between them. In one device, the motor and fan were integrated, making it difficult to repair, although on the other, the fan can be replaced independently. This contrast highlights that, although the index provides an overview, specific design features, such as the ability to disassemble and replace individual components, play a crucial role in repairability.

These findings have significant implications for the formulation of future policies and legislation related to product repairability. Specifically, they indicate a need to revise current repairability indices to include user-centred factors. Empirical observations show that aspects such as the ease of opening a device significantly affect both the perceived and actual feasibility of repair. Consequently, it is recommended that future indices adopt a more comprehensive approach by integrating practical, user-relevant criteria alongside existing technical measures. Such an approach may enhance the alignment between assessment frameworks and real-world repair experiences, ultimately supporting more sustainable patterns of consumption. This index should include ease of opening, an issue observed in broader literature on reparability challenges across various categories of electrical products.

Future research should focus on developing a more comprehensive Repairability Index and expanding the study to a wider range of devices and product categories.

The study has some limitations. While the sample size was adequate for exploring user perceptions from a qualitative perspective, expanding the sample to include a more diverse range of socioeconomic variables would be beneficial for a more robust generalisation of results and a deeper understanding of how different consumer groups perceive and interact with product repairability. Another potential limitation of the study is that the same devices were used throughout all sessions. This could theoretically have made them easier to open for subsequent participants due to prior manipulation. However, this effect was not observed in the results: for instance, only participants 5 and 8 (out of 26) successfully opened the devices, while many subsequent participants were unsuccessful. This lack of correlation between participant order and success suggests that the difficulty of the procedure remained consistent and that a saturation point was reached. As such, the validity of the observations is reinforced.

CRediT authorship contribution statement

Laura Torca-Adell: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Fabrizio Ceschin:** Writing – review & editing, Supervision, Methodology, Conceptualization. **María D. Bovea:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2025.05.024.

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