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A network analysis of factors influencing the purchase intentions for refurbished electronics

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ABSTRACT

Refurbishment can extend the lifetime of an electronic product and reduce its environmental footprint. However, consumers often perceive refurbished electronics as less attractive than new ones, resulting in lower purchase intentions. While prior research has identified several factors that influence consumer choices regarding refurbished electronics, we lack understanding of the interrelations between the different factors related to the consumer, product and context. To model the complex interplay of the factors involved in the intention to purchase refurbished speakers and earbuds, we conducted a survey with 1801 participants. A network encompassing both product categories revealed that the most central factors influencing the intention to purchase refurbished electronics were the product category, the perceived risk and the perception that refurbished electronics are uncomfortable to use because they remind the consumer of their prior user (territorial contamination). For refurbished earbuds, participants' concerns about territorial and hygienic contamination had the strongest negative relations to purchase intentions. For refurbished speakers, the purchase intentions were most negatively related to their perceived risk and positively related to their financial attractiveness. Hence, strategies aiming to enhance the consumer acceptance of refurbished electronics should aim at reducing risks and contamination concerns. Potential strategies to reduce the risks associated with refurbished electronics are discussed.

1. Introduction

Global warming will exceed 1.5–2 °C during the 21st century unless greenhouse gas emissions are heavily reduced in the next 30 years (IPCC, 2022). The average carbon footprint of a person living in the European Union amounted to 6.7 tons of CO_2 in 2019 (Eurostat, 2021), of which 70 % are related to the way we live, move and consume (Bocken et al., 2022). The production and use of electronics specifically, contribute highest to the environmental impact of consumption (Porcelijn, 2016). To decrease our environmental impact, we need to adopt more sustainable consumption patterns than taking, making, using and disposing of electronics.

A key strategy to reduce the environmental footprint of our consumption is to extend a product's lifetime through refurbishment (Ellen MacArthur Foundation, 2016). By collecting, testing, repairing and reselling electronics as refurbished, products can be kept in the loop and therefore have a lower environmental impact compared to manufacturing new products (Pigosso et al., 2010). For example, refurbishing smartphones instead of manufacturing new ones can reduce their carbon footprint by 87 % (Zumegen, 2020). To ensure that refurbished electronics retain both their material and economic value, it is necessary for these products to be technically durable so that they can last multiple life cycles but also remain attractive to consumers (Blomsma and Tennant, 2020). While there are established markets for certain refurbished electronic and mobility products, such as smartphones, tablets, computers, bicycles and cars, not all refurbished electronics are desirable to consumers (Mahmoodi and Heydari, 2021; Mugge et al., 2017b). However, in a transition to a circular economy,

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more electronics need to be refurbished.

One problem faced in refurbishment is that consumers tend to have lower purchase intentions for refurbished electronics (Esmaeilian et al., 2021; Harms and Linton, 2016; Michaud and Llerena, 2010; Mugge et al., 2017a). Consumer perceives various barriers that prevent them from considering these products as viable alternatives for new electronics. To improve the success of refurbishment and contribute to a Circular Economy, consumer perceptions of refurbished electronics need to be enhanced. To make refurbishment a financially viable business model, consumer perceptions of refurbished electronics need to be enhanced. Prior literature has explored how marketing-related factors can make refurbished electronics more desirable (Alqahtani and Gupta, 2017; Atasu et al., 2008; Esmaeilian et al., 2021; Govindan et al., 2019; Mugge et al., 2017a). Our research contributes to the existing literature on refurbishment in two ways. First of all, in contrast to prior research, we use a network approach to explore the (inter)relationships between the factors influencing consumers' purchase intentions of refurbished electronics, thereby shedding light on the underlying psychological processes. Consumer decision-making for or against refurbished electronics involves a complex interplay of product, marketing and consumer-related factors. Nevertheless, prior research on refurbishment has focused on a limited set of factors and investigated how these linearly predict purchase intentions regarding refurbished electronics. For example, Mugge et al. (2017a) used regression to demonstrate that environmental benefits, awareness, performance risk and innovativeness influences purchase intention. It is however unlikely that the uncovered factors are truly independent (as proposed in linear regression) and thus some research is needed on how these factors (inter)relate to each other and which factors are most influential in the consumer choice. Second, prior research has focused primarily on studying refurbished smartphones (Mugge et al., 2017a; Sharifi and Shokouhyar, 2021; Van Weelden et al., 2016). We aim to extend this research by exploring how consumers respond to other refurbished electronics and in particular product categories that differ in the extent to which they evoke contamination concerns. In a true Circular Economy, most consumer electronics will be refurbished. However, some categories may be linked to specific concerns such as increased contamination worries that influence consumers' purchase intention. Understanding these factors and how these differ between categories with different degrees of evoked contamination will have important scientific and managerial implications.

Through our research, we aim to develop more sophisticated strategies for the successful design and marketing of refurbished electronics to enable them to retain their value over multiple lifecycles. We can summarize our objectives in the following two research questions:

- *What are the underlying (inter)relationships between the factors influencing consumer acceptance of refurbished products?*
- *How do these relationships differ between product categories varying in consumers' contamination concerns?'*

2. Literature review

Consumer decision-making regarding refurbished electronics is frequently described as a trade-off between advantages and disadvantages that are weighed against alternatives, such as new electronics or second-hand electronics (Van Weelden et al., 2016). Compared to second-hand electronics, refurbished electronics are seen as a safer choice because they are provided with money-back guarantees and warranties (Alqahtani and Gupta, 2017; Mahmoodi and Heydari, 2021; Mugge et al., 2017a). Compared to new electronics, refurbished electronics have a lower price and are seen as an environmentally friendly option (Abbey et al., 2015b; Harms and Linton, 2016; Mahmoodi and Heydari, 2021; Michaud and Llerena, 2010; Mugge et al., 2017a; Sharifi and Shokouhyar, 2021; Wahjudi et al., 2020).

These benefits are however often not strong enough to compensate for the perceived disadvantages. Consumers typically perceive refurbished electronics to be a riskier choice than new electronics because of their previous use (Chun et al., 2022; Hamzaoui Essoussi and Linton, 2010; Singhal et al., 2019; Van Weelden et al., 2016). Consumers expect refurbished electronics to have lower utility (e.g. decreased battery capacity), to have a shorter product lifetime, to become technically obsolete quicker and to be contaminated by their prior use (Abbey et al., 2015a; Baxter et al., 2015; Nasiri, 2021; Van Weelden et al., 2016; Wallner et al., 2022a, 2022b). This can cause a feeling of unease in the consumer for two reasons: First, it can decrease their trust in the refurbished product as a satisfactory financial investment and consequently they may dispose of it earlier than they would dispose of a new one (Guide and Li, 2010; Hamzaoui Essoussi and Linton, 2010; Michaud and Llerena, 2010; van Weelden et al., 2016; Wang et al., 2013). Second, it may cost them time if the product needs to be sent back (van Weelden et al., 2016). Prior qualitative research has indicated that the balance between the advantages and disadvantages is influenced by a complex interplay of factors related to the product, marketing and the consumer (Gomes et al., 2022; Van Weelden et al., 2016; Wallner et al., 2022b).

2.1. Product-related factors influencing the advantage-disadvantage trade-off

A central factor in determining how advantageous consumers perceive a refurbished product to be is the product itself, more specifically its *perceived utility* (Abbey et al., 2015b; Aydin and Mansour, 2023; Chen et al., 2020; Wahjudi et al., 2020). Consumers find it hard to evaluate the utility of refurbished electronics because they are the result of an often opaque refurbishment process in which they are cleaned, disassembled, inspected, tested and brought into an acceptable state (Tereyağoğlu, 2016). Consumers therefore often fall back on determining the utility of the product based on their product appearance (Creusen and Schoormans, 2005; Crilly et al., 2004; Krippendorff, 1989). In general, *aesthetically attractive electronics* are associated with higher quality, trustworthiness (Page and Herr, 2002; Veryzer Jr. and Hutchinson, 1998) and greater ease of use than less attractive electronics (Hassenzahl, 2004). Another factor that reflects on the utility of a product is how durable the product appearance is perceived to be (Mugge et al., 2018a). A product that has a *durable* appearance is also perceived to have a lower probability of malfunctioning and suffering from an insufficient product lifetime. It is therefore not surprising that the perceived attractiveness and durability of refurbished electronics have been shown to strongly relate to purchase intentions (Wallner et al., 2021).

Another product-related factor that can potentially make refurbished electronics undesirable is *the presence of signs of wear and tear*, such as scratches. Signs of wear and tear are associated not only with a lower product functionality, a shorter product lifetime and an increased perceived risk but also with a feeling of unease or even disgust (Mugge et al., 2018b). Signs of wear and tear indicate that the product has been used extensively and might be contaminated by the prior user (Wallner et al., 2022b). *Contamination* is based on the law of contagion, according to which a source (e.g. a previous user) transfers its essence (e.g. skin particles or their smell) to a recipient (e.g. headphones). These traces of contamination remain on the recipient even after the contact with the source is broken (Mauss, 2005; Rozin et al., 2015; Rozin and Nemeroff, 1990). The feeling that a product has been contaminated by its prior user can cause consumers to feel uncomfortable and has been shown to be an influential factor decreasing purchase intentions in various product categories, such as recycled water, used shopping carts and second-hand clothing (Huang et al., 2017; O'Reilly et al., 1984; Rozin et al., 2015).

Baxter et al. (2017) distinguished three different types of contamination in circular electronics: hygienic contamination, utility contamination and territorial contamination (HUT model; Baxter et al., 2017). Qualitative research has shown that all three make refurbished electronics less desirable (Wallner et al., 2022b). *Hygienic contamination*

describes the risk consumers perceive concerning objects that were used before and which may pose a threat to one's health as a result of pathogens or dirt (Baxter et al., 2017). *Utility contamination* has a functional nature; consumers feel unease because the prior use of the product is believed to have decreased its functionality (Baxter et al., 2017). *Territorial contamination* suggests that the product is perceived to be uncomfortable to use because it interferes with one's personal space (Baxter et al., 2017), such as headphones smelling like a previous user.

Contamination is dependent not only on the condition of the electronic product but also on its context (Baxter et al., 2017; Wallner et al., 2022a). For example, whether a product is expected to have a decreased functionality due to its prior use (utility contamination) does not only depend on whether it shows signs of wear and tear but also on its warranty and price (Wallner et al., 2022b).

2.2. Marketing-related factors influencing the advantage-disadvantage trade-off

A widely researched marketing factor predicting the purchase intentions for refurbished electronics is their *price* (Abbey et al., 2015b; Atasu et al., 2008; Bittar, 2018; Chun et al., 2022; Grewal et al., 1998; Mugge et al., 2017a; Subramanian and Subramanyam, 2012; Wahjudi et al., 2020). Refurbished electronics are an economical choice for consumers because their market value is 10–50 % lower than the market value of new electronics (e.g. Refurbed, 2022). A low price has the potential to decrease the perceived risk that the product is a bad financial investment, while at the same time it serves as a financial incentive to buy refurbished electronics over new electronics. It is not clear, however, whether price decreases the perceived riskiness of refurbished electronics or serves as a financial incentive to consumers.

In addition to the price, *warranties* can incentivize consumers to buy refurbished electronics over new electronics. Wallner et al. (2022b) discussed that a warranty can compensate for the risk that consumers associate with refurbished electronics, even those with visible signs of wear and tear. Moreover, for a consumer to trust the retailer to grant the promised warranty, the retailer needs to be trustworthy. *A good brand reputation* has been shown to decrease the perceived risks associated with refurbished smartphones (Agostini et al., 2021; Sharifi and Shokouhyar, 2021; Van Weelden et al., 2016) and lead to a higher perceived value of the product. The decreased risk and the higher perceived value in turn lead to higher purchase intentions for refurbished electronics (Agostini et al., 2021).

2.3. Consumer-related factors influencing the advantage-disadvantage trade-off

To add another level of complexity, consumers have different needs, desires and characteristics, which drive their consumption decisions (Alyahya et al., 2023; Hunka et al., 2020). Consumers who are *environmentally concerned* are not only more likely to buy refurbished electronics in general (Barber et al., 2014; Fransson and Gärling, 1999; Mugge et al., 2017a; Schultz, 2001; Wallner et al., 2022a, 2022b; Wallner et al., 2021) but also more likely to choose a refurbished product that shows signs of wear and tear, such as scratches (Wallner et al., 2022a). Furthermore, prior research has pointed out that consumers who are keen to find good financial deals and receive *good value for money* are incentivized to buy refurbished electronics because of their lower price (Chun et al., 2022; Mugge et al., 2017a). For these value-conscious people, a lower price might be the most important factor in determining their choice to buy refurbished electronics. Additionally, in a qualitative study, consumers who described themselves as *disgust sensitive* had more concerns about the hygienic and territorial contamination of refurbished personal care products (Wallner et al., 2022b).

2.4. Differences between product categories

Consumers are more willing to purchase refurbished technology products than personal care products (Mahmoodi and Heydari, 2021). Abbey et al. (2015a) distinguished between three different types of reused electronics that differ in the level to which they evoke consumers' contamination concerns and therefore determine their desirability in a refurbished state: *around-you electronics* (e.g. speakers), *on-you electronics* (e.g. headphones) and *in-you electronics* (e.g. earbuds). While reused around-you electronics evoke low levels of repulsion in consumers, reused on-you electronics and reused in-you electronics evoke high levels of repulsion and are therefore deemed unfit for reuse strategies (Abbey et al., 2015a). In contrast, other studies have indicated that some consumers are open to purchasing refurbished electronics that have been intimately used (Mugge et al., 2017b; Wallner et al., 2022b). For example, Mugge et al. (2017b) found that more than half of their interviewees were open to the idea of acquiring a refurbished electric toothbrush. This shows that with adequate incentives (e.g. a low price), some consumers may adopt refurbishment for product categories with high levels of contamination. How product categories with high levels of contamination can be made desirable to consumers and how this differs from product categories with low levels of contamination remains unexplored. In our research, we therefore aim to explore which factors influence the purchase intentions for refurbished electronics that differ in terms of how intimately they are used.

To summarize, consumers' decisions to purchase refurbished electronics are a complex process that involves the interaction of factors related to the refurbished *product itself*, the *marketing* and the *consumer*. While researchers have identified factors that might be at play in predicting the purchase intentions for refurbished electronics (Mugge et al., 2017a; Sharifi and Shokouhyar, 2021; Van Weelden et al., 2016), knowledge on how these factors interplay and which factors are most important is lacking.

2.5. The network approach

In this study, we address the aforementioned complexity by performing a network analysis of consumer characteristics and beliefs about refurbished electronics. In a network, different influencing factors – such as beliefs and consumer characteristics – are represented by nodes. Links between nodes, also called edges, represent their statistical relationship to one another (Newman, 2018). More specifically, an edge indicates a statistical relation between two nodes after controlling for every other node in the network as the network is based on partial correlations. These edges are weighted (between −1 and 1) and undirected (i.e. the direction is not indicated). Moreover, by including intentions to purchase as a node in an attitude network one can gain insights into which elements meaningfully predict behaviour (Dalege et al., 2016), such as buying refurbished electronics. Node centrality indicates the relative importance of nodes in the network, and illustrates the effect that influencing one node can have on the entire network. Node strength, a form of node centrality, can provide information on the predictive value of nodes in an attitude network (Dalege et al., 2017; Bringmann et al., 2019). To display the structure of the network, we used an algorithm that places clusters of connected nodes close to each other. Red (blue) edges indicate negative (positive) partial correlations and the width of the edges is proportional to the absolute value of the corresponding partial correlation (Newman, 2018).

A network analysis (Dalege et al., 2016) was chosen for our research because this approach allows us to capture the interactions between the beliefs about refurbished electronics involved in the decision to purchase refurbished electronics and thereby goes beyond predicting a single outcome measure, such as purchase intention. By using network analysis, the direct and indirect relationships between different factors influencing purchase intention of refurbished electronics can be visualized and interpreted. The added value of network analyses over other

approaches (e.g., regression analysis; Mugge et al., 2017a) is that networks provide visualisations of the (in)direct relationships between different factors and their interconnectedness. Thereby, network analysis is better able to capture the complexity of consumer responses than linear regression, which expects independent variables to be unrelated to each other. Furthermore, via a network analysis information is provided on the structural importance of the different factors, which may help to decide which factors are most critical in consumer response to refurbished electronics and should thus be considered by companies to improve their refurbishment practice. We can also note that network analysis is gaining interest in various fields including modelling social networks (Losee et al., 2022), climate adaption policies (Ingold and Balsiger, 2015), attitude formation (Dalege et al., 2016) and recently, in the area of sustainable consumption (Dalege et al., 2016; Verschoor et al., 2020; Zwicker et al., 2020; Zwicker et al., 2023). For example, Zwicker et al. (2020) used the network approach to determine factors that influence consumers' purchase intentions for bio-based plastic bottles.

3. Materials and methods

3.1. Choice of methodology and contribution

We conducted the network analysis for two reasons. First, we aim to provide an overview of factors involved in the purchase intention for refurbished electronics, including beliefs about refurbished electronics, their marketing and consumer characteristics and how they interact. Studies investigating consumers' purchase intentions for refurbished products have provided interesting insights on factors that linearly predict the intention to purchase refurbished products (Sharifi and Shokouhyar, 2021; Van Weelden et al., 2016). However, it would be interesting to have an overarching view on the relationships between factors to guide more detailed theory building and analysis. Thus, our second aim is to perform a network analysis that can yield a comprehensive understanding of these overarching relationships across different variables related to the refurbished electronics themselves, the marketing of refurbished electronics and the consumer. Networks are based on partial correlations, which allow the models to cancel out the effects that variables have on each other. Insights on how product-related factors, marketing-related factors and consumer-related factors interact can lead to more sophisticated strategies for how electronics need to be designed and marketed to have multiple life cycles. Additionally, by identifying which factors differ in predicting the purchase intentions for refurbished electronics in different categories, we hope to contribute to the understanding of how these strategies should differ between different product categories.

3.2. Choice of product categories

At the moment, refurbishment practices are well-established for certain product categories within consumer electronics (e.g., laptops, smartphones) but not for many others. For the transition to a Circular Economy and to significantly reduce the environmental impact of our consumption, it is important that consumers adopt refurbishment as a viable alternative for many different consumer electronics. As this research aims to offer valuable insights for the widespread implementation of refurbishment, we chose to investigate consumer adoption of refurbishment to some product categories that are less conventional, yet available for consumers in a refurbished state. This will give us an understanding of how consumers perceive refurbishment for these products and what risks they may experience that would need to be addressed via the product and service design. Furthermore, differences are likely to exist between different product categories, depending on their characteristics. One factor that was raised in prior research is the degree to which a product is believed to be personal or intimate to the consumer (Abbey et al., 2015a). Accordingly, in our research, we aimed to compare two product categories that would vary strongly on this dimension of use intimacy and are likely to differ in the factors influencing consumers' purchase intention. Based on the three categories of Abbey et al. (2015a; around-you products, on-you products and in-you products), we chose to investigate two electronic products that differ in the degree to which they are perceived as intimate (and thereby evoke different contamination concerns) but have similar functional values. Speakers (around-you product) are representative of a product category that is unlikely to be seen as very intimate. In contrast, earbuds (in-you product) are worn in close contact with the ear and are perceived as very intimate. We selected these two product categories based on a pre-test (see S3 and table S1 in the supplementary information for more details). In the pre-test ($n = 50$), we showed each participant a visual representation of an in-you product (earbuds), an on-you product (headphones) and around-you product (speakers). Subsequently, they rated the products' intimacy of use ("Please rate how intimately the following products are used"; 1 = Not intimate at all, 7 = Extremely intimate) and the degree to which the products evoked contamination concerns when bought in a second-hand state ("Can you please indicate how comfortable you would be to use the products below if these were second-hand?"; 1 = Not comfortable at all, 7 = Extremely comfortable, reversed). A repeated measures ANOVA showed that earbuds, headphones and speakers greatly differed in how intimate their use is perceived to be ($F(2,48) = 35.35$, $p < .001$) and the degree to which they are perceived to be contaminated ($F(2,46) = 50.19$, $p < .001$). We chose speakers and earbuds (see Fig. 1) because they had the highest mean differences in the intimacy of their use ($M = 2.68$, $SD = 1.84$, $M = 5.86$, $SD = 1.59$, respectively; $t(49) = 26.05$, $p < .001$) and their perceived contamination ($M = 2.10$, $SD = 1.27$, $M = 5.58$, $SD = 1.92$, respectively $t(47) = 8.71$, $p < .001$).

3.3. Participants

A detailed description of how we calculated the number of necessary participants can be found in S2 of the supplementary information. We used Prolific as a data collection service because this database has many members and is considered to result in higher quality data than other databases (Douglas et al., 2023). Prolific is also known to offer a wide variety of participants. This variety was important for our study as refurbishment can only reduce the environmental impact of consumption if many consumers perceive it as a viable alternative for new products. Accordingly, a broad sample with variety in terms of age, gender and education was needed to provide valid and generalizable findings. Furthermore, Prolific enabled us to gather a large sample, which is needed to perform a network analysis. To obtain a sufficiently large number of valid responses, we initially recruited 1896 participants. Seventy-six participants were excluded because they did not pass the attention check and 19 participants were excluded because their survey response time was under 2 min (Mtime = 5.2 min), resulting in a sample of 1801 participants to obtain a sufficiently large number of valid responses, we initially recruited 1896 participants via the data collection service Prolific. Seventy-six participants were excluded because they did not pass the attention check and 19 participants were



Fig. 1. Stimuli used in study.

excluded because their survey response time was under 2 min (M_{time} = 5.2 min), resulting in a sample of 1801 participants. Participants were compensated at a rate of £8.80/h on average.

Of these 1801 participants, 895 (49.4 %) were male, 899 (49.8 %) female and 7 (0.4 %) other, with ages ranging from 18 to 84 years old (M_{age} = 37.33, SD = 13.43). The majority of the participants had either a high school diploma (32.8 %) or a bachelor's degree (44.1 %). Eighteen per cent had a master's degree, 2.2 % had a PhD and 5.3 % indicated that they had completed another type of education. Most participants resided in the United Kingdom (72.1 %), on the European continent (12.5 %), on the American continent (7.4 %) or in South Africa (7.4 %); a minority resided in Japan, Korea, Israel, New Zealand and Australia (< 0.5 % each).

3.4. Procedure and measures

Upon clicking the link to the questionnaire, participants were first presented with an information letter which described the research topic, the amount of time the questionnaire would take (i.e., 5 min.), the fact that their data would be treated confidentially and anonymously and would be stored safely, and that there were no known risks for taking part, with the exception of a potential breach due to the online activity. Furthermore, contact details of the first author and of the data steward were given in case any questions would arise. Finally, based on a statement indicating that they had read the information letter, had the opportunity to ask questions, were taking part voluntarily and knew that they could withdraw from participating without any further explanation, participants were asked to provide consent for their participation in the study.

After providing informed consent, participants were shown a graph explaining the refurbishment process. Furthermore, refurbishment was clarified as follows: '*Refurbished products are recollected after their first use by a refurbisher. At the refurbishment facility, they are cleaned and tested. If necessary, parts are replaced, renewed or repaired. Then the product is sold by a retailer.*'

Depending on the condition they were randomly assigned to, participants were instructed to imagine themselves considering the purchase of either earbuds or speakers with the following statement: '*Please imagine yourself to be in the following situation: You are considering buying speakers/earbuds*' and were shown a visual representing this category (see Fig. 1). Next, they filled in a question about their purchase intentions for either refurbished earbuds or speakers. Here, we define purchase intention based on Dodds et al. (1991) as the willingness to purchase the product in the future when a need for the product category would arrive. Subsequently, we assessed their beliefs about refurbished earbuds or speakers in general. Beliefs that predict the purchase intentions for refurbished electronics were categorized into groups related to the retailer (trust in the brand and warranty), the perceived advantages (i.e. financial and environmental benefits), the perceived disadvantages (i.e. perceived risk, hygienic contamination, territorial contamination, utility contamination, expected obsolescence, lack of social status) and the product design of refurbished electronics (aesthetic attractiveness, durability, signs of wear and tear). To prevent fatigue in participants, we used single-item scores to assess the beliefs about refurbished electronics, as has been done in other network studies (e.g. Chambon et al., 2021; Zwicker et al., 2020). Finally, participants answered questions assessing their consumer characteristics (environmental concern, value consciousness and disgust sensitivity) and demographics, such as age, gender, nationality and highest level of education (high school, bachelor's degree, master's degree, PhD or other). All questions are based on validated scales and adapted to the context of refurbishment and were measured on 7-point Likert-scales (1 = strongly disagree, 7 = strongly agree). An overview of all items can be found in Table A1 in the appendix and the full questionnaire is provided as Supplementary information (S10).

3.5. Statistical analysis

We chose Mixed Graphical Models (MGMs; Haslbeck and Waldorp, 2020) as the network model because these explicitly allow us to include and model categorical variables, such as product category. Other network models, such as Gaussian Graphical Models (GGMs), assume that all variables are continuous-Gaussian, an assumption that is clearly violated when some variables are binary, as in our case. This is similar to the more common problem of predicting a binary outcome. Then, logistic regression is preferred over linear regression. In fact, MGMs are constructed by factorizing univariate members of the exponential family (such as Bernoulli random variables or conditional Gaussians), which means that the reasons for choosing MGMs over GGMs are the same as the reasons for choosing logistic regression over linear regression, when the predicted variable is binary. In addition, this class of models allows us to compare the two product categories in one statistical model without the need for additional post-hoc tests (Haslbeck, 2022). Table S2 in S4 of the supplementary information reports the relevant statistics for each of the nodes in the network (means, standard deviations and significance of mean differences for earbuds and speakers). Finally, we assessed the stability of the network via bootstrapping (Haslbeck and Waldorp, 2020) (see S8 in supplementary information). The network models are estimated with L1-regularized (lasso) nodewise regression as implemented in the R-package MGM (Haslbeck and Waldorp, 2020). The *mgm* package was used with default settings. In L1-regularized estimation the negative log-likelihood of the model is minimized together with a penalty that consists of the sum of the absolute value (i.e. the L1-norm) of all interaction parameters, which is weighted by a regularization parameter λ. The regularization term has the effect that all parameters are shrunk towards zero and small parameters are set to exactly zero. It thereby also performs edge-selection, which makes the additional use of hypothesis testing unnecessary (Hastie et al., 2015). By choosing a good regularization parameter λ, we achieve an optimal trade-off between model fit and generalizability (i.e. avoiding overfitting). Here, λ is chosen by 10-fold cross validation. The nodewise regression scheme yields two estimates for each partial correlation, which we combine with the OR-rule by taking the average of both estimates. The OR-rule is more liberal compared to the AND-rule, which requires that both estimates are nonzero and otherwise sets the overall edge to zero. We chose the OR-rule due to the exploratory nature of the analysis and because we report the stability of all estimates in S8 in the supplementary information. The code can be found in the supplementary information S9.

4. Results

4.1. Network of total sample

Fig. 2 shows the network of nodes related to refurbished electronics based on the total sample. The nodes represent consumer characteristics and the beliefs that participants have about refurbished speakers or earbuds. A complete overview of the edge weights for all networks can be found in the supplementary information (S5). In the following section, we describe the relationships between several selected variables and report their regression weights in parentheses. These variables were selected because of their importance (centrality) in the network, which is visualized by how central they are in the network and their link to the purchase intentions for refurbished electronics (Fruchterman and Reingold, 1991).

4.1.1. Node centrality

A graph displaying the importance (centrality/strength) of nodes in our network can be seen in S1 - Fig. S1 in the supplementary information. The nodes that ranked highest on centrality are the perceived risk associated with refurbished electronics, the purchase intentions, territorial contamination and the product category (condition). This

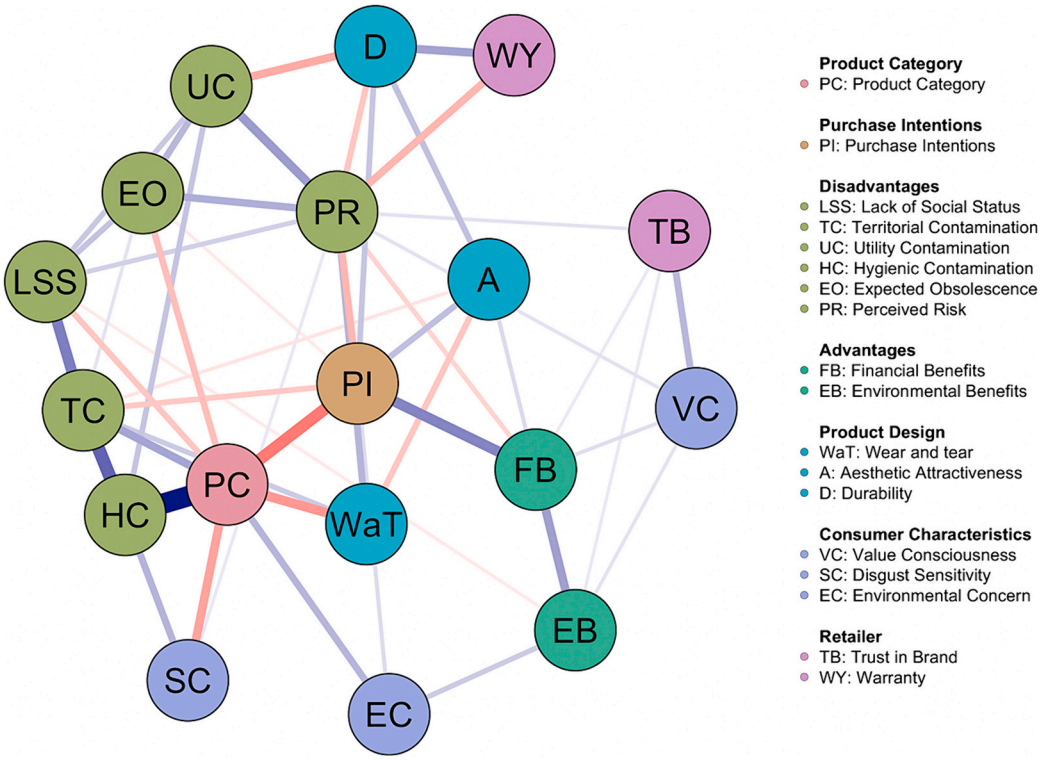


Fig. 2. Network of beliefs about refurbished electronics, their purchase intentions and consumer characteristics. Nodes represent the measured factors, and edges represent relations between these factors. Blue edges describe positive relationships and red edges describe negative ones. The strength of the relations is indicated by the colour intensity and edge width.

illustrates the importance of these nodes in the network. The centrality measure indicates that the most effective way to positively change beliefs about refurbished electronics would be to reduce the risks associated with refurbished electronics.

4.1.2. Nodes related to the purchase intentions for refurbished electronics

To explore which nodes are related to the purchase intentions for refurbished electronics and how these nodes are related to one another, we will elaborate on their edge weights (in parenthesis). The nodes with the strongest relationship with the purchase intentions for refurbished electronics are the financial benefits, perceived risk, territorial contamination and perceived durability of refurbished electronics.

If participants perceive refurbished electronics to be a financially attractive alternative to new electronics (0.28) and to be as durable (0.13) as new electronics, they have higher purchase intentions for refurbished electronics in general. Moreover, a weak edge indicates that environmentally concerned consumers are slightly more likely to purchase refurbished electronics (0.07). Participants are less likely to purchase refurbished electronics if they feel that refurbished electronics are a riskier choice (−0.18), are uncomfortable to use because they are reminded of the prior user (territorial contamination; −0.13) or will become technically obsolete in the near future (−0.05). Furthermore, we see that the product category is highly related to the purchase intentions for refurbished electronics. This indicates that the degree to which people are willing to purchase a refurbished electronic product depends on whether they are asked to consider refurbished speakers or earbuds (−0.32). This is also reflected in the average values of variables showing that the purchase intentions for refurbished speakers are significantly higher ($M = 4.71$, $SD = 1.82$) than those for refurbished earbuds ($M = 2.95$, $SD = 2.01$), $t(1799) = 19.54$, $p < .001$.

Before further elaborating on the differences between refurbished speakers and earbuds, we describe the relations of the four strongest predictors of the purchase intentions for refurbished electronics. The relationships between all other variables can be found in S5 in the supplementary information.

4.1.3. Relationships of the four most important nodes predicting the purchase intentions for refurbished electronics

Financial benefits are most strongly related to the purchase intentions for refurbished electronics. Whether refurbished electronics are perceived to be a financially attractive option compared to new electronics is positively related to their perceived environmental benefits (0.22), the attractiveness of the electronics' appearance (0.08), the expected product's durability (0.04), trust in the brand (0.04) and the consumer's value consciousness (0.07). The riskier refurbished electronics are believed to be, the lower the perceived financial benefit of buying them (−0.10).

Perceived risk involves participants' beliefs that they would lose time or money by buying refurbished electronics or run the risk of purchasing a refurbished product that does not function satisfactorily; the perceived risk is the second-largest predictor of the purchase intentions for refurbished electronics. Nodes that have a positive relationship with risk perception are the utility contamination (0.22), the expected obsolescence of the refurbished device (0.18) and the expectation that refurbished electronics show wear and tear (0.17). Perceived risk has weak positive relations with the perception that refurbished electronics lack social status, the need to look for a trustworthy brand (0.06), the consumers' value consciousness (0.06) and disgust sensitivity (0.05). Nodes that are negatively correlated with perceived risk are the belief that refurbished electronics have a sufficiently long warranty (−0.18), are durable (−0.14) and are a financially attractive option compared to new electronics (−0.10).

Perceived durability describes the belief that refurbished electronics last as long as new products. In addition to being related to the purchase intentions (0.13), it also has strong positive relationships with the belief that refurbished electronics have a sufficiently long warranty (0.21) and are as aesthetically attractive as new products (0.14). Perceived durability is negatively related to the perception that refurbished electronics

have a lower functionality (utility contamination; −0.20) and are a riskier choice (−0.14).

Experienced territorial contamination describes the belief of consumers that they would be reminded that the product was previously used by somebody else. Territorial contamination is negatively related to the purchase intentions for refurbished electronics (−0.13) and shows a weak relationship with the belief that refurbished electronics are less attractive (−0.06). Territorial contamination is highly positively related to the belief that refurbished electronics are unhygienic due to their prior use (0.36), participants' concerns that refurbished electronics lack social status (0.29), show signs of wear and tear (0.11) and are expected to become technically obsolescent soon after purchase (0.06). Furthermore, territorial contamination is also highly related to the product category, indicating that there might be differences between refurbished earbuds and speakers (0.20).

4.2. Comparing product categories: differences between refurbished earbuds and speakers

To compare product categories, we estimated a moderated network model, which is visualized in two graphs (Haslbeck et al., 2021). The weighted and undirected networks of both speakers and earbuds can be seen in Fig. 3. Fig. 3 shows that the strengths of the edges differ, which is visualized through the thickness and intensity of the colours. All edge weights can be found in the supplementary information (S6 and S7). To compare these networks, we first elaborate on differences in nodes relating to the purchase intentions for refurbished speakers and earbuds and then on differences in centrality.

4.2.1. Differences in factors related to the purchase intentions

The strongest positive relationship with purchase intentions for refurbished speakers is the belief that refurbished speakers are a financially attractive option compared to new speakers (financial benefits; 0.28). Purchase intentions show negative relations with the belief that refurbished speakers are a riskier choice (perceived risk; −0.18) and territorial contamination (−0.13). In comparison, the purchase intentions for refurbished earbuds are most strongly negatively related to concerns about the fact that the earbuds had belonged to somebody else (territorial contamination; −0.31) and that earbuds are unhygienic because of their prior use (−0.28). Financial attractiveness is the third most important relationship with the purchase intentions for refurbished earbuds (0.28). The purchase intentions for refurbished speakers and earbuds are both equally related to the product's durability (0.13) and the consumer's environmental concern (0.07).

4.2.2. Differences in centrality

The differences between refurbished speakers and earbuds are also reflected in the centrality of the network (for centrality plot, see S1 - Fig. S2 in the supplementary information). For refurbished earbuds, perceived hygienic contamination is the most central node in the network, whereas the strongest node for refurbished speakers is the perceived risk of refurbished speakers. Interestingly, the feeling that the product is uncomfortable to use because one is reminded of the product's previous use remains one of the most central issues for both refurbished speakers and earbuds.

5. Discussion

Prior research has identified factors that linearly predict consumer choices regarding refurbished electronics (Abbey et al., 2015b; Agostini et al., 2021; Chen et al., 2020; Mahmoodi and Heydari, 2021; Mugge et al., 2017a; Nasiri, 2021; Sharifi and Shokouhyar, 2021; van Weelden et al., 2016). However, consumer decision-making for or against refurbished electronics involves a complex interplay of product-, marketing- (Hazen et al., 2012; Mugge et al., 2017a; Wallner et al., 2022a) and consumer-related (Sharifi and Shokouhyar, 2021; Van Weelden et al., 2016) factors that influence each other (Wallner et al., 2021), which was not well understood. This study provides a novel contribution to this body of knowledge by demonstrating how beliefs about product, consumer- and marketing-factors influencing the purchase of refurbished products relate to each other and how much these are influential in consumer choice. Furthermore, while prior literature suggested that the psychological processes leading to consumer choice for refurbished products differ between product categories, these differences were not quantified (Abbey et al., 2015a; Mugge et al., 2017b; Wallner et al., 2022b). By comparing two product categories with different levels of intimacy, we add to the current body of knowledge and show how the interplay between the factors leading to purchase intention differs based on the product's degree of use intimacy. Understanding which factors are at play can ultimately facilitate theory building on the consumers' decision to purchase refurbished electronics and to develop sophisticated strategies for how refurbished electronics need to be designed and marketed.

5.1. Theoretical implications

To summarize, we found that the factors that were most strongly related to the purchase intentions for refurbished electronics were the product category, perceived risk and the perception that refurbished electronics are contaminated by their prior use (hygienic and territorial

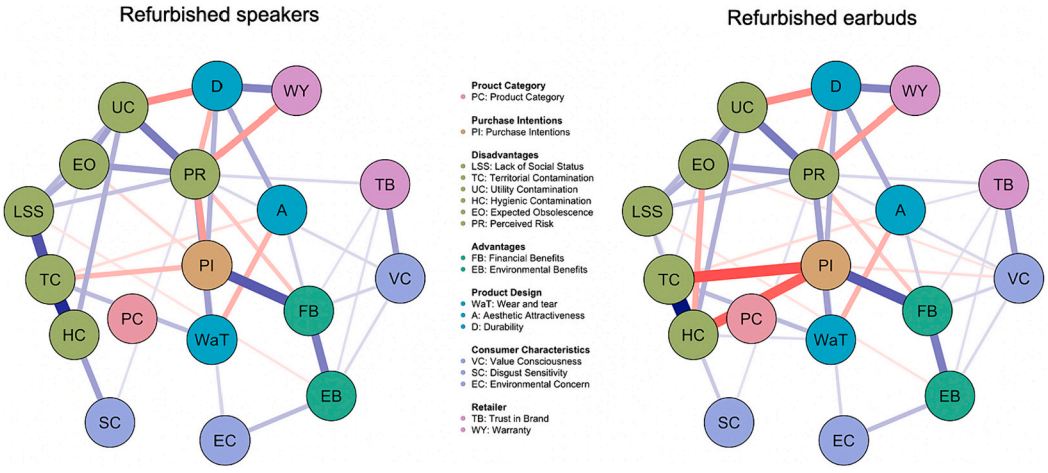


Fig. 3. The weighted and undirected networks of beliefs about refurbished speakers (left) and earbuds (right), their purchase intentions and consumer characteristics.

contamination). Hence, we argue that the most effective way to change beliefs about refurbished electronics for the positive would be to reduce the risks and contamination concerns associated with them. This is also reflected in the factors that relate to the purchase intentions for both product categories separately. Participants had higher purchase intentions for refurbished speakers than earbuds. This is in line with literature stating that consumers are less likely to buy reused electronics for intimate use because they feel repulsed by them (Abbey et al., 2015a; Mugge et al., 2017b; Baxter et al., 2017).

With refurbished earbuds, participants' concerns about territorial contamination (thinking about the fact that the product had belonged to somebody else) and that earbuds are unhygienic because they had been previously used were most strongly related to the purchase intentions. In comparison, the belief that refurbished electronics are financially attractive and the perceived risk were most strongly related to the purchase intentions for refurbished speakers. This is in line with research on refurbished smartphones showing that the financial benefits (e.g. Mugge et al., 2017a; Sharifi and Shokouhyar, 2021) and perceived risk were important in determining the choice for refurbished smartphones. However, territorial contamination had the third-strongest relationship with the purchase intentions for refurbished speakers. This shows that contamination not only plays a role in in-you products that are intimately used (Abbey et al., 2015a), such as earbuds, but is also an important factor in products that are barely touched (around-you products). Our study is hence the first to show that territorial and hygienic contamination have a quantifiable role in the purchase intentions for refurbished electronics. It furthermore adds to the literature by underlining the negative effect of utility contamination, the perception that the product has lower functionality due to its prior use. We hence argue that contamination concerns need to be added to existing decision-making models about consumer choice for refurbished electronics, such as the model proposed by van Weelden et al. (2016).

5.2. Practical implications

Prior research has often suggested the use of eco-labels as an effective strategy to enhance refurbished electronics' desirability among environmentally concerned consumers (Harms and Linton, 2016; Ihemezie et al., 2018). Confirming prior research (Harms and Linton, 2016; Mugge et al., 2017a; Wallner et al., 2021, 2022a), we also found that participants who were more environmentally concerned also had higher purchase intentions for refurbished electronics. However, our data suggests that environmental concern had only a weak association with the purchase intentions. Similarly, Khor and Hazen (2017) described that while green awareness might be a driving force behind consumers' initial purchase intentions of refurbished electronics, the actual buying behaviour is related to other factors. To conclude, this highlights that underlining the environmental benefits of refurbished electronics may not be the most effective way to increase consumers' purchase intentions for them. Similarly, research indicates that circularity labels can enhance consumers' willingness to pay for reused or refurbished products (Boyer et al., 2021); most consumers like refurbished products that are more "circular" when they have the same features as new ones. However, consumers are only willing to pay extra for products that have a little or moderate amount of circular content. But when the product is too circular (have been used more often), consumers' willingness to pay decreases because products are perceived to be riskier.

Based on our results, we suggest that strategies aiming to enhance consumer acceptance of refurbished electronics should, first and foremost, aim at reducing risks and contamination concerns related to refurbished electronics. Risk can be reduced in various ways including a good pricing strategy, warranty, fostering a good brand name and eco-labelling, thereby confirming the findings of prior research (Agostini et al., 2021; Mahmoodi and Heydari, 2021; Mugge et al., 2017a; van Weelden et al., 2016). The perceived financial benefits were strongly related not only to the purchase intentions but also to the perceived risk. If a product is cheaper, the risk of making a bad investment is lower and the financial incentive is higher.

Our data also suggests that in addition to the aforementioned strategies that are mainly aimed at marketing the product correctly, the role of the product is of great importance for enhancing the purchase intentions for refurbished electronics and reducing the risk associated with them. The perceived risk can be reduced by developing refurbished electronics that are durable and updatable from a functional perspective and which do not show signs of wear and tear after multiple lifecycles (Mugge et al., 2018b).

Furthermore, for both refurbished speakers and earbuds, the belief that refurbished electronics are a riskier consumer choice can be reduced by tackling contamination concerns. Territorial contamination is hard to reduce in refurbishment because refurbished electronics are second-hand by definition. Confirming prior research, we demonstrate that contamination (territorial) relates to the presence of signs of wear and tear (Baxter et al., 2015; Wallner et al., 2021; Wallner et al., 2022b) and refurbished electronics are more likely to be chosen with an attractive (as new) appearance (Wallner et al., 2022a). Future research could therefore explore what is more effective in reducing contamination: reducing the amount of signs of wear and tear or making products that age gracefully and remain attractive over time (Bridgens et al., 2015).

Moreover, utility contamination is related to the risks associated with refurbished electronics (confirming Baxter, 2017; Mugge et al., 2017a; Wallner et al., 2022b). Utility contamination concerns could be mitigated by ensuring optimal performance by replacing underperforming parts during the refurbishment process; this should, however, be done with care, as the more parts are changed during refurbishment, the greater the environmental impact. Another idea would be to simply manage consumers' expectations by being transparent about the estimated performance (e.g. battery capacity in smartphones) and by providing an estimation of how long the product was used and is estimated to last (van den Berge et al., 2022). Furthermore, consumers' concerns about refurbished electronics were related to the expectation that refurbished electronics would become technically obsolete soon after purchase. Concerns about electronics' obsolescence could be solved by making electronics upgradable (Mugge et al., 2017a). Our data also showed that there are differences between product categories depending on how intimate their use is. For products that are not intimately used, we suggest underlining the financial benefits of refurbished electronics and their guaranteed functionality, as this can decrease the risk of making a bad financial investment when buying an unsatisfactory product. For product categories that are intimately used, such as earbuds, we strongly recommend the additional step of counteracting consumers' hygienic contamination concerns. For those, we not only recommend eliminating signs of wear and tear to lower hygienic contamination (Wallner et al., 2022b) but also changing parts that touch the skin (Wallner et al., 2022a). To achieve this, refurbished earbuds need to have parts that can be renewed during the refurbishment process. This underlines the importance of not only marketing refurbished electronics differently, but also designing these in a manner that prevents contamination concerns.

5.3. Limitations and future research directions

In this study, we explored factors involved in the purchase intentions for refurbished consumer electronics with different levels of intimacy, but we only included refurbished speakers and earbuds. While we show that this comparison leads to differences in the extent to which perceived contaminations influence purchase intentions, it is also possible that other factors such as the price range, the frequency of use or the extent to which the product is used in a social context may lead to variations in the relationships within the network. For example, refurbished electronics which are frequently used or high-end refurbished electronics with a high price tag might be considered riskier and, as a

result, might be related to a lower perception that the warranty is sufficiently long than infrequently used or lower-end electronics, which may in turn lead to lower purchase intentions. Similarly, the worry that the refurbished product lacks status or that it is less attractive than a new one might be stronger for a product that is used in a social context than for a product that is used privately, which may in turn lead to stronger negative influences on purchase intentions. Another limitation is that our research focuses on consumer electronics. Future research should also include more categories that are purely utilitarian. It should be validated whether the underlying processes are the same or whether they differ depending on the use of the product. For example, for purely utilitarian products (e.g. tools), factors related to hygienic contamination might be less prominent, while factors related to utility are more important.

Arguably, the environmental improvement of refurbishing earbuds and speakers will only be limited in comparison to the complete market of consumer electronics. We would like to highlight that these categories only serve as exemplary categories for consumer electronics that are more and less personal and intimately used (Abbey et al., 2015a). Our insights can apply to other product categories that have similar characteristics in terms of intimacy and thus our impact is expected to go beyond these specific categories. Yet, the environmental footprint of the product categories used in this study was not considered during the selection process. It is important to note that while we emphasize that in a functioning Circular Economy, consumers must adopt refurbishment for most consumer electronics, refurbishment practices are presently still in development. In this trajectory and when targeting products for refurbishment, the environmental performance of products should always be considered (Harris et al., 2021). In this respect, innovative electronic products are often relevant (Bakker et al., 2014), but refurbishing products with a high environmental footprint first will lead to a fast substantial effect in the reduction of the environmental impact of electronic products consumption.

Furthermore, we only included 18 variables in our network. While this served the purpose of exploring the factors that are frequently mentioned in the decision-making process regarding refurbished electronics, not all possible factors could be included. For example, we did not include variables related to the consumer's culture (Chun et al., 2022; Gaur et al., 2019) or consumer's mindset (Gomes et al., 2022) or their moral values (Alyahya et al., 2023). Their prior experience with refurbished products was also not included in the factors tested in this study (Abdulla et al., 2023). One issue with refurbished electronics is that they require more effort for the consumer to buy because they are not always available or easy to find online. Future research could therefore add other factors depending on the product category and further validate our findings. Moreover, we only measured beliefs about refurbished electronics and how they relate to the purchase intentions for refurbished electronics. While this was sufficient for the exploratory nature of our research, it is unclear whether the factors we identified would lead to actual buying behaviour. Intentions do not necessarily lead to actual behaviour (Behaviour-Intention-Gap; Sheeran and Webb, 2016). It is therefore important to validate our findings by testing real purchase decisions. Finally, we would like to stress that we only considered statistical relationships. To establish causality between variables, one requires an experimental setup or additional assumptions required for causal inference (Peters et al., 2017).

6. Conclusions

Refurbishment is a key strategy to reduce an electronic product's environmental footprint by extending its lifetime. However, consumers have lower purchase intentions for refurbished electronics, which thus far has made them an unattractive business opportunity for manufacturers. This study contributes by providing an overview of the factors that relate to consumers' purchase intentions for refurbished electronics. With this exploratory work we hope to contribute to theory building on the consumer acceptance of refurbished electronics. Manufacturers could use these insights to design electronic products that retain their value over multiple life cycles and establish a promising market strategy for them that is both commercially relevant and creates a substantial environmental benefit.

CRediT authorship contribution statement

T.S. Wallner: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft, Writing – review & editing. J. M. B. Haslbeck: Conceptualization, formal analysis, coding, 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.

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Appendix A

Table A1
Items and scales used in the study.

Scale name	Item	Based on
	7-point Likert scale from 1 = strongly disagree, 7 = strongly agree	
Purchase intentions	If I were to buy speakers/earbuds, I would consider buying refurbished speakers/earbuds.	Dodds et al., 1991
Trust in brand	If I were to buy refurbished speakers/earbuds, I would look for a brand that is trustworthy	Grewal et al., 1998
Warranty	I believe that the warranty period of refurbished speakers/earbuds is sufficiently long.	Mugge et al., 2017a
Financial benefits	I believe that refurbished speakers/earbuds are a financially attractive alternative to new earbuds.	Mugge et al., 2017a
Signs of wear and tear	Refurbished speakers/earbuds probably show signs of use (e.g., have scratches on them).	
Environmental benefits	Refurbished speakers/earbuds are an environmentally friendly option.	Mugge et al., 2017a
Lack of social status	Buying refurbished speakers/earbuds, I would worry that the product lacks status.	Grewal et al., 2004
Aesthetic attractiveness	The look of refurbished speakers/earbuds is as attractive as the look of new speakers/earbuds.	
Durability	Refurbished speakers/earbuds last as long as new earbuds.	Grewal et al., 1998

(*continued on next page*)

Table A1 (*continued*)

Scale name	Item	Based on
	7-point Likert scale from 1 = strongly disagree, 7 = strongly agree	
Hygienic contamination	Refurbished speakers/earbuds are unhygienic because they have been previously used by somebody else.	Baxter et al., 2015
Utility contamination	Refurbished speakers/earbuds have a lower performance than new speakers/earbuds simply because they have been used by somebody else.	Baxter et al., 2015
Territorial contamination	Using refurbished speakers/earbuds, I would always think about the fact that they had belonged to somebody else.	Baxter et al., 2015
Expected Obsolescence	Buying refurbished speakers/earbuds, I would worry that they would be technologically out of date soon after the purchase.	
Perceived risk	1. I would consider buying refurbished speakers/earbuds as extremely risky in terms of how they would perform. [Performance Risk] 2. I am concerned that I would waste my time having to return dysfunctional refurbished speakers/earbuds. [Time risk] 3. I would worry to lose a significant amount of money, if I ended up with refurbished speakers/earbuds that didn't work. [Financial risk]	DelVecchio and Smith, 2005 Stone and Grønhaug, 1993 Van Weelden et al., 2016
Value consciousness	1. When shopping, I compare the prices of different brands to be sure I get the best value for the money. 2. When purchasing a product, I always try to maximize the quality I get for the money I spend. 3. I generally shop around for lower prices on products, but they must still meet certain quality requirements before I buy them	Lichtenstein et al., 1990; α =0.72
Disgust Sensitivity	In the next section, you will be asked to rate the extent to which you feel comfortable or uncomfortable about specific situations below. 1. Using a game controller that your friend, who has a cold, used before. 2. Touching the door handle of a public toilet. 3. Using a rental car of which the steering wheel is stained.	Based on Olatunji et al., 2012, and pre-tested α =0.79
Environmental concern	1. I make a special effort to buy products that are made from sustainable materials. 2. I have changed which products I use because of sustainability-related reasons. 3. I have avoided buying a product because it had potentially harmful effects to people and/or the environment	Kim and Choi, 2005, Mugge et al., 2017a α =0.88
Sex	What is your sex (male, female, other)	
Age	How old are you (number of years)?	
Education	What is your highest level of education? 1. High school 2. University Bachelor Degree 3. University Master Degree 4. PhD 5. Other	

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2024.03.009.

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