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Closed for Repair: Design Affordances for Product Disassembly

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Abstract: A common understanding is that modern products are becoming increasingly difficult to repair. While there are many broad contributing and systemic reasons for this, it is equally important to investigate actual products and how they are designed for disassembly. This research looks at consumer electrical and electronic devices and identifies product design features that "afford" disassembly - thereby enabling or discouraging self-repair. An affordance for disassembly offers a user a perceivable means to commence a disassembly process, removing external housings, covers and primary sub-assemblies, in order to gain access to internal repairable components. This research involves, identifying disassembly features of a selection of consumer electronic and technology devices from the 1950s through to the 2000s, documented product teardowns of domestic kitchen appliances undertaken by design students, and a survey of users experience at identifying fastener types.

Importance of disassembly

Product repair has an important role to play towards achieving a circular economy for electronics. Repair has many beneficial social and environmental consequences (EPA, 2018). Repair, and related activities of maintenance and refurbishment, reduces waste, extends the functional lifespan and retains product value (WEF, 2019). Numerous factors contribute to determine repairability. From specific product features, availability of parts, cost of repair (Cooper, 1994; McCollough, 2010) and to broader societal and economic circumstances. Psychological obsolescence (Packard cited in Cooper 2010) also has an important role to play in shaping perceptions about repairability and decisions to replace rather than repair. This has led to the belief that modern products are increasingly difficult, and less desirable to repair. Designers, manufacturers, recyclers, consumers, policymakers and others all have a role to play to facilitate product repair. (WEF, 2019).

This research focuses upon one specific dimension concerning repair – product disassembly. It asks how and why products are becoming increasingly difficult to disassemble and what design features enable or discourage repair? For a product to be repairable it needs to be disassembled in a non-destructive way – so it can be reassembled following a maintenance or repair procedure, without damage.

Consumer electronics and technology devices

Consumer electrical and electronic products, notably mobile phones, laptops, electronic gadgets and small domestic appliances, are strong candidates to study disassembly as they illustrate the magnitude of our throwaway society and short product lifespans (Park, 2010; Slade, 2007). The production and consumption of these devices continues to escalate, while operational lifespans are increasingly shortened and e-waste continues to be one of the fastest growing waste streams (Baldé et al., 2017). Moreover, consumer electrical and electronic products are increasingly discarded rather than repaired (Slade 2007).

Product design features

Product design is key in determining the ease of disassembly. If a product enables logical or easy disassembly it can reduce a significant barrier to repair (Rivera & Lallmahomed, 2015). Equally, products designed for disassembly reduce the time and, accordingly, the cost associated with repair activities. Design for disassembly also offers benefits for end of life for the separation of parts and material recovery. However, unlike a complete disassembly required for recycling, it is often unnecessary for a product repair. Instead, selective or partial disassembly is more likely to be performed for any attempted repair once the problem for its failure has been diagnosed. If faults are traceable, failed parts reachable via a simple and straightforward process then we can say that the product is repairable enough (Sabbaghia, et a., 2016)

Barriers to repair

If repair is indeed declining, then it is useful to first look more broadly at business and economic contributing factors. “Right to repair” environmental and consumer advocates in the United states and Europe, claim that some businesses seek to profit through making products difficult or uneconomic to repair (Matchar, 2016), so they will be replaced. Some businesses seek to prevent owners, third-party suppliers and independent servicing businesses being able to maintain, repair and refurbish their products. These barriers to repair can be further enhanced by restricting or controlling access to spare parts, and the unavailability of repair information and service manuals (Sabbaghia et al., 2016).

Increasingly, as products contain embedded micro-electronics or are controlled by software systems, repair opportunities can be further complicated. For example, repairability can be restricted through measures such as Digital Rights Management (DRM) copyright and encrypted security systems to lock-out self-repairer’s and third-party repairers. Such measures prevent attempts at fault finding, servicing, upgrading, modifying and/or repairing equipment (Repair to Repair, 2019).

Attitudes and behaviour

Consumer attitudes and the way people think about product repairability can be a self-imposed barrier to repair. Repairability may be a desirable feature for consumers when purchasing a product, but it is often not made explicit or clearly understood (Sabbaghia et al., 2016) as to what is feasible. Many working or repairable products are discarded because they are perceived to be ‘irremediably’ broken. A UK survey of vacuum cleaner users revealed a reluctance to carry out maintenance or repair. (Salvia et al., 2015). This reluctance is influenced by perceptions of the costs associated with repair. The cost of spare parts and specialist repair services have been found to be a key consideration for consumers in choosing the option to replace instead of repair (Cooper 2004). The higher the repair price compared to the replacement price, the less likely the consumer is to repair a product (McCollough (2007). Consumers need to be confident that repairs will be performed properly and at a fair price. Self-repair may be an option to save costs, but the repairer will also need to weigh-up the cost and availability of spare parts, tools, their repair skills and the perceived easiness of product disassembly. Success or otherwise will remain uncertain as the repair process requires commitment to investigate, diagnosis and a repair strategy. The first stage of this process commences with disassembly. Preventative product design features can be the first line of defence as a barrier to repair. For example, design features that discourage or prevent disassembly include, security (proprietary tool) fasteners, friction welded parts, sacrificial snap-fits, hidden fixings and adhesive tape bonding.

Assessing disassembly

Various methods now exist to assess repairability through a range of qualitative to quantitative evaluation methods. A qualitative approach to assessing repair can determine if certain criteria have been met – the provision of repair manuals and product information, product design features and service availability. This approach is used by various eco-labelling schemes, such as Blue Angel, Nordic Label and the European eco-label. (Bracquené et al., 2018). Meanwhile, a popular example of a semi-quantitative method is iFixit’s repairability scores for laptops, smartphones and tablets. They use a ten points scale to rate devices using a combination of qualitative criteria. Points are awarded for disassembly, availability of servicing information, upgradability, use of non-proprietary tools for servicing, and component modularity (iFixit 2009a). Quantitative methods, such as the Ease of Disassembly method (eDIM) calculate the amount of time required to disassemble and then reassemble a product (Peeters et al., 2018). Re-assembly time is also included into the metric as it is an important part of the repair process. As fasteners play a key role in determining disassembly, another quantitative method, the U-effort index models the effort required for separating components or subassemblies from each other by removing fasteners or by detaching parts with integral attachments (Sodhi et al., 2004) and adhesives.

Methodology

A premise of this research is that for a product to be repairable it first needs to be disassembled. This needs to be undertaken in a non-destructive way for it to be reassembled without damage - following a maintenance or repair procedure. This can be described as a product's "affordance" for disassembly. That is, its propensity to be disassembled and reassembled. In design, an affordance can be described as the*, "action possibilities of a user when the user interacts with an artefact. They (*affordances) *can be "directly", perceived based on the structural features of the artefact"* (Kannengiesser & Gero, 2010, p50). In this paper, a mix of research methods were employed to discover product design features that can enable or discourage product repair.

Timeline of product samples

Investigating how products have changed in construction and function over time, can offer some insight about how perceptions of repairability may be changing. A sample of products from a design collection held at the University of New South Wales, Australia. were assessed for their affordance to be disassembled. A selection of small consumer technology devices from the 1950s through to the 2000s were examined and photographed to identify disassembly design features.

Product teardowns

A teardown is an ideal way to understand the "anatomy" of a product. It enables part identification and an assessment of product construction, fastenings, materials, function and components. Moreover, it provides an insight into a product's repairability, refurbishment and end-of-life recyclability. A teardown exercise was undertaken with a selection of small kitchen appliances provided by Breville, Australia. Undergraduate design students were required to systematically disassemble and document an allocated product using a process devised by iFixit (2019b). They were asked to identify and record all significant components and attachments (Figures 1, 2 & 3). Results were then uploaded to iFixit for online publication iFixit (2019c).

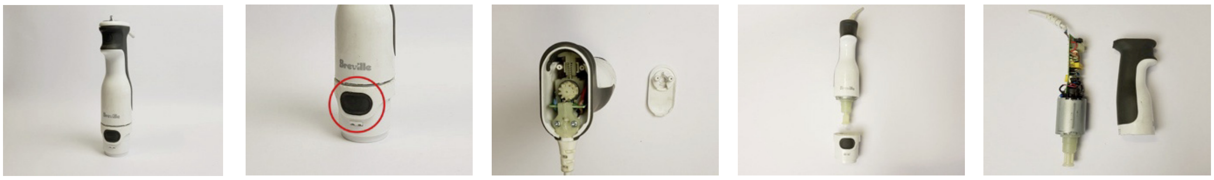

Figure 1. Breville immersion blender teardown.

Figure 2. Breville coffee grinder teardown.

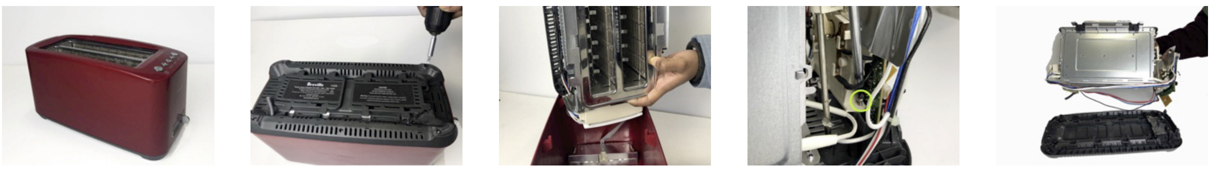

Figure 3. Breville toaster teardown.

Fastener survey

Fasteners, if present, are often encountered at the first stage of any attempted product disassembly process. The type of fastener used can influence perceptions of repairability, or more directly determine actions and capabilities by the would-be repairer - to contemplate and commence a disassembly project. A survey of 66 respondents were asked to identify various fastener types they had encountered during previous product repair experiences (Figure 4).

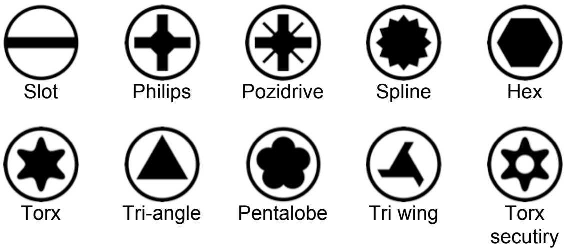

Figure 4. Survey screw fastener heads.

Discussion

Changing products

As products change over time, so does the level of "convenience" for self-repair (Mashhadi et al., 2016). This "convenience" can be expressed through product design features (affordances) for disassembly. Of the products sampled for this research, it was found that older products offered more direct access to internal components than many equivalent contemporary products. For example, a 1950s Braun slide projector and a 1960s National Panasonic radio offer direct, no-tool access to internal components (Figure 5 & 6). This is a necessity affordance for the replacement of consumable items, such as bulbs and batteries, and for periodic maintenance - cleaning and recalibration. If an actual repair is required, then disassembly is relatively intuitive and straightforward with commonly available tools.

Figure 5. 1950s Braun slide projector.

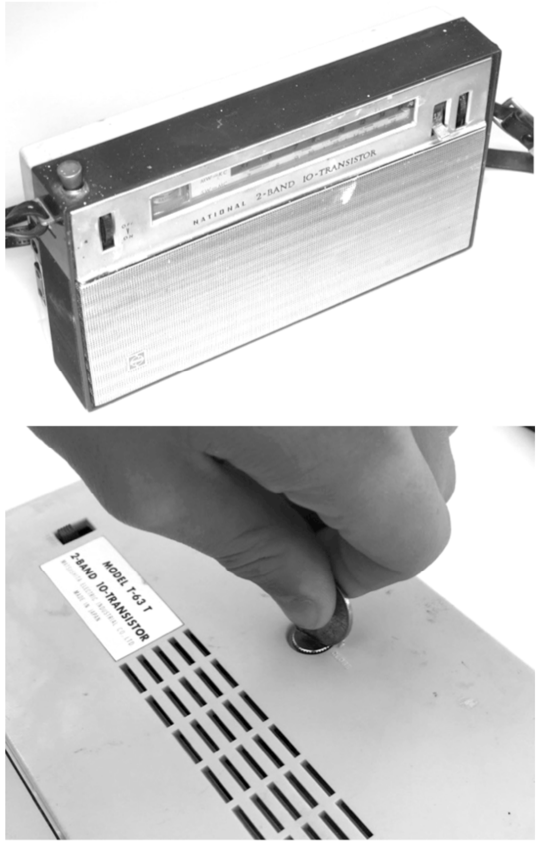

Figure 6. 1960s National Panasonic radio. Single slot head fastener, no tool is required for primary disassembly.

Declining need for maintenance

The requirement for periodic maintenance has diminished for many categories of contemporary products investigated in this study. Before the advent of microelectronics and purely "solid state" and digital devices, electro-mechanical devices required periodic maintenance to be recalibrated, tune or replace consumable components. For example, typewriters required lubrication and replacement of ink ribbons, pre-transistor radios required replacement vacuum tubes (valves), and portable electrical items require replacement batteries or possibly belts and fuses. However, as these devices have become progressively displaced by solid-state digital equivalents or become obsolete altogether, the requirements for maintenance has diminished in proportion to the decline of their mechanical complexity. An added benefit by removing maintenance or ease-of-repair disassembly features is that simplified product construction can reduce the number of parts and can save manufacturing and prime purchasing costs (Sauerwein et al., 2019). The consequences, intended or otherwise by manufacturers, is that if disassembly is required it then becomes more difficult or in some instances impossible without causing further damage through destructive disassembly methods. As was discovered during the student product teardown activity. Certain products, notably a stick blender, could only be dismantled by using destructive methods.

Batteries and Repair

Preventative disassembly features have emerged as important issue when it comes to battery replacement for contemporary mobile technology devises (iFixit, 2019a; Park, 2018). Until the advent of embedded "sealed for life" products containing rechargeable Lithium and nickel-metal hydride (NiMH) cells, battery replacement was a common necessity for many electrical products. For example, products such as a Garmin GPS III and Sony CD Walkman (circa 1990s) afford the user a simple means for battery access for routine replacement. Many variants of earlier generations of mobile phones (for example the Nokia 3310 series) offered partial no tool disassembly with "click-on/off" covers - even though the need for battery access was a less frequent necessity. Since the mid-2000s onwards, the design trend for similar products has often been to eliminate internal user access altogether - despite the need for periodic battery replacement or any other parts. In one notable instance concerning the Apple iPhone, since 2009 Apple has actively discouraged users attempting a disassembly for battery replacement and other commonly required repairs. It has achieved this through the use of a highly specialised type of fastener, the Pentalobe five-point-screw head, and aggressive adhesive tapes. Although Apple is not alone when it comes to the use of specialist security fasteners. It was discovered that for other earlier generations of mobile technology products and more recent small kitchen appliances have also adopted similar practices. However, this was not to prevent access to batteries, but rather to deny access users to delicate or high-voltage electronics.

Screw fasteners

As has already been identified screw fixings are often the first line of defence in determining a user's prospects for disassembly. The shape of a screw head is a significant contributing factor to disassembly effort and time (Sodhi et al., 2004). Respondents to a fastener survey, most of whom claimed some knowledge and skills of product repair, reported that familiarity the most common screw head types (Philips and Hex), and somewhat familiarity with more technical fasteners (TORX and Spline). This survey found that 80% of respondents agreed that if encountered, a Pentalobe screw head it would likely prevent progress while attempting to disassemble a product. Less than 4% of respondents recognised the shape of this head or associated it with Apple products (Table 1).

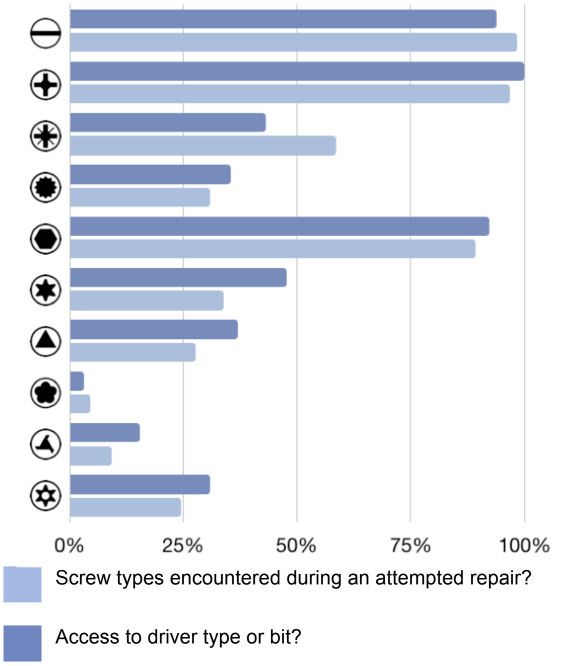

Table 1. Identifying and encountering fastener head types.

Conclusion

This research attempts to highlight the importance of external product features as a first line of defence that can afford product disassembly. User perceptions of how easily a product can be disassembled greatly improves the opportunities for a user self-repair. What opens and shuts (battery compartments), unwinds and tightens (screw fastenings) are key indicators for ease of disassembly. The way products are designed and configured enables or prevents nonprofessional individual consumers from attempting a disassembly for self-repair. No tool disassembly features and availability of 'universal' or generally available non-proprietary tools for common fastener types offer an affordance for disassembly and promote positive attitudes and behaviours towards repair. Unlike many electro-mechanical products of the past, many contemporary devices are perceived to be "sealed for life". They are often not designed for maintenance or repair. Making a product difficult to disassemble and uneconomic to repair may save costs for producers and create demand, but it contributes to premature obsolescence and e-waste. Disassembly empowers us and our ownership of stuff. This is summed up by the refrain 'If you can't open it you don't own it' (Jalopy, 2005).

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