Veilig ontworpen. Veilig te repareren.

Julieta Bolanos Arriola, Francesco De Fazio, Ruud Balkenende, Conny Bakker, Bas Flipsen

Faculteit Industrieel Ontwerpen, TU Delft

Project uitgevoerd in oktober-december 2019 (rapportage 15 December 2019)
in opdracht van het Ministerie van Infrastructuur en Waterstaat

Samenvatting

In een circulaire economie is het belangrijk dat producten langer gebruikt worden en gerepareerd kunnen worden. Maar zelf repareren door onervaren reparateurs kan veiligheidsrisico's opleveren. Om dit beter te begrijpen is onderzoek gedaan naar veiligheidsaspecten van zelf uitgevoerde reparaties. De manier waarop producten opgebouwd worden en hoe dat samenhangt met veiligheidsrisico's is onderzocht. Ook is gekeken hoe gebruikers een koffiezetapparaat repareren en welke veiligheidsrisico's dan optreden tijdens en na reparatie.

Bij zelf uitgevoerde reparatie zijn er elektrische, mechanische, thermische en chemische risico's. Deze risico's kunnen optreden tijdens de reparatie, maar ook daarna als het reparatieproces niet correct is afgerond. Hiermee moet rekening worden gehouden bij het ontwerpen van veilig te repareren producten. Uitgezocht is dat veiligheidsrisico's gelokaliseerd kunnen worden door het productontwerp op een specifieke manier in kaart te brengen. Dit kan een belangrijk hulpmiddel worden voor productontwerpers om rekening te houden met zelf uitgevoerde reparaties. Daarnaast is gebleken dat een gedetailleerde reparatiehandleiding nauwelijks effect heeft op het voorkomen van reparatierisico's. Verder onderzoek is nodig naar andere manieren om tijdens de reparatie informatie te verstrekken. Tenslotte zou onderzocht moeten worden hoe onfeilbare ontwerpoplossingen mogelijk gemaakt kunnen worden. Zulke oplossingen verbeteren de repareerbaarheid van producten en waarborgen tegelijkertijd de veiligheid tijdens en na het reparatieproces.

Inleiding

Het belang van repareerbaarheid voor levensduurverlenging van producten en de circulaire economie

In het EU-actieplan voor de circulaire economie (European Commission, 2015) wijst de Europese Commissie op de noodzaak van een transitie naar een meer circulaire economie. Uit onderzoek dat sindsdien is verricht, komt repareerbaarheid naar voren als essentiële ontwerpvoorwaarde voor levensduurverlenging van producten en als belangrijke factor in de bevordering van circulariteit (Bakker, 2014a, 2014b; Bracquené e.a., 2018; Cordella e.a., 2019; Flipsen e.a., 2016). Het idee voor bevorderen van repareerbaarheid werd gepresenteerd in het werkplan inzake Eco-design 2016-2019 (European Commission, 2016) en nader uitgewerkt door Bracquené e.a. (2018) en Cordella e.a. (2019). De Europese Commissie publiceerde vervolgens de nieuwe Eco-design richtlijnen (European Commission, 2019), waarin een begin wordt gemaakt met beleid voor repareerbaarheid, zoals een voorgeschreven periode waarin reserveonderdelen beschikbaar moeten zijn.

Een belangrijk discussiepunt in verband met repareerbaarheid geldt de doelgroepen die reparaties aan consumptiegoederen mogen uitvoeren binnen de wettelijke beperkingen met het oog op de veiligheid. Bracquené e.a. (2018) en Cordella e.a. (2019) maken ten aanzien van de gebruiksveiligheid in hun onderzoek duidelijk onderscheid tussen particuliere gebruikers en professionele reparateurs. Als echter uitsluitend professionele reparateurs producten zouden

kunnen repareren, zou dit het effect van reparaties als circulaire strategie ondermijnen. Daar staat tegenover dat zelf repareren door onervaren reparateurs een aanmerkelijk veiligheidsrisico zou kunnen opleveren.

In dit verkennende onderzoek worden zowel de risico's tijdens de reparatie van het product (reparatierisico's) als de risico's en onbedoelde consequenties als gevolg van een slecht uitgevoerde reparatie (risico's na reparatie) in aanmerking genomen. De nadruk ligt op het verband tussen de veiligheid bij zelf repareren en het productontwerp, en op mogelijke ontwerpoplossingen. Ook wordt gekeken naar gebieden waarop nader onderzoek wenselijk is.

Achtergrond

Reparatiekennis

De reparatiekennis van gebruikers verschilt. De volgende vier groepen zijn gedefinieerd om verschillende gebruikersgroepen te onderscheiden:

- *Onervaren reparateurs* zijn mensen die niet over voldoende technische kennis beschikken om een reparatie zonder risico's uit te voeren en zich niet bewust zijn van mogelijke risico's na reparatie.
- *Semiprofessionele reparateurs* zijn mensen met voldoende technische kennis om zich bewust te zijn van de risico's van een bepaalde reparatie - en die risico's te vermijden - die regelmatig reparaties uitvoeren in een informele setting.
- *Ongecertificeerde professionele reparateurs* zijn mensen die beroepsmatig consumptiegoederen repareren en over de kennis en ervaring beschikken om risico's te vermijden, maar die geen reparatieopleiding of -informatie hebben gehad van de fabrikant en daarom niet officieel bevoegd of gecertificeerd zijn om herstelwerkzaamheden te verrichten.
- *Gecertificeerde professionele reparateurs* zijn mensen met professionele kennis en ervaring die beschikken over officiële reparatiegegevens, -opleidingen en -bevoegdheden voor specifieke producten van een bepaalde fabrikant.

Risicocategorieën

Er is uitgegaan van vier soorten risico's die consumptiegoederen tijdens het demonteren met zich meebrengen:

- *Mechanische risico's* zijn aanwezig wanneer een component of een (de)montagehandeling lichamelijk letsel bij de gebruiker (bijv. snijwonden of kneuzingen) of mechanische schade aan de directe omgeving van het product kan veroorzaken.
- *Elektrische risico's* omvatten niet alleen het risico van een elektrische schok tijdens de reparatie maar ook mogelijke kortsluiting en gevolgen voor de directe omgeving (bijv. brand als gevolg van een slecht uitgevoerde reparatie).
- *Thermische risico's* hebben betrekking op het risico dat een component of een (de)montagehandeling brandwonden bij de gebruiker of brandschade in de directe omgeving van het product veroorzaakt.
- *Chemische risico's* zijn de risico's dat een component of een (de)montagehandeling de gebruiker in contact brengt met gevaarlijke stoffen (bijv. via de huid of de luchtwegen).

Scope

Het ontwerp speelt een belangrijke rol bij het mogelijk maken van reparaties, het voorkomen van gevaarlijke situaties en het tot stand brengen van een veiliger reparatieproces voor de consument. De identificatie van risico's in het productontwerp maakt het voor ontwerpers mogelijk de onderliggende oorzaken van de risico's vast te stellen, het ontwerp van het apparaat te herzien, richtinggevende ontwerpkenmerken toe te voegen en/of de consument doeltreffende informatie te geven. In dit onderzoek worden de risico's in verband met de reparatie van twee specifieke producten geïdentificeerd en beoordeeld middels een analyse van het productontwerp.

Onderzoeksvragen
Tijdens het onderzoek is een antwoord gezocht op de volgende onderzoeksvragen:
1. Welke veiligheidsrisico's zijn te onderscheiden tijdens en na de reparatie van een product, uitgevoerd door een onervaren gebruiker?
2. In hoeverre houden deze risico's verband met het ontwerp van het product?
3. Hoe kan het ontwerp zelf-uitgevoerde reparaties van consumptiegoederen veiliger maken voor onervaren reparateurs?

Tot slot is een meer specifiek aspect van onderzoeksvraag 3 in de praktijk getest:
4. In hoeverre vergroot de verstrekking van demontage- en veiligheidsinformatie de veiligheid van zelf uitgevoerde reparaties (tijdens en na de reparatie)?

Methode

De in dit onderzoek hanteerde methode is gebaseerd op vier stappen:
1. Selectie van de te onderzoeken producten.
2. Demontage van het product en in kaart brengen van het ontwerp met behulp van Disassembly Mapping (De Fazio, 2019).
3. Identificatie en lokalisering van verschillende risico's in het productontwerp binnen de Disassembly Map.
4. Gebruikersonderzoek om niet opgemerkte risico's te identificeren en het effect van beschikbare informatie op de veiligheid van zelf uitgevoerde reparaties te onderzoeken.

Selectie van de producten
Het onderzoek is geconcentreerd op de volgende productcategorieën: stofzuigers en koffiezetapparaten. Deze producten zijn om verschillende redenen voor dit onderzoek geselecteerd: ze worden regelmatig gerepareerd (Repair monitor, Repair Cafe, 2019), ze werken op 230 V wisselstroom (waarmee ze een elektrisch risico opleveren) en met name het koffiezetapparaat werkt bij een hoge temperatuur in combinatie met elektriciteit en water.

In kaart brengen van het productontwerp
Het ontwerp van de producten is in kaart gebracht met behulp van een ontwerpmethode genaamd Disassembly Map (De Fazio, 2019). Deze stap is uitgevoerd om veiligheidsproblemen tijdens reparaties aan het licht te brengen en die toe te kunnen schrijven aan ontwerpaspecten. De Disassembly Map is een logische boomstructuur (afbeelding 3 en 4) waarin alle demontagestappen worden getoond die nodig zijn om verschillende componenten te verwijderen. *Componenten* worden aangeduid met nummers in lichtblauwe cirkels; deze staan in een volgorde die het demontageproces weerspiegelt. *Actieblokken* in verschillende kleuren en vormen geven verschillende demontagehandelingen aan die noodzakelijk zijn om een onderdeel te verwijderen. Componenten die zich onderaan de Disassembly Map bevinden, zijn diep 'ingebed' in het product en meestal ook moeilijk bereikbaar.

Identificatie en lokalisering van veiligheidsrisico's
Door gebruik te maken van de Disassembly Map en de beide producten volledig te demonteren konden de vier risicocategorieën in het productontwerp worden gelokaliseerd. Een eerste risico-indeling werd gemaakt door video-opnamen te analyseren die tijdens de demontage en montage van het product waren gemaakt.

De mogelijke risico's in de geanalyseerde producten werden gedefinieerd door middel van ideevormende sessies tijdens het demontageproces en interviews met Ongecertificeerde professionele reparateurs die als vrijwilliger actief zijn bij het Repair Cafe in Delft en Rotterdam-West. Ook de risicoscenario's na reparatie werden op deze wijze geclassificeerd. De uitkomsten van deze analyse werden verder besproken met fabrikanten.

Gebruikerstest. Invloed van informatieverstrekking op de veiligheid van zelf uitgevoerde reparaties en validatie van de risicoanalyse
Om te onderzoeken welke invloed informatieverstrekking op de veiligheid van zelf uitgevoerde reparaties heeft en om de met de Disassembly Map uitgevoerde risicoanalyse te valideren, werd aan 18 onervaren reparateurs gevraagd een koffiezetapparaat te demonteren. Het koffiezetapparaat kreeg voor deze test de voorkeur boven de stofzuiger omdat het een groter scala van risico's tijdens en na reparatie met zich meebrengt. De veiligheid van de deelnemers werd gewaarborgd door de testopstelling. Om de test zo objectief mogelijk te maken, werden de deelnemers echter niet op de hoogte gebracht van voorzorgsmaatregelen in verband met de veiligheid. Door observatie van de demontage in een gecontroleerde omgeving konden risico's worden geïdentificeerd die niet eerder in aanmerking waren genomen.

De deelnemers werden in twee groepen verdeeld. Beide groepen kregen de opdracht hetzelfde model koffiezetapparaat te demonteren en dezelfde component (de pomp) te vervangen. Ze behoorden allen tot dezelfde leeftijdsgroep (21-32 jaar). De eerste groep werd geobserveerd tijdens het 'repareren' (demonteren en weer volledig in elkaar zetten) van het product zonder enige informatieve documentatie. De tweede groep moest dezelfde operatie uitvoeren terwijl een demontage- en veiligheidshandleiding beschikbaar was (Appendix A). De deelnemers mochten er vrijwillig gebruik van maken. Wanneer deelnemers de handleiding na 5 minuten niet gebruikt hadden, werd nadrukkelijk verzocht de handleiding erbij te nemen.

De informatie in de handleiding was gebaseerd op de voorafgaande Disassembly Map en analyse van het product. De informatie bestond uit:
- Alle *stappen van het demontageproces* in tekst en afbeeldingen.
- *Veiligheidsinformatie*, met gebruik van kleuren en pictogrammen om onveilige stappen te markeren. Deze indicatoren werden vermeld bij elke demontagestap met een risico.
- *Montage-informatie,* met gebruik van kleuren en een pictogram om aandachtspunten in de montage te markeren.

Alle reparaties werden op video opgenomen en de observaties werden genoteerd. Alle deelnemers werd gevraagd tijdens de reparatie hardop te denken en zo hun gedachten over te brengen. De deelnemers kregen voorafgaand aan de test het verzoek een vragenlijst in te vullen om hun mate van deskundigheid te kunnen beoordelen. Na afloop werd hun gevraagd persoonlijke overwegingen met betrekking tot de reparatie te noteren. In Appendix B wordt het volledige onderzoeksprotocol beschreven.

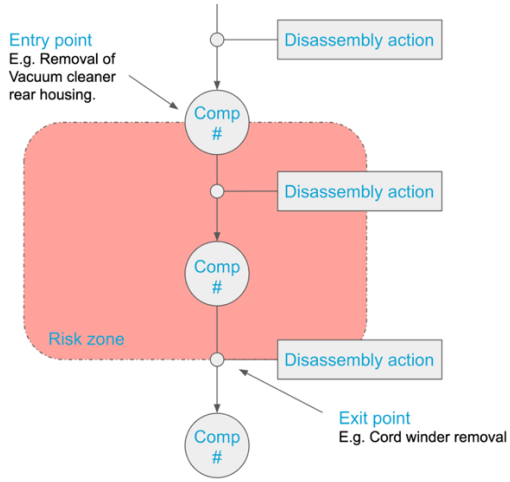
Resultaten

Definitie en morfologie van 'risicozones'
In het ontwerp van de geselecteerde producten werden 'risicozones' geïdentificeerd. Risicozones zijn gedefinieerd als "een interval van demontagehandelingen dat veiligheidsrisico's oplevert voor de gebruiker die de reparatie uitvoert, ongeacht zijn of haar deskundigheidsniveau". Een risicozone wordt bereikt via een 'beginpunt', gedefinieerd als een "component of demontagehandeling die bij verwijdering of uitvoering de gebruiker blootstelt aan een zeker veiligheidsrisico". Een risicozone wordt afgesloten door een 'eindpunt', gedefinieerd als een "component of demontagehandeling die bij verwijdering of uitvoering het gehele risico waaraan de gebruiker tot dat moment was blootgesteld wegneemt" (afbeelding 1).

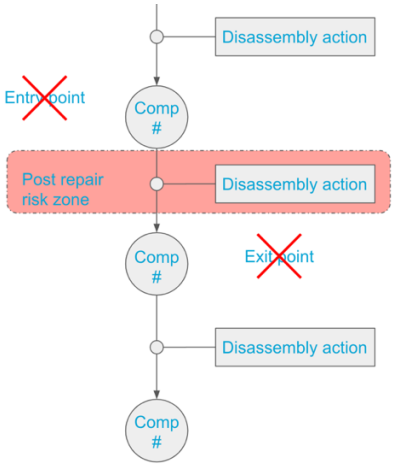
Risicozones worden ook gedefinieerd volgens het type risico. Sommige zones bevatten meer dan één risico en worden daarom gedefinieerd als 'multi-risicozones'. Een ander type risicozone is de 'risicozone na reparatie'. Dergelijke zones kunnen worden aangetroffen wanneer het ontwerp van een bepaald onderdeel of een bepaalde verbinding niet garant staat voor een correcte en veilige montage. Een voorbeeld hiervan zijn de waterslangen van het koffiezetapparaat, die bij onjuiste

bevestiging na de reparatie lekkage kunnen veroorzaken. In dit geval is er geen sprake van duidelijke begin- en eindpunten (afbeelding 1 en 2), omdat deze sterk afhangen van de manier waarop de reparatie wordt uitgevoerd.

De risicozones zijn in eerste instantie geïdentificeerd door de demontageprocessen - die nodig zijn om alle prioriteitscomponenten te bereiken - te observeren en in kaart te brengen. Deze analyse is vervolgens verfijnd door de uitkomsten te bespreken met ongecertificeerde professionele reparateurs. De risicozones en hun begin- en eindpunten zijn zorgvuldig gelokaliseerd en weergegeven op de demontageschema's van de beide voor dit onderzoek geselecteerde producten.



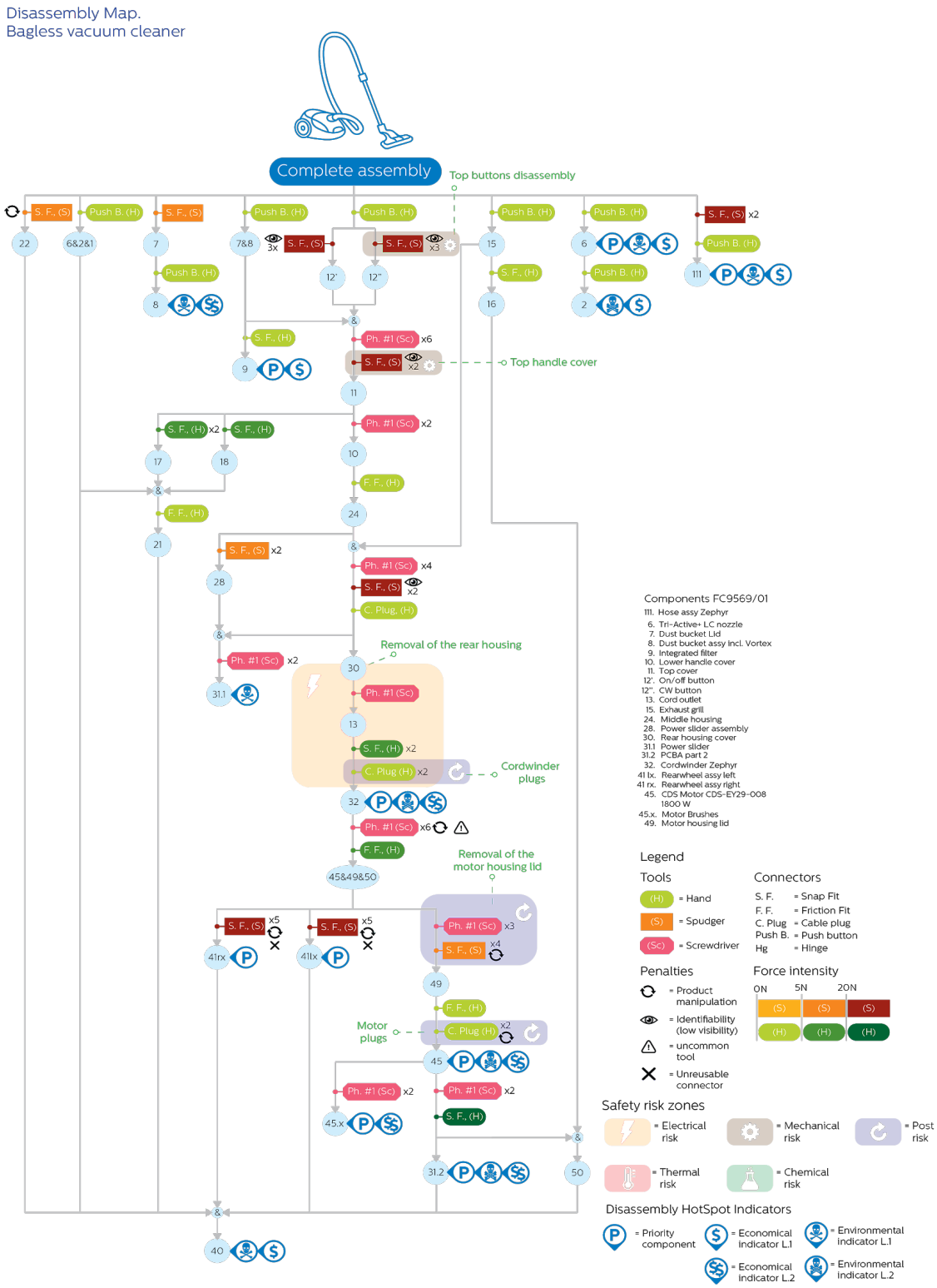
Afbeelding 1 *Morfologie van een risicozone*



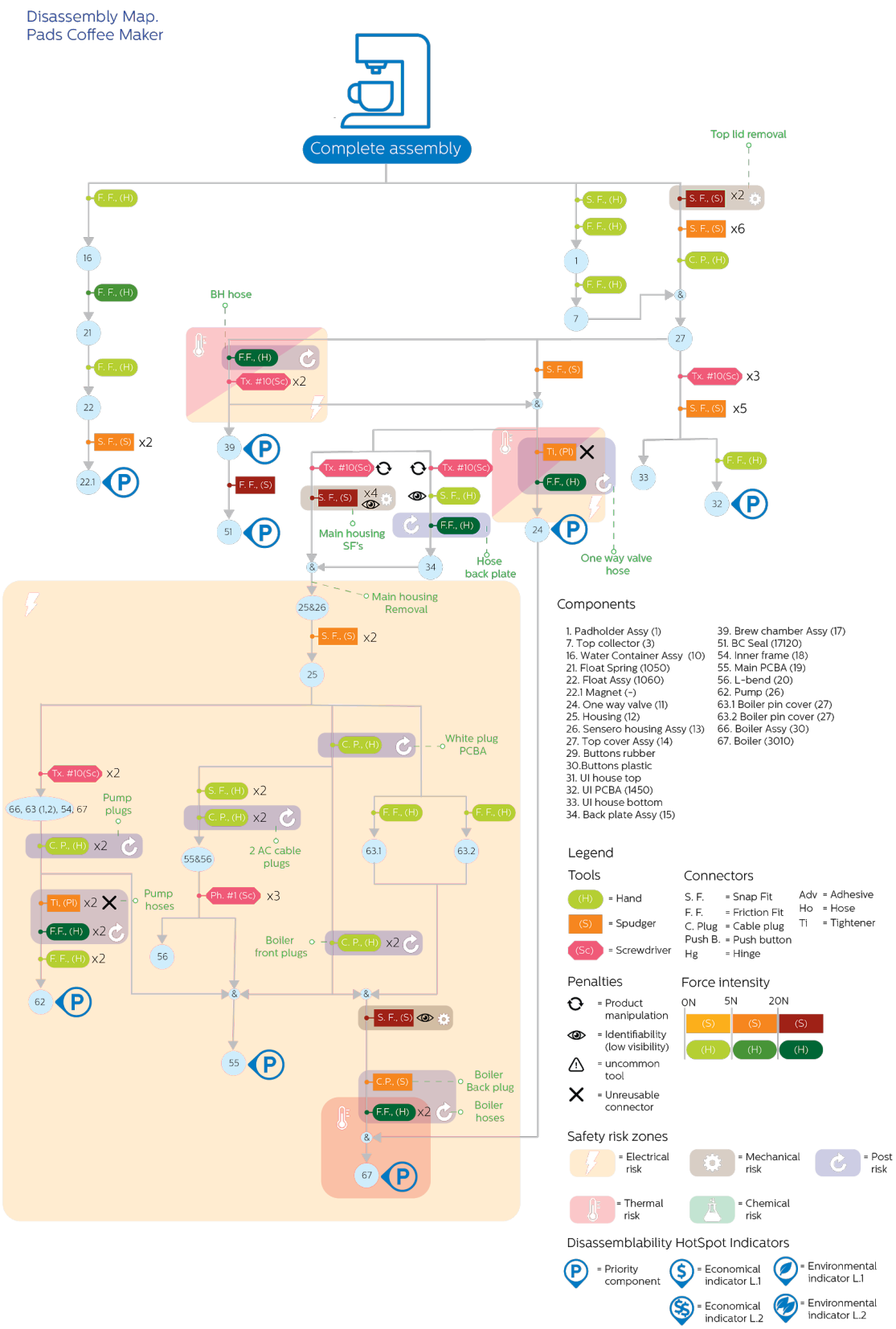
Afbeelding 2 *Morfologie van een risicozone na reparatie*

Productontwerp en risicozones in kaart gebracht

In afbeelding 3 en 4 worden de demontageschema's van de twee geanalyseerde producten getoond met de risicozones.



Afbeelding 3 *Disassembly Map met risicozone-indeling van een zakloze stofzuiger*



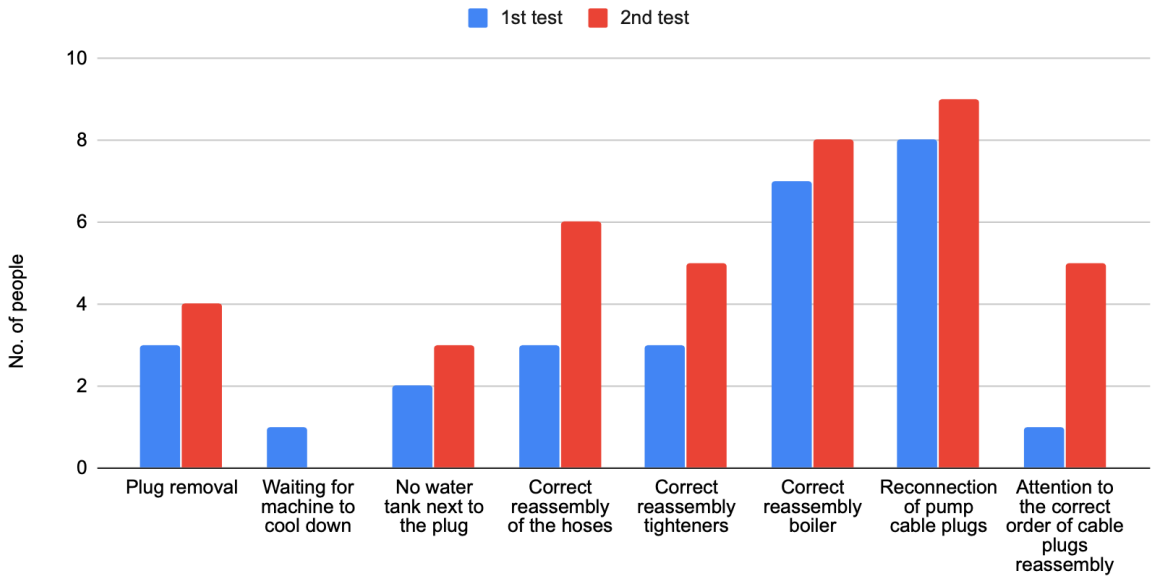
Afbeelding 4 *Disassembly Map met risicozone-indeling van een koffiezetapparaat met pads*

Resultaten van de gebruikerstest

In afbeelding 5 zijn de resultaten van de gebruikerstest samengevat. De afbeelding toont de voornaamste risico's tijdens de demontage van het koffiezetapparaat en ook de risico's die na de reparatie tot onveilige situaties kunnen leiden. Als we de groepen zonder en met een handleiding vergelijken, lijkt de tweede groep iets beter te presteren, maar de verschillen zijn klein.

Binnen de groep met een handleiding maakten slechts twee van de negen deelnemers daarvan spontaan gebruik zonder dat dit hun gevraagd was. Aan alle overige deelnemers werd vijf minuten na het begin van de test gevraagd de demontage- en veiligheidshandleiding te gebruiken. Uit de videoanalyse kan worden opgemaakt dat de meeste deelnemers de handleiding niet in een logische volgorde lazen en afgingen op direct beschikbare en snel verkrijgbare informatie zoals afbeeldingen. De meeste deelnemers verklaarden de handleiding bij voorkeur alleen te gebruiken wanneer zij een bepaalde stap niet zelfstandig kunnen uitvoeren. Vijf van de negen deelnemers bleven de handleiding gedurende de hele test gebruiken.

Daarnaast werd aan de deelnemers specifiek gevraagd of zij informatie zoals de rode veiligheidswaarschuwingen en blauwe montagewaarschuwingen nuttig hadden gevonden. Vijf van de negen vonden de veiligheidswaarschuwingen niet nuttig en zeven van de negen vonden montagewaarschuwingen niet nuttig.



Afbeelding 5 *Resultaten gebruikerstest ten aanzien van veiligheid. Demontageproces zonder informatieverstrekking (test 1) versus demontageproces met verstrekte veiligheids- en demontage-informatie (test 2)*

Discussie

Productontwerp en risicozones in kaart gebracht
De Disassembly Map methode blijkt toepasbaar op de verschillende productgroepen en maakt het mogelijk de risicozones in de schematische productarchitectuur te integreren. In de structuur van het diagram kan niet alleen de locatie van een specifiek type risico goed worden weergegeven, maar ook de mate waarin de gebruiker aan dat risico blootstaat. Bovendien kunnen de demontagehandelingen die een specifiek risico met zich meebrengen, correct worden geïdentificeerd. Dit impliceert dat de hier voorgestelde uitbreiding van de Disassembly Map inzicht verschaft in de veiligheidsrisico's naast inzicht in reparaties.

Risicozones voor stofzuiger en koffiezetapparaat
In afbeelding 3 en 4 worden de risicoschema's voor de twee geselecteerde producten getoond. De meeste risicozones in beide afbeeldingen hebben betrekking op elektrische risico's en risico's na reparatie. De risicozones wijzen op onveilige gebieden die als input kunnen dienen voor aanpassingen in het ontwerp, bijvoorbeeld door een ander type aansluiting te gebruiken, de noodzakelijke kracht te verminderen en/of de zichtbaarheid te vergroten. Bij beide producten worden bijvoorbeeld mechanische risico's waargenomen bij demontagehandelingen, waaronder knipsluitingen die veel kracht vergen en/of slecht zichtbaar zijn. In zulke gevallen loopt de gebruiker het risico zich bij het losmaken te verwonden met de component of het gebruikte gereedschap.

Vergeleken bij het koffiezetapparaat is de *elektrische risicozone* van de stofzuiger kleiner. In dit specifieke geval kan worden opgemerkt dat de elektrische risicozone van de stofzuiger 'ophoudt' nadat de snoerhaspel is losgemaakt (eindpunt), terwijl de elektrische risicozone van het koffiezetapparaat gedurende het hele demontageproces blijft bestaan omdat een eindpunt ontbreekt (de draden van de stroomtoevoer blijven in het product aanwezig tijdens de hele reparatie). Met dit inzicht kan de mogelijkheid worden onderzocht om een eindpunt in het ontwerp van het koffiezetapparaat op te nemen om de risicozone te verkleinen.

Bij beschouwing van de *risicozones na reparatie* bij beide apparaten, kan worden opgemerkt dat deze verband houden met de juiste montage van kabelaansluitingen, slangen en behuizingselementen. Uit de observaties tijdens de gebruikerstest van het koffiezetapparaat is op te maken dat de juiste montage van de slangen en kabelaansluitingen zeer afhankelijk is van het geheugen van de reparateur en de juiste positionering van bevestigingsklemmen. Ook werd duidelijk dat een montagehandleiding nauwelijks leidde tot vermindering van dit risico. Dit betekent dat op dit gebied verder onderzoek naar herziening van het ontwerp, waarmee wordt voorkomen dat onderdelen onjuist worden teruggeplaatst, nodig is.

Beperkingen van schema's met risicozones
Bij de integratie van risicozones in de Disassembly Map zijn verschillende beperkingen geconstateerd. Voor de volgende aspecten is nader onderzoek vereist:
- Er zijn vier verschillende typen risico en een algemeen risico na reparatie onderzocht. Aanvullend onderzoek is nodig om andere risicocategorieën te identificeren.
- Risico's hebben een verschillende mate van ernst, uiteenlopend van een oppervlakkige huidbeschadiging of schroeiplek tot elektrocutie en brand. Er is nader onderzoek vereist om een risicoranglijst te kunnen opstellen.
- Met het oog op de beperkte beschikbare tijd en simplificatie van het systeem zijn de risico's na reparatie onder één type risico geschaard. Zoals werd aangegeven in gesprekken met fabrikanten, zijn er echter ook verschillende categorieën risico's na reparatie die nader onderzocht dienen te worden.
- Voor elektrische en thermische risico's konden gemakkelijk begin- en eindpunten worden geïdentificeerd, maar dat was moeilijker voor mechanische risico's. Er is meer onderzoek nodig om vast te stellen hoe begin- en eindpunten in het algemeen kunnen worden geïdentificeerd voor alle risicocategorieën.

Veiligheid en aansprakelijkheid bij zelf repareren
Het huidige ontwerp van de geanalyseerde producten kan als veilig voor gebruikers worden beschouwd, omdat de risicozones diep zijn ingebed in de productarchitectuur (zoals te zien is in Disassembly Maps). De hieruit voortkomende moeilijke bereikbaarheid leidt echter tot problemen bij de reparatie van componenten in die zones. Dit houdt verband met de aansprakelijkheid die fabrikanten ervaren op grond van richtlijn 2001/95/EG inzake algemene productveiligheid, waarin producenten onder normale of redelijkerwijs voorzienbare omstandigheden aansprakelijk worden gesteld voor de veiligheid van de gebruiker. Dit wordt door fabrikanten als reden genoemd om reparatiehandleidingen en reserveonderdelen niet beschikbaar te stellen aan particuliere consumenten. Op de juridische details is in dit verkennende onderzoek niet nader ingegaan, maar ze zullen in een uitgebreider onderzoek wel in aanmerking moeten worden genomen.

Mogelijke ontwerpoplossingen
Deze verkennende studie wijst op twee gebieden die nader onderzoek verdienen om de veiligheid bij zelf uitgevoerde reparaties te vergroten. Ze betreffen de verstrekking van veiligheidsinformatie aan reparateurs, met name onervaren reparateurs, en de implementatie van onfeilbare ontwerpeigenschappen gericht op preventie van risicosituaties. Deze twee onderzoeksgebieden zijn nader verkend met gebruikers en besproken met fabrikanten.

Informatieverstrekking
Uit de resultaten van de gebruikerstest met en zonder handleiding (zie boven) blijkt dat de verstrekking van veiligheidsinformatie aan onervaren reparateurs nauwelijks positief effect op verbetering van de veiligheid lijkt te hebben. Bovendien laten de resultaten zien dat de meeste deelnemers - met of zonder handleiding – zelfs geen aandacht besteden aan basale veiligheidsvoorzorgen, zoals het verwijderen van de stekker uit de voedingsbron, het niet plaatsen van volle waterhouders naast een stroombron of het in de juiste volgorde terugplaatsen van de bedrading op het schakelbord.

De meeste gebruikers hebben om diverse redenen de neiging om het gebruik van de verstrekte handleiding gedurende het reparatieproces te vermijden of tot een minimum te beperken. Opgemerkt werd dat gebruikers in het algemeen vertrouwen op hun eigen vermogen om de demontage uit te voeren en een praktische benadering hanteren waarbij ze zo veel mogelijk tijd proberen te besparen wanneer ze de verstrekte informatie lezen. De vorm waarin de informatie werd aangeboden was een papieren handleiding met tekst en afbeeldingen. De meeste gebruikers volgden de instructies niet in volgorde op, vertrouwden op de afbeeldingen en negeerden in de regel alle veiligheids- en montagewaarschuwingen.

De uitkomsten van de test zijn nader besproken met ontwerpers en met kwaliteits- en veiligheidsverantwoordelijke constructeurs van fabrikanten, die aanvoeren dat het geven van informatie geen effectief middel is om de veiligheid te vergroten. Vervolggesprekken met gebruikers lijken er echter op te wijzen dat de effecten van informatieverstrekking ter vergroting van de veiligheid bij zelf uitgevoerde reparaties nader kunnen worden onderzocht door te experimenteren met andere media. Dit zou de informatieverstrekking effectiever kunnen maken. Voorbeelden zijn het geven van informatie op het product zelf, in video's over veiligheid en reparaties, of door middel van virtual en augmented reality.

Onfeilbaar ontwerp
Een andere interessante ontwerpoplossing is het zogenaamde 'failproof design' (onfeilbaar ontwerp). De definitie van een onfeilbaar ontwerp, geformuleerd in samenwerking met fabrikanten, is een "ontwerp dat de veiligheid van de gebruiker te allen tijde waarborgt tijdens een reparatieproces bestaande uit diagnose, demontage, reparatie, montage en testen. Daarnaast wordt met een onfeilbaar ontwerp vermeden dat het product op onjuiste wijze weer in elkaar wordt gezet, zodat risico's na reparatie worden voorkomen."

Ter illustratie worden hier enkele voorbeelden gegeven van onfeilbare ontwerpoplossingen die nader onderzoek verdienen:

- Automatische onderbreking van de stroomtoevoer wanneer de laatste kap van interne elektrische componenten wordt verwijderd. Hiermee wordt in feite een eindpunt voor elk elektrisch risico gecreëerd.
- Aanbrengen van kleurindicatoren om de reparateur te helpen bij de juiste terugplaatsing van kabelaansluitingen en slangen.
- Eliminatie van 'losse' bevestigingssystemen zoals klemmen. Aanbieden van aansluitmogelijkheden die reparateurs maar op één manier (en dus correct) kunnen gebruiken.
- Modulair repareren, dat wil zeggen "reparaties waarvoor basale demontage- en montagehandelingen vereist zijn, zoals de vervanging van modules door een paar eenvoudige en zichtbare klemmen te verwijderen met alledaags gereedschap". Sommige fabrikanten definiëren dit type reparatie als "reparatie door vervanging", met als voorbeeld de vervanging van een oplaadbare batterij. In het ontwerp van dergelijke modules moet direct contact met kritieke interne componenten zo veel mogelijk worden vermeden en moet de correcte terugplaatsing van alle aangesloten systemen worden gewaarborgd, zonder dat een elektrische storing of waterlekkage ontstaat.

Het is van belang erop te wijzen dat deze voorbeelden van ontwerpoplossingen nader verkend moeten worden en in veel gevallen niet door fabrikanten worden toegepast vanwege de gevolgen voor de kosten en de algehele complexiteit van het productontwerp.

Conclusie

Dit onderzoek betrof de veiligheid van zelf uitgevoerde reparaties. Het is uitgevoerd door het ontwerp van bestaande consumptiegoederen te analyseren en in kaart te brengen, door verschillende typen veiligheidsrisico's en hun morfologie te identificeren, door gebruikers te observeren in een gecontroleerde omgeving en door inzichten te bespreken met Ongecertificeerde professionele reparateurs en fabrikanten. De belangrijkste bevindingen van het onderzoek:

- Er zijn verschillende soorten risico's waarmee rekening moet worden gehouden bij ontwerpen met het oog op veilige zelf uitgevoerde reparaties. Deze risico's kunnen optreden tijdens de reparatie, maar ook daarna als het reparatieproces niet correct is afgerond.
- In kaart brengen en visualiseren van het productontwerp (zoals uitgevoerd met de Disassembly Map) maakt de identificatie en lokalisering van veiligheidsrisico's mogelijk. Dit zou een belangrijk hulpmiddel kunnen worden voor productontwerpers om rekening te houden met zelf uitgevoerde reparaties.
- Uit de gebruikerstest bleek dat een meerderheid van de onervaren reparateurs geen basale voorzorgsmaatregelen treft, zoals het afschakelen van de spanning.
- Het verstrekken van veiligheidsinformatie aan onervaren reparateurs, zoals in dit onderzoek is getest, heeft nauwelijks positief effect op verbetering van de veiligheid. Wel zijn andere vormen en media voor de informatieverstrekking naar voren gekomen als een terrein waarop nader onderzoek de moeite waard is.
- Onfeilbare ontwerpoplossingen die de repareerbaarheid van producten verbeteren en tegelijkertijd de veiligheid tijdens en na het reparatieproces waarborgen, lijken een veelbelovende optie te zijn voor het ontwerpen van repareerbare, maar volledig veilige producten.

Literatuur

Bakker, C., den Hollander, M., Van Hinte, E., & Zljlstra, Y. (2014a). Products that last: Product design for circular business models: TU Delft Library.

Bakker, C., Wang, F., Huisman, J., & Den Hollander, M. (2014b). Products that go round: exploring product life extension through design. Journal of cleaner production, 69, 10-16.

Bocken, N. M., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering, 33(5), 308-320.

Bracquené, E., Brusselaers, J., Dams, Y., Peeters, J., De Schepper, K., Duflou, J., & Dewulf, W. (2018). Repairability criteria for energy related products.

CEN/CLC TC10 European Standard. (2017). General methods for the assessment of the ability to repair, reuse and upgrade energy related products. DRAFT DOCUMENT. In (Vol. prEN 45554).

Cordella, M., Alfieri, F., & Sanfelix, J. (2019). Analysis and development of a scoring system for repair and upgrade of products - Final Report. (EUR 29711 EN). Luxembourg: Publications Office of the European Union

European Commission. (2015). Closing the loop– An EU action plan for the circular economy. COM 614 final.

European Commission. (2016). Ecodesign Working Plan 2016-2019. COM(2016) 773 final.

European Commission (2019). New rules make household appliances more sustainable

De Fazio, F. (2019). Enhancing Consumer Product Repairability. A case study on Vacuum Cleaners.

Flipsen, B., Bakker, C., & van Bohemen, G. (2016). Developing a reparability indicator for electronic products. Paper presented at the 2016 Electronics Goes Green 2016+(EGG).

Flipsen, B., Huisken, M., Opsomer, T., Depypere, M. (2019). Smartphone Reparability Scoring: Assessing the Self-Repair Potential of Mobile ICT Devices.

Safe by Design. Safe self-repairs.
Appendices

MSc Ir. Julieta Bolaños Arriola
MSc Ir. Francesco De Fazio

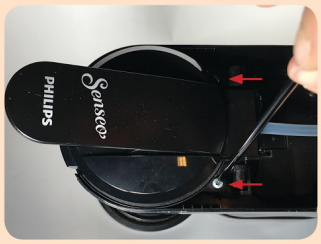
Supervisors
Prof. dr. Ruud Balkenende
Prof. dr. Conny Bakker
Dr. ir. Bas Flipsen

Faculty of Industrial Design Engineering, TU Delft
Project commissioned by: Ministerie van Infrastructuur en Waterstaat

Appendix A. Extract from the Disassembly and safety manual.

12. Brewing Head

Please skip this section if you are not interested in disassembling this component.



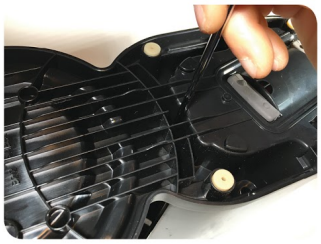
The next step may cause water leakage. Please check that the device is unplugged and far from any electric source!

12.1 Remove two screws, Torx 10, positioned next to the brewing head as in picture. Then extract the component.

Please remember in reassembly to put back the brewing head in the right position, by sliding in the front part in the main plastic casing as in pictures

The next step may cause water leakage. Please check that the device is unplugged and far from any electric source!

13. Turn the product upside down and remove the two bottom screws, Torx 10, idicated in picture.



The next step may cause water leakage. Please check that the device is unplugged and far from any electric source!

14. Remove the back plate assy, where the water container was connected, by unplugging the water hose.

Please remember in reassembly to push back the hose completely in the connector on it in order to avoid future leakage!

Appendix B. Test protocol 1st and 2nd round.

Aim
Identifying, through observation, possible risk points inexperienced repairers may encounter during the disassembly of a coffee machine and the related design or architecture characteristics of the product that influence them.

Identify and compare the effects of the presence and absence of supporting information regarding disassembly and safety throughout a repairing or disassembly procedure. The comparison will be made through 2 test rounds with 10-20 participants each. The results from the 1st round, where participants will not count with any type of supporting information, will be implemented in the preparation of supporting information material that will be made available to participants of the 2nd testing round.

Objective of the research
Determine if risks can be identified through observation and analysis of the recorded videos.
Determine the risks present in a simulation of a 'real scenario' for an un experienced repairer.

Determine and analyse the differences between the provision and absence of supporting information.

Determine the reliability and effectiveness for similar studies in future.

The first round is aimed to determine different parameters and variables to be considered and included in the preparation of the information package that will be made available to the participants during the second round.

Number of participants
10-20 participants 1st round
10-20 participants 2nd round

*The requirement for the participants is to have little to no previous experience or expertise in relation to repairs and product architecture.

Test Protocol, Round 1

Preparation

Preparing a laptop with an initial questionnaire ready to be filled up.

Preparing a 'fake' setup that represents a machine that has just been used to prepare coffee.

Preparing an additional machine that does not have a working power cord in order to be able to plug it in without generating a current, to protect the participant from electric shocks in case he/she forgets to unplug the device.

Prepare a cord and extension setup that simulates a normal working power source.

Setup and two cameras (top and side) with laptop and check if everything works properly.

Place screwdriver kit, Torx 10 screwdriver, pliers and additional replacement tighteners on the side of repair table.

Prepare a stopwatch.

Test

- Time required: 1hr - 1hr 10min(max)
- Two researchers will be present. One will be in charge of taking notes, for this the focus of the observation has to be clear. The notes will help in “landmarking” the video which will be helpful for the analysis stage of the experiment. The second researcher will be in charge of managing the experiment and interacting with the user.
- Participant is given a brief introduction about the structure of the test. s/he will be mentioned that there will be someone taking notes. The consent form is explained and signed. 5 min.
- Participant is given an initial questionnaire. 5min.
- Participants are shown the ‘fake’ setup of a working coffee machine that just finished making coffee.
- Participants are asked to disassemble the just used coffee machine. They are explained that the objective of the disassembly is to reach an internal component, which has been properly marked using a sticker with the legend ‘target’ (the pump). The participant does not know the name or the appearance of the component to be disassembled. Moreover, he/she is also explained to work within the working area indicated on the table.

- The participant is asked to think out loud while trying to disassemble the product in order to gain additional insights.
- Start stopwatch and video recording. The video recording is started and observations are made for whether the participant is aware of electrical and thermal precautions. 5min.
- Participants are asked to disassemble the coffee machine just used to make them coffee. This device will be actually connected to the current supply and the water heater will be hot. This step is important to analyse how many participants do not realise how unsafe disassembly a product connected to electricity and with very hot components inside can be. For safety reasons, any participant trying to actually open the product still plugged in and warm will be stop.
- Regardless of the participant being aware or not of the mentioned elements, the experiment of the 'fake' setup is stopped, the participant is asked to wait outside the test room and another coffee machine, prepared for disassembly, is shown to the participant who is asked once again to disassemble the product until they are able to reach and fully disassemble the marked component. This device is safely to disassemble, since all the inner components are cooled down. In this case, the cable plug will be connected to a not-working socket. This allows to study the number of participants that properly remember to disconnect the product from the supply and which would carry on the entire disassembly with the plug in.
- Participant performs the disassembly. Maximum time is 25min.
- Participants are not stopped even if they are risking to break components or if they are following a wrong disassembly order. However, for time limitation, simple hints are provided if participants spend more than 5 minutes on a single disassembly stem. *At this point, it will be helpful to ask the user for a proper explanation. E.g. "what is the part that you are having trouble with now? Why?* These hints are properly registered, in order to take track of which participant and at what disassembly step has been facilitated.
- After 25 min the participant is asked to stop.
- The participant will be asked if s/he wants a 5min break
- The participant will start assembling the product back together. The participant has a maximum of 15 min for this activity.
- Video camera is stopped once the product is completely re-assembled or after the 15 min have passed.
  An interview regarding the procedure difficulty and safety, is then conducted.

Post activity questions

1. Please rate the difficulty in disassembly of the product from 1 – 11 – 1 being very easy, 11 being very difficult
2. What where the elements during disassembly process you found difficult.
3. What where the elements during disassembly process you found easy. Please rate the difficulty in re-assembly of the product from 1 – 11 – 1 being very easy, 11 being very difficult
4. What were the elements during reassembly process you found difficult?
5. What were the elements during reassembly process you found easy?
6. Did you consider your safety at all throughout the disassembly process?

7. Please indicate what would make the procedure of disassembling and reassembling easier for you.

Post Processing

- Detailed observation of video and disassembly process.
- Definition of critical risk points observed in the video, noting the type of risk, severity and potential cause.
- Definition of critical points caused by lack of information.

Analysis and quantification of participants who took safety into consideration throughout the process.

Protocol step summary ROUND 1

1. Explain test. Offer coffee [very important that the participant sees that the coffee was “made” (the coffee was previously made with a different source and just poured into the testing coffee machine pot) with the plugged coffee machine].

2. Consent Form.

3. Initial questionnaire.

4. Start video

5. Explain and ask to disassemble:
- Explain to disassemble the component labelled ‘target’.
- Explain “Imagine this is coffee maker and you need to replace the target so you want the coffee maker to work after the procedure”

- Explain to work with the available tools and to stay within the working area.

6. Check if the participant is aware of electric and thermal risk. STOP THEM regardless of result and ask them to leave.

7. Replace the “working machine’ for the machine to disassemble. MAKE SURE THE “FAKE” PLUG IS REALLY UNPLUGGED!

8. 25min to disassemble. Help them if they are stuck more than 5 min. TAKE NOTES (time- quote- component)

9. 15 min to reassemble. TAKE NOTES (time- quote- component)

10. Post questionnaire. And DONE!!!

Test Protocol, Round 2

Preparation

Preparation of information package for the 2nd test round using observations and results from round 1.

Preparing a laptop with an initial questionnaire ready to be filled up.

Preparing a ‘fake’ setup that represents a machine that has just been used to prepare coffee.

Preparing an additional machine that does not have a working power cord in order to be able to plug it in without generating a current, to protect the participant from electric shocks in case he/she forgets to unplug the device.

Prepare a cord and extension setup that simulates a normal working power source.

Setup with two cameras (top and side) with laptop and check if everything works properly.

Place screwdriver kit, Torx 10 screwdriver, plyers and additional replacement tighteners on the side of repair table.

Prepare a stopwatch.

The disassembly and safety manual is placed on the working table.

Test

- Time required: 1hr - 1hr 10min(max)
- Participant is given a brief introduction about the structure of the test. The consent form is explained and signed. 5 min.
- Participants are offered coffee. Participants are shown the ‘fake’ setup of a working coffee machine that just finished making coffee.
- Participant is given an initial questionnaire. 5min.
- The video recording is started.
- Participants are asked to disassemble the just used coffee machine. They are explained that the objective of the disassembly is to reach an internal component, which has been properly marked using a coloured sticker (the pump). The participant does not know the name or the appearance of the component to be disassembled. Moreover, he/she is also explained to work within the working area indicated on the table. Eventually, the participant is asked to think out loud while trying to disassemble the product in order to gain additional insights. Additionally, the participant is indicated to use any of the tools and materials available on the working table. The participant is also warned to do the4 procedure as if it was their own coffee maker, hence, the machine needs to be assembled back together.
- The information package including safety and disassembly instructions is on the table but not pointed out to the participant.
- The video recording is started and observations are made for whether the participant is aware of electrical and thermal precautions. Observations are made for whether the participant pays attention to the disassembly and safety manual.
- Participants are asked to start the procedure. This device will be actually connected to the current supply and the water heater will be hot. This step is important to analyse how many participants do not realise how unsafe disassembly a product connected to electricity and with very hot components inside can be. For safety reasons, any

participant trying to actually open the product still plugged in and warm will be stop. Clear safety information about not repairing the product in this condition (Warm and plugged in) are provided in the repair manual provided at the beginning of the test.

- Regardless of the participant being aware or not of the mentioned elements, the experiment of the 'fake' setup is stopped, the participant is asked to wait outside the test room and another coffee machine, prepared for disassembly, is shown to the participant who is asked once again to disassemble the product until they are able to reach and fully disassemble the marked component. This device is safely to disassemble, since all the inner components are cooled down. In this case, the cable plug will be connected to a not-working socket. This allows to study the number of participants that properly remember to disconnect the product from the supply and which would carry on the entire disassembly with the plug in.
- Participant sits down and performs the disassembly. Maximum time is 25 min.
- Participants are not stopped even if they are risking to break components or if they are following a wrong disassembly order. However, for time limitation, simple hints are provided if participants spend more than 5 minutes on a single disassembly stem. These hints are properly registered, in order to take track of which participant and at what disassembly step has been facilitated.
- After 25 min the participant is asked to stop and start assembling the product back together. The participant has a maximum of 15 min for this activity.
- Video camera is stopped once the product is completely re-assembled or after the 15 min have passed.
- An interview regarding the procedure difficulty and safety, is then conducted.

Post activity questions

1. Please rate the difficulty in disassembly of the product from 1 – 11. 1 being very easy, 11 being very difficult
2. What where the elements during disassembly process you found difficult.
3. What where the elements during disassembly process you found easy.
4. Please rate the difficulty in re-assembly of the product from 1 – 11. 1 being very easy, 11 being very difficult
5. What were the elements during re-assembly process you found difficult?
6. What were the elements during re-assembly process you found easy?
7. What do you think this research is about?
8. How useful was the disassembly and safety manual during the disassembly procedure? 0 being not useful and 10 being very useful. Why?
9. How useful was the disassembly and safety manual during the reassembly procedure? 0 being not useful and 10 very useful. Why?
10. Please rate the quantity of information provided. 0 being too little, 10 being too much
11. How would you improve this guide? what to include and what to leave out?
12. Did you consider your safety at all throughout the disassembly process?
13. Please indicate what would make the procedure of disassembling and reassembling easier for you.
14. Any additional remarks.

Post Processing

- Detailed observation of video and disassembly process.
- Definition of critical risk points observed in the video, noting the type of risk, severity and potential cause.
- Definition and analysis of critical points avoided by the provision of the information package in comparison to the results of round 1.
- Analysis and quantification of participants who took safety into consideration throughout the process.

Protocol step summary ROUND 2

1. Explain test. Offer coffee [very important that the participant sees that the coffee was “made” with the plugged coffee machine (the coffee was previously made with a different source and just poured into the testing coffee machine pot)].

2. Consent Form.

3. Initial questionnaire.

4. Start video

5. Make sure the disassembly and safety manual is on the side of the table. DO NOT POINT IT OUT.

6. Explain and ask to disassemble:
- Explain to disassemble the component labelled ‘target’.
- Explain “Imagine this is coffee maker and you need to replace the target so you want the coffee maker to work after the procedure”.
- Explain to work with the available tools and materials and to stay within the working area.
- Ask the participants to think out loud.

7. Check if the participant pays attention to the manual before operating the machine. Check if the participant is aware of electric and thermal risk. STOP THEM regardless of result and ask them to leave.

8. Replace the “working machine’ for the machine to disassemble. MAKE SURE THE “FAKE” PLUG IS REALLY UNPLUGGED!

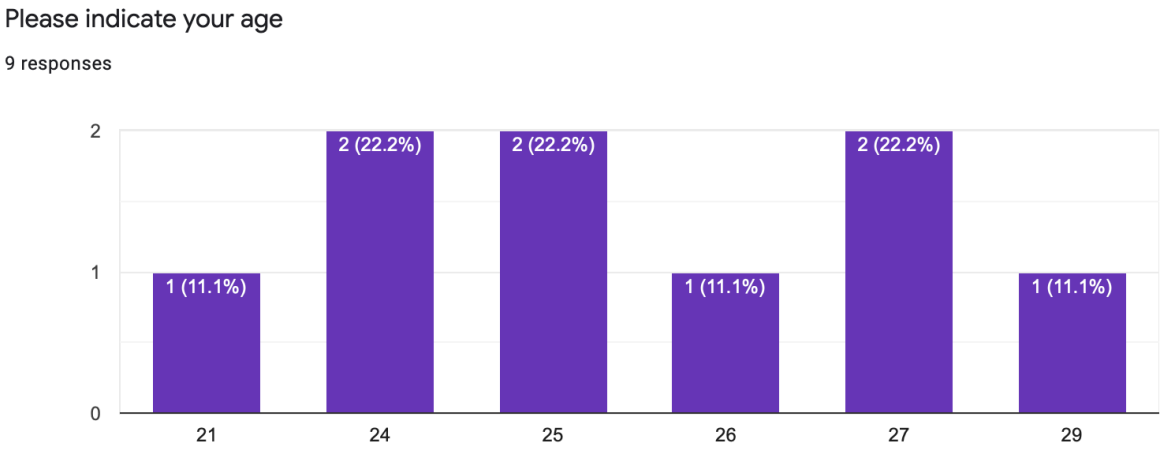
9. If they didn’t realize the safety and repair manual point it out and ask them to use it. Note down if a participant purposely decided not to use it or ignore it.

10. 25min to disassemble. Help them if they are stuck more than 5 min. TAKE NOTES (time- quote- component)

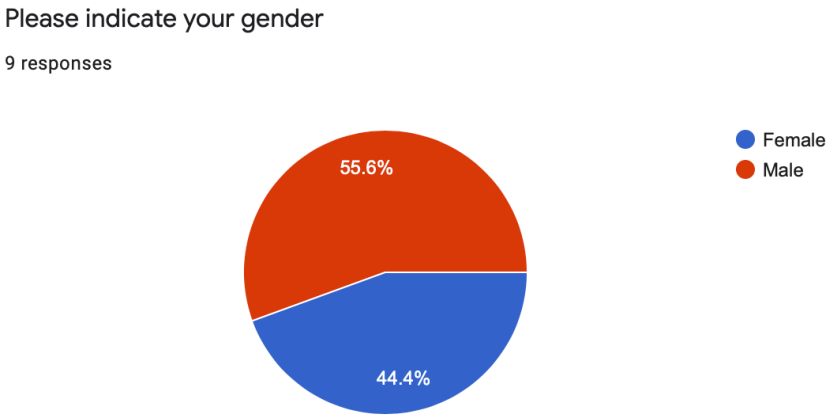
11. 15 min to reassemble. TAKE NOTES (time- quote- component)

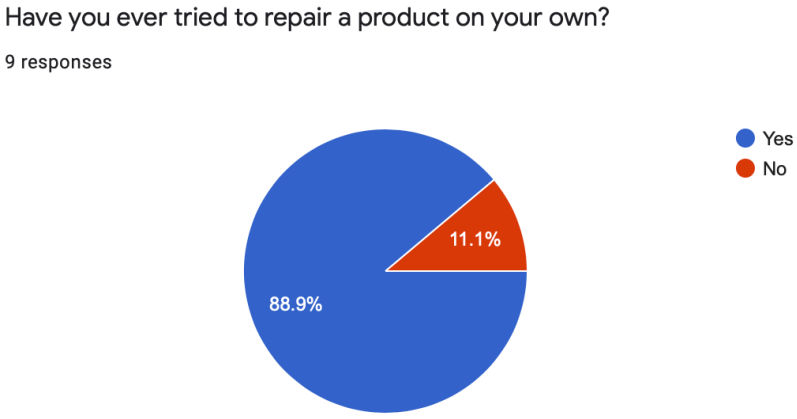
12. Post questionnaire.

Appendix C Results from user tests questionnaires



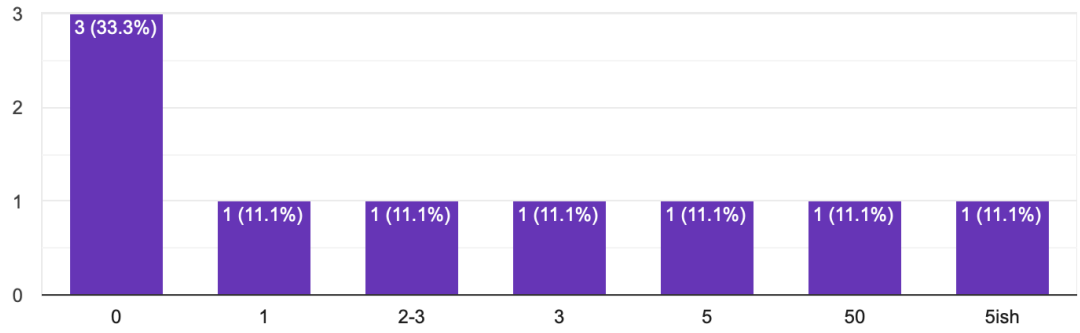
Round 1 Initial questionnaire results





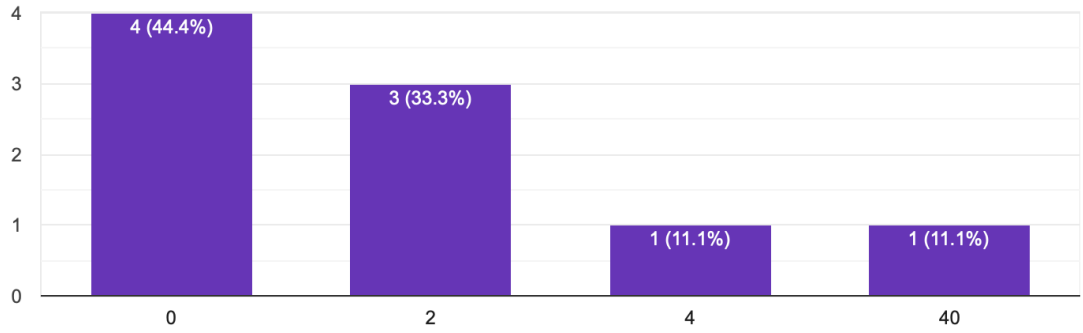
How many products have you tried to repair in the last 2 years? (doesn't matter if the repair was unsuccessful)

9 responses



How many products have you successfully repaired in the last 2 years ? (Indicate the number)

9 responses



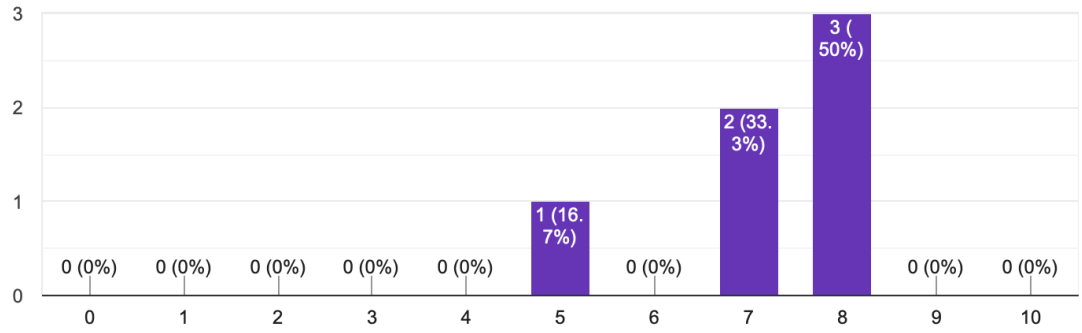
Mention the type(s) of products you have tried to repair. (Doesn't matter if it was an unsuccessful repair)

- None
- Bikes, sinks, boiler
- Bed
- Fishing rod, bike, household appliance
- Shower, bike, phones, house appliances in general, etc.
- PlayStation 3
- Bike, fan, little electronic devices
- Raincoat, plant spray bottle

Round 1 Post disassembly questionnaire results

How much impact did talk out loud did towards the disassembly process. (0 very negative impact -5- no impact 10 very positive impact)

6 responses

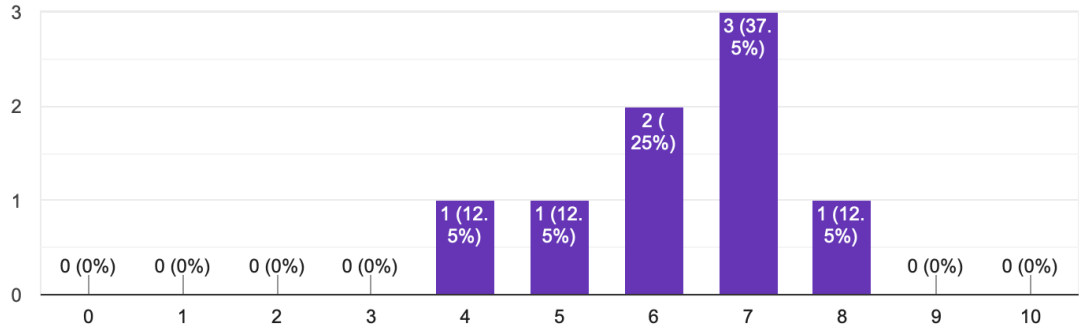


Please expand your answer

- speaking many times help you realize what you are saying and thinking.
- Sometimes I talk out loud and it helps me think
- Sometimes it was distracting. Most of the time I am by myself when I disassemble stuff so no talking helps me concentrate.
- Because when talking out loud I could map out to myself what I am doing.
- Before saying something, I think twice if it makes sense, then I understand or feel if the thought can help or not

Please rate the difficulty in disassembly of the product from 0 – 10. 0 being very easy, 10 being very difficult

8 responses



What where the elements during disassembly process you found difficult?

- Finding the screws, super hidden, in the bottom
- I didn't know which steps to follow, need to figure out which part to remove. Afraid to break something. No indication what to remove, snap-fits. Some steps within the device. Not much space for the hands to attach and detach, waste long time trying to avoid it.
- Finding the first screw. normally when you take out screws, you expect everything to come out, but was not the case. The rubber stand seems like there was screw in it,

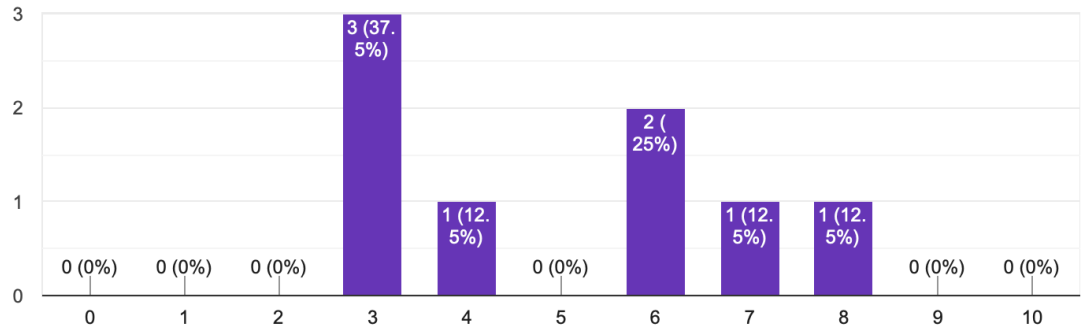
there was danger of breaking it. Thought boiler connection had to be taken out. Didn't know wire connector came off.
- Assuming you have to pinch to be able to pull out the compartment from-the bottom, no clear indication for grooves.
- Locating the screws (not exposed enough)
- Finding the screws. It is all black so the screws don't pop out. Unscrewing was complicated because they were very deep down. With electronics in the middle I am more cautious cause I do not want to break that part, because I do not know how to repair it (soldering, etc.).
- One of the main things was the target part, the rubber rings holding them were cable tights which I thought I needed to break. The other difficult part was to find the way the housing was attached to the body, hidden screws, non-intuitive regarding the order.
- It was difficult to find the screws on the bottom. It was difficult to open the top lid since it was difficult to open it without ruining the aesthetic.

What where the elements during disassembly process you found easy?

- Understanding where the fundamental parts are
- Detaching the pipe easy, there is noting that could go wrong with it. Dethatching the part under the water container was easy. to have all the tools.
- Unscrewing, taking out the tubes.
- Only two screws to hold them together, top just pops up.
- Top lid was easy to disassemble. Removing the tubes was easy as well.
- There are quite a few snap fits and there are not many pieces that I forget were they go. If there are many pieces, I forget their place but this was not the case. The water tubes were easy to put back together and separate.
- Top panel I could figure out. The hoses were easy to remove as well.
- To unplug the water hoses. Once you find the screws, it is quite easy to disassemble the product since there are just 2 of them.

Please rate the difficulty in reassembly of the product from 0 – 10. 0 being very easy, 10 being very difficult

8 responses



What were the elements during reassembly process you found difficult?

- Remembering how many screws there were
- I didn't remember well which cable went where, not much space from hand, e.g. for the pipes, was harder to attach.

- I wasn't aware ask assembling, did not pay attention where the cables went. Reassembling the tube was difficult, was hard to put the connection.
- Spaces get very small, tubing, very fiddly. Bottom cup holder is annoying to get in.
- Top lid and brewing head I forgot how they fitted together; it was quite difficult to put them back. I also forgot the brewing head screws out and had to disassemble it again.
- It was not too difficult but it takes some time. The snap fits, if you open them too many times, they lose their shape and they don't feel like they fit anymore. The cable positioning, they seem to be too loose inside the structure. I had to put them back inside to be safe.
- The screw beneath the back part made sounds making me think i fitted it wrong.
- The reassembly of the brewing head and top lid, since it was difficult to understand how to correctly position back the BH. Maybe if I had more time, I could have understood the right positioning. It was difficult to position back the water tank base valve as well, since I had to flip the all machine upside down, holding it with one hand, and put the screw back in the bottom part with another hand. It was also difficult to put back the screws of the BH, since there is not much space to put them back manually.

What were the elements during reassembly process you found easy?

- Remembering the steps
- Knew what to do, what steps now. less chance to break when you assemble, so a bit easy, already through the process.
- Connecting other hoses was easy. Cable that goes in the plastic was hard to reassemble
- Main compartment is easy and just sliding in, if you figure it out.
- Putting back the tubes in the pumps. Putting back the main plastic casing was easy as well.
- The water tubes were easy to put back together. Most of the parts fit together just by shape. It makes it visible.
- I already knew how to disassemble it. I also found the way the clip worked with the clip of the heater.
- The connections of the wires back to the pump, the reconnections of all the water hoses.

What do you think this research is about?

- Regarding accessibility of a non-technical person for day to day problem. how normal problem would be able to solve such a problem.
- It has to do with how products are design to enhance repairability and prolong the life cycle of the product.
- Repairing products, disassembly procedures. Making products better to repair.
- The way assembly and disassembly can be designed to be easy.
- It is about making it easier for a person to understand how to fix products by yourself.

How often did you consider safety throughout the process?

- At the beginning I was scared about the heat & and liquid. After removing the plug, no concern about my safety as I thought I removed all the things that would danger me. More concern about breaking the device
- I didn't realize that was plugged it, considered too late during the process.
- I did not consider it
- No, not at all. I didn't think it could be dangerous at any point.
- Every time I have to work with cables. Not really with screws but with those the screwdriver can also snap off and hurt you. Sometimes I also think about that. The screws from the pump were too tight for example and seemed like it could happen.

- At times it was a question because of the clips because I could hurt my fingers and while removing the clip from the heater. the tools would hurt me while removing. Since i thought it was an experimental set up I assumed I was safe.
- I considered at the end when I had to unplug the electric connectors from the pump, since the machine was connected to electricity. Although, I don't think you can get electrified by them, but you never know. I don't think you can get an electroshock since the wires are surrounded by plastic and you cannot touch the copper inside.

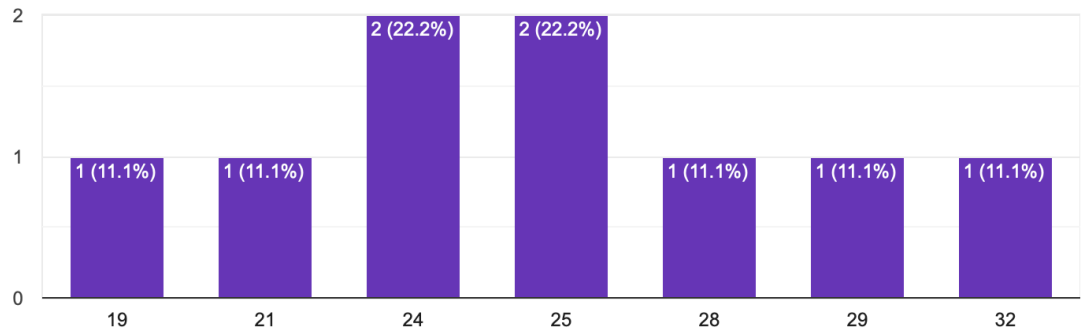
Please indicate what would make the procedure of disassembling and reassembling easier for you.

- Be more organized with the steps, put the screw in one place. Also noting down where to put screws. Product - If the screws more visible
- Just having the tools I need. having some guidelines e.g. written instructions, what steps I should remove - how hard you should apply force, or video. Indicator of what to remove, what not to remove, no space for top cover deathwatch from snap-fit.
- When reassembling, not working in confined space makes it difficult. Screws were more visible, arrows indicating what to put out.
- Manual - specifically for disassembly. Whole machine is black, indication of area to disassemble.
- The rubber holder of the pump was not optimal. It was difficult to put back the tubes in the pump because that part was in the middle. I would make screws more visible
- If the screws were more visible. First hunting is less time consuming. If all the cables were more secure and not dangling there in the middle. It would be easier to operate around them.
- Partition lines to indicate parts and screws. Easier to locate.
- It should be clearer where to apply the spudger and apply force to open the top lid. Make it clear that you should open the product from the bottom as well. Make the screws on the bottom more visible and accessible with fingers: they were too deep. I could not remove the external main body chasing; I don't know why. So, I had to access the pump using my fingers in a very limited space, trying to reach connectors and hoses with low visibility. I would position the screw of the bottom water tank valve plastic cover on the side and not bottom, since it was difficult to keep in place the plastic cover, flip the product, put the screw in at the same time. Moreover, if you could take out from the top the water tank, I would have more visibility of the components inside immediately after opening the top lid, without having to disassemble the bottom.

Round 2 Initial questionnaire results

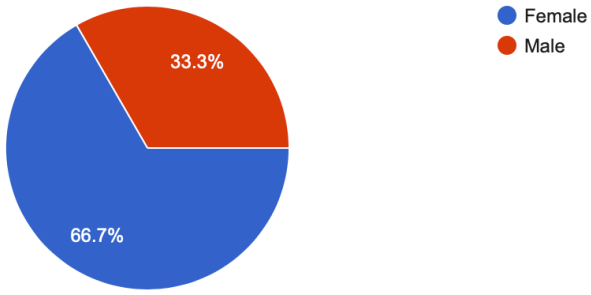
Please indicate your age

9 responses



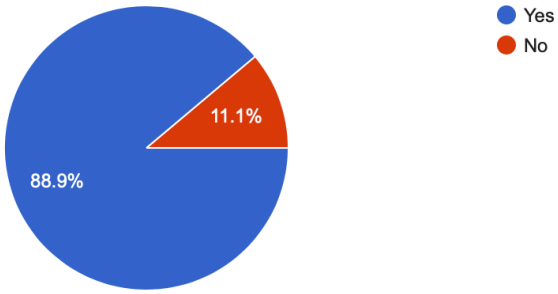
Please indicate your gender

9 responses



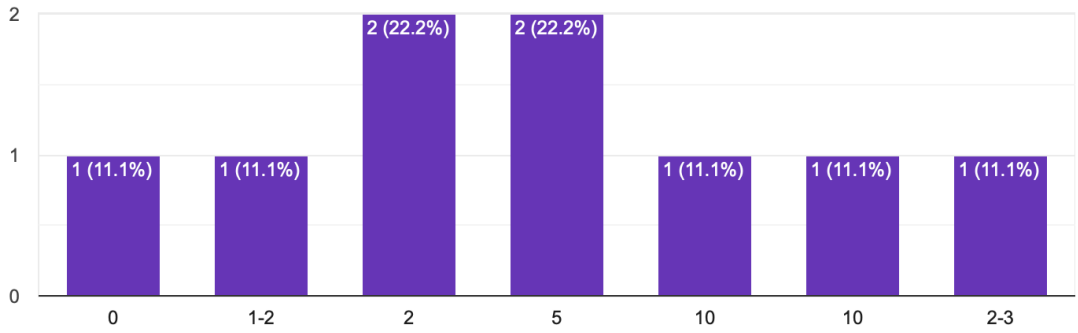
Have you ever tried to repair a product on your own?

9 responses



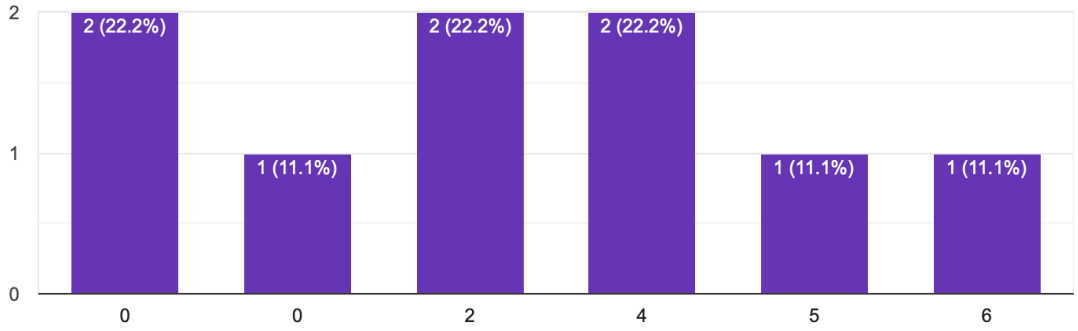
How many products have you tried to repair in the last 2 years? (doesn't matter if the repair was unsuccessful)

9 responses



How many products have you successfully repaired in the last 2 years ? (Indicate the number)

9 responses



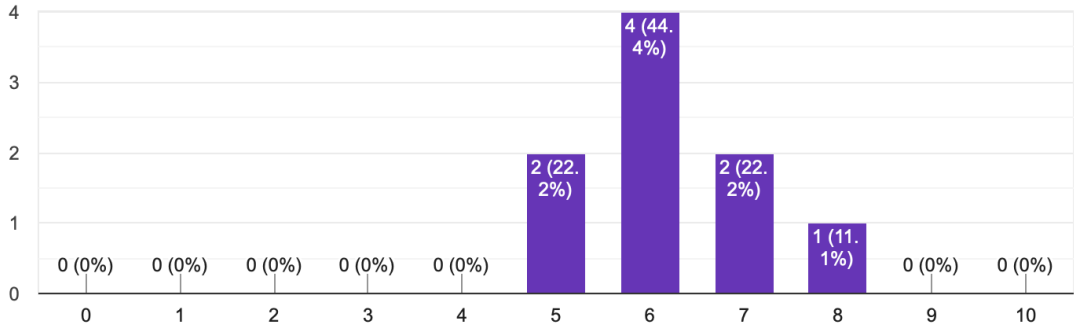
Mention the type(s) of products you have tried to repair. (Doesn't matter if it was an unsuccessful repair)

- Laptop mouse, Router
- An electric oven and a bike
- Bike, flower pot, my oven, my jacket (button), a light.
- wardrobe, fan, plug multiplier, probably some clothes
- -
- Bike, lamp, shelf (furniture), computer and didn't work, eye glasses, clothes…
- Bike, Laptop, Phone
- Induction stove, bike lights
- my car, skateboard, electric oven

Round 2 Post disassembly questionnaire results

How much impact did talk out loud did towards the disassembly process. (0 very negative impact -5- no impact 10 very positive impact)

9 responses

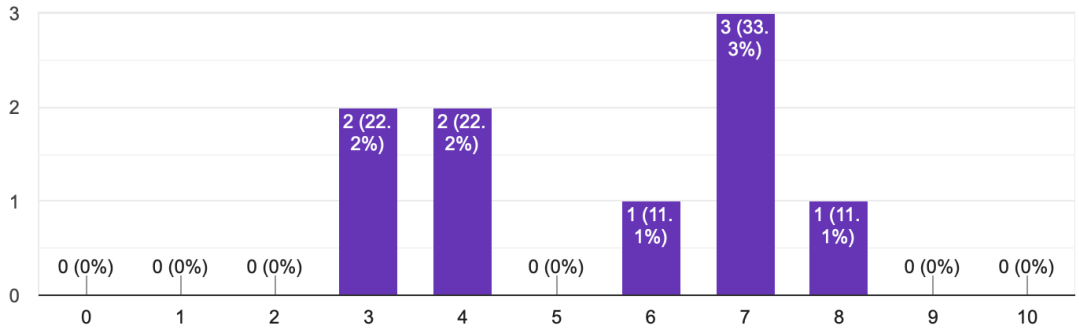


Please expand your answer

- Talking out loud it made me think more and reflect and to go through the process faster
- It helped me emotionally. I would course a lot if you were not there.
- It did help, it is not influencing in a negative way and it helps a little because you hear your own thoughts and it is like giving yourself feedback on what you are doing.
- It was pushing me to do better, also because you were there. however, I don't think it helped too much.
- You think what you are going to say so you think about what you are going to do
- I have a habit of talking to myself anyway
- no... it did not feel like it was doing anything…
- Because it is easy to get lost in your head and saying it out loud makes it clear or more obvious.

Please rate the difficulty in disassembly of the product from 0 – 10. 0 being very easy, 10 being very difficult

9 responses



What where the elements during disassembly process you found difficult?

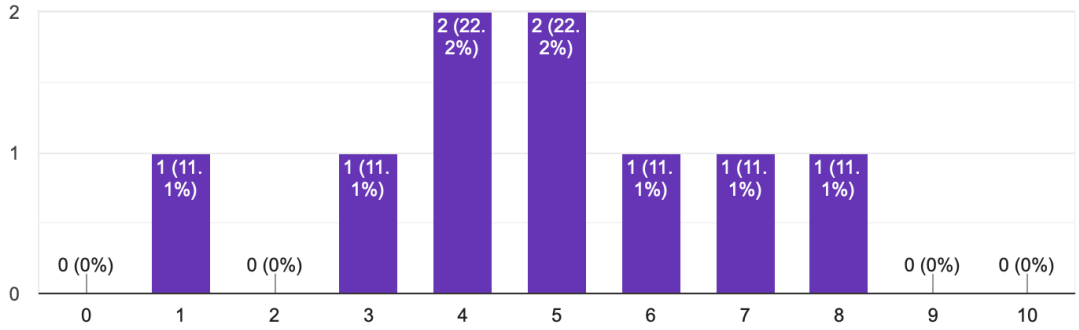
- Finding screws. I spent time to try to disassemble screws where there were not. Electronic parts were also difficult to disassemble. It was difficult to find the right position of the UI pcba.
- I was very worried not to be able to put it back. I was really afraid of breaking parts. Taking the pump out was quite difficult cause I was really scared to break the rubber holder, that is why I started to unscrew the body.
- Snap fits are always difficult, it is good to include them but it is really hard to know if you are pulling too hard or in the right direction. I was reassembly in the wrong order and in the reassembly you start getting impatient and I stop reading the manual. I hurry to the end. Numbering the components could help. She was not aware of the reassembly notes, this was an assumption because they never give you reassembly instructions usually that is the hardest part because you no longer have info.
- I was not sure about what to do, that was the most difficult part. I was not sure if I was ruining the machine or not. Taking away the target was also difficult, because you had a lot of things to remove, but it was not too difficult.
- It was difficult to find the screws on the bottom. It was difficult to remove the top lid snap fits.
- Cables.
- No.
- I think this product is built of really big components connected by snap fits making it complicated to know what to do and there are a lot of connections electrical, water etc.
- That you have to disassemble everything instead of just the top or bottom. The manual made it harder sometimes and easier some other times.

What where the elements during disassembly process you found easy?

- Finding the split lines was easy. It made me understand that the top panel had to be pulled out. the BH was easy as well to remove. Where the screws were visible it was easy.
- The upper part was very easy to remove. Also, the hoses where quite easy to disassemble.
- All the parts that are loose, the screws and also the very end was easy to get the target out.
- The first part, taking away the water tank, those that did not require any particular disassembly.
- The screws of the brewing head and the wires connected to the pump.
- Screws.
- The parts that were visible at the start.
- Removing the top part was really easy. The manual helped.
- Getting all the loose parts out.

Please rate the difficulty in reassembly of the product from 0 – 10. 0 being very easy, 10 being very difficult

9 responses



What were the elements during reassembly process you found difficult?

- The reassembly was easier. It was difficult to put back the pump in the right way. I forgot how it was placed at first. I did not understand where to put back the plastic cover of one of the boiler connectors.
- I found some annoying stuff but not difficult. It was annoying to place back the screws of the L shaped inner frame since the main casing was still connected on it and I did not have enough space. I also did not like to have a complete overview of the inner components.
- The order of the back plate reassembly was difficult.
- It was difficult to remember where things had to go back. I mixed the order of reassembly, placing back the back panel before them main plastic body.
- Assembling back the brewing head and the top lid, it would not fit back
- Making sure nothing was loose or any cable got trapped
- The few parts that I did not know where they were from which turned out to be easy
- The top part, also because I was not being super mindful. If I had been more mindful, I would have remembered.
- The wires the hoses were also a little bit harder

What were the elements during reassembly process you found easy?

- All the tube connections were easy, they were few and obvious. you. just had to push them back. Putting back the main housing was easy as well, it fit almost immediately.
- Putting back the bottom part was easy and the top lid.
- Snap Fitting the things back. In which direction? when you are putting them back you already know the direction.
- The last part, putting back the water tank and the coffee pot. The electrical connector of the UI pcba was also easy.
- Aside for the top part all the rest was easy cause I already know how to do it from the disassembly.
- The things that are like pieces that go together. matching puzzle pieces.
- the tubes, the parts that click
- The bottom part, even if I made an error. I think I knew what goes where.
- Removing the screws and snap fits back on

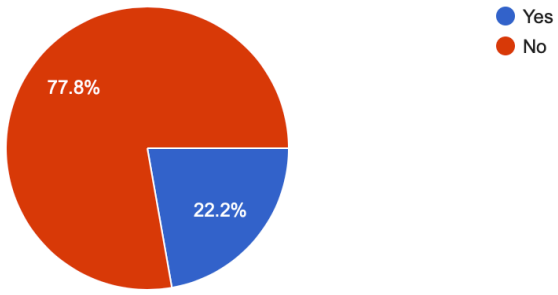
What do you think this research is about?

- Making it easier for people to disassemble and reassemble the machine.
- It is about identify barriers to disassembly of products, enhancing their repairability.

- To make clear what steps to follow or how to disassemble or reassemble the product.
- Enhancing product repairability to be more user friendly.
- I read this but I forgot. I would say it is about to make people more able to fix their own product.
- How to make things easier to repair by common people.
- How people at TU Delft that do technical studies can't really actually do something practical. Also maybe assembling and disassembling stuff.
- Product longevity how can you repair by yourself instead of discarding.
- At first, I thought it was about improving the product reassembly and disassembly.

Did you use the repair and safety manual at first?

9 responses

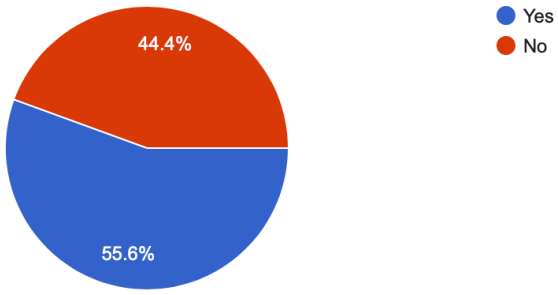


If not why?

- I want to start trying by myself, and when I get stuck, I read the manual
- I forgot about it even if it was next to me. But it was very useful to disassemble some parts that I could not understand how to disassembly
- If I knew the product or first steps I would not use it. I was using it to get me started to not start on the wrong way
- I just started to read it when I did not know what to do
- I like discovering myself how to do things
- I like doing it on my own
- I will only look at it when it gets complicated.
- I always try myself first but if it is more complex then I check the manual

Did you keep using the manual during all the steps?

9 responses



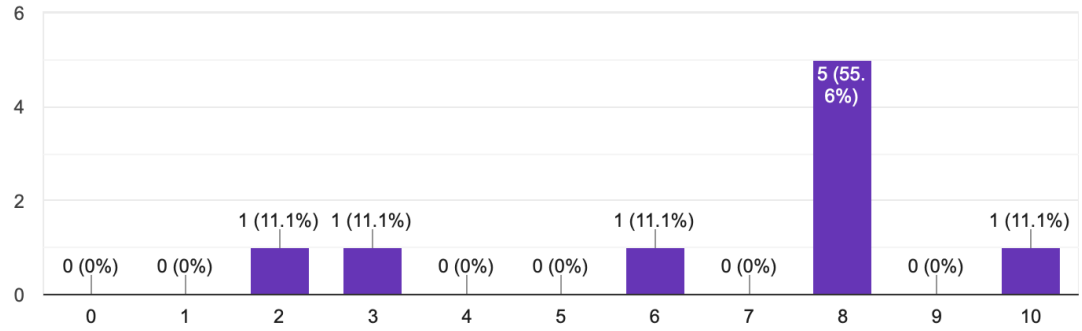
If not why?

- I used it when I was getting stuck

- Some steps were a bit obvious so I did not use it. But the manual had a lot of pictures so when I needed, I just looked at pictures.
- Because at the end I was seeing the target and I saw what I needed to disconnect to get to the target
- Once you pointed it out, I continued expect for reassembly
- Sometimes, mostly to see what went where and in the disassembly maybe the order.
- Mostly, I used during disassembly but did not look at it that much for reassembly because I assumed "I should know this by now"
- Not during reassembly, because I already knew how to do it. Except for some pictures.

How useful was the repair and safety manual during the disassembly procedure? 0 being not useful and 10 being very useful

9 responses

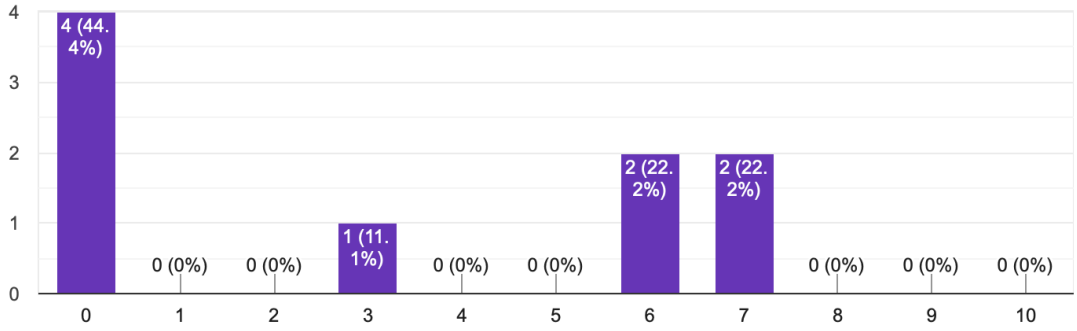


Why?

- Most of the pictures were not very visible. I could see exactly where to place the screw driver since they are small and dark. Some pictures were very dark
- I liked it because there were a lot of pictures and I did not have to read any text. If you have to read through everything it becomes too long and you want to make it done very fast. Compared to other manuals this had a lot of pictures and I liked it a lot, because instead of using technical drawings you also had real colors.
- Because if I had a question about a step it was there. I did not read it all but if I had a question it was there.
- It gave me directions.
- It was easy to see what you needed to do from the pictures and the arrows.
- Because I kept reading things that were not important at the moment and it took time and focus
- Because I didn't really use it as much but because I did not want to use it. I was looking mostly at pictures.
- It was clear for a large part but it was unclear in some cases "the one-way valve" I don't know what is the "one-way valve".
- Because some parts were unclear.

How useful was the repair and safety manual during the reassembly procedure? 0 being not useful and 10 very useful.

9 responses

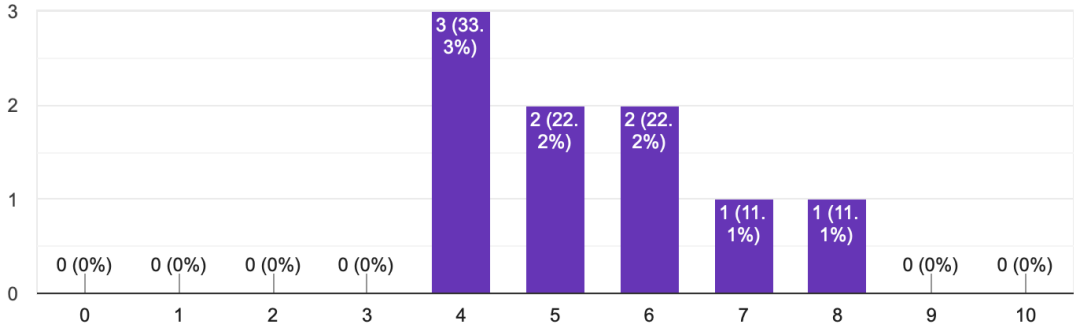


Why?

- I didn't use it; I just followed the same steps of the disassembly. The manual is about disassembly not reassembly. It would have been useful if I read it.
- I did not use it a lot in reassembly, but it was very useful when I had to check in which right position to connect the wires on the pump.
- I did not look at it. If I had I would not do wrong steps. It would be useful if you have the patience to look at it.
- It was still useful (e.g. I forgot where two screw had to go and I found it out in the pictures). It was a bit confusing to have different disassembly parts in the middle.
- I did not use it. for the reassembly.
- Color coding. It was important to make sure there was no leakage. But that was an easy thing to do anyway. Because it was not like a complicated connection.
- reassembly is harder and you need to put things on the right place. It is easier to look at pictures of what it is supposed to look like.
- Because I did tame at it a bit of time for the top part, where I struggled.
- Because the cables part was wrong.

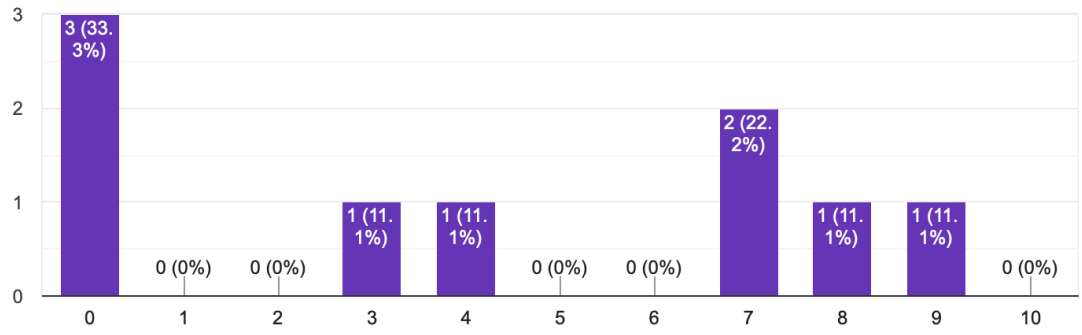
Please rate the quantity of information provided. 0 being too little, 10 being too much

9 responses



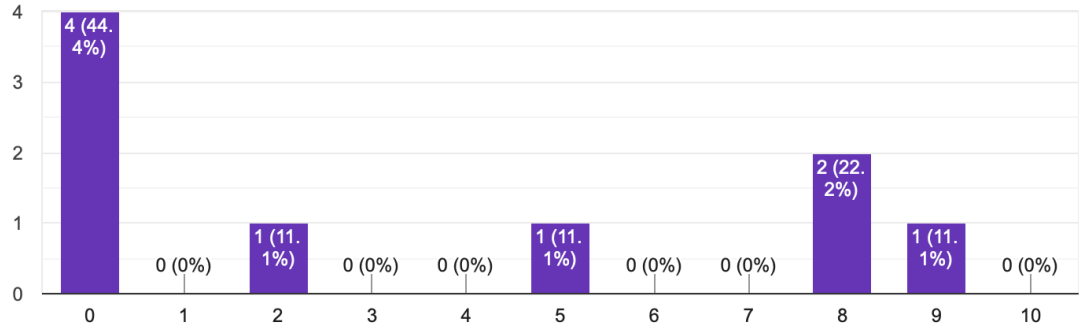
Please rate the clearness of having to skip certain disassembly steps in order to get to the target component.

9 responses



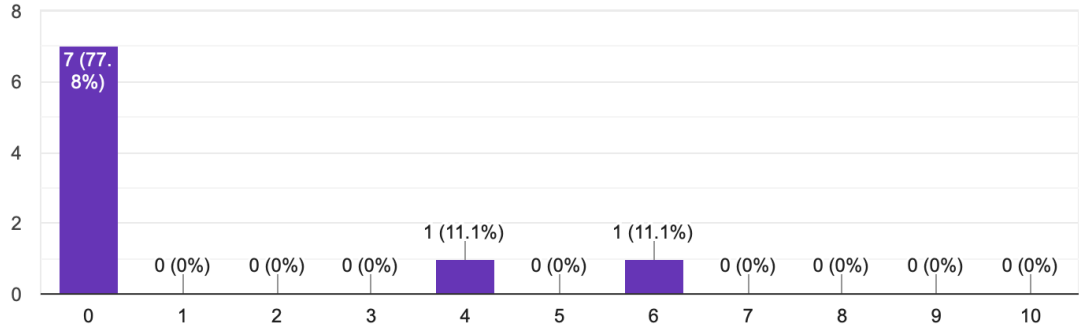
Please rate how useful were the safety information provided in red

9 responses



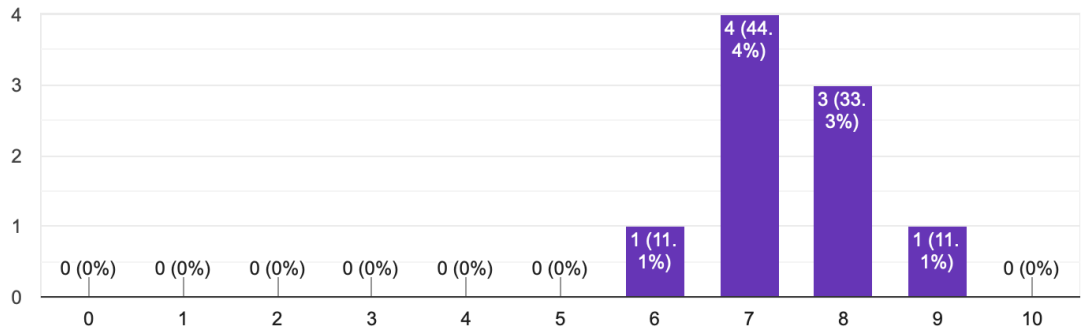
Please rate how useful were the reassembly suggestions provided in blue

9 responses



Please rate the overall clearness of the Repair&Safety document

9 responses



How would you improve this guide? what to include what to leave out?

- I don't like to read the manual; it was full of text. An exploded would be very helpful. Sometimes I would disassemble parts that were not necessary for the target. I did not see the reassembly guidelines. for the safety I noticed the electricity icon. Now that I see that there was all this info, I think it would have been very useful to read. The pictures should be clearer, perhaps you could use drawing pictures. Using different colors, I skipped some steps in between different disassembly operations. I did not notice the text telling me to skip some steps if not interested in that specific component. I was confused about the disassembly order. A part list listed according to the disassembly order at the beginning of the manual would be helpful.
- I could not find an info about how to disassemble correctly the pump, that is missing. There is just information for one side, not for the other. I liked the use of pictures. I would add a video as a very useful source that could help people to repair the product.
- You are always working towards your goal sometimes you stop reading things. It is not really a repair manual. Missing information for diagnosis.
- The numbering, the order is not very clear I don't understand I am disassembling a different part of the product. Put reassembling steps at the end.
- The instructions were a bit confusing because they had parts mixing together. You should put in bold the most important parts of the text, keywords (e.g. two bolds). The pictures were not always super clear. I was not understanding what was top and bottom of components. Pictures should be easier to understand where parts are located in the overall product. Where is a specific connector located? Bottom part or top part? It was not clear to have to skip the big cluster of information; I would leave the specific disassembly info at the end. I would also use shorter text, mainly in the reassembly and safety instructions. I would leave out all the "please" and get to the point.
- Maybe it would be good to have separate parts for disassembly and reassembly, but it was very clear. Maybe you could make a safety icon that indicates Cleary a plug.
- some of the arrows show movement and some point to things... so I was confused when to do something and when it was only indicating... Some instructions were lacking an action element
- -
- I ignored the red and blue. There are a lot of codes that are not clear at all. It does not make me follow.
- Some more details, like the wires, the motion of the housing, the hose of the back of the pump, there are many ways to do it so more details could be provided. Make clear in the start of the guidelines.

How often did you consider about safety throughout the process?

- Initially I just thought about not spilling water around. The voltage symbol in red made me think about the plug.
- Not really. I thought it was unplugged. I could not see anything that was sharp or something like that. It was not a product with batteries, if it was, I would have been more careful. I just removed the water and cattle immediate; I was worried about it.
- In the beginning and at the moment I plugged in the wires. Also, when i smelled the electronics.
- At the beginning I thought about it because I read the safety in the manual. After that I did not consider it anymore. I also payed attention to water leakage since there was written in the manual.
- I did not consider it. I thought about that just when I had to cut the tighteners, I was afraid of cutting the tubes.
- I did not consider it. I did not read it. I don't remember anything of the info in red. I would unplug it at home because I would work on it in a different place than the kitchen. I was only interested on moving forward.
- Only once, when I saw it was till plugged in.
- Not at all, except for the plug. Own decision no manual.
- Several times.

Please indicate what would make the procedure of disassembling and reassembling easier for you.

- None
- It would be nice if you could identify inner parts per color. When it's a very complex product you could write names or numbers on it. For instance, it was very easy to identify the pump because it was red as the picture on the manual. You should think about people with a not good vision and coordination. If it is someone with bigger hands or someone with less motor skills it would be very hard to remove those small things (e.g. the electric wires of the pump). It would be nice if as soon as you remove the external case of the product you can have a complete and clear overview of all the components. It was very difficult to disassemble the snap fits of the top lid without ruining the aesthetics, you could just have a rough texture around the spot where you have to use the spudger so that it gets more difficult to ruin the aesthetics. Sometimes you want to buy spare parts but you don't know the specific name; it would be nice to have a clear and trackable reference, a name that you can look for on the internet in order to find the spare part. Or on the machine itself placing a tag that can provide you info.
- Using arrows to indicate the pull directions, for instance with the grey cable. It looks like an internet cable but is it not , it was just about pulling out harder.
- The top lead gets very ruined when you have to disassemble the top lid with a spudger. I don't want to ruin my coffee maker. I would replace them with something you could do with your hands. It was not so difficult overall. It cannot be too easy otherwise is not a coffee maker.
- The snap part on the top is not good, since you risk to damage the casing when you have to open It with the screw driver. Apart from that it was quite easy to disassemble.
- Clearer cues of where am I supposed to put a screwdriver. On the product. And maybe less cables.
- Maybe if the parts that click were more visible. It would be much easier to have visible parts (referring to the plastic part assembly not clear they can be disassembled).
- Having clearer instructions. I am not sure, a video? If it is slow passed and I can do it along with the video.
- The screw here is really hard for example, but definitely the main part is improving the design. Improving the overall order of assembly.

Any additional remarks.

- I did not ready anything of the text, I just looked the pictures and that I liked. I could find clusters of information for different part and I liked it. I did not notice that there was written that you could skip clusters if you were not interested in that specific part but I understood from the colors and I liked it. I wasn't worried about getting a shock because I was not really going into the wires. I assumed that the plug was disconnected. I think I assumed it because it was a test, but I am not sure. The first thing I do usually is to disconnect the plug. I did not read anything, so safety and blue info were not useful, but it is good that they are there; better more than less. I really liked the pictures and the cluster of information. What I usually do home is to look at the manual first. I did not do it today because it was a test so I started immediately. I would take more time home. I usually check videos as well
- I don't like to read, I just looked at the pictures.
- It was not clear to me I had to skip certain parts, but I just did it by myself looking for what I needed. I did not ready any of the safety and reassembly comments in blue and red.
- I am very surprised That I prayed absolutely no attention to the things in red.
- Using the manual is not something that people do naturally. They want to do it by themselves. A possible more effective solution is YouTube videos.