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Do consumers mind contamination by previous users? A choice-based conjoint analysis to explore strategies that improve consumers' choice for refurbished products

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ABSTRACT

Refurbishment is an effective strategy to extend product lifetimes in a circular economy. However, consumers believe that refurbished products are contaminated with traces of prior use, which can be indicated by the appearance (e.g., scratches) or functionality (e.g., lower battery capacity) of refurbished products. This research explores strategies to improve consumer adoption of refurbished products by reducing contamination. In a choice-based conjoint analysis, 785 participants were exposed to refurbished headphones varying in features related to contamination, warranty, and price. We tested three contamination-reducing strategies, including (1). Communication about the clean object state, (2). Eliminating signs of use (aesthetic and functional wear-and-tear) and (3). Renewing parts that touch the skin (e.g., ear-cushions). Additionally, we analysed whether different consumer groups are driven by different attributes of refurbished products. Results showed that most consumers value refurbished products that show no signs of wear-and-tear and that have parts touching the skin renewed during the refurbishment process. These attributes are even more important than the reduced price or warranty, even though these are frequently used to market refurbished products. Depending on the consumer group, other contamination-reducing strategies were of great influence. While some consumer groups highly valued that signs of prior use are eliminated through an as-new appearance, others preferred refurbished products without functional wear-and-tear. In conclusion, four design strategies to deal with contamination during multiple life cycles of refurbished products are discussed.

1. Introduction

In the European Union, almost 8.5 million tonnes of electronic waste are produced annually, while at the same time, valuable resources needed to produce consumer electronics become increasingly scarce (European Union, 2019). A solution to this issue is to design products with a longer lifetime. Then, fewer products are produced and discarded, resulting in less waste and the use of fewer virgin resources. The longer a product is kept in a loop by increasing its lifetime, the lower the negative environmental impact (Ellen MacArthur Foundation, 2016) compared to manufacturing a new product. This, however, requires a shift from our current take, make, waste model of consumption to a circular economy.

The circular economy is described as a "regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al., 2017, p. 766). Evidence suggests that to support a transition to the circular economy, manufacturers, waste managers, and policymakers should shift their focus from recycling to reuse strategies to retain the value of products for as long as possible (Zacho et al., 2018). Refurbishment is a powerful reuse strategy to slow or close loops, keep products at a high value, and should therefore be a priority to policymakers and

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manufacturers (Reike et al., 2018).

Refurbished products are second-hand products that were recollected after their first use and then brought into an acceptable state. This entails that the products or components are cleaned, tested, and repaired before being resold to consumers (Pigosso et al., 2010; Reike et al., 2018; Ellen MacArthur Foundation, 2020). Refurbishment has the potential to lower the environmental impact of many electronic products. For example, refurbishment can reduce a smartphone's carbon footprint by 87% and its water footprint by 76% (Zumegen, 2020) compared to manufacturing a new product. To ensure that refurbished products retain their value, it is necessary that refurbished products are technically durable so that they can last multiple life cycles and remain attractive to large groups of consumers (Blomsma and Tennant, 2020).

While there is an established market for refurbished cars, bicycles, or smartphones, other refurbished electronic products, such as headphones, are often seen as less desirable compared to new products (Mugge et al., 2017b). Previous research has shown that consumers often have lower purchase intentions for refurbished products because they associate them with a higher financial risk, lower performance and lower durability (van Weelden et al., 2016; Baxter et al., 2017). Consumers additionally fear that refurbished products are contaminated with traces of a former user and miss a thrill of newness when purchasing them. Strategies aiming to improve the consumer adoption of refurbished products have focused on minimising the risks associated with refurbished products by offering them with extended warranties, providing a money-back guarantee and by offering them at lower prices (Mahmoodi and Heydari, 2021). However, these marketing strategies are peripheral to the product, they improve the trade-off for the refurbished products but do not make the product itself more desirable.

With this research, we contribute by extending the consumer-centric perspective on refurbishment and inform manufacturers and designers about potential strategies related to (perceived) contamination that may help to retain the value of refurbished products over multiple life cycles.

1.1. Consumer perceptions of refurbished products – a literature review

Currently, consumers are willing to pay less for refurbished products compared to new products (Esmaeilian et al., 2021; Harms and Linton, 2016; Michaud and Llerena, 2010). Correspondingly, literature has focussed on the marketing of refurbished products to increase the willingness to pay and therefore make refurbishment an economically viable option for manufacturers. Refurbished products are differentiated from new products by the fact that they are sold at a lower price and from second-hand products by the fact that warranties and money-back guarantees are provided (Mahmoodi and Heydari, 2021; Mugge et al., 2017a). Esmaeilian et al. (2021), for example, explored the positive effect of probabilistic selling on the willingness to pay for refurbished products. Other studies have focused on more intrinsic motivators and shown that eco-labels can increase consumers' willingness to pay for refurbished products; however, this strategy only has an effect on consumers who are motivated to decrease their environmental impact (Harms and Linton, 2016; Sharifi and Shokouhyar, 2021).

Secondary factors that are critical for consumers when buying refurbished products are the seller's reputation, the distribution of refurbished products on the market (Agostini et al., 2021; Sharifi and Shokouhyar, 2021), and the products' characteristics (Mugge et al., 2017a; Nasiri and Shokouhyar, 2021; Wallner et al., 2021). A good reputation of the seller and a widely present distribution of the refurbished product on the market has shown to decrease the perceived risks associated with refurbished smartphones and lead to a higher valuation of the product. The higher perceived value and the decreased risk subsequently lead to higher purchase intentions (Agostini et al., 2021). While the sellers' reputation and product distribution focus on the marketing of the product, other research indicates that product characteristics influence the risks associated with refurbished products and hence consumers' purchase intentions. The products' perceived quality, attractiveness, and durability (Wallner et al., 2021), as well as a good appearance and functional state, have been shown to decrease the perceived risks of refurbished products (Mugge et al., 2017a; Nasiri and Shokouhyar, 2021; Wallner et al., 2021), which in turn, increases their purchase intentions. Additionally, Wallner et al. (2021) zoomed in on the value of a timeless product appearance of refurbished products as a way to evoke quality and durability.

However, it is questionable whether these factors are sufficient to widely increase the adoption of refurbished products and to make refurbishment an attractive option for all consumers. In fact, there are other concerns consumers have regarding refurbishment that have not yet received much research attention. Consumers may have lower purchase intentions for refurbished products because they were used by others, and therefore, deemed to have lower durability, quality performance and to be contaminated with traces of prior use (van Weelden et al., 2016; Baxter et al., 2017; Nasiri and Shokouhyar, 2021). Even though refurbished products are thoroughly cleaned, and some parts are even changed during the refurbishment process, this is often not clearly communicated, thereby resulting in contamination concerns amongst potential consumers. Actually, contamination with traces of prior use has been shown to negatively predict the purchase intentions of refurbished products more strongly than other factors, such as the positive influence of the consumer's environmental concern (Wallner et al., 2021).

Despite the important role that contamination plays for refurbished products, research on the effects of possible strategies to counter such contamination is lacking. This research contributes to the literature on refurbishment by investigating the effects of several contamination-reducing strategies on consumers' choice for refurbished products. Specifically, we propose that contamination concerns can be alleviated by changes in the product design, the refurbishment process and the communication strategy when marketing them.

1.2. Contamination

Perceived contamination of refurbished products describes feelings of unease or even disgust consumers experience because of the prior use of a product. Contamination operates according to the law of contagiousness (see Fig. 1), which describes that a source (e.g., the first user) transfers its essence (e.g., skin particles) to a recipient (e.g., headphones). These traces of contamination remain on the recipient even after the contact with the source is broken (Mauss, 1972; Rozin et al., 1986).

According to Baxter et al. (2017), there are different types of contamination; which can be hygienic, utilitarian or of territorial nature (HUT model). Hygienic contamination is characterised as the negative associations that consumers have when they think that an object may be contaminated with pathogens or dirt, and therefore, may pose a threat to one's health. Utilitarian contamination describes the feeling of contamination that occurs when consumers believe that the functionality of an object is decreased. This functionality can be of technical, but also of social or economic nature (Aurisicchio et al., 2011). One example would be a product that is heavily scratched. As a result of these scratches, consumers may believe it has a decreased functional value because it is not water-resistant anymore. Furthermore, these scratches may lower the social value if one is embarrassed to be seen with a worn-off artefact. Finally, scratches may reduce the economic value because the product cannot be easily resold. Territorial contamination entails that an object has belonged to someone else, which interferes with one's personal space because of the previous user's signs of use. One example would be an object that smells like a previous user's perfume or is marked with the previous user's name.

Furthermore, Baxter et al. (2016) described that the contamination of a (circular) product depends on multiple factors and is indicated by the product state (e.g., how clean the product appears), the product characteristics (e.g., signs of wear-and-tear), the object setting (is a

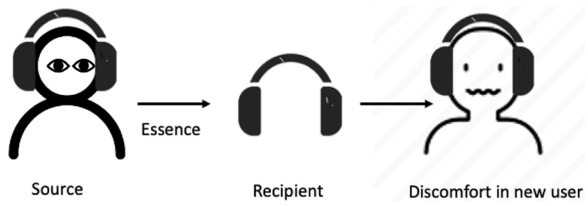

Fig. 1. The contamination of an object (recipient) by a source can lead to discomfort in a new user.

product turned on or off) and the context (e.g., in which store the product is sold; which objects accompany the refurbished product) and the knowledge of previous use (e.g. who and how many people used the object before you). While the object settings are less likely to be relevant for refurbished products as these are often returned to factory settings, the importance of the context and the knowledge of previous use for triggering feelings of contamination should not be underestimated. For example, most consumers would feel uncomfortable to buy a second-hand or refurbished shaver because it is believed to be dirty as a result of the first owner's usage. However, this contamination problem, does not occur at a hairdressers', when a shaver is used that has also been extensively used on multiple others. This example also illustrates that contamination is not always purely rational.

1.3. Improving consumer choice for refurbished products by reducing contamination

The three types of contamination described in the previous section can be present in refurbished products. Despite the cleaning procedure during the refurbishment process, consumers may fear hygienic traces, such as pathogens or oil-residues on the refurbished products. Utilitarian contamination can be present as a result of a lower functionality in refurbished products. This type of contamination commonly occurs because refurbished products are by definition brought into "an acceptable state", which often comes with a lower functionality, such as the presence of scratches and/or a lower battery capacity in electronic products. Territorial contamination is less common, but consumers may nevertheless fear that the refurbished product could be contaminated with smells or data traces indicating a former user's territory. While utilitarian contamination can have a physical manifestation, territorial contamination is a good example of mostly perceived contamination and hence is harder to reduce.

It is unclear which types of contamination are most relevant to consumers when they encounter refurbished products and with which contamination-reducing strategy they can be alleviated. In this research, we examine the influence of three strategies that are likely to reduce contamination, and that may therefore increase the adoption of refurbished products: (1) Communication about clean object state, (2) Eliminating signs of use, and (3) Renewing parts that touch the skin.

1.3.1. Communication about clean object state

Consumers may not be aware that refurbishment includes a thorough cleaning procedure. A possible strategy to reduce the perceived contamination is to provide more information about the cleaning procedure during the refurbishment process via a 'clean' label. Labels have shown to be effective in different contexts. For example, eco-labels have been shown to increase consumers' purchase intentions of circular products (Boyer et al., 2021; Harms and Linton, 2016). Furthermore, reviews containing words such as cleanliness or clean have been shown to enhance the favourability for short-term rentals in times of the COVID-19 pandemic (Shen and Wilkoff, 2020). Hence, we expect that communicating clearly that the product was cleaned can decrease contamination concerns for refurbished products. However, there could be reasons why this strategy may not have the desired contamination-reducing effect. First, it tries to counteract a perhaps irrational feeling of contamination with a rational approach. Second, to trust that the product is clean, the consumers' needs to trust that the (re-)manufacturer cleaned the product well, and this is likely dependant on the manufacturer's reputation (Sharifi and Shokouhyar, 2021). Finally, for second-hand clothing items, it was found that highlighting the fact that the product was cleaned and sterilised may also trigger undesired feelings that the clothing was previously used and is contaminated (Ackerman and Hu, 2017).

1.3.2. Eliminating signs of use

Signs of wear-and-tear on a product indicate that it has been used. If a product is received second-hand or refurbished, this means that it could be contaminated with traces of the previous user. Indicators of use include visual signs of use or a decreased functionality (Baxter et al., 2017). Appearance-related wear-and-tear has shown to have a negative effect on consumers' evaluation of refurbished products (Mugge et al., 2018). Furthermore, the lower functionality that many refurbished products have, as a result of their prior usage, could trigger a utilitarian contamination concern. Similarly, Nasiri and Shokouhyar (2021) found in an analysis of post-purchase online reviews that signs of use related to the function (battery health) and appearance (scratches on the surface) of refurbished smartphones are the most worrying to consumers.

We believe that offering refurbished products without signs of use will decrease contamination concerns because of the 'out of sight is out of mind' principle. By eliminating signs of use through giving a product an as-new functionality or an as-new appearance, one could reduce contamination concerns.

1.3.3. Replacing parts that touch the skin

Products that touch the skin are especially prone to hygienic contamination because the object is more intimately used and therefore has a higher chance of carrying and transferring harmful substances (Abbey et al., 2015; O'Reilly et al., 1984). While rationally, problems with hygienic contamination should be solved, the irrational feeling that the product is contaminated may still persist due to the knowledge that somebody else owned the product before. Indeed, several studies indicate that an object can still feel contaminated, even after it has gone through a purification procedure (Hejmadi et al., 2004; Rozin et al., 2015). The last strategy to reduce contamination is therefore to replace parts that are in contact with the skin, such as the ear-cushions on headphones. This strategy aims to decrease hygienic contamination. Specifically, the overall feeling of contamination could be decreased by renewing the most contamination-sensitive part (Hazée et al., 2019).

1.4. Consumer groups

The importance of attributes of refurbished products may differ between consumers because consumers are not a homogenous bloc" (Hunka et al., 2021, p. 548); they have different needs and desires, which drive their consumption decisions. For example, some consumers may be more easily disgusted, which could make them more sensitive to hygienic contamination of refurbished products (disgust sensitivity; Olatunji et al., 2012; Wallner et al., 2021). These consumers may be incentivised more by information about the cleaning process of the product or the replacement of parts that touch the skin.

Furthermore, prior research has shown that consumers who are less tolerant to ambiguous situations (ambiguity intolerance; Hazen et al., 2012) are willing to pay less for refurbished smartphones. These consumers might hence value warranties of refurbished products. Additionally, we could expect that consumers who are not tolerant of ambiguous situations would prefer a product with little functional and aesthetic wear-and-tear and would value the replacement of parts that touch the skin because they dislike the uncertainty that comes with the prior use of a refurbished product. Furthermore, if consumers are keen on good deals and receive good value for money, they may be more incentivised by the lower price of refurbished products (value

consciousness; Lichtenstein et al., 1990). Some consumers may be driven by the environmental benefits of refurbished products because this fits well with their identity as environmentally concerned people and would, therefore, be willing to compromise on many aspects to avoid buying a new product (Mugge et al., 2017a). For consumers who value money or are very conscious of the environment, we would expect that contamination- related attributes are less important as long as the financial or environmental costs are attractive. Hence, we will explore whether attributes of refurbished products incentivise different consumer groups and how these consumer groups can be portrayed with the aforementioned consumer characteristics.

To summarise, this research contributes to the literature on the consumer acceptance of refurbished products by investigating how refurbished consumer electronics can be optimised by implementing three contamination-reducing strategies. We aim to test their effects on consumer choices for refurbished products and examine how important these strategies are compared to other more commonly applied strategies, such as years of warranty and different price reductions. Furthermore, we will explore whether there are differences between consumer groups, how these consumer groups can be characterised and which attributes of refurbished products incentivise them most.

2. Method

To operationalise strategies reducing contamination, we focused on wireless headphones because, similar to clothing (Meng, and Leary, 2021; Tunn et al., 2021), headphones are likely to trigger contamination concerns due to their direct contact with the skin (Abbey et al., 2015; Mugge et al., 2017; Hazée et al., 2019). Furthermore, wireless headphones have a battery and other electronic components, for which an extension of the product lifetime (through refurbishment) may lower its environmental impact. Wireless headphones are also interesting for studying refurbishment because they can be leased (e.g., Gerrard Street). As such, contamination concerns can arise because products circulate between different users, however leasing offers an opportunity for companies to recollect and refurbish their products, providing them with opportunities to tackle possible contamination issues in the refurbishment process.

We conducted an online choice-based conjoint analysis with the Qualtrics conjoint software to closely model consumer choices and investigated the importance of the contamination-reducing strategies for consumer choice in comparison to other marketing strategies for refurbished products, such as price reduction and years of warranty (Mugge et al., 2017a; van Weelden et al., 2017). A choice-based conjoint analysis is a method in which consumers' decisions are realistically portrayed as a choice between trade-offs amongst multi-attribute products (Huber, 1987) and has been used in the past to explore consumer choices for sustainable products (Esmaeilian et al., 2021; Hao et al., 2019; Rokka and Uusitalo, 2008). We chose to conduct a choice based-conjoint analysis over other forms of conjoint analysis for three reasons. First, a choice-based conjoint is suggested to best model actual shopping behaviour because it mimics an actual buying situation by giving participants two products with fixed choice-sets (Hair et al., 2006). Second, compared to other conjoint approaches, choice-based conjoint works best for six or fewer attributes. In addition, choice-based tasks are easy to understand for participants and less time consuming than more traditional forms of conjoint analysis such as ranking profiles (Hair et al., 2006). The study was approved by the Human Research Ethics Committee of Delft University of Technology.

2.1. Design of the choice task and pre-test

The design of our choice task was based on six design strategies: four (design) strategies to reduce contamination and two strategies (extended warranties and lower price) commonly applied to enhance the consumer choice for refurbished products, which were included in the choice task as attributes.

To select these attributes, we first pre-tested the following characteristics of refurbished headphones: information about the cleaning procedure during the refurbishment process, aesthetic state (aesthetic wear-and-tear), functional state (battery capacity), renewal of a contamination-sensitive part, year of production, warranty and price.

By providing a certificate that the refurbished product is clean during the refurbishment process, we expected that hygienic contamination and territorial contamination (no smell of a prior user) could be decreased. This decrease in contamination could in turn positively influence participants' choice for the product. The aesthetic appearance and performance of the headphones inform the consumer about their previous use. For wireless headphones, battery capacity is an important functional attribute that may wear out during usage. Similarly, the aesthetic appearance can decrease by showing scratches and discolouring of the material. We, therefore, included attributes in which the functional and aesthetic state of the headphones varied from used to as-new. By replacing components that are sensitive to hygienic contamination with new components during the refurbishment process may reduce contamination. For headphones, the ear-cushions may provide an important contamination risk. Therefore, the ear-cushions were either preserved or changed during the refurbishment process. By providing users with information about the year of production, they can make inferences about the length of the previous life of the product, which may also influence participants choice. Additionally, we included price reduction and years of warranty to analyse how important critical contamination-related attributes are compared to other attributes that usually incentivise consumers to purchase refurbished products.

In order to select realistic levels for these attributes, we looked at different websites selling refurbished headphones and chose either two or three attribute levels accordingly. We used attribute levels that were on the lower end of the available spectrum of options, one that was average and one that was in the higher end (e.g., price differences between refurbished and new headphones of 20%, 30% and 40%, respectively).

In the pre-test, to narrow down the number of attributes we measured the importance of all attributes and subsequently assessed the desirability of the attribute levels. For the choice-based conjoint analysis to yield valid results, the attribute levels across all attributes need to be comparable (Orme, 2010). The selection of an extreme value for one level of a variable could wrongly increase its utility levels. Therefore, to select the final list of attributes and attribute levels for our conjoint analysis, we conducted a pre-test. We exposed 51 participants (32 males; Age: 18–71 years; $M = 30.6$) to different attributes of refurbished headphones. Participants first assessed the importance of the attributes on a 7-point scale (1 = not important at all; 7 = very important). Subsequently, participants were asked to assess the acceptability of attribute levels.

To choose attributes with a sufficient level of importance, we conducted pairwise comparisons, which showed that production year was significantly less important than all other attributes (p's < 0.05, see appendix A for pairwise comparisons). We, therefore, included six attributes in the conjoint analysis, excluding the year of production of the headphones (see Fig. 2).

Finally, we assessed the acceptability of each attribute level with a 4-

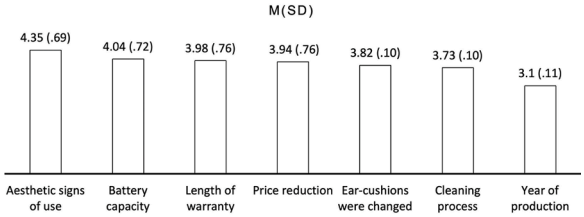

Fig. 2. Average importance of attributes.

Table 1
The final list of attribute levels and acceptability ratings.

Attribute	Attribute level	Acceptability M (SD)
State of the product (aesthetic wear-and-tear)	The appearance is in an as-new state (product does not show any signs of use and looks new).	1.08 (0.27)
	The appearance shows light wear-and-tear (scratches on the surface that are only visible from close proximity).	2.08 (0.39)
	The appearance shows visible wear-and-tear (larger scratches on the plastic surfaces).	2.92 (0.59)
Battery capacity (functional wear-and-tear)	The battery has 100% battery capacity (~25 h playtime).	1.02 (0.14)
	The battery has at least 80% battery capacity (~ 20 h playtime).	1.80 (0.49)
Length of warranty	One year	2.12 (0.59)
	Two years	1.39 (0.49)
Price reduction	The refurbished headphones have a 40% price reduction compared to new headphones.	1.59 (0.50)
	The refurbished headphones have a 30% price reduction compared to new headphones.	2.12 (0.71)
	The refurbished headphones have a 20% price reduction compared to new headphones.	2.84 (0.86)
Ear-cushions	The ear-cushions were cleaned during the refurbishment process.	2.33 (0.82)
	The ear-cushions were changed during the refurbishment process and are new.	1.06 (0.24)
Cleaning process	There is extensive information on how the cleaning process was executed on the company website of the refurbished headphones.	1.29 (0.50)
	There is extensive information on how the cleaning process was executed on the company website of the refurbished headphones, and the specific headphones are certified with a sparkling clean label.	1.20 (0.45)

point scale (1 = Preferred; 2 = Acceptable, 3 = Undesirable; 4 = Unacceptable, see Table 1) for all attributes (Tunn et al., 2021). Results supported that all attribute levels were considered appropriate, ranging in means between preferred and undesirable ($1 < M < 3$; see Table 1) and were therefore included in the conjoint analysis.

2.2. Main study

2.2.1. Participants

For the choice-based conjoint analysis, we recruited a convenience sample of 785 participants with the Dutch Nationality (Age = 18–91, M_{Age} = 44,32; 348 females, 432 males and five others). First, we recruited 385 Dutch nationals via a university-based testing panel and additionally sampled 400 participants via Prolific to obtain a more diverse sample. The university panel consists of people living in Delft and surrounding area, who have signed up to participate in scientific studies. Participants from this panel were invited to participate in this study via email. The Prolific platform consists of registered individuals who can choose between various experiments. If they fit the criteria of the study, participants can take the study on a first-come, first-served basis. An inclusion criterion for all our participants was the Dutch nationality to minimise cultural factors, and participants could choose to do the questionnaire in Dutch or English. The highest level of education was varied: 31% of the participants were high school educated, 32,6% had a bachelor's degree, 34,1% had a master's degree, and 2,3% had a PhD). We excluded 10 participants from our sample because they did not pass the attention check.

2.2.2. Procedure and materials

After filling in the informed consent, participants were asked to read a scenario in which they were instructed to imagine themselves looking for refurbished wireless headphones. Subsequently, participants saw a graph explaining that during the refurbishment process, products are recollected, tested, repaired and cleaned. Then participants were informed that they would be presented with two different versions of wireless headphones and should choose one of the two options based on their preference (see Fig. 3). The conjoint software automatically computes two random options in which the attribute levels vary per choice. After four choice sets, participants filled in a survey assessing different consumer characteristics and demographics, such as (year of birth), gender (female, male, other), nationality and the highest level of education (high school, bachelor's degree, master's degree, postdoctoral degree).

We assessed consumers' environmental concern with three items on a 7-point Likert scale (Kim and Choi, 2005; Mugge et al., 2017) (1 = strongly disagree, 7 = strongly agree; $\alpha = 0.87$). An example item was "I make a special effort to buy products that are made from sustainable materials". We assessed the extent to which consumers want value for money with a value consciousness scale that consists of three items on a 7-point Likert scale (Lichtenstein et al., 1990; 1 = strongly disagree, 7 = strongly agree; $\alpha = 0.70$). While the three items version of this scale had shown high levels of reliability in another study ($\alpha = 0.82$ in Mugge et a., 2017a), the three items version only showed low reliability (0.63). We, therefore, deleted one item because it improved the reliability of the scale ($\alpha = 0.7$ when the item was deleted). An example item was: "When shopping, I compare the prices of different brands to be sure I get the best value for the money". We assessed how frequently and intensively participants experienced disgust using the pathogen disgust domain of the Three Domains of Disgust Scale (Olatunji et al., 2012). We measured the disgust sensitivity with seven items on a 7-point Likert-scale (0 = Not disgusting at all, 6 = Extremely disgusting; $\alpha = 0.77$). An example item was: "Please rate how disgusting you find the concepts described in the items, where 0 means that you do not find the concept disgusting at all and 6 means that you find the concept extremely disgusting: Seeing some mould on old leftovers in your refrigerator". We assessed how tolerant participants were to ambiguous situations with four items of the ambiguity intolerance 7-point Likert scale (Hazen et al., 2012; McLain, 2009; 1 = strongly disagree, 7 = strongly agree; $\alpha = 0.76$). An example item was: "I am tolerant of ambiguous situations". All scales are displayed in Appendix B.

3. Results

3.1. Statistical analyses

The results were analysed in two steps. First, based on the choice data from the conjoint analysis, we estimated the overall importance of the attributes, the relative utility of the attribute levels and the individual utilities of all attribute levels with hierarchical Bayes estimation (for a description of the method, see Allenby and Ginter, 1995). This method provides individual utility (part-worth) estimates for the respondents on the basis of only a few product choices by each participant (Allenby and Ginter, 1995). By analysing the importance of attributes and relative utility, one can see which attributes are most important and which attribute levels weigh the heaviest in the choice participants make. Second, we used the individual utility values to conduct a cluster analysis in order to reveal differences between different consumer groups. The optimal number of clusters is determined with the gap statistics method (Berget, 2018). This technique uses the output of a clustering algorithm (K-means in our case) and compares the change in within-cluster dispersion with the within-cluster dispersion expected under an appropriate reference null distribution (Tibshirani et al., 2001). The optimal number of clusters is therefore indicated with the lowest gap statistics value. Subsequently, we clustered the participants

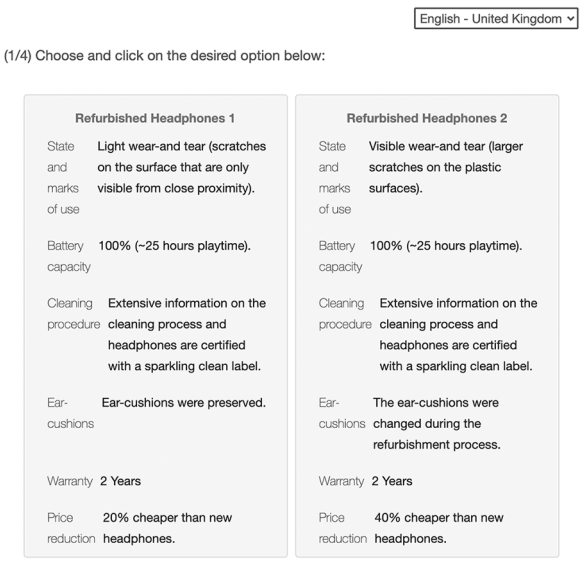

Fig. 3. Design of the choice-task.

with the k-means clustering method (Hair et al., 2006) using a fixed number of four clusters to determine the optimal cluster partitioning.

3.2. Relative importance of attributes

In our study, we tested three contamination-reducing strategies, including (1). communication about the clean object state, (2). eliminating aesthetic and functional signs of use and (3). renewing parts that touch the skin (e.g., ear-cushions). Overall, for the participants in our study, the two most important attributes were related to contamination (see Fig. 4) and were an impactful factor in their consumer choice for refurbished headphones. First, participants deemed eliminating signs of aesthetic wear-and-tear as most important, accounting for 28% of consumer choices. Whether the ear-cushions were replaced during the refurbishment was considered the second most important attribute (24%), closely following the aesthetic wear-and-tear. The price reduction (19%) was only the third most important factor; the battery capacity (functional wear-and-tear) (14%), a description of the cleaning procedure or the provision of a sparkling-clean label (7%) and extended warranty (7%) were deemed less important overall.

3.3. Relative utility of attribute levels

The relative utility for each attribute level is shown in Fig. 5. Higher positive scores suggest that the attribute level is, on average, of greater influence on the consumer choice.

The results indicated that the level of aesthetic wear-and-tear was the most impactful attribute on the consumer choice. The aesthetic as-new state was the most preferred attribute level with a relative utility of 17.30 (contamination-reducing strategy 3a), compared to light (−0.62) or visible wear-and-tear (−16.68). A nearly equally important attribute level was whether the ear-cushions were renewed during the refurbishment process, with a relative utility level of 14.15 (strategy 2). The third most important attribute level was the price reduction of 40% compared to a new product (10.71). A price reduction of 30% at a utility level of 0.11 and a 20% price reduction had a utility level of −10.82. The battery capacity (functional wear-and-tear; strategy 3) had a relative utility of 7.86 for 100% battery capacity. The two least significant attributes were the cleaning procedure (strategy 1) with a preference for a certified clean product (3.70) and the warranty for which participants preferred a product with two years of warranty (3.33).

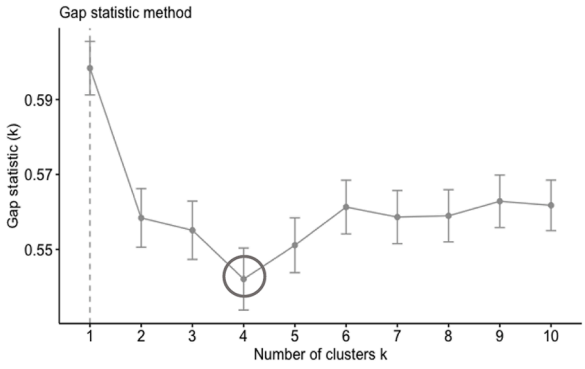

Fig. 4. Importance of attributes.

The average relative utility of the attributes displays how all participants valued the different product attributes on average. In the following section, we will go beyond the average relative utility by identifying distinct consumer groups that differ in their attribute preferences.

3.4. Consumer segments based on attribute level preferences

Not all consumers are incentivised by the same features. To analyse whether there are differences between different consumers, we clustered consumers into consumer groups based on their choice preferences. The optimal number of clusters (consumer groups) was determined following the gap statistics method (Berget, 2018), which revealed four different consumer groups (see Fig. 6). This technique uses the output of a clustering algorithm (K-means in our case) and compares the change in within-cluster dispersion with the within-cluster dispersion expected under an appropriate reference null distribution (Tibshirani et al., 2001). The optimal number of clusters is therefore indicated with the lowest gap statistics value (see Fig. 6). Subsequently, we clustered the participants with the k-means clustering method (Hair et al., 2006) using a fixed number of four clusters to determine the optimal cluster partitioning.

The participants were grouped into four clusters based on the similarity of their preferences for the attribute levels (see Table 2).

3.4.1. Cluster 1–Budget focused with desires for a new product

The largest consumer group (37% of our sample) is characterised by a strong preference for an as-new product in terms of aesthetics (i.e., no wear-and-tear and new ear-cushions) as well as battery capacity (functional wear-and-tear). This consumer group seems very budget minded, as they are strongly valuing a price reduction of 40%. They also highly appreciate it if the product is certified clean and has a warranty comparable to new products. This group is probably not prone to buy refurbished products yet. However, they can be incentivised by a refurbished product that is cheaper than a new product but is practically in an as-new state.

3.4.2. Cluster 2–Function-over-aesthetics

The second-largest group (27% of our sample) is composed of consumers who are focused on price and prefer a refurbished product with an as-new functionality (100% battery). While the aesthetics of the product and the cleaning label are of less importance to this group, they do appreciate it if the ear-cushions are renewed during the refurbishment process. They can be incentivised by an important price reduction and (guaranteed) good functionality.

3.4.3. Cluster 3- Aesthetics-over-function

The third cluster (consisting of 27% of our sample) seems to be less sensitive to the price of the product and is most incentivised by as-new aesthetics. They also highly value if the ear-cushions are renewed during the refurbishment process and are less concerned about the product's functionality. They can be incentivised by a product that is refurbished

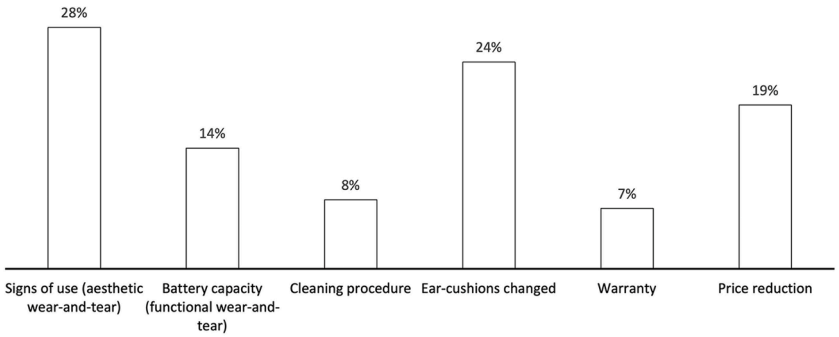

Fig. 5. Average utility of the attribute levels.

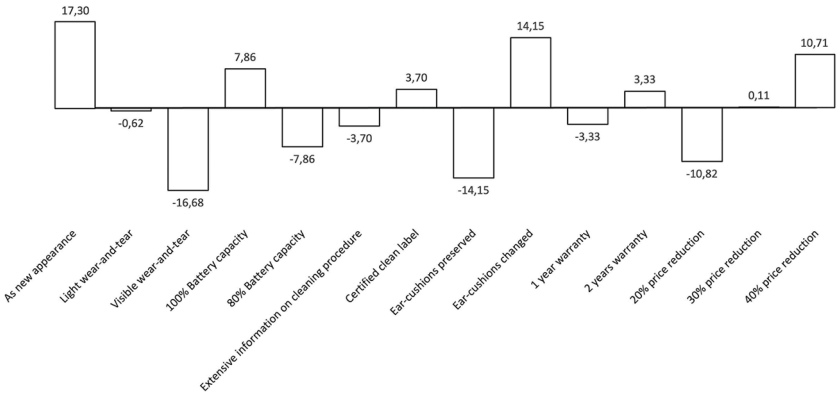

Fig. 6. The optimal number of clusters was identified as four clusters according to the gap statistics method.

to look as new.

3.4.4. *Cluster 4–Reuse-enthusiasts*

The fourth is the smallest cluster (9% of our sample) and is quite distinct from the first three clusters. These reuse-enthusiasts appreciate it if the product's ear-cushions are preserved and are probably less sensitive to contamination. This consumer group does not mind aesthetic and functional wear-and-tear if the product comes with a small price reduction. This consumer group is most likely already buying second-hand products and could be incentivised by refurbished products with original parts for a lower price than new products.

3.5. *Individual differences in the characterisation of consumer groups*

We also analysed and profiled our respondent groups in terms of demographic variables (age, education, gender) and (psychological) consumer characteristics (i.e., disgust sensitivity, environmental concern, value consciousness and ambiguity intolerance), and found that the reuse-enthusiasts scored significantly higher on environmental concern than other groups $F(3, 781) = 2.98$, $p < .05$. Concerning the other variables, no significant differences between the groups were found, as shown in Table 2.

4. Discussion

This paper contributes to the literature on consumer-centric design for refurbishment by exploring how different attributes of refurbished headphones influence consumer choice. Thus far, refurbishment literature and practice have focused on the rational side of consumer decision-making, mostly exploring factors of an economic nature, such as price reduction and years of warranty as important attributes for marketing refurbished products (Harms and Linton, 2016; Michaud and Llerena, 2010).

We argue that there are also more affective processes at work and believe that contamination is important to understand the behaviour of consumers.

Our findings demonstrate that to make refurbishment an attractive offering to consumers, products need to be designed to retain their value through dealing with (sometimes irrational) contamination issues arising due to the multiple lifecycles/ users of a refurbished product. Specifically, our findings demonstrate that for refurbished headphones, an as-new aesthetic, as-new functionality, and the renewal of parts touching the skin (ear-cushions) have a stronger influence on consumer choice than the reduced price or years of warranty. Our research indicates that consumers have adverse reactions to refurbished products that are in contact with the skin. This was suggested by previous research in the context of reused circular products; however, to the best of our knowledge, strategies aiming to counter these adverse reactions had never been empirically tested (Abbey et al., 2015; Baxter et al., 2017; Clube and Tennant, 2020; Tunn et al., 2021).

Furthermore, our findings indicate that depending on the consumer group, contamination-reducing strategies may be more or less important. While some consumer groups highly value that signs-of-prior-use are eliminated through an as-new appearance, others want the functional wear-and-tear to be eliminated. Communicating about the cleaning process is appreciated but was less impactful than other contamination-reducing strategies.

4.1. *Contamination-reducing design strategies*

With our findings, we aim to inform manufacturers and designers about strategies to deal with contamination issues arising from the multiple lifecycles of refurbished products and address different consumer groups. For designers interested in designing products that can be successfully refurbished, we recommend the following strategies:

First, we suggest designing for an as-new look. Because many consumers value an as-new appearance, designers should think about the aesthetic durability of a product. Designers could implement materials

Table 2
Average utility values of attribute levels per consumer group.

Attributes	Attribute levels	Cluster 1	Cluster 2	Cluster 3	Cluster 4
		Budget-focused with as-new desires	Function-over aesthetics	Aesthetics-over-function	Reuse-enthusiasts
		($N = 295$)	($N = 210$)	$N = 209$)	($N = 71$)
		Average part-worth utilities (Cluster centres)	Average part-worth utilities (Cluster centres)	Average part-worth utilities (Cluster centres)	Average part-worth utilities (Cluster centres)
State of the product (aesthetic wear-and-tear)	As-new appearance	28.32	6.35	19.98	−3.31
	Light wear-and-tear	−1.53	−0.46	−0.16	1.36
	Visible wear-and-tear	−26.79	−5.89	−19.82	1.94
Battery capacity (functional wear-and-tear)	100% battery capacity	12.22	9.67	3.52	−2.28
	80% Battery capacity	−12.22	−9.67	−3.52	2.28
Cleaning procedure	Information on the cleaning procedure	−5.79	−1.57	−4.14	−0.24
	Information on the cleaning procedure and certified-clean label	5.79	1.57	4.14	.24
Changed parts	Preserved ear-cushions	−22.19	−9.85	−13.98	6.43
	Changed ear-cushions	22.19	9.85	13.98	−6.43
Warranty	1 year warranty	−5.11	−3.24	−2.45	.98
	2 years warranty	5.11	3.24	2.45	−0.98
Price reduction compared to new products	20% cheaper	−17.80	−12.98	−3.59	2.46
	30% cheaper	.05	.63	−0.55	1.21
	40% cheaper	17.75	12.36	4.14	−3.68
Consumer characteristics M(SD)	Environmental Concern	4.42 (1.46)	4.43 (1.46)	4.20 (1.47)	4.78 (1.29)
	Value Consciousness	6,07 (0.89)	5.97 (0.93)	5.98 (1.03)	5.70 (1.20)
	Disgust Sensitivity	4.97 (1.03)	4.88 (0.99)	5.03 (1.08)	5.18 (0.96)
	Ambiguity Tolerance	4.04 (0.98)	3.99 (1.07)	3.93 (0.99)	4.14 (1.06)
Demographics M(SD)	Age	43.09 (18.32)	45.11 (19.27)	43.84 (18.83)	48.51 (19.78)
	Education	10.26 (4.92)	10.36 (5.08)	9.65 (4.96)	9.17 (5.24)
	Gender (f/m/o)	139/154/1	83/126/1	94/114/1	32/38/1

that either keep an as-new appearance in time or can be easily returned into an as-new state. Interesting options would be to use materials that can be easily sanded off (e.g., stainless steel), self-healing materials (Toohey et al., 2007; Wool, 2008), or to use coatings that can easily be renewed.

Second, we suggest designing for an as-new functionality. Some consumers seem to value functionality more than appearance. Designers could aim to design products in a way that it is easy to change critical parts to ensure an as-new functionality. This includes planning for disassembly and repair early in the design process. Methods, such as the hotspot mapping for product disassembly (Flipsen et al., 2020), can be used to evaluate how repairable and therefore refurbishable the product is. This can be supported by making the product (partly) modular (Meehan et al., 2007). Modular design additionally facilitates that contamination-sensitive parts touching the skin can be easily renewed during the refurbishment process. Note, however, that manufacturers should be careful not to replace too many parts containing critical materials due to their large environmental impact (Liu et al., 2015).

Third, we suggest designing for an easy-to-clean product. This includes using materials that are durable enough to endure multiple cleaning procedures and avoiding split lines in which dirt can assemble.

Fourth, for the smallest consumer group (reuse-enthusiasts), we propose a strategy in which contamination is not reduced but embraced. Designing products that are timeless (Wallner et al., 2020), durable and become more beautiful with age could incentivise the last consumer group. This strategy is probably the most environmentally friendly because little resources are needed to refurbish the product. Another interesting finding of this consumer group was that these consumers were more environmentally concerned than other consumer groups; this group might therefore be more receptive to other strategies, such as eco-labels.

4.2. Limitations and future research

Although our study offers valuable implications for researchers and practitioners, some limitations deserve attention and should be taken into account in further research. Most of the psychometric variables were not significantly related to the participants' choices. This is however, not a single occurrence as psychometric variables often cannot be linked to consumers' buying behaviours (Anderson and Cunningham, 1972; Uusitalo, 1990; Rokka and Uusitalo, 2008). In our study, we believe that this could have happened for two reasons: First, consumers do not always practice what they preach. While some consumers intend to make more sustainable behavioural choices, their attitudes do not necessarily translate into behaviour, a phenomenon known as the action-value gap (Olson, 2013). This further underlines the importance of behavioural testing and putting consumers in choice situations when researching how to enhance the consumer acceptance of circular products. Furthermore, variables that were found to significantly predict the purchase intentions of refurbished products arise from studies comparing refurbished products to new products (Hazen et al., 2015; Mugge et al., 2017a; Wallner et al., 2021). As the products presented in the choice-based conjoint were all refurbished, these variables may not have predictive power because they are more relevant to predict the choice between new and refurbished products.

In practice, consumers often choose between a refurbished premium product and a cheaper new alternative. Past research has compared new and refurbished products and revealed that the contamination of refurbished products is a critical factor in determining the product choice for or against refurbished products compared to new products (Wallner et al., 2021). In this research, we therefore focused on uncovering how strategies aiming to reduce contamination concerns can enhance the overall preference of refurbished products. Future research could however further compare refurbished products to new and perhaps even second-hand products to single out factors that differ in consumers' product choices.

Another limitation of our study is that we explored contamination-related strategies with a choice-based conjoint analysis, which did not allow us to measure the effect of the strategies on contamination perceptions. Future research should consolidate our findings and explore whether the proposed strategies indeed decrease the perceived contamination or just make the product more attractive in general.

In our study, we additionally left out the year of production due to the findings of our pre-test. We initially included the year of production as means to signify the number of lifecycles a product might have had. While the year of production may not be as important in the case of headphones, we believe that the number of life cycles and the year of production can be more relevant for other products for which technological advancement is important, such as smartphones or cars and should be explored in future research.

Moreover, prior research about refurbishment has indicated that the product category can be of influence when it comes to the level of contamination. Abbey et al. (2015) made a distinction between products that are in-you products (e.g., electric toothbrushes, in-ear earplugs), which create the highest level of contamination, products that are close to you ('on-you' products, such as headphones, smartwatches), which create a medium level of contamination and products that are around-you (food containers, laptops) which may trigger the least amount of contamination. In our research, we made the conscious decision to focus on a product that represents the middle ground. As an 'on-you' product, headphones trigger contamination issues but may still be considered desirable when refurbished, while electric toothbrushes (in-you products) are not likely to be bought in a refurbished state because these are completely rejected by consumers due to contamination concerns (Mugge et al., 2017b). Our findings may be specific to on-you products, and we, therefore, encourage future research to also look into other product categories and explore how they can be optimised for contamination, as this may differ per product category depending on the level of contamination.

4.3. Conclusions about refurbishment and resource conservation

Refurbishment is a key strategy in the circular economy to loop reused products back into the market. While for some products, strategies such as prolonging the product use-phases through making product repairable for the consumers may be even more resource-efficient (Achterberg et al., 2016), refurbishment is an especially interesting strategy for products that are difficult or dangerous for consumers to repair (e.g., high power batteries). Additionally, it is a good strategy for products that are sensitive to contamination and circulate between different users, such as in renting business models (Wallner et al., 2021). One problem that manufacturers face when refurbishing products is that products are often not properly divested after their use (Poppelaars et al., 2020). Renting business models can potentially solve the problem of product divestment because products need to be returned after they have been rented and thus ensure that products are kept in the loop. By ensuring the product returns and giving the product multiple life cycles through refurbishment, manufacturers also need to ensure that contamination issues are minimised during the refurbishment process. Our research revealed that one of the most important strategies is to change parts that are sensitive to contamination and to give a product an as-new functionality and as-new appearance. However, the more parts are replaced during the refurbishment process, the more negative the environmental impact will be. It is therefore not favourable from a resource-preservation perspective to change as many components as possible so that the product appears to be as-new. Manufacturers should rather look to explore how product components can be refurbished and brought back into an as-new aesthetic and functional state without replacing parts that contain critical materials. To manufacture products that are both resource-efficient as well as desirable to consumers and manufacturers, it is, therefore, crucial to explore and design products in a manner that takes the contamination into account but helps to keep products at their highest value.

CRediT authorship contribution statement

T.S. Wallner: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing. **L. Magnier:** Supervision, Writing – review & editing. **R. Mugge:** Funding acquisition, Supervision, Writing – review & editing.

Declaration of Competing Interest

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

Appendix A: Pre-test results and pre-test scales

Importance of attributes refurbished headphones differ in several features. Please indicate how important you find the following features when choosing refurbished headphones.

Items	1. Not at all important – 5 Extremely important	M (SD)
There is information on whether the ear-cushions were changed during refurbishment process.		3.82 (1.01)
There is information on the cleaning process.		3.73 (1.04)
There is information on the product state (signs of use on the product, such as scratches on surfaces).		4.35 (.69)
There is information on the battery capacity.		4.04 (.72)
There is information on the length of the warranty.		3.98 (.76)
There is information in which year the headphones were produced.		3.10 (1.06)
There is information on the price reduction of refurbished headphones compared to new ones.		3.94 (.76)

Pairwise Comparisons on importance (see above which items corresponds to which characteristic)

Item		t	p
1	2	.098	1.000
	3	-.529*	.047
	4	-.216	1.000
	5	-.157	1.000
	6	.725*	.002

(*continued on next page*)

(*continued*)

Item		t	p
	7	-.118	1.000
2	1	-.098	1.000
	3	-.627*	.002
	4	-.314	1.000
	5	-.255	1.000
	6	.627	.126
	7	-.216	1.000
3	1	.529*	.047
	2	.627*	.002
	4	.314	.464
	5	.373	.283
	6	1.255*	.000
	7	.412	.076
4	1	.216	1.000
	2	.314	1.000
	3	-.314	.464
	5	.059	1.000
	6	.941*	000
	7	.098	1.000

Based on estimated marginal means

*The mean difference is significant at the .05 level.

[b]Adjustment for multiple comparisons: Bonferroni.

Items	Scale: (1) Preferred (2) Acceptable (3) Undesirable (4) Unacceptable	M (SD)
Signs of use		
The appearance is in an as-new state (product does not show any signs of use and look as-new).		1.08 (.27)
The appearance shows light wear-and tear (scratches on the surface that are only visible from close proximity).		2.08 (.39)
The appearance shows visible wear-and-tear (larger scratches on the plastic surfaces).		2.92 (.59)
The appearance shows very visible wear-and-tear (larger scratches on the plastic surface and discolorations of headpiece).		3.47 (.64)
Battery functionality		
Battery has 100% battery capacity (~25 hours playtime)		1.02 (.14)
Battery has at least 90% battery capacity (~ 22,5 hours playtime).		1.39 (.53)
Battery has at least 80% battery capacity (~ 20 hours playtime).		1.80 (.49)
Battery has at least 70% battery capacity (~ 17,5 hours playtime).		2.27 (.57)
Battery has at least 60% battery capacity (~ 15 hours playtime).		2.55 (.67)
Battery has at least 50% battery capacity (~ 12,5 hours playtime).		3.16 (.67)
Battery has at least 40% battery capacity (~ 10 hours playtime).		3.49 (.64)
Cleaning process		
There is no information on the cleaning process, only a general statement that the refurbishment process of the headphones involves cleaning.		2.96 (.77)
There is extensive information on how the cleaning process was executed on the company website of the refurbished headphones.		1.29 (.50)
There is extensive information on how the cleaning process was executed on the company website of the refurbished headphones and the specific headphones are certified with a sparkling clean label.		1.20 (.45)
Changed parts		
The ear-cushions were cleaned during the refurbishment process.		2.33 (.82)
The ear-cushions were changed during the refurbishment process and are new.		1.06 (.24)
Length of warranty		
6 months		3.16 (.70)
1 year		2.12 (.59)
2 years		1.39 (.49)
3 years		1.04 (1.96)
Year of production		
Produced in 2020		1.10 (.30)
Produced in 2019		1.47 (.50)
Produced in 2018		1.86 (.66)
Produced in 2017		2.49 (.61)
Produced in 2016		2.96 (.69)
Produced in 2015		3.33 (.77)
Price of the product		
The refurbished headphones have a 5% price reduction compared to new headphones.		3.82 (.38)
The refurbished headphones have a 10% price reduction compared to new headphones.		3.53 (.58)
The refurbished headphones have a 15% price reduction compared to new headphones.		3.20 (.63)
The refurbished headphones have a 20% price reduction compared to new headphones.		2.84 (.86)
The refurbished headphones have a 25% price reduction compared to new headphones.		2.43 (.64)
The refurbished headphones have a 30% price reduction compared to new headphones.		2.12 (.71)
The refurbished headphones have a 40% price reduction compared to new headphones.		1.59 (.50)
The refurbished headphones have a 50% price reduction compared to new headphones.		1.10 (.30)

Appendix B: Scales of the main study

Scale and items	Scale points
Value consciousness, (based on Lichtenstein et al., 1990)	Strongly disagree (1) – strongly agree (7)
When shopping, I compare the prices of different brands to be sure I get the best value for the money.	
When purchasing a product, I always try to maximise the quality I get for the money I spend.	
I generally shop around for lower prices on products, but they must still meet certain quality requirements before I buy them.	
Environmental concern (based on Mugge, Jockin, and Bocken, 2017a)	Strongly disagree (1) – strongly agree (7)
I make a special effort to buy products that are made from sustainable materials.	
I have changed which products I use because of sustainability-related reasons.	
I have avoided buying a product because it had potentially harmful effects to people and/or the environment	
Disgust Sensitivity (Three Domains of Disgust Scale (TDDS) – Pathogen disgust (based on Olatunji et al., 2012)	Not at all disgusting (0 – Extremely disgusting (6)
Seeing some mould on old leftovers in your refrigerator	
Standing close to a person who has body odour.	
Shaking hands with a stranger who has sweaty palms	
Stepping on dog poop	
Accidentally touching a person's bloody cut.	
Seeing a cockroach run across the floor.	
Sitting next to someone who has red sores on their arm.	
Ambiguity intolerance (based on McLain, 2009; Hazen etal., 2012)	Strongly disagree (1) – strongly agree (7)
I am tolerant of ambiguous situations.	
I enjoy tackling problems that are complex enough to be ambiguous.	
I generally prefer novelty to familiarity.	
I prefer a situation in which there is some ambiguity.	

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