

GRACEFULLY AGEING PRODUCTS

**A practical toolkit on how to prevent
aesthetic obsolescence**

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"Designing products with the capability to deliver complex, enduring narrative experiences is not simply a matter of specifying materials that age well, although this is a part of it. Instead, provocative design concepts must emerge that challenge our social desire for a scratch-free and box-fresh world, illustrating how the onset of ageing could concentrate rather than dilute the experience of an object."

(Chapman, 2014, p141)

PREFACE

This thesis was written for designers seeking guidance on how to design products that age gracefully to stimulate product retention. It may also be of interest to researchers and practitioners in the fields of sustainable product design and material perception.

Looking back, the road to this thesis has been shaped by more than just academic work. During my bachelor's, a board year at my rowing club, an internship at WAACS, and restoring my fixer-upper home, I discovered my love for making and sustainability. Pursuing a Master's in Integrated Product Design in the city where I was born has felt like a full-circle moment. These years have challenged and shaped me, personally and professionally, for which I am deeply grateful.

This thesis combines several of my passions: prototyping, an ability to find positives in negative situations, and sustainability. The writing process came with its own challenges. At first, I lacked confidence in my academic writing and often felt uncertain about where to begin. Still, I committed to sharing an interim version at every graduation meeting, no matter how unfinished or imperfect it felt. (And yes, I still cringe when I look back at version one.) I will never forget Bas and Ruth's response after the greenlight meeting; their encouragement gave me the confidence to trust myself and helped me grow, not just as a writer, but as a designer.

I would like to thank my graduation committee for their guidance and support throughout this project. Bas, thank you for sharing your infectious enthusiasm for prototyping and making. Ruth, thank you for your critical questions, which pushed

me to reframe my ideas and reflect more deeply. Thank you both for helping me stay within scope and for showing me the importance of enjoying the process. Thank you also to Lise Magnier for stepping in for Ruth during the final stages.

A special thank you to my parents, Herman and Jodi, for supporting me when I needed it most. To my dear friends, thank you for your help in every form: from participating in creative sessions and proofreading my report, to offering a hug or making dinner when I needed a break. Finally, thank you to Wouter for your endless support, asking the right questions at the right time and believing in me. You helped me recognise the things I already knew, but had not yet seen.

Jet Polderman
Delft, July 2025

ABSTRACT

Cosmetic obsolescence, characterised by visible wear that diminishes a product's perceived value, contributes to premature replacement (Manley, 2018). While material ageing can add to a product's identity, practical guidance for designing products that age gracefully is lacking. This project focuses on how designers can use ageing and changing materials to stimulate product retention.

A research-through-design approach was employed. The literature on replacement behaviour and perceptions of material ageing was combined with user research and an observational study of worn headphones to form key takeaways. These takeaways guided ideation and prototyping for headphones that age gracefully. Design directions were generalised into early strategy principles and refined through an expert session, a creative session, and coach meetings. The scope of this project is limited to cosmetic obsolescence; functional strategies, such as modularity and repair, are excluded.

The resulting Design Toolkit for Gracefully Ageing Products (Figure 1) supports designers in addressing cosmetic obsolescence. It presents four strategies: Prevent (protect against wear), Heal (enable maintenance), Hide (camouflage wear), and Show (highlight wear as a value).

The final concept demonstrates the toolkit and integrates the four strategies into a coherent design called Scratch Art (Figure 2). The concept focuses on Show: A black coating wears away to reveal coloured scratches, redefining the perception of wear in plastic. It prevents dirt buildup at the cup-headband connection through a connection design

that reduces dirt accumulation. It heals through washable cushions that restore cleanliness. Lastly, it hides dirt with a patterned mesh that visually masks stains.

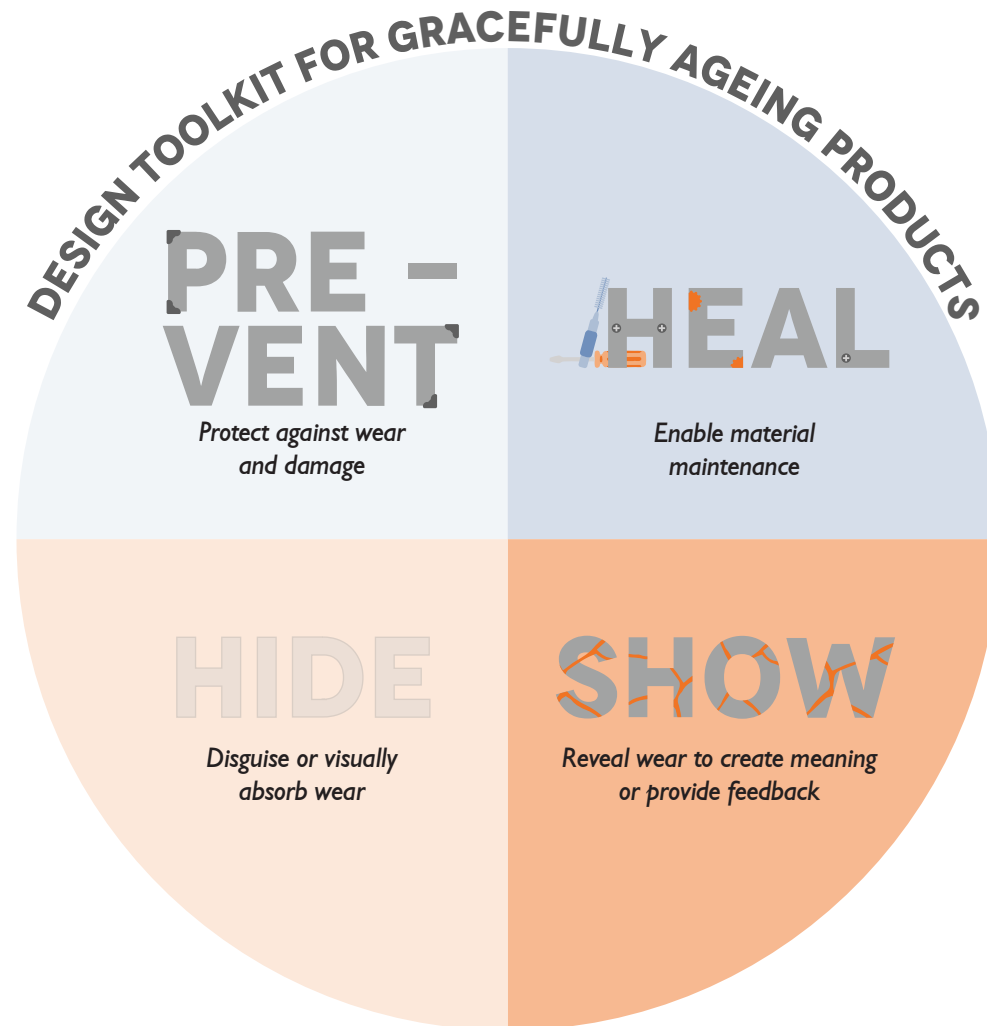


Figure 1: Newly developed Design Toolkit for Gracefully Ageing Products

SCRATCH ART HEADPHONES

Headphones designed with the Design Toolkit for Gracefully Ageing Products. They are designed to get scratched. With every scratch, a colourful layer emerges. Turning everyday use into evolving art and redefining the perception of wear in plastic.

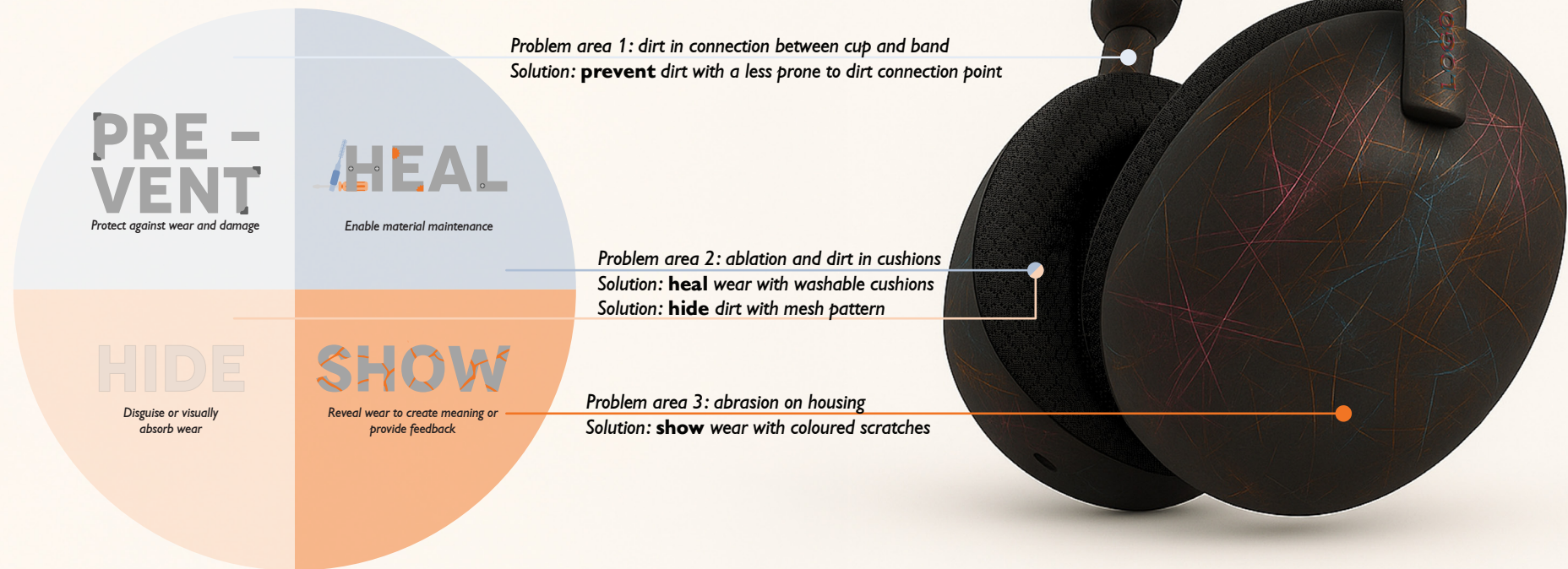


Figure 2: Final concept, Scratch Art, as a showcase for the toolkit

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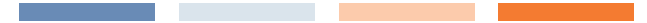
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1. INTRODUCTION

1.1 BACKGROUND AND PROBLEM

We live in a consumer-driven society where products are often discarded too early and replaced by newer models promising improved performance at lower prices (Lobos, 2014). As a result, people tend to value their possessions less and frequently dispose of them before their actual end of life. This phenomenon, known as premature obsolescence, refers to the early disposal of products that are still functional or require only minor repair (Magnier & Mugge, 2022).

From an environmental standpoint, such premature replacement is highly undesirable. It decreases resource efficiency, counteracting efforts toward sustainability. This is especially prevalent in electronics, where manufacturers may design products prone to failure, and consumers often opt for replacement over repair.

To reduce premature obsolescence, it is essential to maintain or enhance the perceived value of the owned product, which helps resist the attraction of new products on the market (van den Berge et al., 2021). However, this perceived value is not static; it changes over time (Mugge et al., 2023). Consumers often experience satiation, where repeated use diminishes enjoyment, making the product feel outdated or less desirable, even without any functional or aesthetic losses (Mugge et al., 2023; van den Berge et al., 2021).

While functional aspects have received considerable attention, the aesthetic value of products over a long time is often overlooked. Examples of functional aspects include

upgradability through Product Service Systems and reparability via the right-to-repair movement (European Parliament, 2024). Wear and changing trends can diminish the aesthetic value of a product, often leading to early replacement. Designers can utilise the Sustainable Aesthetics Strategy; however, more practical guidance is needed to follow the strategy effectively.

1.2 IMPORTANCE AND OPPORTUNITY

The Sustainable Aesthetics Strategy is a way of extending the product's lifetime. Extending product lifetimes and use cycles is a key strategy for increasing resource efficiency (Cooper, 2016, p. 20; Reuter & van Schaik, 2008; Richard Crompton, 2012). This strategy aligns with the principles of the circular economy, which promotes sustainable consumption and waste reduction (Jaeger-Erben et al., 2021; Tudor et al., 2021). By incorporating materials that change or age 'gracefully', products can maintain or even increase their perceived value over time, making material ageing an opportunity to reduce premature replacement (van den Berge et al., 2021).

By focusing on how materials change over time and how consumers perceive these changes, designers can explore new ways to keep products desirable for a longer period. This contributes to product retention, emotional durability, and ultimately, a more sustainable society.

1.3 MAIN QUESTION

This research explores how product design can support long-term product retention by focusing on materials that age gracefully. Specifically, it investigates the main research question:

How can designers use ageing and changing materials to stimulate product retention?

1.4 METHOD FOR THE STUDY

The study employs a Research through Design (RtD) approach, where knowledge is generated through designing and prototyping (Stappers & Giaccardi, 2014). Insights are gathered through literature research, consumer perception analysis, observational study, and iterative prototyping. Four research questions (RQ's) guide the main research question for this process (Figure 3).

1.5 SCOPE OF THIS PROJECT

This project emphasises the aesthetic value and graceful ageing of materials rather than functional aspects, such as repair or modularity. It focuses on a single household appliance to enable an in-depth exploration of how material ageing plays out in a practical design context. A headphone was chosen based on specific criteria derived from the literature and consumer relevance (Appendix B).

RESEARCH QUESTIONS

RQ1. How does material ageing influence the consumer's perception of the product?

RESEARCH QUESTIONS

Understand how ageing materials are emotionally and aesthetically evaluated

RQ2. How does the use context of a product influence the consumer's perception of aged materials?

Understand if and how the context of products influences material perception

RQ3. What types of wear and tear can be found in the selected household appliance?

Outline the problem areas

RQ4. How can the selected household appliance be redesigned to engage with material ageing and enhance long-term product retention?

Explore design strategies to support product longevity through material aging

Figure 3: Research questions and their respective research purpose

1.6 STRUCTURE

Design methods help structure complex and often messy design processes. One of the most well-known models is the Double Diamond model, which breaks the process into two main phases: Defining the problem and developing the solution (Design Council, 2005). Each phase includes exploring many possibilities (diverging) and then narrowing them down to a clear focus (converging). The report's structure follows a more linear path, while the project followed a messier, intrinsic design process structured by the double diamonds (Figure 4).

- Chapter 2 explores literature on replacement behaviour to define the scope of this project.
- Chapter 3 explores literature on material ageing to address RQ1.
- Chapter 4 presents the user research on their perception of aged products and addresses RQ2.
- Chapter 5 presents a systematic observation of 65 headphones to identify signs of wear and their locations, and addresses RQ3.
- Chapter 6 analyses and synthesises phase 1 (discover) into a toolkit for gracefully ageing products.
- Chapter 7 introduces design concepts developed through iterative prototyping and addresses RQ4.
- Chapter 8 presents the final concept as a showcase for the toolkit.
- Chapter 9 presents the user study on the perception of the final concept.
- Chapter 10 discusses the limitations of and recommendations for this project.

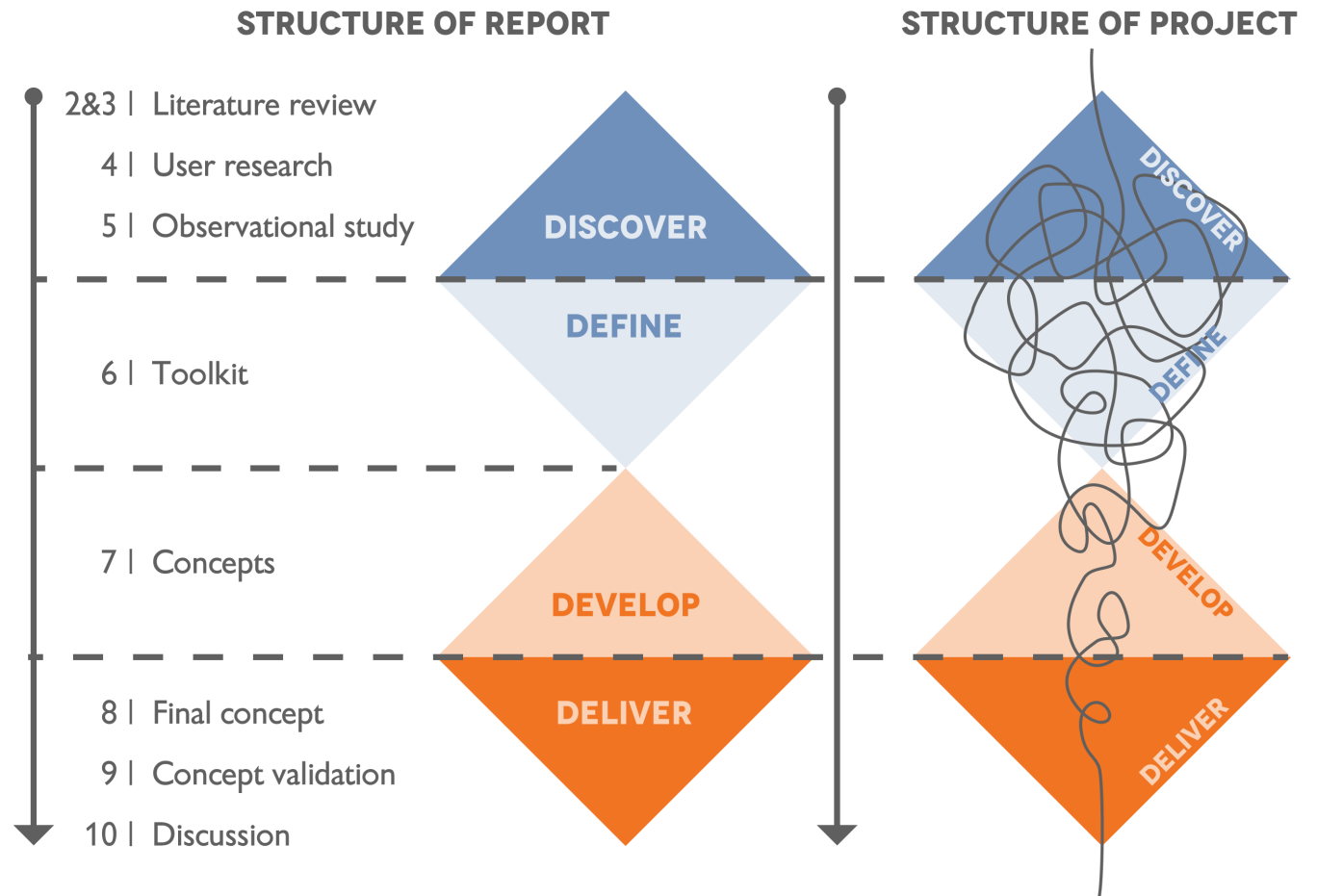
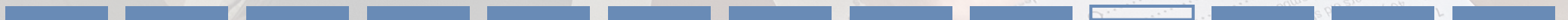


Figure 4: Structure of the report and the project

DISCOVER

Phase 1

This phase involved collecting insights, understanding the user and product, and identifying promising opportunities. It involves literature research on consumer replacement behaviour (Chapter 2) and ageing and changing materials (Chapter 3). It also includes user research on the perception of aged products (Chapter 4) and an observational study on wear in headphones (Chapter 5).



2. LITERATURE REVIEW ON REPLACEMENT BEHAVIOUR

Consumers do not simply replace products when they break. A complex interplay of values, such as functional performance, emotional attachment, curiosity for novelty, social context, and conditional circumstances, influences replacement behaviour (van den Berge et al., 2021). Understanding these values is crucial for determining how design can enhance both the perceived and actual lifespan of products. This chapter explores these motivations through a literature review. This chapter aimed to investigate what has already been researched and to outline the focus and scope of this project. Chapter 2.1 examines different types of obsolescence. Chapter 2.2 explores how design can respond to drivers of obsolescence by introducing Product Lifetime Extension (PLE) strategies that specifically address cosmetic wear. Chapter 2.3 presents the multiple layers of product aesthetics. The chapter is concluded in Chapter 2.4, and takeaways are mentioned in Chapter 2.5.

2.1 RELATIVE AND COSMETIC OBsolescence

To understand how to design products that people want to keep using over time, it is first needed to explore why people stop using them. Product obsolescence can be broadly divided into two categories: absolute and relative obsolescence (Haug, 2019).

- Absolute: a product physically breaks or stops functioning.
- Relative: the user no longer finds it appealing, or because newer, more attractive, or more advanced products emerge, even if the product still works.

A subset of relative obsolescence is cosmetic obsolescence. Cosmetic obsolescence refers to the visible degradation of a product's appearance, such as wear, discolouration, or outdated styling, that diminishes its perceived value (Manley, 2018). Unlike absolute obsolescence, this form is driven by aesthetic disapproval rather than performance decline. This form of obsolescence is increasingly relevant in consumer electronics and lifestyle products, which are often discarded due to their appearance rather than function (Bridgens et al., 2018).

A product's lifespan is a technical metric, such as durability or failure rate, and a subjective, user-determined period influenced by aesthetic judgments and emotional responses. Consumers often determine that a product has "served its time" not because it has ceased functioning, but because it no longer aligns with their identity, lifestyle, or sense of value (Haug, 2019). Because, while they prefer long-lasting, well-functioning products, the desire to fulfil their evolving needs is essential (van den Berge et al., 2020). In this sense, product lifespan is dynamic and personally constructed. This subjective perception is particularly present in lifestyle products and consumer electronics, such as headphones, where both functional issues (e.g., sound degradation) and cosmetic wear (e.g., damaged and dirty appearance) influence replacement decisions (Figure 5). Aesthetic degradation can act as an early trigger for emotional detachment, even when the product remains technically operational. This leads to 59% of users using headphones for less than a year (Figure 6).

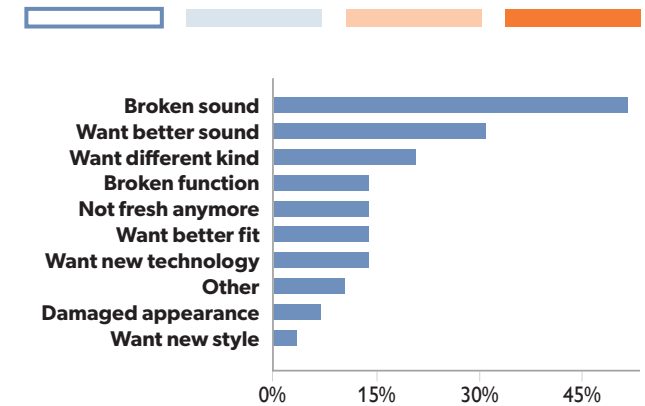


Figure 5: Reasons for end of use for the last bought headphones (Philipson & Wallner, 2018)

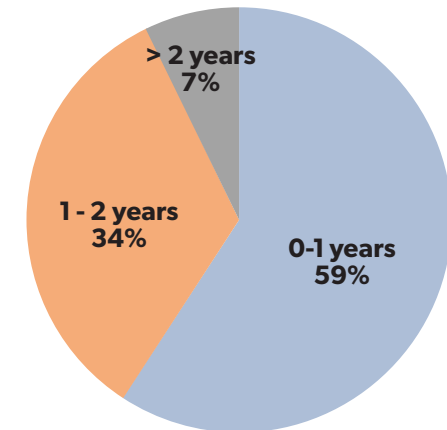


Figure 6: Usage time of the last bought headphones (Philipson & Wallner, 2018)

Various frameworks have been developed to categorise the causes of obsolescence, allowing for a systematic understanding of why users stop using otherwise functional products. Table 1 presents a summary of key studies compiled by Haug (2019). It illustrates the complexity and diversity of the causes of product obsolescence. Causes range from technical failure to aesthetic decline, lifestyle change, and evolving user identity. The bolded elements in the table highlight causes within this project's scope.

Table 1: Causes of product obsolescence, summarised by Haug (2019)

Source	Dimensions
Bayus (1991, 43)	1) Style; 2) Features and technological advantages; 3) Price and sales promotions; 4) Changed family circumstances; 5) Improved financial situation
Mowen (1995)	1) Technical condition; 2) Style; 3) Price and sales promotions; 4) Previous decisions; 5) Changed circumstances and aspirations; 6) Changes in financial situation; 7) Ageing ; 8) Physical or psychological changes
Heiskanen (1996)	1) Failure; 2) Dissatisfaction; 3) Change in consumer needs
Creusen (1998)	1) Practical function; 2) Ergonomic function; 3) Hedonic function; 4) Symbolic function
Van Nes et al. (1999)	1) Technical obsolescence; 2) Economic obsolescence; 3) Ecological obsolescence; 4) Aesthetic obsolescence ; 5) Feature obsolescence; 6) Psychological obsolescence
Cooper (2004)	1) Absolute obsolescence; 2) Relative obsolescence (a. psychological obsolescence; b. economic obsolescence; c. technological obsolescence)
Van Nes and Cramer (2005)	1) Wear and tear ; 2) Improved utility; 3) Improved expression; 4) New desires
Mugge et al. (2005)	1) Performance decrease (function and appearance); 2) Technological obsolescence; 3) Legislation change; 4) New features/technology; 5) Fashion; 6) Family/financial circumstances
Burns (2010, 45)	1) Aesthetic ; 2) Social; 3) Technological; 4) Economic
Hebrok (2014)	1) Changing life phases of users; 2) Use of materials that age poorly ; 3) Products that are difficult, time-consuming and/or costly in maintenance and repair; 4) Poor repair and maintenance services; 5) Missing knowledge about and motivation for maintenance and repairs; 6) Stylistic features that violate desired ones; 7) Negative emotional ties to a former owner
Haug (2017)	1) Product (a. Physical durability ; b. Physical resilience); 2) Consumer (a. Changing tastes ; b. Changing needs); 3) Supplier (a. Service limitations; b. Component limitations); 4) Technology (a. Construction-enabling technology; b. Product embedded technology); 5) New product (a. Products with similar qualities; b. Products with other qualities); 6) Competition (a. Overexposure; b. Bad publicity)

2.2 COSMETIC WEAR AND PRODUCT LIFETIME EXTENSION

Product Lifetime Extension (PLE) strategies offer a framework for addressing cosmetic obsolescence. These strategies range from improving durability to fostering emotional attachment and embracing material ageing. Table 2 presents a synthesis of cosmetic obsolescence factors and corresponding PLE strategies (Manley, 2018). Examining the PLE strategies in terms of cosmetic obsolescence reveals that sustainable aesthetics and product attachment best fit the scope of this project.

Sustainable Aesthetics: Encouraging materials and finishes that age gracefully or gain character over time, rather than deteriorate. This includes resilience thinking, which suggests that the most responsive to change will survive.

Product attachment: The level to which a product can elicit an emotional connection from the user. In the context of cosmetic obsolescence, this emotional bond plays a critical role in extending a product's use, even as its appearance changes over time. According to Manley (2018), product attachment is not only about how users feel emotionally (e.g., happy or sad). It also includes their attitude towards the product, for example, cognitive reactions such as liking, acceptance, or tolerance toward signs of ageing. This distinction is important: attitudes like *"I still like this even though it is scratched"* or *"I do not mind the fading because it shows it has been used"* can delay the decision to replace it. Users with strong attachment may reinterpret wear as part of the product's identity or history, rather than as a flaw. This highlights the

potential for design to support emotional and attitudinal resilience, encouraging users to maintain their relationship with a product beyond its initial pristine state.

However, there are gaps in the existing research on how designers can implement these strategies in practice, further narrowing the scope of this project. More practical tools for designers are needed to present resilience thinking.

Table 2: Comparison of product lifetime extension strategies and aesthetic obsolescence (Combined tables from Manley (2018)): Product attachment and Sustainable aesthetic strategies best fit the scope of this project.

Product lifetime extension Strategy	Description	Cosmetic obsolescence
Durability	Products that are designed to 'stand the test of time'	Expected resistance to material change
Re-use	Products designed for second/third lives or appropriated for second use in different contexts	Using objects that have previous owners and accepting the cosmetic appearance
Upgradability	Products designed to have 'upgrading' as part of ownership	Changing a product when it becomes cosmetically unacceptable
Variability	Products that are changeable in their appearance (external, but also internal)	Accepting the uniqueness of individual material changes that alter the cosmetics; the appreciation of imperfection in manufacturing techniques (Pedgley, 2009; Salvia et al., 2010)
Product attachment	Products are intended to engender an emotional connection to the user	Being attached to the cosmetic changes that occur over time; being attached to the cosmetic changes that occur through association (Chapman, 2005)
Timeless or Iconic design	Products that are resistant to fashion changes and potentially retain value (monetary, societal, fashion)	Products are appreciated because of a 'timelessness' in proportion, material quality, embedded significance of the aesthetic
Designed for repair	Products that encourage repair, servicing and maintenance	Repairing a part when it becomes cosmetically unacceptable
Sustainable aesthetic	Products that maintain or improve upon the quality of production, e.g. ageing gracefully	Materials are accepted as they age; objects and materials are resistant to material change, thus maintaining the way a product looked from new (Chapman, 2005; Walker, 1995)
Extended warranty	Products that are guaranteed for long/extended use	One user ownership and reassurance that technical obsolescence does not affect length of use

2.3 LEVELS OF PRODUCT AESTHETICS

To better understand how cosmetic wear leads to product replacement, this subchapter explores how aesthetics has been conceptualised in design research. Figure 7, adapted from Manley (2018) and based on Zuo (2003), outlines a hierarchical model of product aesthetics. This model categorises aesthetic experience into five interrelated levels: sensory, technological, functional, psychological, and cultural aesthetics. Each layer represents a different way users perceive and engage with a product. While technological and functional aesthetics are relevant in broader discussions of product experience, they fall outside the scope of this project, which focuses on how cosmetic wear impacts the more subjective, perception-driven aspects.

In the context of this project, the focus is primarily on cosmetic obsolescence, which is most directly related to sensory aesthetics, the outermost layer of product aesthetics. This level is most directly affected by cosmetic degradation, including scratches, fading, and other forms of wear and tear. When a product's visual or tactile qualities deteriorate, users often perceive it as worn out, even if it continues to function perfectly.

However, psychological and cultural aesthetics also influence how users interpret cosmetic flaws. Psychological aesthetics relate to the personal meanings, memories, or identities associated with a product. For example, users may overlook cosmetic damage if the product holds sentimental value or represents part of their self-image. Similarly, cultural aesthetics influence how people assess product

appearance based on shared values, social norms, or fashion trends; what is seen as “outdated” or “still stylish” is culturally determined (Zuo et al., 2003). The deeper layers help explain why some users may be more tolerant of cosmetic flaws.

In summary, while this project focuses on cosmetic changes that affect sensory aesthetics, these changes cannot be fully understood in isolation. Psychological and cultural aesthetics shape whether such wear is tolerated, accepted, or leads

to replacement. Therefore, acknowledging these interrelated layers enhances our understanding of how design can influence the perceived lifespan of a product and inform strategies for delaying obsolescence.

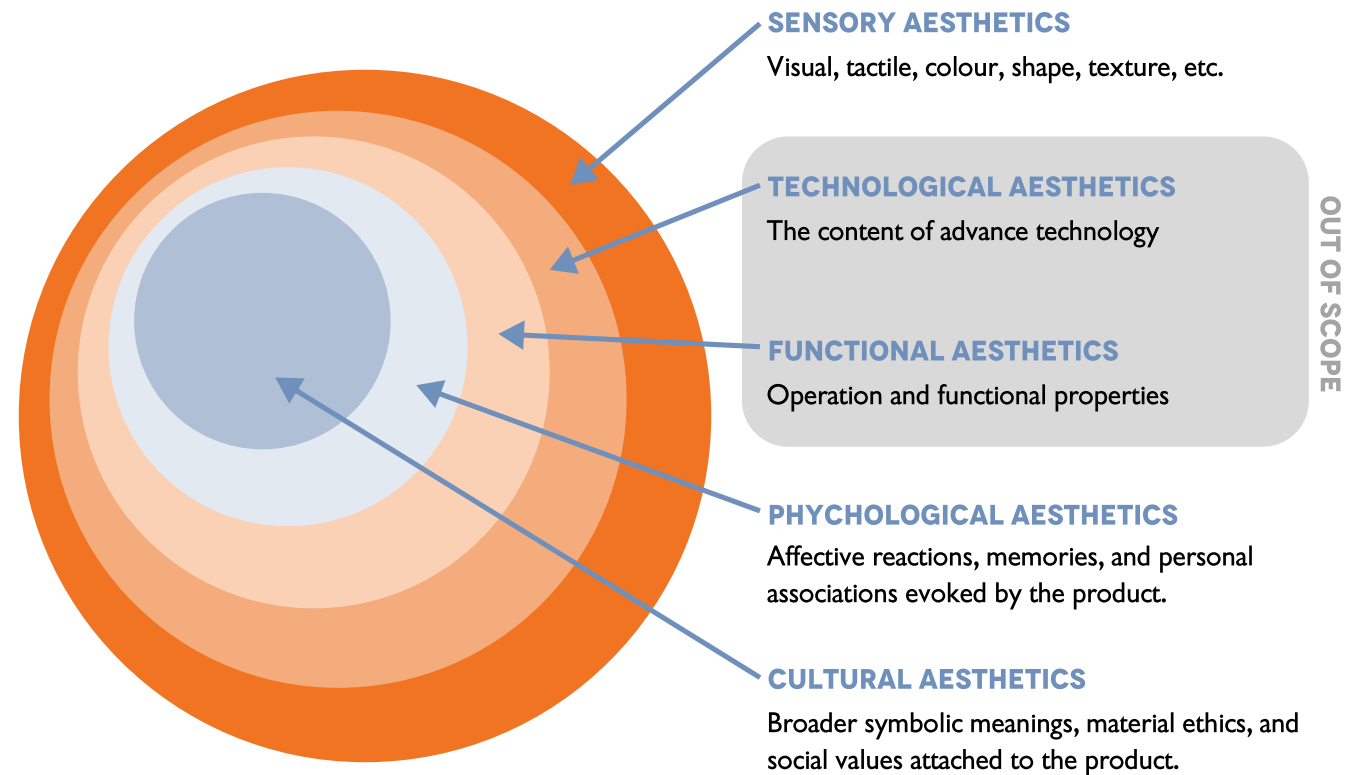


Figure 7: Levels of product aesthetics (adapted by Manley (2018) from Zuo, 2010)

2.4 CONCLUSION: CONSUMER REPLACEMENT BEHAVIOUR

Consumer replacement behaviour is driven not only by functional failure but also by more subjective and complex factors such as emotional and aesthetic perceptions. Cosmetic obsolescence, where a product is replaced due to visible wear or outdated styling, is apparent in headphones. Where, next to functional reasons, cosmetic reasons come into play when replacing.

This chapter has shown that such replacement behaviour is deeply tied to a product's sensory aesthetics and visual, tactile, and surface qualities. As these qualities degrade, users may detach emotionally or view the product as outdated, even when it remains functional. However, this challenge presents a design opportunity: instead of resisting change, products can be designed to age in a way that is perceived positively. This aligns with the Sustainable Aesthetics strategy, which proposes that wear and ageing can enhance rather than diminish a product's identity. Coupled with product attachment, which reinforces emotional resilience to cosmetic change, this approach can help extend product lifespans. This research does not address functional strategies such as repairability or modularity, as the focus is on the aesthetic and emotional dimensions of product longevity.

For this project, the scope is to implement these strategies in a practical manner. The aim is to guide designers in creating products that age well. Changing the mindset from *"it has served its time"* to *"it is evolving with me"* is key to stimulating product retention and countering throwaway culture.

2.5 SCOPING TAKEAWAYS

On the project's scope and aesthetic focus

- 2.1 The focus of this project is on cosmetic obsolescence.
 - Cosmetic obsolescence = the visible degradation of a product's appearance, such as wear, discolouration, or outdated styling, that diminishes its perceived value (Manley, 2018).
- 2.2 This project will focus on finding the "how" of the sustainable aesthetics strategy.
 - The sustainable aesthetics strategy encourages materials and finishes that age gracefully or gain character over time, rather than deteriorate.
 - More practical tools are needed to support this resilience thinking (the most responsive to change will survive)
- 2.3 This project focuses on sensory aesthetics (i.e., visual, tactile, and surface-related aspects) and psychological and cultural aesthetics (memories, associations, and symbolic meanings).
- 2.4 Wear and tear and reduced novelty are often the first triggers for emotional disconnection. Design should address ways to make this wear and tear less disruptive or attractive, and make the product feel new.
 - Finding what wear and tear is perceived negatively is the next step. Chapter 3.1 discusses this.

3. LITERATURE REVIEW ON MATERIAL AGEING AND PERCEPTION

Chapter 2 on consumer behaviour showed that cosmetic obsolescence plays a role in product replacement. This chapter delves deeper into how cosmetic and material changes shape user perception. As products are used, their materials inevitably change. Some materials are perceived as developing a 'graceful patina', while others show signs of wear that make them look damaged or obsolete (Bridgens et al., 2015). The line between positive and negative ageing is subtle, and the reasons are complex. However, they affect whether consumers feel emotionally attached to a product or inclined to replace it (Bridgens et al., 2015; Ranscombe & Blijlevens, 2024).

This chapter presents a literature-based exploration of how material ageing affects user perception. It aims to eventually answer RQ1, *"How does material ageing influence the consumer's perception of the product?"* It begins by exploring how signs of ageing can influence emotional attachment (Chapter 3.1). Chapter 3.2 focuses on how specific material characteristics are perceived. The chapter concludes in Chapter 3.3, and takeaways are mentioned in Chapter 3.4.

3.1 AGEING

This subchapter explores how wear and tear, often seen as damage, affects user perceptions and emotional connections with products. It examines the consumer and designer mindsets focused on pursuing perfection, and contrasts these with more positive approaches that embrace imperfection and 'graceful ageing'. By understanding these attitudes toward material ageing, this section highlights how ageing is perceived and how it can be reframed.

Wear and tear

Ordinary use inevitably introduces changes (Bridgens et al., 2018); this subchapter focuses on the negative sides of change. 'Wear and tear' is often interpreted as damage, which reduces a product's perceived value and likelihood of retention. According to the Cambridge Dictionary (2025b), wear and tear is the "damage that happens to an object in ordinary use during a period." Scratches on a smartphone, flaking paint on a bottle, or scuffs on furniture are not just physical marks; they signal ageing and are often associated with loss of value or hygiene (Harmer et al., 2019; Wallner et al., 2022). Figure 8 illustrates an example of an aged product with wear and tear that could be perceived negatively. As a result, many users begin to see the product as outdated or damaged. This perception can reduce people's emotional connection with a product, leading to replacement (Baxter et al., 2017).

The way wear is perceived depends on the product context. Signs of use may add value to products like leather bags or musical instruments, but are often seen as damage in electronics. This highlights the idea of "acceptable wear", where some signs of ageing are embraced, while others are rejected (Karana, 2012; Pedgley, 2014; Salvia et al., 2010). Chapter 4 delves deeper into the influence of product context on perception.



Figure 8: Plastic water bottle with mould on inside and scratches and flaking plastic on the outside

Pursuit of perfection

Consumers rarely consider how a product looks or feels after years of use, and designers often overlook its ageing process (Ranscombe & Blijlevens, 2024). This short-sighted focus on perfection contributes to unsustainable consumption patterns, where products are quickly discarded once they appear used (Spinney et al., 2012). We live in a “scratch-free world of slick polymers,” designed to remain visually pristine, but these materials often fail to live up to this ideal (Bridgens et al., 2018). Because product design rarely anticipates material change, the appearance of wear often feels like a failure rather than a natural transformation. This mismatch between expectation and reality leads to premature rejection (Lilley et al., 2019).

Both Walker and Bridgens et al. (2018) critique high-gloss, monochrome finishes, which make wear more visible and diminish user satisfaction. Bridgens et al. (2018) describe such finishes as creating a “sterile and lifeless aesthetic,” isolating the product from tactile and emotional engagement. However, Manley (2018) cautions that such judgments are context-dependent: while high gloss might seem cold on a smartphone, it may feel appropriate on a Swiss watch, for example.

The consumer mindset that a product “*is never going to be worth as much as soon as you take it out of the box*” reinforces the idea that ageing equals a loss of value (Manley, 2018). This mindset affects how products are valued and reinforces a consumption pattern driven by the pursuit of the “new.” As soon as they appear “used,” they lose their appeal, even if they remain functional (Hennies & Stamminger, 2016; Magnier & Mugge, 2022). As long as

product ageing is viewed as degradation rather than transformation, consumers and designers will continue to undervalue longevity and emotional durability.

Imperfection

Materials that embrace texture, variation, and surface complexity offer an alternative to the obsession with flawlessness (Manley, 2018). In contrast to high-gloss finishes that highlight wear as damage, materials with natural irregularities can hide or reframe signs of use. Rather than resisting change, designers can deliberately incorporate imperfection to enhance a product’s emotional value and longevity.

This way of thinking aligns with the Japanese philosophy of wabi-sabi, which sees imperfection as a source of authenticity and beauty (Figure 9). A material’s flaws, such as its irregular grain, uneven colouration, or tendency to change over time, can be seen not as defects but as features that enrich its story (Pedgley, 2014). Surfaces that invite touch, reveal their origins, or gracefully accept marks tend to become more engaging as they age. By leaning into imperfection, products can become more meaningful over time. Rather than chasing perfection or hiding signs of use, designers can celebrate the true nature of materials.



Figure 9: The art of imperfection, practice of kintsugi (Salie Leiden, 2025)

Proud plastics

The “proud plastics” movement encourages designers to express care and intention when working with synthetic materials (Hinte et al., 2004). Plastics are often perceived as lifeless or cheap because designers use them for the wrong reasons and without expressing appreciation for the material. Positive properties, such as low production cost and easy, high-speed processing, are not experienced directly by users. Hinte et al. (2004) argue that designers should use plastics for their unique performance qualities, including various colour options, thermal isolation, and flexibility. When designers are impressed and appreciative of a material, it can then be experienced by consumers as such.



Figure 10: Aged bronze with patina (Author's image)

Graceful ageing

Despite the negative associations with wear, some materials evolve in ways users value and cherish. ‘Graceful ageing’ refers to material changes that add character, tell stories, and deepen emotional connection (Karana et al., 2017). Rather than signs of damage, these changes are often viewed as enhancements reflecting use over time.

A common expression of graceful ageing is ‘patina’. According to the Cambridge Dictionary (2025c), patina is a thin surface layer that develops on something because of use, age, or chemical action. Materials like leather, brass, and wood can often develop such changes (Figure 10). It is a visible memory of use that is often viewed positively (Chapman, 2005). For instance, a bronze handle may darken where it is frequently touched (Figure 11), creating a unique fingerprint of ownership. Alternatively, the fretboard of a well-played guitar becomes worn under the player’s fingers, not as damage, but as a mark of skill and history (Figure 12). Similarly, statues in public spaces often develop shiny spots where people touch them repeatedly (Figure 13). Suggesting that wear can be informative of the use, and in some cases, desirable.



Figure 11: Used stair railing (Author's image)

These signs of ageing may also help explain why some worn products remain aesthetically appealing. As Ranscombe and Blijlevens (2024) suggest, patina development may introduce a subtle novelty to the product over time. This evolving appearance can offset users’ increasing familiarity with the design, helping to balance what feels typical and what still feels interesting. In this way, ageing may satisfy the consumer’s ongoing pursuit of the “new”, not by replacing the product, but by allowing it to change visually.



Figure 12: Guitar with a worn fretboard (Tdpri, 2018)



Figure 13: Statue rubbing (Author's image)

3.2 MATERIAL CHARACTERISTICS

This subchapter explores how different material characteristics influence the way consumers perceive ageing. It examines how the type of material (natural vs. man-made), its honesty or authenticity, and the nature of its transformation over time (gradual vs. sudden) shape whether wear is interpreted as damage or character.

Natural material vs man-made

Whether natural or artificial, materials significantly shape how their ageing is perceived. Natural materials like leather, wood, and stone are often praised for their “maturity” over time. This positive term of maturity is usually used for natural materials to explain the aesthetic and emotional value they gain as they age (Chapman, 2009; Fisher, 2004). Their imperfections become part of their identity, enhancing uniqueness and emotional value. In contrast, man-made materials such as plastic or coated composites are often expected to remain visually consistent. The result is often perceived as failure rather than character when they age. For example, a worn wooden chair might be seen as charming, while a worn plastic chair feels damaged. This expectation is rooted in assumptions about authenticity and durability, making natural materials more forgiving in how they age.

Maintaining vs deteriorating

Wood, leather, brass, bronze, copper, stone, ceramic and porcelain are known for their ability to age gracefully (Lefteri, 2014). However, without regular maintenance, these materials will deteriorate (Figures 14 and 15). For example, leather darkens and softens with conditioning, while wood

develops a richer tone when routinely oiled or waxed (Lilley et al., 2019). Deterioration, such as cracking, drying, or discolouring, results in losing their potential to develop desirable character. Research further shows that neglect often follows a perceived decline in emotional connection or relevance, increasing the likelihood of cosmetic wear and eventual replacement (Harmer et al., 2019; Jaeger-Erben et al., 2021). At the same time, care practices strengthen the user’s sense of ownership and value, encouraging longer use (Fisher, 2004; Mugge, Schoormans, et al., 2005). However, not all materials invite this kind of care. Bridgens et al. (2018) note that consumers feel that synthetics will not benefit from care.



Figure 14: Darkened leather with a crack (Author’s image)



Figure 15: Wooden chair left outside without maintenance, turning green over time (Author’s image)

Honest vs fake

Consumers often value “honest” materials, those that reveal their structure, origin, and potential for change. Bridgens et al. (2018) argue that material honesty supports emotional engagement by allowing users to anticipate and appreciate change. Real wood carries a sense of honesty and integrity, allowing for ageing that is perceived as beautiful rather than flawed. In contrast, fake or deceptive materials that hide their true nature can feel disappointing or inauthentic to users when flaws emerge. For example, laminated wood (Figure 16) can feel deceitful when the surface deteriorates and reveals something less desirable underneath (Lilley et al., 2019). This disconnect between expectation and reality can diminish the perceived quality and value of the product. Using materials that match their expected life cycle and do not mislead consumers about their authenticity enhances a product’s perceived value as it ages.



Figure 16: Peeling veneer on plastic (Author’s image)

Even imitation patina (Figure 17) or “pre-aged” products can feel inauthentic if users know the marks were not earned through use. Bridgens et al. (2018) caution that “performative imperfection” risks reducing genuine material expression to a stylistic gimmick, undermining user trust and long-term appreciation. An example is the “relic” guitar model (Figure 18): artificially aged instruments with fake scratches, faded lacquer, and simulated cigarette burns on the headstock. These factory-made guitars are marketed to resemble decades of use, often at premium prices. While these products may look worn, they undermine user trust and long-term appreciation. Thus, materials that communicate their vulnerability and transformation, rather than hiding or faking it, can turn ageing into a strength (Bridgens et al., 2018).



Figure 17: Imitated aged bronze with patina (Author’s image)



Figure 18 : Authentic (Paul, 2019) and imitation (The Guitar Colonel, 2025) Rory Gallagher Stratocaster guitar

Gradual vs sudden

How a material changes, not just that it changes, shapes the user's perception. Users tolerate, and sometimes appreciate, wear when it occurs gradually and blends into the material's character (Lilley, Smalley, et al., 2016; Manley, 2018). Because they unfold slowly, the users can emotionally and aesthetically adapt to the changes. These changes, such as a leather chair slowly darkening with use, can make a product feel more personal and lived in. In contrast, sudden or uneven changes, like a cracked seat or a peeled coating in one spot (Figure 19), tend to feel like damage, even when the product remains functional. Abrupt changes can disrupt the user's sense of control and reduce trust in the product's reliability. The difference in perception is especially clear in how users interpret the surface changes, rust versus patina. While patina is often romanticised as a marker of character, rust tends to symbolise decay and neglect. This line between positive and negative ageing is subtle but crucial. One classic car owner explains, *"I keep my classics long enough for them to show their age. They can grow old with me. However, if I see rust, I do everything I can to fight it."* (Peeters, 2020).



Figure 19: Crackling and peeling polyester plastic of a backpack (Author's image)

3.3 CONCLUSION: REPLACEMENT BEHAVIOUR

This chapter aimed to determine how material ageing influences the consumer's perception of the material. The line between positive and negative perception of aged materials is subtle, complex, and context-dependent. Ageing perception is tied to consumer expectations, emotional attachment, and other associations. We live in a world where consumers dislike wear and tear and want flawless, perfect, and new products. This unrealistic mindset of consumers is unsustainable. Designing for imperfection and showing appreciation for materials are alternatives to the impossible ideal of pristine products. Not all wear is perceived negatively; 'graceful ageing' refers to material changes that add character, tell stories, and deepen emotional connection. Materials that age gracefully, especially when supported through maintenance, can foster longer lifespans and stronger emotional attachment. When looking at products that age, users prefer natural, honest materials that change gradually over artificial or factory-aged materials. Ageing is not inherently good or bad, but it inevitably happens, which means that designers should design with ageing in mind.

3.4 TAKEAWAYS: REPLACEMENT BEHAVIOUR

Unrealistic expectations drive negative perceptions of wear.

- 3.1 Consumers often want flawless, new-looking products and view wear as a loss of value.
- 3.2 Consumers rarely anticipate how a product will look after extended use.
- 3.3 Wear in synthetic materials is often perceived negatively.

Not all wear is bad; graceful ageing adds value.

- 3.4 The line between desirable and undesirable ageing is subtle and context-dependent.
- 3.5 Imperfection can be a design asset, not a flaw.
- 3.6 Surface variation and irregular textures can make the product more authentic.
- 3.7 Designers can shape how wear is perceived by showing appreciation for materials, even synthetics.
- 3.8 Graceful ageing can add emotional depth, tell stories, and foster user attachment.
- 3.9 Graceful ageing and patina can add a sense of newness.
- 3.10 Natural and honest materials (e.g., solid wood, leather) are likely to age in a way that is perceived positively.
- 3.11 Regular maintenance (conditioning leather, oiling wood, polishing silver) enables desirable ageing; without it, materials degrade.
- 3.12 Encouraging care behaviours (e.g., maintenance rituals, cleaning, warranties) can promote emotional retention.

- 3.13 Authentically ageing materials are appreciated for reflecting use over time, reinforcing emotional connection and trust in the product.
- 3.14 Artificial wear or imitation patina can feel performative or disingenuous, reducing user trust and undermining long-term appreciation.
- 3.15 Gradual wear allows consumers to adapt to aesthetic changes emotionally.
- 3.16 Abrupt aesthetic changes can disrupt the user's sense of control and reduce trust in the product's reliability.
- 3.17 Designing with ageing in mind means accepting that change is inevitable and potentially desirable.

4. USER RESEARCH ON PERCEPTION OF AGED PRODUCTS

The previous chapter highlighted that the line between desirable and undesirable ageing is nuanced and context-dependent. While materials age differently, their perception is shaped by more than their physical properties alone. This chapter presents user research on how contextual factors influence consumer perception of aged products to address RQ2: *“How does the use context of a product influence the consumer’s perception of aged materials?”* Next to the contextual factors, more qualitative data was gathered on which elements of materials influence consumer perception. This resulted in richer insights on material ageing, building on the theoretical insights from Chapter 3. It begins by outlining the gap in existing literature that motivated this investigation (Chapter 4.1), followed by a description of the research method (Chapter 4.2). The findings are presented in three key themes (Chapter 4.3). The chapter is concluded in Chapter 4.4, and takeaways are mentioned in Chapter 4.5.

4.1 INTRODUCTION: USER PERCEPTION OF AGED PRODUCTS

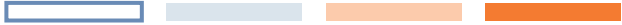
The way materials age can change the users’ perception of the products they are using (Ranscombe & Blijlevens, 2024). While existing studies (Bridgens et al., 2015; Lilley, Manley, et al., 2016; Manley, 2018; Veelaert et al., 2020) have primarily examined material ageing in isolation, often using material samples, less attention has been paid to how material ageing is perceived within the context of specific products. Although the participants in earlier studies could evaluate aged materials without considering the product they are part of, that does not mean that the context could not influence their perception. This study addresses that gap by exploring how consumers perceive aged materials as part of complete products from different product categories. This research distinguishes between three product categories:

- **Workhorse products**

Workhorse products are valued for reliability, are mainly discarded when broken, making aesthetic factors less relevant (Cox et al., 2013). These products are similar to static products (Mugge et al., 2017), which maintain their functionality over time and are less vulnerable to technological obsolescence. Products like charging cables and cutting boards, which serve their utilitarian function for many years without significant technological advancement, fall into this category.

- **Up-to-date products**

Up-to-date products are frequently replaced due to aesthetics or technological trends rather than functionality (Cox et al., 2013). These products are closely aligned with dynamic products (Mugge



et al., 2017), which are affected by technological advancements and are often discarded due to (planned) obsolescence. Examples include laptops and phone cases, which consumers replace not because they no longer function, but because newer models offer more features or improved design.

- **Investment products**

Investment products are valued for quality, longevity, and emotional or financial investment, and typically expected to age well both functionally and aesthetically (Cox et al., 2013). These products, such as premium furniture, are kept for extended periods and may gain value or personal meaning over time.

By embedding materials within real product contexts, the study identified which material features were appreciated or rejected and how those evaluations were shaped by the product type and its intended use.

4.2 METHOD: USER PERCEPTION OF AGED PRODUCTS

Ten participants (3 male, aged 17–62, Dutch) were recruited through convenience sampling to participate in in-depth semi-structured interviews. To ensure a range of perspectives, participants came from diverse educational backgrounds, from vocational (in Dutch: MBO) to university level. All interviews were conducted in Dutch, as this was the native language of all participants. During the interviews, each participant was presented with pictures of eleven used and aged products. The products were chosen because they varied in material (plastic, aluminium, steel, leather, cork, bamboo, wood), product category (e.g., workhorse, up-to-date, investment products), price point, and use context. This variety allowed for a rich exploration of which materials and product types evoked positive or negative perceptions of ageing. The selected products included a backpack, laptop, dresser, phone case, letterbox, wallet, coaster, belt, wrench, cutting board, and computer charger. As shown in Figure 20, each product was presented with an overview image and a close-up detail of the material surface. Labels indicated the age and type of material (e.g., “40-year-old wood”). Only real, naturally aged products were used, avoiding the artificiality of simulated wear seen in prior research. This approach was intended to capture participants’ reactions to material ageing within realistic, recognisable contexts. Additional interview materials, including the consent form, can be found in Appendix C.

The participants were asked to perform two tasks. First, they rated each of the eleven materials-in-products on a 7-point scale from “aged badly” (1) to “aged well” (7). After each rating, they were asked to clarify what aspects stood out, what specific details they found visually appealing or unattractive in the ageing process, and if the product category influenced their answer. This was done to determine their perception of the aged product and if the context influenced their answer. Second, the participants were asked to rank two personal products: one they believed had aged well and one that had aged poorly. This task encouraged

them to apply their perceptions to familiar, real-life objects, grounding their judgments in personal experience. Each interview lasted approximately 30 minutes and was audio recorded. Transcriptions were generated for all interviews and analysed using qualitative content analysis. This was done to identify key themes that illustrate how consumers perceive material ageing within the context of different products.

20 year old steel (staal)

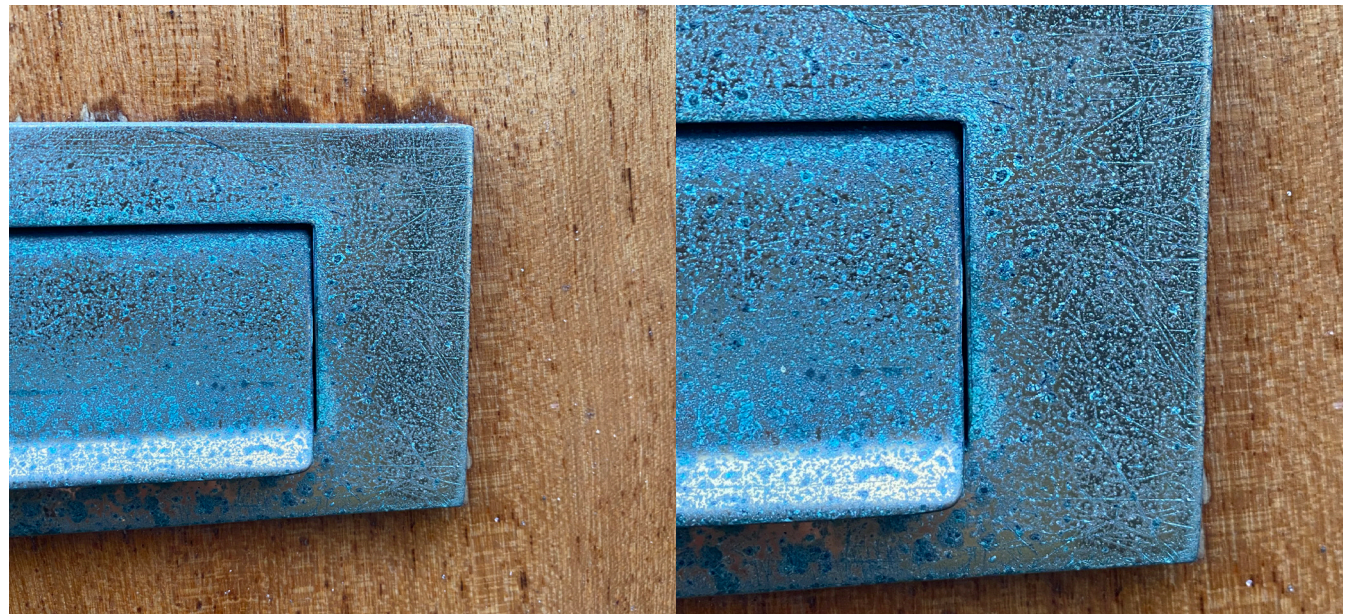


Figure 20: Example of presented product pictures

4.3 RESULTS: USER PERCEPTION OF AGED PRODUCTS

The findings showed three themes:

1. Perceptions of degradation vs enhancement

Participants distinguished between materials that degrade over time and those that can be improved or maintained. Plastic was commonly linked to deterioration, with participants describing it as prone to scratching and lacking aesthetic potential. One noted, “You will not have the same phone case in 20 years. The ageing per year is better with steel” (P5). Plastic was seen as offering no chance for restoration, as wear was equated with loss. This perception aligns with its relatively low rating scores (Table 3 and Figure 21).

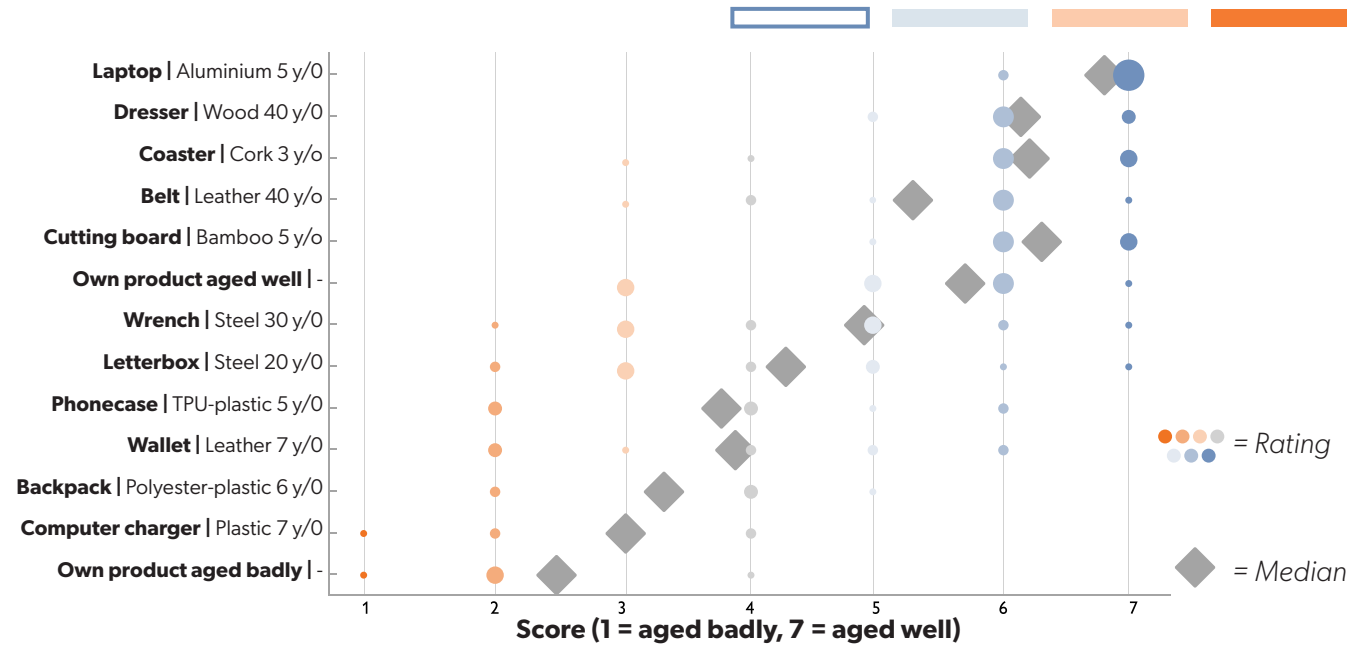


Figure 21: Visualisation of the participant ratings of aged products

Table 3: Heatmap of participant ratings for aged products (1 = Aged Badly, 7 = Aged Well), sorted by median score from worst to best aged appearance

Aged material appearance		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Median
Laptop	5 years old aluminium	6	7	7	6	7	7	7	7	7	7	7
Dresser	40 years old wood	7	6	7	7	6	6	5	6	5	6	6
Coaster	3 years old cork	4	7	6	7	7	6	6	6	7	6	6
Belt	40 years old leather	7	6	3	6	6	4	6	4	6	5	6
Cutting board	5 years old bamboo	6	7	6	6	7	6	6	5	7	7	6
Own product	Aged well	5	7	5	6	6	6	5	6	6	5	6
Wrench	30 years old steel	5	7	5	4	2	4	5	5	6	6	5
Letterbox	20 years old steel	5	7	2	5	5	2	4	4	6	3	5
Phonecase	5 years old TPU-plastic	6	4	2	6	4	3	5	2	4	2	4
Wallet	7 years old leather	3	5	6	6	4	5	4	2	2	2	4
Backpack	6 years old polyester-plastic	3	4	4	2	2	3	5	3	3	4	3
Computer charger	7 years old plastic	4	3	3	5	1	2	3	4	2	3	3
Own product	Aged badly	1	3	2	2	2	3	4	3	2	3	2

1 Aged badly
 2
 3
 4
 5
 6
 7 Aged well

In contrast with plastics, wear on wood, leather, and metal was not perceived with loss. These materials were described as capable of ageing gracefully or being rejuvenated. One participant reflected: *"If it had been in my house for 40 years, I would look past the scratches. If I were to buy it in this condition now, the scratches would bother me, but I would know that I could do something about it"* (P4). These materials were not only seen as durable and received the highest median rankings (Table 3) but also as possessing the potential for maintenance, repair, or even increased character through use. This sense of controllability, the belief that ageing could be managed or reversed, proved crucial in shaping acceptance. Participants were far less tolerant when wear was seen as irreversible (e.g., chipped plastic or cracked stitching).

2. Functionality and use context

Participants consistently interpreted the product's function first and then described their perception of the aged material within that context. A typical example was when a participant read *"20-year-old steel"* aloud and said, *"Okay, a mailbox. It is almost hard to tell that it is steel, it has a funny pattern nicely spread across the whole material."* (P4). Participants also prioritised functionality over aesthetics when evaluating aged products. Wear was largely tolerated if it did not interfere with use. This was especially evident in responses to workhorse products such as the charging cable and cutting board. *"I would only buy a new one if it stopped working,"* remarked one participant (P7). Conversely, wear that compromised function, such as cracks in a wallet that might allow coins or cards to fall out, was deemed unacceptable: *"If there are cracks in it, you might lose your money"* (P8).

Product function and social visibility also shaped perceptions of acceptability. As said above, *"Workhorse"* products like the wrench or cutting board were judged more leniently in their aged states. In contrast, participants were more critical of aged materials in products with expressive value or frequent public exposure, such as wallets or phone cases. For instance, in reaction to a worn phone case, one participant noted, *"If these were my headphones, I would really find it a shame"* (P9). These findings suggest that both product category and use context modulate consumer tolerance for visible material change.

3. Preferred, accepted, and not accepted characteristics

Participants expressed clear preferences for specific patterns and appearances of wear. Wear that was evenly distributed was generally interpreted as natural and non-disruptive. For example, one participant remarked: *"You cannot see the forest for the trees because of all the scratches, but in this case, that works positively, because of the gradual distribution of the scratches. In the end, the surface becomes even again"* (P9). In contrast, localised damage, such as isolated stains or worn patches, was often described as accidental or unattractive. As another participant explained: *"Here it is really one spot where it is worn off, that just makes it ugly. It would probably look better if it were a little everywhere"* (P6).

The material's surface structure also influenced perceived acceptability. Natural features such as wood grain helped to mask scratches, rendering them less noticeable visually. *"Because of the grain, the scratches are less visible. They disappear into*

the texture" (P2). By contrast, smooth and glossy materials like plastic were seen as less forgiving in terms of how they aged and how users expected them to age. *"With plastic, you see every scratch because it is so smooth,"* explained one participant (P6). Participants also noted that the perceived original intention of the plastic finish, perfect and shiny, made its visible ageing more jarring.

Forms of wear that suggested irreversible damage, such as yellowing, fraying, or cracked stitching, were typically linked to aesthetic rejection. For example, one participant observed, *"It really looks like it could fall apart. Then it does not matter if it is leather; if it is coming apart, it just looks broken."* (P7). These forms of wear were perceived not as signs of character, but as evidence of decline.

4.4 CONCLUSION: USER PERCEPTION OF AGED PRODUCTS

This study contributed to a better understanding of how consumers evaluate aged materials within the context of real, functional, and used products. The findings show that material perceptions are formed within the product's context. The product context forms how the wear is perceived and what the users expect. Aspects include the function, category (workhorse, up-to-date, and investment products) and visibility during use. Wear was tolerated in workhorse products as long as they remained functional. However, it was less acceptable in personal or expressive products, especially when it signalled damage or dirtiness. These insights highlight the importance of designing with both material behaviour and product context in mind to support more sustainable and emotionally resilient product use.

This research also reflected Chapter 3's theoretical insights into material characteristics. Some examples include the visual forgiveness of wood through its grains and the evenly distributed changes in steel. In contrast, wear on products originally intended to look smooth and shiny can appear visually jarring and unintentional. These specific elements, combined with the users' explanations for their perceptions, provided richer insights into the theoretical insights of Chapter 3.

4.5 TAKEAWAYS: USER PERCEPTION OF AGED PRODUCTS

On usage context

- 4.1 The product category and use context shape how the aged material is perceived.
- 4.2 Consumers assess wear based on what they consider normal or expected for that product's use and material. People are more critical of wear in expressive products or those used frequently in public.
 - Wear like discolouration and scratches were less accepted in headphones than in utilitarian products.
- 4.3 Wear is tolerated if it does not interfere with use, in utilitarian (workhorse) products.
- 4.4 Wear is more accepted when users feel it can be controlled or reversed.
- 4.5 Patterns or textures that visually absorb or diffuse wear (e.g., wood grain, brushed metal, speckled plastic) increase user tolerance.
- 4.6 Evenly distributed wear can blend in with the material's texture, making it less noticeable and natural.
- 4.7 Localised, patchy, or irregular wear is seen as accidental or unattractive, making it disruptive.

5. OBSERVATIONAL STUDY ON WEAR IN HEADPHONES

Visible signs of wear and tear can influence consumers' decisions to replace a product, even when it remains functionally intact. Such signs may create perceptions of ageing, reduced hygiene, or lowered performance quality, ultimately shortening the perceived lifespan of the product (van den Berge et al., 2020; Wallner et al., 2022). This chapter presents the observational study on wear in headphones to address RQ3, *"What types of wear and tear can be found in headphones?"*. This research aims to find out what the problem areas are. These problem areas are used in Chapter 6 to guide the toolkit creation and in Chapter 8 to determine the strategy applied to each part of the final headphone.

It begins by outlining background information on the current state of headphones and wear types (Chapter 5.1), followed by a description of the research method (Chapter 5.2). The findings are presented in three key themes (Chapter 5.3). The chapter is concluded in Chapter 5.4, and the takeaways are stated in Chapter 5.5.

5.1 BACKGROUND AND CURRENT STATE OF HEADPHONES

This section maps the materials in headphones, how they are used, and which types of wear are relevant to this study. Understanding these aspects provides a basis for identifying where and how signs of wear develop.

Headphones are mainly made of polymers, metals, and electronics (Herrmann et al., 2023) (Figure 22). As discussed in Chapter 3, these materials show

wear differently and evoke different perceptions as they age. Most headphones are in direct contact with the user's skin, are frequently used outdoors, and are often stored without a case (Manley, 2018). Manley's study (2018) showed that 82% of users do not use a case when transporting their headphones. These use patterns (Figure 23) expose headphones to friction, sweat, dirt, and mechanical stress.

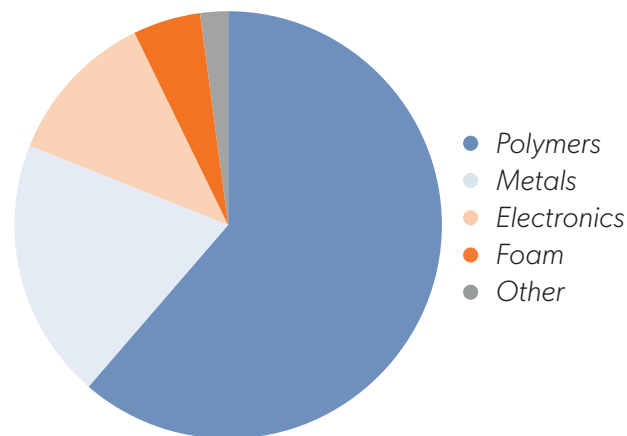


Figure 22: Materials used in headphones (Herrmann et al., 2023)



Figure 23: Regular use scenarios that can cause wear in headphones

Manley (2018) introduces a taxonomy of wear to categorise different types of damage or changes (Table 4). The framework outlines four primary types of wear, each with different causes and consequences. Figure 24 visualises the different types of wear in an iPhone; these types are frequently perceived negatively as damage rather than character.

Table 4: Taxonomy of wear by Manley (2018)

Type of wear	Description	Causes	Leads to
Ablation	Chipping of the surface or the removal of material	Wear over time, friction, or minor impacts	Loss of protective coatings, exposure of underlying material, rough or uneven surfaces.
Abrasion	Scratching and rubbing that wears down a surface over time	Repeated contact with rough surfaces or handling	Surface damage, loss of texture and finish.
Accumulated dirt	Build-up of dust, oil, or other substances on surfaces	Regular use, exposure to environment, lack of cleaning	Aesthetic deterioration, hygiene concerns, potential impact on functionality (e.g., clogged ports).
Impact	Deformation or cracking of material due to a drop	Accidental drops, knocks, or pressure	Structural damage, reduced functionality, potential breakage.

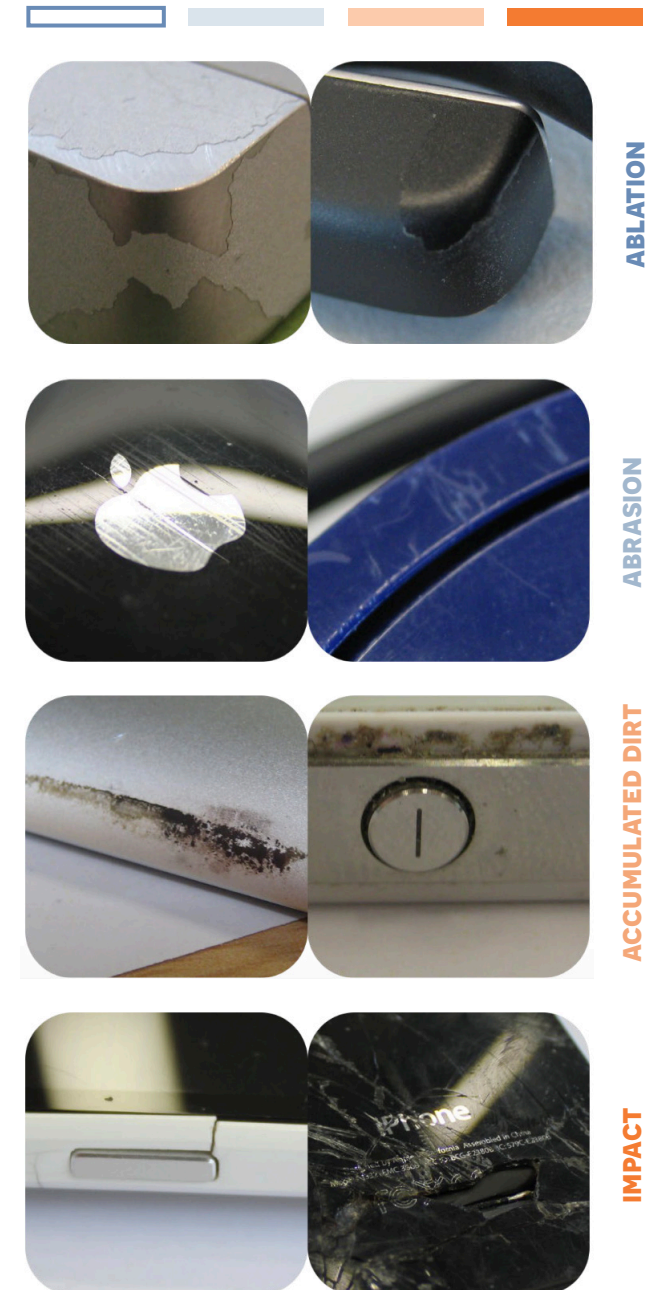


Figure 24: Types of wear in an iPhone (Manley, 2018)

5.2 METHOD: HEADPHONE WEAR

STUDY

65 Participants (36 male, ages not recorded) took part in the observational study of used headphones. The participants were recruited via convenience sampling at a public library on the TU Delft campus and through snowball sampling in student WhatsApp groups. As a result, the sample mainly consisted of young adult university students. In-person participants at the library were asked for permission to photograph their headphones. Overview images were taken from the front, back, and side, along with close-ups of specific components such as the headband, ear cups, cushions, and connection points (Figure 25). Participants on WhatsApp were asked to send the images on a neutral background.

Because the study focused on used headphones, three short questions were included to map how intensely the products were used over time.

1. How old are the headphones?
2. Did you ever replace the cushions?
3. How often do you use your headphones?

Answers to the questions were noted during face-to-face conversations or sent via WhatsApp.

The wear analysis was conducted by observing all 65 headphones (Figure 26) and documenting the type of wear (ablation, abrasion, accumulated dirt, impact) on each part (cup, headband housing, connection, cushion, headband soft, and cord). The raw data was then put into a frequency table to see how the types of wear were distributed over the parts.



Figure 25: Example of pictures taken



Figure 26: All 65 observed headphones

5.3 RESULTS: HEADPHONE WEAR STUDY

The analysis of 65 used headphones, with a median age of 3 years, revealed patterns in the types and locations of wear and tear. Table 5 reveals the frequency of observed wear types by headphone parts, and Figure 27 presents these data as bar charts. The most common types of wear were ablation (e.g., peeling of synthetic leather), abrasion (e.g., scratches on the plastic housing), and accumulated dirt. Figure 28 visualises the placement of the different types of wear in headphones. Together, these findings highlight three main problem areas, which are discussed in the following section.

Table 5: Frequency of observed wear types by headphone parts in 65 used headphones. The coloured-in data forms the problem areas.

Part / Wear Type	Ablation	Abrasion	Accumulated dirt	Impact
Cup	3	36	9	0
Headband housing	3	13	3	1
Connection	1	2	23	0
Cushion	25	0	29	0
Headband soft	18	0	14	0
Cord	0	0	1	0

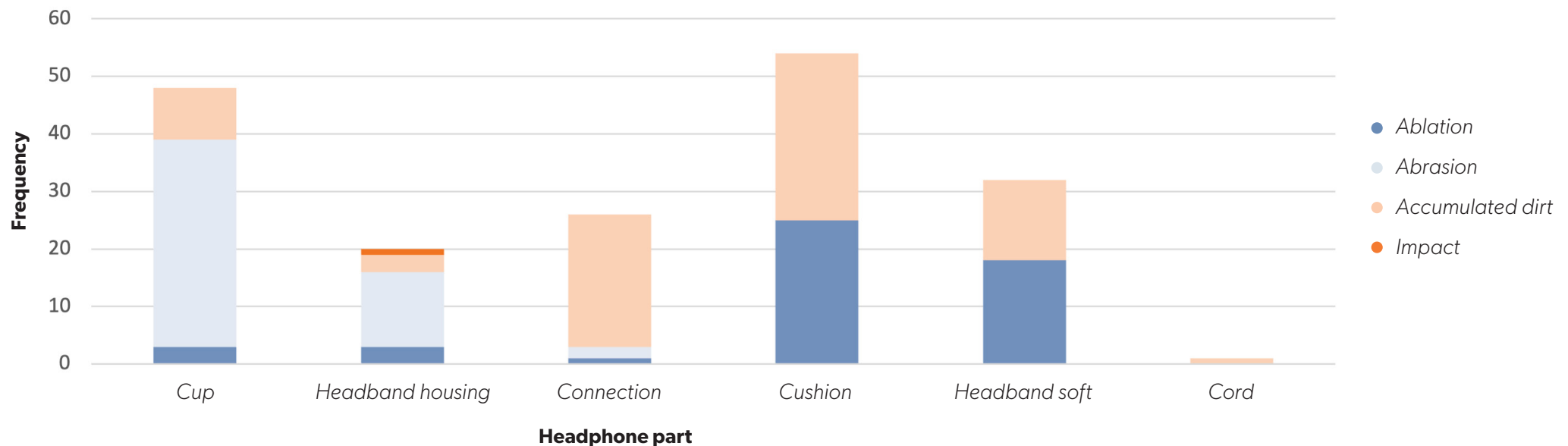


Figure 27: Wear types in headphone parts



Figure 28: Most common placement of wear types visualised

The observation showed three problem areas:

1. Abrasion on the housing

Abrasion was primarily present in the hard materials of the headphones, which often consisted of plastic cups and headband parts. Abrasion was more noticeable on cups and headbands with a glossy finish (Figure 29).

2. Accumulated dirt on the cup-headband connection

Accumulated dirt was particularly present in crevices around the cups, cushions, connection, and the soft headband, suggesting that these areas are harder to clean and more susceptible to dirt (Figure 30).

Impact-related wear was observed only once, though the reason for this remains unclear. It could be that headphones showing impact were discarded earlier, or that headphones do not break easily during impact.



Figure 29: Abrasion in cups with glossy, semi-gloss, and matt finishes



Figure 30: Accumulated dirt in the connection points between the cup and the headband

3. Ablation and dirt on the cushion and soft headband

Ablation was primarily observed in the cushion and soft headband (Table 5), often made from foam with faux leather. Ablation signs, such as cracking and peeling, were apparent on 25 of 65 cushions (38%). Cushions from another six had already been replaced and did not show signs of wear, while two cushions that had been replaced previously did show signs of wear again. This indicates that cushions are prone to developing signs of wear. Often, the cushions were in worse condition than the rest of the headphones, which made the overall appearance appear worse (Figure 31).

5.4 CONCLUSION: HEADPHONE WEAR STUDY

This study reviews wear types and their locations in 65 used headphones. It builds on earlier research showing that visible wear can trigger product replacement, particularly when linked to hygiene or performance (Wallner et al., 2022). The goal was to identify the types of wear in headphones. The observation showed three problem areas. Made primarily of plastic, abrasion (scratching) and dirt were frequently observed in the housing, especially on glossy surfaces, where scratches were more visible. At the connection points, accumulated dirt was prevalent, suggesting these areas are difficult to clean. Ablation (peeling and flaking) and accumulated dirt were most observed in the soft parts, which often consisted of foam coated with faux leather prone to peeling and cracking. In 38% of cases, cushions showed signs of ablation, and many had already been replaced, indicating a high wear risk. The final design later (Chapter 8) tackles these three problem areas.

5.5 TAKEAWAYS: HEADPHONE WEAR STUDY

Problem areas

- 5.1 Abrasion is frequent on plastic housing parts.
- 5.2 Accumulated dirt was a problem between the headband and the cups, especially when the connection part had hooks and crevices that hindered easy cleaning.
- 5.3 Ablation and accumulated dirt can often be found in the soft parts of the headphone.

Not all wear is bad; graceful ageing adds value.

- 5.4 Deteriorating cushions made the overall headphones look worse.
 - Even though repairability and modularity are out of scope, faux leather cushions do not age well and need a solution.
- 5.5 Accumulated dirt was more apparent on white or light-coloured parts

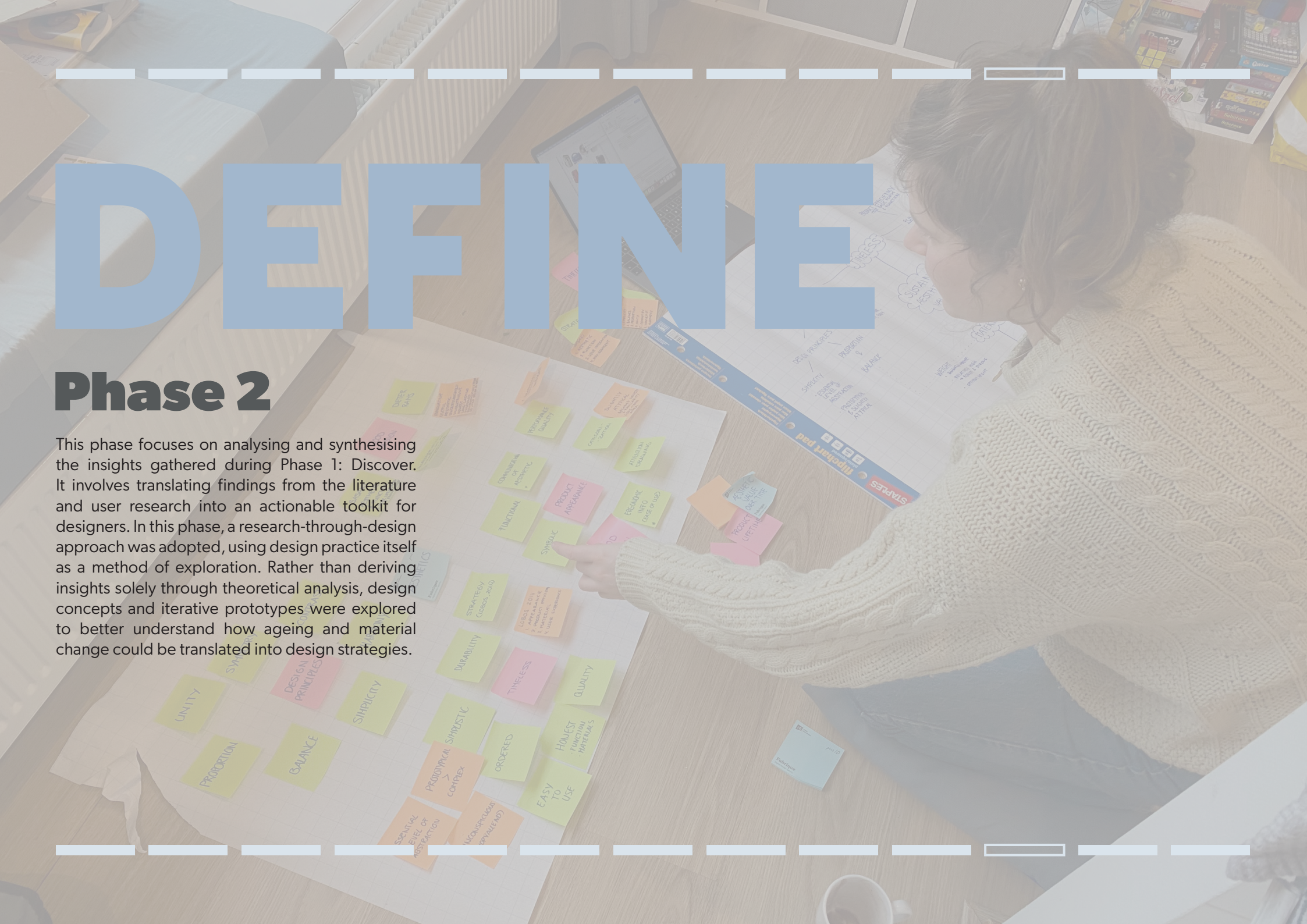


Figure 31: Examples of cushion ablation contributing to a worn appearance of the headphones

DEFINE

Phase 2

This phase focuses on analysing and synthesising the insights gathered during Phase 1: Discover. It involves translating findings from the literature and user research into an actionable toolkit for designers. In this phase, a research-through-design approach was adopted, using design practice itself as a method of exploration. Rather than deriving insights solely through theoretical analysis, design concepts and iterative prototypes were explored to better understand how ageing and material change could be translated into design strategies.



6. A TOOLKIT FOR GRACEFULLY AGEING PRODUCTS

This chapter presents the main outcome of this research: a Design Toolkit for Gracefully Ageing Products. It synthesises the insights from previous chapters into a practical framework that supports designers in addressing cosmetic obsolescence. The toolkit was designed to answer the main question of this study: *“How can designers use ageing and changing materials to stimulate product retention?”* As established in Chapter 2, sustainable aesthetics refers to designing products whose appearance evolves meaningfully or appealingly, thus encouraging long-term use. The products most responsive to change will survive. However, there are multiple ways designers can tackle this problem.

Chapter 6.1 describes the process behind developing the Design Toolkit for Gracefully Ageing Products. The core of the toolkit is formed by four design strategies: Prevent, Heal, Hide, and Show, which are discussed in Chapter 6.2. These strategies were validated during a creative session, which is discussed in Chapter 6.3. Examples of existing products that align with each strategy are presented in Chapter 6.4. Chapter 6.5 translates the research’s takeaways into specific design requirements, organised according to the four design strategies. The chapter is concluded in Chapter 6.6.

6.1 THE DESIGN TOOLKIT PROCESS

The Design Toolkit for Gracefully Ageing Products was formed during the headphone design process. Figure 32 on the next page, illustrates the development of the toolkit. Initial ideas for promoting graceful ageing were generated based on the takeaways gathered throughout the research. These ideas were then translated into early product concepts. These concepts were generalised into more general design strategies (Show, Prevent, Heal), forming the toolkit’s first iteration. Then, the strategies were validated through one-on-one meetings with fellow design students, discussions in the coach meeting, informal exchanges (e.g. WhatsApp conversations), and a creative session (Chapter 6.3). Insights from these interactions confirmed the relevance of the strategies and inspired the refinement and expansion of the toolkit strategies. The generated concepts are presented in Chapter 7, and the final concept is presented in Chapter 8. Validation of the final concept (Chapter 9) is presented afterwards. In conclusion, the design toolkit was generated through an iterative process within a research-through-design approach.

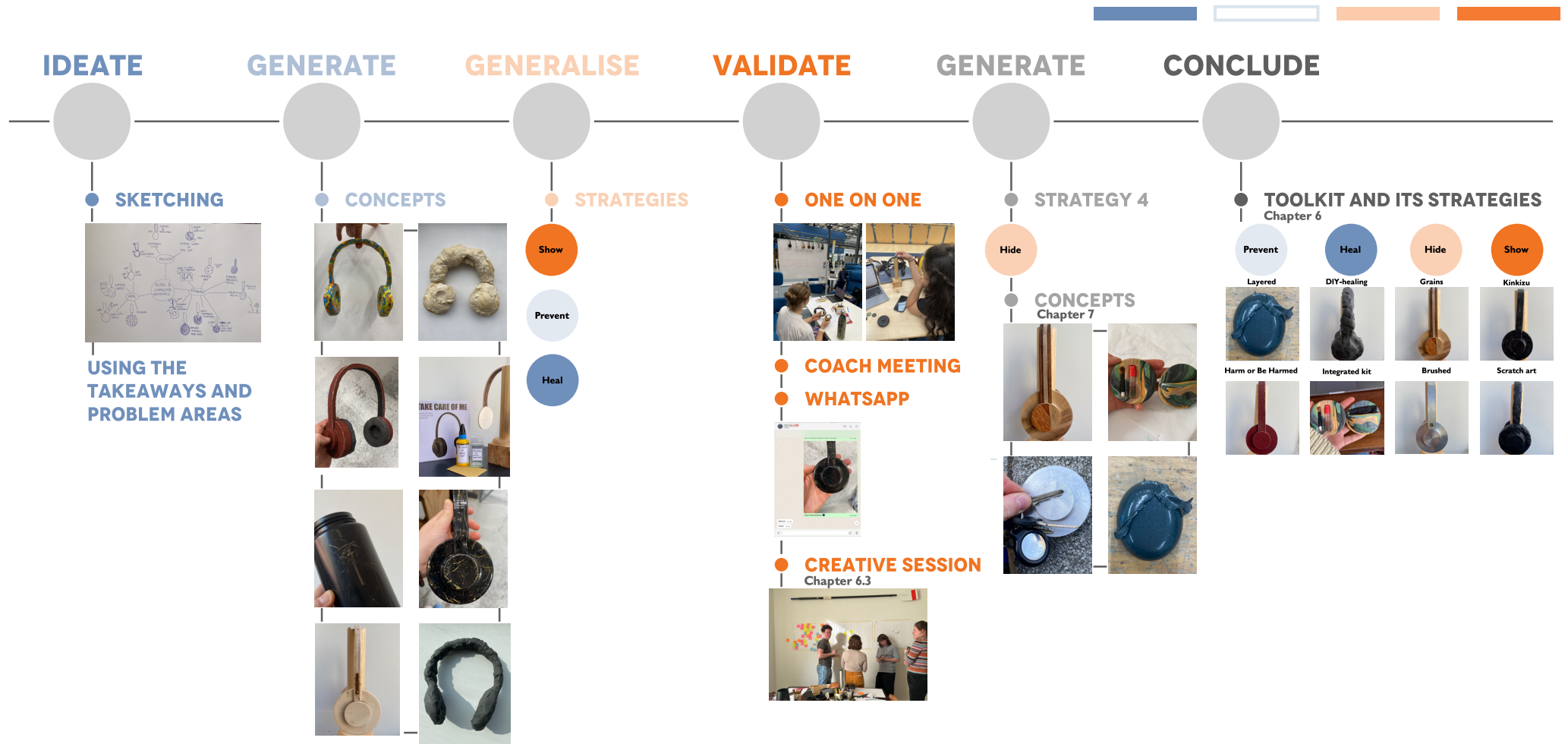


Figure 32: Visual of the toolkit generation process

6.2 THE TOOLKIT STRATEGIES

Chapter 4 established that the perception of aged materials is context-dependent. Thus, the toolkit allows designers to approach designing with ageing products in different ways. Since users tend to prefer flawless products (Takeaway 3.1), some designers might fight wear by 'preventing' it or supporting users in restoring or 'healing' the product when wear occurs. Alternatively, others may accept that wear is inevitable but 'hides' its appearance, while others may celebrate and 'show' it as part of the design. Since perception of wear varies depending on context, in one scenario, one path makes more sense than another. Four distinct design strategies emerged for the toolkit through ideating, prototyping, and validating (Figure 33). Each strategy provides a practical response to cosmetic obsolescence. These are the four strategies that include material ageing into the design process instead of ignoring it:

Prevent: *Protect against wear and damage.*

This strategy minimises visible ageing by protecting the product's most vulnerable areas. Designers can achieve this by using durable materials in high-contact zones or incorporating sacrificial components that can be replaced over time. The focus is on extending the product's pristine appearance for as long as possible. The needed designer mindset is to fight the fact of ageing.

Heal: *Enable material maintenance.*

Gracefully ageing products requires more than selecting materials that age well; they need care and maintenance to do so. The Heal strategy focuses on maintaining and repairing materials

to extend a product's lifespan. It accepts that wear is inevitable and prepares the user for it. Designers should support maintenance, allowing users to restore or care for the product through accessible repairs, care rituals, or the integration of self-healing materials. These strategies increase emotional engagement and extend the product's functional and aesthetic lifespan. The needed designer mindset is to accept that products age but offer solutions for when it happens.

Hide: *Disguise or visually absorb wear.*

This strategy tactfully hides wear. Designers can use textures, patterns, or colour variations that make signs of ageing less noticeable. The aim is to preserve a clean or consistent appearance, even as the material changes subtly over time. The needed designer mindset is to accept that products age, but disguise it as much as possible.

Show: *Reveal wear to create meaning or provide feedback.*

In this strategy, material change is intentionally highlighted. Wear becomes part of the product's narrative, either to embrace it aesthetically, celebrating patina and traces of use, or to inform the user through visible feedback (e.g., wear that signals maintenance needs or usage patterns). The ageing process is used to enhance meaning, storytelling, or functionality. The needed designer mindset is to embrace the fact that products age and use ageing as an advantage.

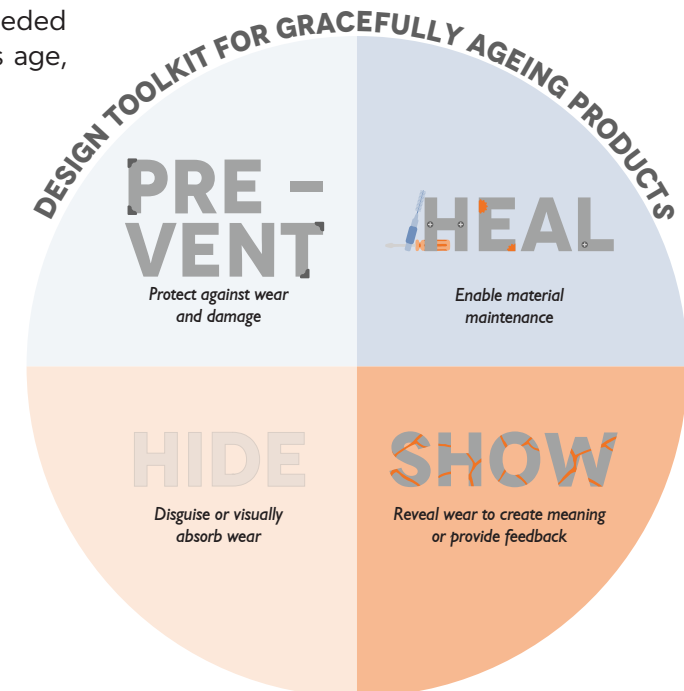


Figure 33: The Design Toolkit for Gracefully Ageing Products

The toolkit is meant for all designers who want to stimulate product retention and prevent cosmetic obsolescence. It is intended to provide designers guidance in designing gracefully ageing products. When choosing which design strategy to adopt, designers must consider various factors to conclude which strategy fits best. Various factors include product type, product category (workhorse, up-to-date, investment), common wear problem areas, brand values, user expectations, and product usage context. While the four strategies offer focus, they are not rigid frameworks. Combining elements from multiple strategies is possible and could be beneficial when it better supports product retention. For example, a design might primarily focus on hiding wear while integrating healing strategies to further extend the product's lifespan. The strategies serve as starting points, and drawing inspiration from other strategies for solving sub-problems is encouraged if it contributes to delaying cosmetic obsolescence. Chapter 8 shows how the four strategies are combined into the final concept. To make the toolkit easily accessible and applicable for designers, its key principles are summarised in a flyer (Figure 34).



Figure 34: Flyer that communicates the toolkit to designers

PREVENT

Protect against wear and damage

HEAL

Repair or maintain materials

This direction accepts that wear is inevitable and prepares the user for it. Designers should support maintenance, allowing users to restore or care for it through accessible repairs, care rituals, or the integration of self-healing materials. These strategies increase emotional engagement and extend the product's functional and aesthetic lifespan.

Needed designer mindset: Accept that products age but offer solutions for when it happens.

SHOW

Reveal wear to create meaning or provide feedback

In this direction, material change is intentionally highlighted. Wear becomes part of the product's narrative, either to embrace it aesthetically, celebrating patina and traces of use, or to inform the user through visible feedback (e.g., wear that signals maintenance needs or usage patterns). The ageing process is used to enhance meaning, storytelling, or functionality.

Needed designer mindset: Embrace the fact that products age and use ageing as an advantage.

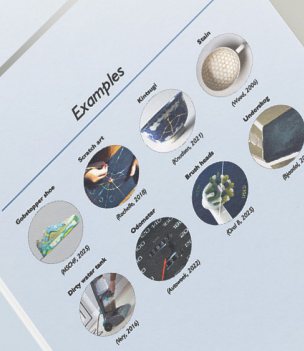
HIDE

Disguise or visually absorb wear

Examples



Examples



6.3 VALIDATION OF THE TOOLKIT STRATEGIES

As mentioned in Chapter 6.1, it was an iterative process to come from the takeaways to the final strategies mentioned in Chapter 6.2. This chapter briefly presents the creative session conducted to validate the toolkit's four strategies. The aim was to test whether the strategies were successful for generating ideas and if they encompass the complete topic of gracefully ageing products. Three fellow students (1 male, aged 24-25, Dutch) engaged in a two-hour creative session, recruited through convenience sampling. The session was held in Dutch, the participants' native language. Various products made from wood, bamboo, aluminium, plastic, and silicone were provided as material inspiration (Figure 35). The participants were first introduced to the topic and problem statement: *"Consumers discard headphones while they are functionally sound, disgraceful ageing is one reason for that."* The problem statement was formed using the main question. The participants were first asked to brainstorm without guidance or strategies. After that, the participants explored the problem through different "How Can We" (HCW) questions that originated from the toolkit's four strategies (Figure 36). The extended explanation of the creative session can be found in Appendix D.

The participants generated a wide range of ideas within all four strategies. Appendix D shows the full overview of the results from the HCW questions, next to the session materials. The participants mentioned that the four strategies provided a good balance between freedom of brainstorming and guidance for the problem statement. Based on the

outcomes and session reflection, some refinements were made to the strategies. For instance, the strategy 'Show' was originally labelled 'Embrace'. However, the session showed that this strategy had more sides than solely embracing wear; wear can also be used to inform users about their usage patterns and educate them. For example, a car's odometer shows consumers the vehicle's usage pattern. Additionally, the Integrated Kit (Chapter 7.5) concept originated from this session.



Figure 35: Brainsketching set-up for the creative session



Figure 36: Post-it brainstorming set-up during the creative session



6.4 EXISTING PRODUCTS WITHIN THE TOOLKIT

This chapter provides examples of existing products that fit within the toolkit. The aim is to give more context to the strategies. Figure 37 illustrates a few examples that engage with product ageing.

PRE-VENT
Protect against wear and damage

Headband cover



(Oidio Sound, 2025)

Tear off visor



(Jones, 2013)

Cover



(WrapCart, 2025)

Hard plastic



(Poliigon, 2025)

Screen protector



(Smartix, 2025)

Suitcase corners



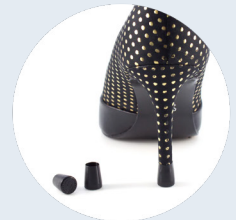
(buchbindermeister.de, 2025)

Bumper feet



(Author's image)

Heel cap



(Ganosales, 2025)

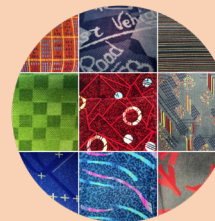
HIDE
Disguise or visually absorb wear

Brushed metal



(Author's image)

Bus chair patterns



(Kronkeling, 2024)

Camo print



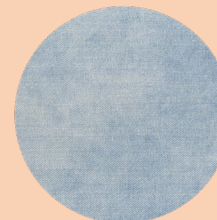
(Feestartikelen.nl, 2025)

Wood grain



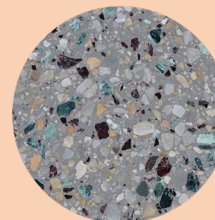
(Author's image)

Stonewashed denim



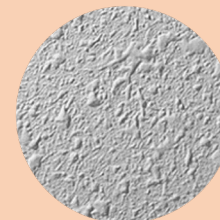
(Andrii, n.d.)

Speckled floors



(A.M. Surfaces, 2024)

Textured ceiling



(skytextexturing, 2025)

Dark colours



(Sure, 2025)

Figure 37: A few examples of current design strategies for engaging with material wear

Maintenance kit



(The instrument place, 2024)

Repair kit



(iFixit, 2025)

Modular electronics



(Blom, 2021)

Ziplock bags



(Manutan, 2025)



Enable material
maintenance

Sugru by Tesa



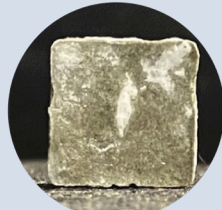
(Tesa, 2025)

Woolfiller



(Pieper, n.d.)

Self-healing



(Arcace, 2022)

Sewing



(Hobbycraft, 2025)

Gobstopper shoe



(MSCHF, 2025)

Stain Sneakers



(Whiting, 2012)

Kintsugi



(Knudsen, 2021)

Stain



(Wood, 2006)



Reveal wear to create meaning
or provide feedback

Dirty water tank



(Very, 2016)

Odometer



(Autoweek, 2022)

Brush heads



(Oral B, 2025)

Underskog



(Bjaadal, 2009)

6.5 DESIGN REQUIREMENTS DERIVED FROM RESEARCH

As described in Chapter 6.1, the takeaways first informed the creation of initial design concepts, which were later generalised into four overarching strategies. During this generalisation process, the takeaways were categorised according to the corresponding strategy within the toolkit (Figure 38). The takeaways were further translated into actionable design requirements by considering the specific design mindset required for each strategy. These requirements provide practical guidance for designers to address material ageing within the four strategies. An overview of these requirements is presented in Table 6 on the next page.

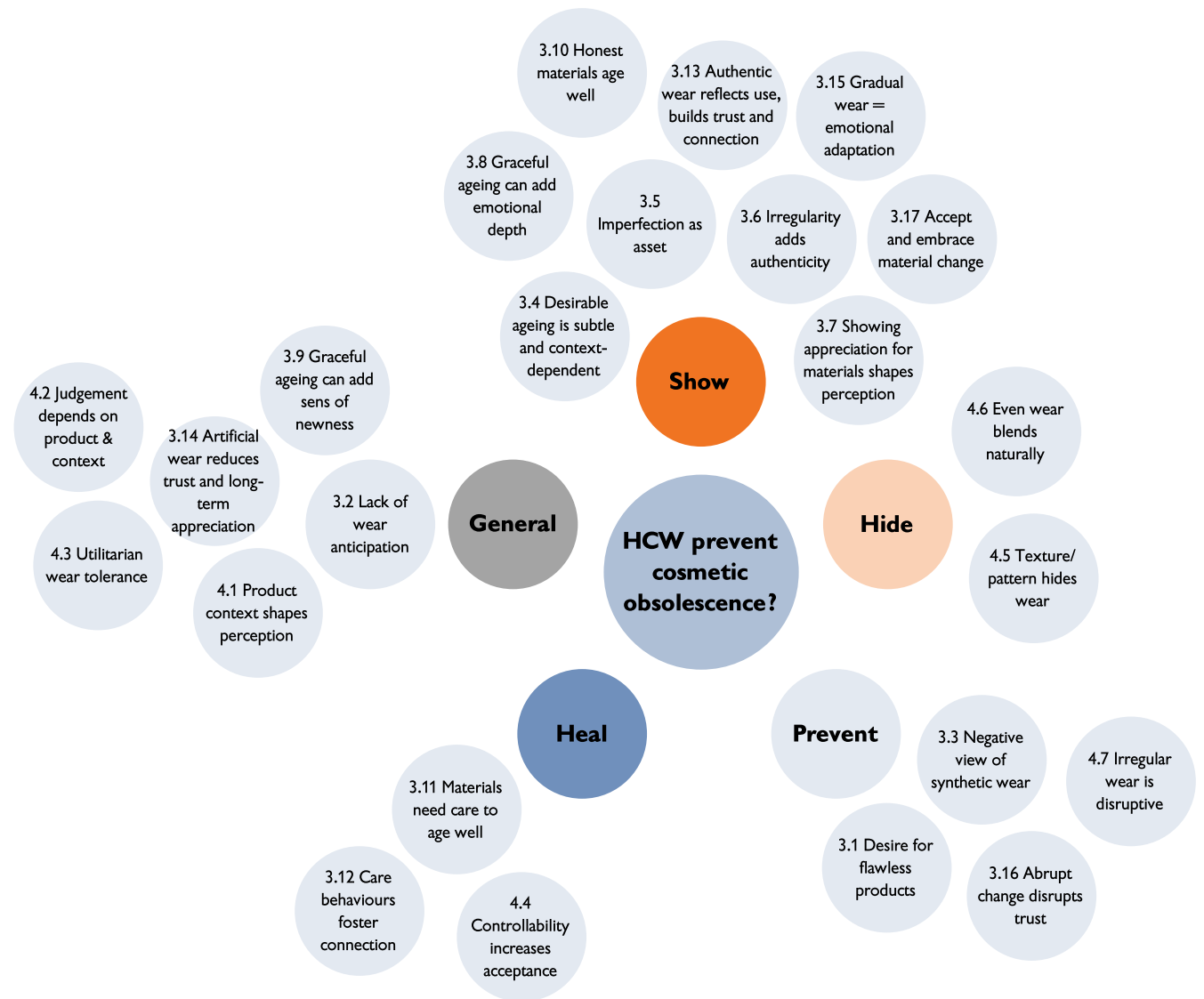


Figure 38: Takeaways ordered per toolkit strategy

Table 6: List of Requirements derived from takeaways, ordered using the four toolkit strategies

		Prevent	Heal	Hide	Show
Nr	Takeaway	Requirements per strategy			
3.1	Consumers often want flawless, new-looking products and view wear as a loss of value.	The design should maintain its flawlessness.	The design should allow healing back to its original state.	The design should hide imperfections.	The design should fight the mindset that wear means a loss of value.
3.2	Consumers rarely anticipate how a product will look after extended use.	-	The design should inform the user what it will look like after extended use.		
3.3	Wear in synthetic materials is often perceived negatively.	The use of synthetic materials should be avoided.	The design should allow synthetic materials to heal (e.g. repair, replace).	The design should hide synthetic wear.	The design should show that synthetic materials can be perceived positively.
3.4	The line between desirable and undesirable ageing is subtle and context-dependent.	-	The design should allow healing from undesirable ageing.	-	The design should sway any ageing to desirable ageing.
3.5	Imperfection can be a design asset, not a flaw.	-			The design should intentionally incorporate elements of visual imperfection to enhance character and user acceptance of wear.
3.6	Surface variation and irregular textures can make the product more authentic.	-		The design should use surface variation and irregular textures to hide wear and make it authentic.	The design should embrace irregularities and variation as part of the design.
3.7	Designers can shape how wear is perceived by showing appreciation for materials, even synthetics.	-		The designer should use remarkable abilities of materials to hide signs of wear.	The design should express the appreciation of the material used.
3.8	Graceful ageing can add emotional depth, tell stories, and foster user attachment.	-			The design should embrace graceful ageing.
3.9	Graceful ageing and patina can add a sense of newness.	-			The design adds a sense of newness.
3.10	Natural and honest materials (e.g., solid wood, leather) are likely to age in a way that is perceived positively.	-			
3.11	Regular maintenance (conditioning leather, oiling wood, polishing silver) enables desirable ageing; without it, materials degrade.	-	The design should support user care.	-	
3.12	Encouraging care behaviours (e.g., maintenance rituals, cleaning, warranties) can promote emotional retention.				
3.13	Authentically ageing materials are appreciated for reflecting use over time, reinforcing emotional connection and trust in the product.	-	The design must foster for authentic wear only; artificial wear affects must be avoided.		
3.14	Artificial wear or imitation patina can feel performative or disingenuous, reducing user trust and undermining long-term appreciation.				

3.15	Gradual wear allows consumers to adapt to aesthetic changes emotionally.	The design should prevent abrupt or gradual aesthetic changes.	The design should aim for gradual and predictable changes to allow users to emotionally adapt to the aesthetic changes.		
3.16	Abrupt aesthetic changes can disrupt the user's sense of control and reduce trust in the product's reliability.		The design should allow healing back abrupt aesthetic changes.	The design should hide abrupt aesthetic changes.	The design should embrace abrupt aesthetic changes.
3.17	Designing with ageing in mind means accepting that change is inevitable and potentially desirable.	Needed mindset for designers for each strategy			
		Fight the fact of ageing.	Accept that products age but offer solutions for when it happens.	Accept that products age but disguise it as much as possible.	Embrace the fact that products age and use ageing as an advantage.
4.1	The product category and use context shape how the aged material is perceived.	These takeaways help with choosing the right toolkit strategy (Prevent, Heal, Hide, and Show) for the designer's chosen context.			
4.2	Consumers assess wear based on what they consider normal or expected for that product's use and material. People are more critical of wear in expressive products or those used frequently in public.				
4.3	Wear is tolerated if it does not interfere with use, in utilitarian (workhorse) products.				
4.4	Wear is more accepted when users feel it can be controlled or reversed.		The design should support repair or care rituals that allow users to actively reverse or reduce wear.		
4.5	Patterns or textures that visually absorb or diffuse wear (e.g., wood grain, brushed metal, speckled plastic) increase user tolerance.			The design should integrate patterns or textures that help wear blend in.	
4.6	Evenly distributed wear can blend in with the material's texture, making it less noticeable and natural.	The design should reduce the change of localised, patchy or irregular wear.	The design should allow targeted repair of localised wear.	The design should encourage evenly distributed wear and visually hide irregular wear.	The design should provide a narrative or function that gives meaning to localised wear, if visible.
4.7	Localised, patchy, or irregular wear is seen as accidental or unattractive, making it disruptive.				
Headphone specific					
5.1	Abrasion is frequent on plastic housing parts.	The design prevents abrasion and accumulation of dirt on the plastic housing parts of the headphone.	The design allows healing of abrasions and accumulated dirt on the plastic housing parts of the headphone.	The design hides abrasion and accumulated dirt on the plastic housing parts of the headphone.	The design embraces abrasion and accumulated dirt on the plastic housing parts of the headphone.
5.2	Accumulated dirt was a problem between the headband and the cups.	The design prevents accumulation of dirt in the connection part of the headphone.	The design allows healing of accumulated dirt in the connection part of the headphone.	The design hides accumulated dirt in the connection part of the headphone.	The design embraces accumulated dirt in the connection part of the headphone.
5.3	Ablation and accumulated dirt can often be found in the soft parts of the headphone.	The design prevents ablation and accumulation of dirt in the soft parts of the headphone.	The design allows healing of ablation and accumulated dirt in the soft parts of the headphone.	The design hides ablation and accumulated dirt in the soft parts of the headphone.	The design embraces ablation and accumulated dirt in the soft parts of the headphone.
5.4	Deteriorating cushions made the overall headphones look worse.	The design prevents cushions that deteriorate.	The design allows healing of deteriorating cushions of the headphone.	The design hides deteriorating cushions.	Deteriorating cushions should add value to the design of the headphone.
5.5	Accumulated dirt was more apparent on white or light-coloured parts.	The design avoids white or light colours in areas prone to dirt accumulation.	The design allows healing of accumulated dirt on light-coloured parts.	The design must avoid white or light colours in areas prone to dirt accumulation.	

6.6 CONCLUSION: TOOLKIT FOR GRACEFULLY AGEING PRODUCTS

This chapter introduced the Design Toolkit for Gracefully Ageing Products (Figure 39), an actionable framework that helps designers address cosmetic obsolescence by designing for material ageing. The toolkit consists of four strategies: Prevent, Heal, Hide, and Show. Each strategy focuses on stimulating product retention in its own way. Prevent aims to protect the product against wear. Heal focuses on enabling repair or maintenance to extend both functional and aesthetic longevity. Hide reduces the visibility of wear. Lastly, Show highlights wear intentionally, either to add meaning or to communicate use. Choosing the most appropriate strategy is context-dependent and should be based on product type, usage patterns, brand identity, user expectations, and the product usage context.

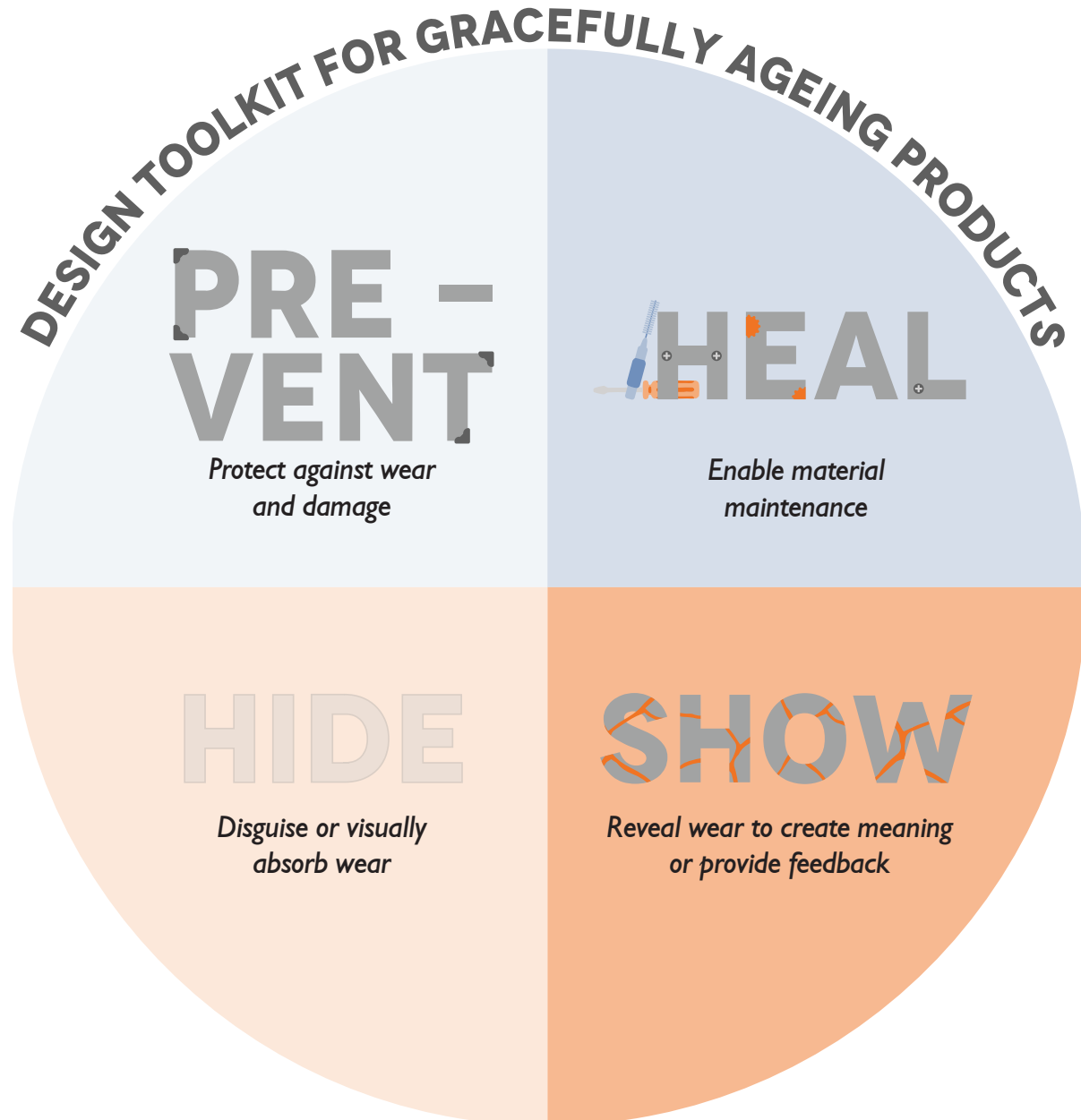


Figure 39: The Design Toolkit for Gracefully Ageing Products



DEVELOP

Phase 3

This phase explores design possibilities that align with the toolkit's strategies. A series of headphone concepts (Chapter 7) is proposed to address RQ4, *"How can a headphone be designed to engage with material ageing and enhance long-term product retention?"* These concepts serve as showcases for the toolkit.

7. THE CONCEPTS

This chapter compiles the concepts developed, following the four strategies from the Graceful Ageing Toolkit presented in Chapter 6: Prevent, Heal, Hide, and Show. Eight concepts have been explored, each aiming to engage with material ageing and enhancing long-term product retention. RQ4, “How can a headphone be designed to engage with material ageing and enhance long-term product retention?” is central to this chapter.

The chapter begins by providing an overview of the concepts based on the Graceful Ageing Toolkit (Chapter 7.1). Chapters 7.2 to 7.9 present the developed concepts using the toolkit. Each subchapter introduces the concept’s name, toolkit strategy, concept explanation and interaction, inspiration, reflection on the process, and reflection on the design requirements. An evaluation on the problem areas of each concept is done in Chapter 7.10. A reflection on the toolkit is done in Chapter 7.11, and the chapter is concluded in Chapter 7.12.

7.1 OVERVIEW OF CONCEPTS

The design toolkit presented in Chapter 6 was developed through a research-through-design approach. By creating and reflecting on iterative design concepts, insights were generated that shaped and refined the toolkit’s four strategies. This chapter discusses these concepts, showing how each one applies a different strategy to address cosmetic obsolescence. The concepts serve as testing grounds for the toolkit and illustrative examples of how designers can translate the strategies into practice. Figure 40 presents an overview of the eight concepts. .

- **Prevent**
Layered: A headphone with peelable layers that reveal fresh colours, letting users remove wear and personalise appearance.
Harm or Be Harmed: A headphone covered in sandpaper that stays pristine by damaging its surroundings before itself.

- **Heal**
DIY-Healing: A malleable headphone that users can reshape or repair themselves, turning maintenance into creative care.
Integrated Kit: A headphone with built-in tools that encourages users to maintain and extend its lifespan.
- **Hide**
Grains: A wooden headphone with irregular grain patterns that hide scratches and wear.
Brushed: A brushed aluminium headphone that disguises wear in its chaotic texture while enabling personalised marks.
- **Show**
Kinkizu: A headphone where scratches are filled with gold, turning damage into decoration.
Scratch Art: A headphone with a coloured base under black coating, where wear reveals vibrant colours as part of its design.



Figure 40: Overview of the concepts

7.2 CONCEPT 1: LAYERED

Concept explanation and interaction

The aim of Layered (Figure 41) is to preserve the pristine state of the headphone. It fits within the preventive direction because it fights ageing by removing the top damaged layer. The headphone is made from plastic and covered with several layers of wrapping foil. The prototype uses a car wrap for this. Once the top layer is damaged or the user experiences satiation of the appearance, a fresh layer can be revealed by peeling the outer layer. Peeling of the layer reveals a pristine new layer with a different colour. The user can personalise the headphones by, for example, peeling the headband first and revealing a different colour from the cups.

Inspiration

Layered was inspired by car wrap (Figure 42) and tear-off visors (Figure 43). Both references use temporary protective layers to preserve the surface beneath. Car wraps mainly change the vehicle's finish (gloss, matte, chrome, etc) or colour. They are also a cost-effective alternative to spraying and are often used for temporary advertisements (Carrillo, 2022). Tear-off visors in motorsports let drivers peel away a thin transparent film when dirty, instantly restoring visibility. By adopting both principles, Layered prevents wear and allows users to change the appearance. Wrapping is not new; it is also common for kitchen cabinets, furniture, books (e.g. protective book covers), nails (nail wraps), and walls (Figure 44). This concept shows that it can apply in headphones as well. Wrapping can help prevent products that people quickly get tired of, such as laptops and other up-to-date products, where appearance trends change rapidly.



Figure 42: Car wrap (Carrillo, 2022)

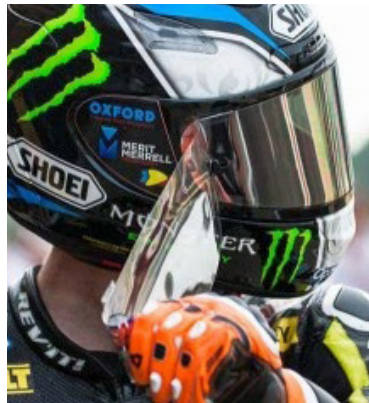


Figure 43: Tear-off visors (Jones, 2013)



Figure 44: Peel and stick wallpaper (RMD decals, 2023)



Figure 41: Concept 1: 'Layered'

Process insight

Many wrapping foils are available on the market, most of which are designed to achieve the best adhesion. This concept, however, needs vinyl that sticks well but can be removed without damaging the layer underneath. The car wrap was effective for this purpose because of its temporary nature. A limitation of wrapping is the shape of the headphone. Smooth, flat, or gently curved surfaces are ideal because the vinyl can be applied neatly without creases or folds. Complex geometries, such as sharp corners and deep recesses, create imperfections in the wrapping, undermining the purpose of the Prevent strategy.

Reflection on design requirements

When reflecting on the requirements for the Prevent strategy, Layered addresses some successfully and some partially (Table 7). The design prevents visible wear by covering the headphone with protective foil (R3.17). Peeling the layer prevents localised damage (R3.15, R3.16 and R4.7) and preserves a flawless appearance over time (R3.1). However, the design is not fully passive in preventing abrupt or gradual changes; users must actively remove a layer when it becomes damaged or visually unsatisfying. This introduces a maintenance action that may not fully align with the ideal of effortless flaw prevention but does offer a controlled, user-driven solution. It is yet unclear whether users would be willing to act on it.

The requirement concerning material choice (R3.3) is partially met. Synthetic materials for the Prevent strategy should be avoided because they tend to age poorly. In Layered, synthetic foils are used deliberately. However, because these foils are designed to be temporary and replaceable, their ageing behaviour becomes somewhat irrelevant; they are removed before negative ageing becomes an issue.

Table 7: Concept Layered rated on requirements

Prevent		
Nr	Requirements	
3.1	Aim: The design should maintain its flawlessness.	●
3.17	Mindset: Fight the fact of ageing.	●
3.3	The use of synthetic materials should be avoided.	●
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should prevent abrupt or gradual aesthetic changes.	●
3.16		
4.7	The design should reduce the change of localised, patchy or irregular wear.	●

- None
- Partially
- Full

7.3 CONCEPT 2: HARM OR BE HARMED

Concept explanation and interaction

Harm or Be Harmed (Figure 45) explores an unconventional approach to preventing wear by making the product more aggressive than its environment. The headphone is entirely covered in sandpaper, which helps it preserve a relatively pristine appearance by damaging other surfaces before being damaged itself. The concept thus aligns with the Prevent strategy and reflects the mindset of fighting the fact of wear, quite literally. This extreme statement challenges the boundaries of what consumers are willing to tolerate to maintain a flawless product. The interaction the user has with the concept is passive in terms of maintenance; the headphone requires no upkeep to keep its appearance relatively pristine.

Inspiration

The previous concept, Layered, was about shielding the headphone from 'danger' from the outside. Harm or Be Harmed takes a more selfish approach. It is inspired by aggressive protective strategies in nature, such as thorny plants (Figure 46) or defensive animal shells. It exaggerates the idea of protection by turning the surface into a tool of destruction rather than passive protection. This concept serves as a counterstatement to the obsession with pristine products, aiming to question whether pristine products are realistic and something we should aim for.



Figure 46: Barrel cactus
(Mygreenscape, 2025)



Figure 45: Concept 2: 'Harm or Be Harmed'

Process insight

This concept demonstrates that it is possible to explore more provocative and unconventional design responses within the Prevent strategy. This process highlights that exploring the boundaries of a design strategy can generate new perspectives, even if the outcome is not directly applicable as a commercial product. It also counterbalanced the more practical and function-driven examples within the Prevent strategy, such as bumper feet on laptops and headphone cases shown in Chapter 6.4.

Reflection on design requirements

This concept literally translates the needed mindset within the Prevent strategy: fight the fact of ageing (R3.17) (Table 8). It avoids the use of synthetic materials (R3.3) and fosters authentic wear only (R3.13 and R3.14). However, sandpaper does not maintain its flawlessness forever (R3.1). Sandpaper loses its grit, gets clogged with dirt or tears along a sharp edge. While it aims to solve the problem of wear for the headphones, it introduces a new problem: harming other products in the process (R3.15, R3.16, and R4.7). This raises the question of whether people still prefer pristine over aged products if it prevents wear at all costs.

Table 8: Concept Harm or Be Harmed ranked on requirements

Prevent		
Nr	Requirements	
3.1	Aim: The design should maintain its flawlessness.	●
3.17	Mindset: Fight the fact of ageing.	●
3.3	The use of synthetic materials should be avoided.	●
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should prevent abrupt or gradual aesthetic changes.	●
3.16		
4.7	The design should reduce the change of localised, patchy or irregular wear.	●

● None

● Partially

● Full

7.4 CONCEPT 4: DIY-HEALING

Concept explanation and interaction

DIY-Healing (Figure 47) aims to extend product longevity by enabling the user to repair and reshape the headphone's material. It aligns with the Heal strategy, as it counteracts visible ageing, such as cracks, dents, or deformation, using self-healing materials. The prototype is made from non-drying modelling clay, a malleable material that retains its softness. When signs of wear occur, the user can press, smooth, or reshape the affected area to restore the product's appearance or further customise it. This creates a flexible product identity that changes with the user's input. The user interaction is active and creative. Rather than relying on invisible or automated repair, the user becomes directly responsible for maintenance. This restores functionality and invites personal expression, making each headphone unique.

Inspiration

DIY-Healing draws inspiration from the field of self-healing materials (Figures 48 and 49). Unlike autonomous self-repair materials, this concept enables users to take control of the healing process. It also builds upon the concept Layered (Chapter 7.2), but instead of peeling to reveal something new, the user reshapes what is already there. These concepts ensure active participation of the user instead of passive protection.

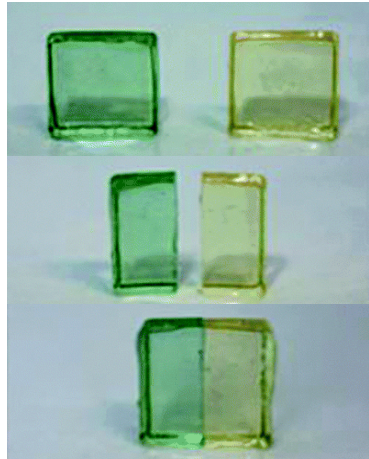


Figure 48: Self-healing material called DABBF(Roy et al., 2015)



Figure 49: Soft self-healing composite (Sanka et al., 2019)



Figure 47: Concept 3: 'DIY-Healing'

Process insight

Plasticine clay was used to represent self-healing materials. Due to its softness, the clay left black marks on surfaces and attracted dirt, making the headphones unpleasant to use. Soft self-healing nanocomposites, such as those developed by Sanka et al. (2019), offer a promising direction. However, these materials still require further development in terms of mechanical strength, stability, and manufacturability before they can be applied in everyday products, such as headphones. The clay served as a proof of concept, highlighting the DIY-Healing interaction. Despite its limitations, three fellow students found the prototype engaging and enjoyable to fidget with (Figure 50).



Figure 50: Fellow students playing with the prototype

Reflection on design requirements

The DIY-Healing concept aligns with several requirements within the Heal strategy, particularly by offering users a sense of control over ageing (Table 9). The material’s malleability allows the product to be restored to a ‘like new’ appearance (R3.1), but also leaves space for personalisation, supporting a mindset that acknowledges ageing as inevitable yet manageable (R3.17). The final appearance after extended use depends on the user’s choices (R3.2). This creates predictability because the user determines the change (R3.15). Engaging in DIY activities or personalising products helps users embed self-expression into the

product. This aligns with insights by van den Berge et al. (2021), indicating that this self-expressive value strengthens people’s emotional connection with the object, increasing the likelihood that they will care for and keep it longer. It is, however, unclear whether users would want this and would be willing to act on it.

The concept partially meets requirements related to supporting reversibility (R3.12, R4.4). The design does allow targeted repair (R4.7), as any wear, whether accidental dents or undesired deformations, can be smoothed out by hand. It does not, however, fully support the user in taking the necessary steps to repair the material. The user has to actively care for it themselves.

Table 9: Concept DIY-Healing ranked on requirements

Heal		
Nr	Requirements	
3.1	Aim: The design should allow healing back to its original state.	●
3.17	Mindset: Accept that products age but offer solutions for when it happens.	●
3.2	The design should inform the user what it will look like after extended use.	●
3.3	The design should allow synthetic materials to heal (e.g. repair, replace).	●
3.4	The design should allow healing from undesirable ageing.	●
3.11	The design should support user care.	●
3.12		
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should aim for gradual and predictable changes to allow users to emotionally adapt to the aesthetic changes.	●
3.16	The design should allow healing back abrupt aesthetic changes.	●
4.4	The design should support repair or care rituals that allow users to actively reverse or reduce wear.	●
4.7	The design should allow targeted repair of localised wear.	●

- None
- Partially
- Full

7.5 CONCEPT 4: INTEGRATED KIT

Concept explanation and interaction

The Integrated Kit (Figure 51) aims to encourage active care and maintenance of the headphone's materials. It aligns with the Heal strategy, enabling users to counteract visible wear and extend the product's lifespan. The concept integrates a maintenance kit directly into the headphone itself (Figure 52). Small compartments in the headphone store essential care tools such as cleaning cloths, isopropyl alcohol, a soft brush, swabs, screwdrivers and a spudger (iFixit, 2025). This design removes the need for users to store supplies elsewhere and acts as a constant physical reminder to perform maintenance.

For a behaviour change to occur, three elements must converge: motivation, ability, and a trigger (Fogg, 2009). Ackermann et al. (2018) applied this framework to product care, highlighting its relevance in encouraging maintenance behaviours. The Integrated Kit addresses the ability by embedding essential tools within the headphone, removing the barrier of having to search for them. The kit also serves as a trigger through its constant visibility, reminding users to take action. To support motivation, the concept integrates auditory prompts, where headphones periodically remind the user to clean or inspect them and suggest appropriate actions. For example, the headphones could notify users of common faults and guide them to step-by-step repair tutorials, addressing the diagnostic and knowledge gaps noted by Magnier and Mugge (2022b). This approach aims to encourage users to care for their product by keeping the process simple and intuitive.



Figure 52: The tools integrated in the housing



Figure 51: Concept 5: 'Integrated kit'

Inspiration and process insights

The Integrated kit is an improved version of the prototype Take Care of Me (Figure 53). Take care of me was further developed during a creative session (Chapter 6.3). It combined a wooden headphone with a care kit stored inside its packaging. The packaging showed what the headphone would look like without proper maintenance. While this prototype supported the ability to maintain, it lacked an ongoing trigger; once the packaging is discarded or put away, the care tools are out of sight. The Integrated Kit improves on this by integrating the care tools into the product itself, thereby aiming to improve the ability to maintain the product.



Figure 53: Concept before the Integrated kit called Take care of me

Reflection on design requirements

Integrated Kit addresses the aim (R3.1) and mindset (R3.17) of the heal strategy by addressing materials' accumulated dirt and ageing by offering maintenance as the solution (Table 10). It also supports R3.3 and R3.4 by providing simple, accessible ways to address undesirable wear. The integrated tools aim to foster regular maintenance behaviours (R3.11 and R3.12) and strengthen users' emotional bond with the product. As Van den Berge et al. (2021) describe, engaging in DIY activities fosters self-expressive value, enhancing emotional attachment. The headphones become not just something the user owns but something they have

the opportunity to actively care for, depending on their willingness to engage. However, the concept does not sufficiently address R3.2, as Take care of me informs the user, but Integrated Kit should be implemented through advertising or other media. Likewise, it does not fully address R3.15, since it does not guide the user through gradual, predictable aesthetic changes but only offers reactive maintenance once wear becomes visible.

Table 10: Concept Integrated Kit ranked on requirements

Heal		
Nr	Requirements	
3.1	Aim: The design should allow healing back to its original state.	●
3.17	Mindset: Accept that products age but offer solutions for when it happens.	●
3.2	The design should inform the user what it will look like after extended use.	●
3.3	The design should allow synthetic materials to heal (e.g. repair, replace).	●
3.4	The design should allow healing from undesirable ageing.	●
3.11	The design should support user care.	●
3.12		
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should aim for gradual and predictable changes to allow users to emotionally adapt to the aesthetic changes.	●
3.16	The design should allow healing back abrupt aesthetic changes.	●
4.4	The design should support repair or care rituals that allow users to actively reverse or reduce wear.	●
4.7	The design should allow targeted repair of localised wear.	●

● None
 ● Partially
 ● Full

7.6 CONCEPT 5: GRAINS

Concept explanation and interaction

Grains (Figure 54) aims to reduce wear visibility by making scratches, dents, and imperfections blend into the material's natural visual complexity. This concept, therefore, aligns with the Hide strategy. The headphones are made from various types of wood, including different wood tints and grains, arranged in multiple orientations. This creates an irregular pattern where signs of wear are less noticeable. Scratches do not stand out against the surface because no uniform direction or colour exists for them to disrupt. In addition, the wood develops a natural patina over time, subtly deepening in tone and texture. This ageing process not only enhances the material's richness but also reinforces the forgiving aesthetic. The interaction with Grains is passive, as the headphone requires no effort from the user to manage visible ageing; the design itself absorbs imperfections. Minor damage becomes part of the overall texture, rather than something that detracts from the product's appearance.

Inspiration

Grains was inspired by butcher block cutting boards, which use wooden pieces with grains arranged in varying directions (Figure 55). Grains takes the principle of arranging wood and makes the orientation more random, aiming to improve the irregularity. The natural material variation is used and enhanced in the concept to mask wear.



Figure 55: Butcher block cutting board (Author's image)



Figure 54: Concept 5: 'Grains'

Process insight

Creating the prototype with wood presented some challenges. Finding the balance between natural randomness and intentional design, and working with wood, was time-consuming. Translating this concept to a mass-produced product will therefore also be challenging. To test the invisibility of wear, accelerated wear testing was conducted. The headphones were first placed in a canvas bag with five keys and five coins, then shaken for 10 minutes. No scratches appeared. To further test how well scratches were absorbed, exaggerated scratches were applied using coarse sandpaper. Figure 56 shows the result of the wear test. Up close the scratches are visible, but from a distance they are absorbed.



Figure 56: Result of wear-test

Reflection on design requirements

Grains addresses the aim (R3.1) and mindset (R3.17) of the hide strategy by offering a passive solution where wear is disguised using wood grain (Table 11). It uses natural wood (R3.7, R3.13) to create imperfection and surface variation (R3.6) and material authenticity (R3.7, R3.13). The use of wood results in irrelevance for R3.3. While the material naturally develops patina, Grains does not actively communicate how the product will look over time (R3.2). It performs well against R4.5, R4.6, and R4.7, as the irregular grain patterns help absorb localised wear and distribute it visually. However, it only partially fulfils R3.15 and R3.16. This is because while

gradual wear is somewhat absorbed, it depends heavily on the type of damage that occurs. Abrupt changes, such as deep dents, may still disrupt the appearance, as the design primarily masks surface-level scratches rather than more severe ageing. In summary, Grains is effective in hiding certain types of wear but relies on the natural properties of wood, meaning its success depends on the type of ageing encountered.

Table 11: Concept Grains ranked on requirements

Hide		
Nr	Requirements	
3.1	Aim: The design should hide imperfections.	●
3.17	Mindset: Accept that products age but disguise it at much as possible.	●
3.2	The design should inform the user what it will look like after extended use.	●
3.3	The design should hide synthetic wear.	●
3.6	The design should use surface variation and irregular textures to hide wear and make it authentic.	●
3.7	The designer should use remarkable abilities of materials to hide signs of wear.	●
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should aim for gradual and predictable changes to allow users to emotionally adapt to the aesthetic changes.	●
3.16	The design should hide abrupt aesthetic changes.	●
4.5	The design should integrate patterns or textures that help wear blend in.	●
4.6	The design should encourage evenly distributed wear and visually hide irregular wear.	●
4.7		

● None
● Partially
● Full

7.7 CONCEPT 6: BRUSHED

Concept explanation and interaction

Brushed (Figure 57) is designed to mask wear by visually blending scratches and imperfections into a deliberately textured surface. It fits within the hide strategy, camouflaging wear through the material finish. The headphone is made from aluminium with an exaggerated brushed texture applied in multiple directions. This heavy brushing breaks up the surface reflection, causing new scratches to disappear into the chaotic pattern rather than standing out. The interaction is mainly passive; the surface disguises wear over time. However, it also invites active engagement for those wanting to personalise their appearance further. Users can add their own scratches, patterns, or directional textures to the surface. This provides the opportunity for accidental wear to be hidden and for intentional design to make the headphones more unique.

Inspiration

Brushed was inspired by engine-turned dashboards (Figure 58) and brushed metal surfaces (Figure 59). These techniques polish a pattern of circles on a piece of metal (Benchoff, 2019). They have long been used in industries where surfaces must stay visually appealing despite regular handling and abrasion. This concept adopts the same principle but exaggerates it to an extreme, turning the headphone into a canvas of controlled chaos that disguises wear.



Figure 58: Engine turned dashboard of a Bentley (Bentley Motors, 2019)



Figure 59: Brushed metal (Author's image)



Figure 57: Concept 6: 'Brushed'

Process insight

The initial goal was to prototype a metal headphone with an extreme brushed finish, similar to the surface shown in Figure 59. However, during the manual scratching the aluminium, the process shifted towards experimenting with varying scratch orientations and writing (Figure 60). This was inspired by the concept Grains, which uses randomly oriented wood grains to hide wear. This exploration gave an unexpected insight: the brushed texture could be more than just functional camouflage. By introducing more chaotic, multidirectional patterns and even testing writing or drawing directly onto the surface with scratches, the concept evolved to incorporate user-driven personalisation. This shifted the design from purely passive hiding toward an interactive surface that encourages creative engagement alongside wear-masking.

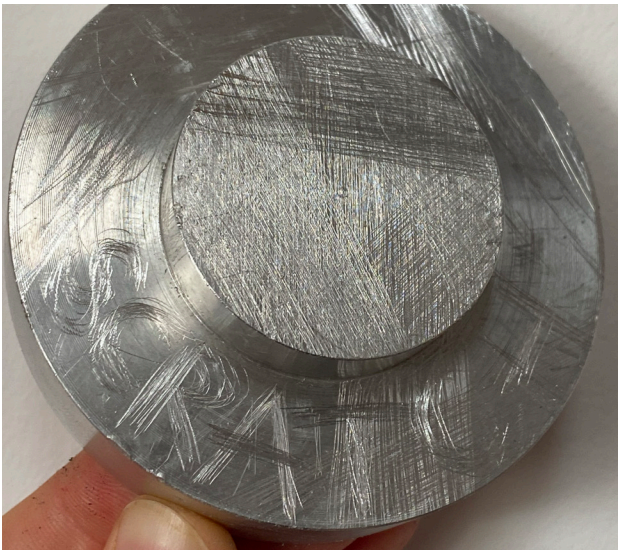


Figure 57: Concept 6: 'Brushed'

Reflection on design requirements

Brushed demonstrates how the hide strategy can be applied to engineered materials, offering a functional and expressive way to manage wear. It complements Grains as the industrial, man-made version, showing that hiding strategies are not exclusive to natural materials but can be designed into processed surfaces as well. The reflection on the design requirements for Brushed (Table 12) is the same as the reflection of Grains (Chapter 7.6).

Table 12: Concept Brushed ranked on requirements

Hide		
Nr	Requirements	
3.1	Aim: The design should hide imperfections.	●
3.17	Mindset: Accept that products age but disguise it at much as possible.	●
3.2	The design should inform the user what it will look like after extended use.	●
3.3	The design should hide synthetic wear.	●
3.6	The design should use surface variation and irregular textures to hide wear and make it authentic.	●
3.7	The designer should use remarkable abilities of materials to hide signs of wear.	●
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should aim for gradual and predictable changes to allow users to emotionally adapt to the aesthetic changes.	●
3.16	The design should hide abrupt aesthetic changes.	●
4.5	The design should integrate patterns or textures that help wear blend in.	●
4.6	The design should encourage evenly distributed wear and visually hide irregular wear.	●
4.7		

● None
● Partially
● Full

7.8 CONCEPT 7: KINKIZU

Concept explanation and interaction

The aim of Kinkizu (Figure 61) is to embrace wear rather than seeing it as a flaw. It fits within the strategy Show, turning abrasion, often undesirable in synthetic materials, into a celebrated feature. The name combines "Kin" (gold) and "kizu" (wound or scratch), reflecting how the product highlights scratches rather than hiding them. The scratches can be filled with gold paint as the headphones are used. The smooth, glossy texture of the plastic allows the paint to adhere only to the rough scratches. Over time, the more the headphones are used, the more distinct and characterful the pattern of golden lines becomes, showing the use over time. The user interacts with the headphone by filling in the scratches with paint. This can be done as often as desired to fill in new scratches and enhance the imperfections with gold. Users could optionally accelerate wear themselves if they wish, turning wear into a form of self-expression.

Inspiration

Kinkizu is inspired by Kintsugi (Figure 62), the traditional Japanese craft of repairing broken ceramics with lacquer dusted or mixed with powdered gold, silver, or platinum. This philosophy highlights imperfections and celebrates repair as part of an object's life story. Kinkizu translates this principle to synthetic materials, particularly plastic, where wear is typically viewed negatively (T3.3). This concept challenges that stigma by elevating scratches into something precious, honouring the beauty of imperfection in a modern, plastic context.



Figure 62: Kintsugi, the Japanese art of repair (Knudsen, 2021)



Figure 61: Concept 7: 'Kinkizu'

Process insight

The prototyping process was iterative and involved many trials and errors. The failed proof-of-concept (Figure 63) showed that the plastic surface needed to be smooth. Material comparison between PLA, ABS, and PETG indicated that PETG would respond best to abrasion. This is because PETG is softer and more flexible, which makes it less resistant to surface abrasion, which in this case is wanted (Protolabs Network, 2025). Translating the proof-of-concept to a headphone showed 3D-printing challenges. Issues included visible layer lines even at the smallest layer height, plastic turning grey after sanding (Figure 64), and internal infill structures becoming visible (Figure 65) when attempting to smooth the surface with a heat gun (Figure 66). The abrasion was achieved by putting the plastic in a canvas bag with five keys and five coins and shaking for 10 minutes (Figure 67). Nonetheless, the depth of scratches needed for the gold to be visible was greater than the abrasion observed on commercial headphones (Chapter 5.3). The desired effect was reached after 10 light passes with a Stanley knife, which created slightly deeper cuts (Figure 68). This raises concerns about whether everyday use will produce sufficiently noticeable marks. This could be solved with softer plastics; however, these need to be tested. Despite these challenges, the contrast between scratched plastic with and without gold paint produced an interesting starry night-like effect.



Figure 63: Failed and successful proof-of-concept



Figure 64: Printing lines showing and plastic turning grey after sanding



Figure 65: Infill showing after smoothing plastic with a heat gun

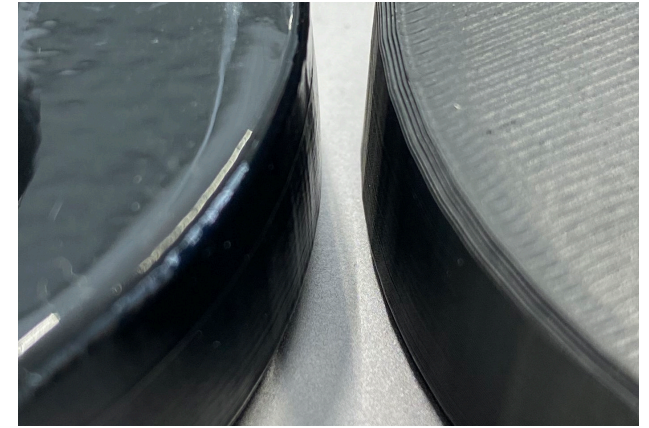


Figure 66: Smooth 3D printed plastic

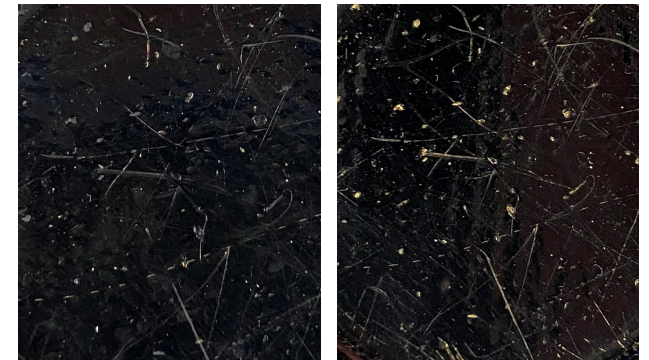


Figure 67: Plastic after abrasion test without paint (left) and with paint (right)

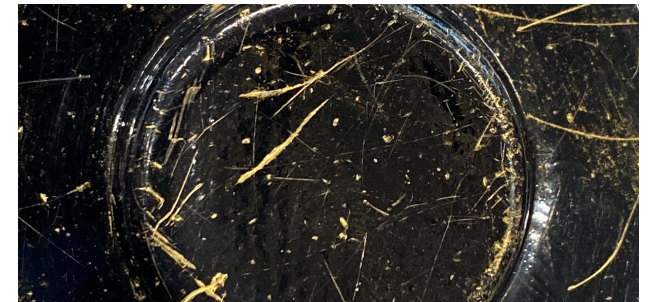


Figure 68: Desired result

Reflection on design requirements

Kinkizu fulfils the aim (R3.1) and mindset (R3.17) of the Show strategy by reframing wear as a positive, meaningful transformation (Table 13). It effectively addresses R3.3, R3.5, and R3.7 by challenging the negative perception of wear in synthetic materials and turning imperfections into an asset. The design fosters emotional attachment (R3.8) by transforming scratches into a unique visual narrative (R3.13, R3.14). The concept aims to steer wear towards desirable ageing (R3.4) by visually rewarding damage with gold accents. It embraces surface variation (R3.6) by highlighting irregular scratch patterns as intentional aesthetic features. Moreover, the gold repairs introduce a renewed visual layer, offering a sense of newness after wear (R3.9).

However, the concept does not fully address R3.2. While the material naturally develops scratches, it does not actively communicate how the product will look over time. As a result, users may not anticipate the future appearance or how wear will evolve. The concept partially meets R3.15 and R3.16. The change is not truly gradual, as the visual transformation depends on the user's decision to apply gold paint, which may happen infrequently, only once, or never. This leads to more abrupt aesthetic shifts rather than a slow, gradual process. Furthermore, the concept embraces localised wear (R4.6, R4.7) by giving meaning to scratches. However, its success depends on the material's ability to accumulate deep wear patterns, which may not occur under normal use conditions. The practical implementation is limited by material behaviour and user effort.

Table 13: Concept Kinkizu ranked on requirements

Show		
Nr	Requirements	
3.1	Aim: The design should fight the mindset that wear means a loss of value.	●
3.17	Mindset: Embrace the fact that products age and use ageing as an advantage.	●
3.2	The design should inform the user what it will look like after extended use.	●
3.3	The design should show that synthetic materials can be perceived positively.	●
3.4	The design should sway any ageing to desirable ageing.	●
3.5	The design should intentionally incorporate elements of visual imperfection to enhance character and user acceptance of wear.	●
3.6	The design should embrace irregularities and variation as part of the design.	●
3.7	The design should express the appreciation of the material used.	●
3.8	The design should embrace graceful ageing.	●
3.9	The design adds a sense of newness.	●
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should aim for gradual and predictable changes to allow users to emotionally adapt to the aesthetic changes.	●
3.16	The design should embrace abrupt aesthetic changes.	●
4.6	The design should provide a narrative or function that gives meaning to localised wear, if visible.	●
4.7		

● None
● Partially
● Full

7.9 CONCEPT 8: SCRATCH ART

Concept explanation and interaction

The aim of Scratch Art (Figure 69) is to make wear intentional and part of the headphone's character. It fits within the strategy Show because, as the product ages, its appearance changes in a way that communicates use and celebrates imperfection. The headphone's housing is made from colourful plastic covered with a thin black coating. The colour layer beneath is gradually revealed as the headphones are used and the surface experiences wear (abrasion). Instead of viewing scratches and surface damage as flaws, they become part of a dynamic aesthetic transformation. This approach resonates with Proud Plastics' philosophy (Hinte et al., 2004), which celebrates one of plastic's unique qualities: its colourfulness. The headphone naturally triggers the aesthetic transformation, making the interaction passive. No additional effort is required from the user. However, users could just as the concept Kinkizu (Chapter 7.8) accelerate this process if they wish, turning wear into a form of self-expression. By integrating abrasion into the product's visual identity, the headphone tells a unique story of ownership, use, and time.

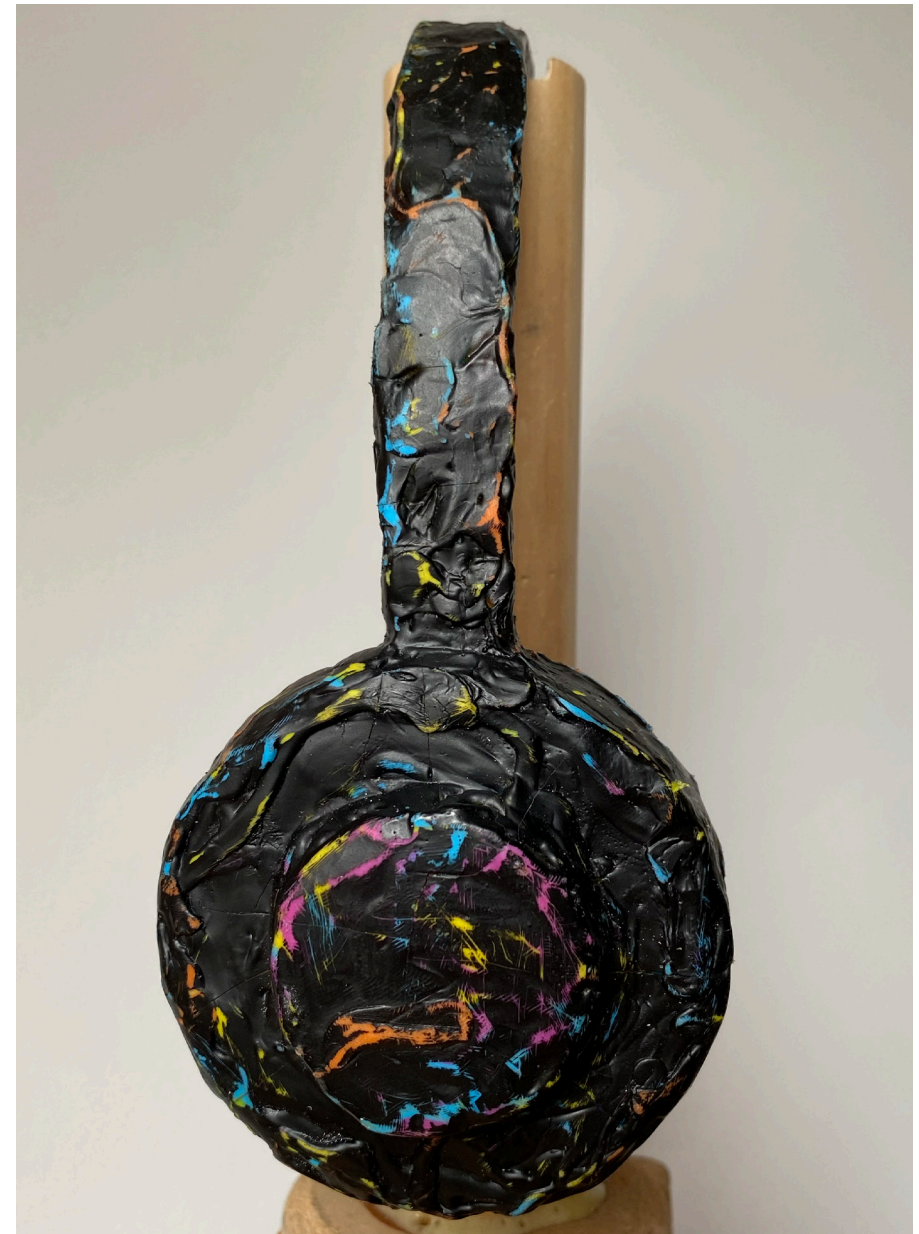


Figure 69: Concept 8: 'Scratch Art'

Inspiration

The concept Scratch Art was inspired by scratch art drawings I made as a child (Figure 70) and the Gobstopper shoe (Figure 71). Both references share a core principle: surface transformation through removing a top layer. Scratch art begins with a dark surface scratched away to expose vibrant colours underneath. Gobstopper shoes reveal different layers of colour as they wear down, much like a Gobstopper candy. The inspiration for customisation has originated from these shoes. Some owners of the shoes have customised them by intentionally accelerating the wear process, using knives, sandpaper, or other tools, to reveal colours in specific patterns (Figure 72). The inspirations are reinterpreted in the context of headphone design, turning abrasion, typically a sign of degradation, into a tool for visual storytelling.



Figure 70: Scratch art drawing as inspiration for the Scratch Art concept (Rochelle, 2018)



Figure 71: The Gobstopper shoe as inspiration for the Scratch Art concept (MSCHF, 2025)



Figure 72: Accelerating the ageing process (Phosphor, 2022)



Figure 73: Proof-of-concept

Process insights

The proof-of-concept was created by melting coloured PLA filament into a flat disc, applying a black spray paint coating, and accelerating abrasion using a key (Figure 73). This proof-of-concept was then translated into a headphone prototype by covering a wooden frame with the same filament (Figure 74). The process revealed that high-contrast, vibrant colours are needed for the scratches to stand out. Additionally, the choice of paint could affect the outcome; some coatings could risk flaking rather than wearing away through abrasion. Flaking is undesirable for this concept because it does not reveal the abrasion gradually. Further exploration is needed to identify coating materials that reliably wear through abrasion without flaking, ensuring the intended gradual surface transformation.



Figure 74: Process of translating proof-of-concept to a headphone

Reflection on design requirements

Scratch Art reframes wear from a sign of degradation into a positive transformation. By revealing underlying colour through abrasion, it challenges the mindset that wear implies a loss of value (R3.1) and instead uses ageing as a design asset (R3.17) (Table 14). The concept aims to steer abrasion toward desirable ageing (R3.4, R3.8) and challenges the stigma around wear in synthetic materials (R3.3) by celebrating the inherent colourfulness of plastic (R3.7). It embraces visual imperfection (R3.5) and surface variation (R3.6), enabling each product to develop a unique and irregular, wear-driven identity (R3.13, R3.14). This development adds a sense of newness to the design; each month, the headphone will look different (R3.9).

While the design implies future transformation through material choice and finish, it does not explicitly communicate how wear will visually develop over time (R3.2). This may limit users' ability to anticipate the aged appearance. The ageing process is aimed to be predictable (R3.15) as scratches emerge naturally during use without additional user effort, unlike the more active interaction in Kinkizu. The user could always choose active interaction by accelerating the ageing process as people did with the gobstomper shoes (Figure 72). While the transformation can be abrupt in specific locations (e.g., high-contact areas), the transformation remains intentional and integrated into the design narrative (R3.16, R4.6, R4.7). Overall, Scratch Art leverages controlled, meaningful wear as an integral part of the product experience.

Table 14: Concept Scratch Art ranked on requirements

Show		
Nr	Requirements	
3.1	Aim: The design should fight the mindset that wear means a loss of value.	●
3.17	Mindset: Embrace the fact that products age and use ageing as an advantage.	●
3.2	The design should inform the user what it will look like after extended use.	●
3.3	The design should show that synthetic materials can be perceived positively.	●
3.4	The design should sway any ageing to desirable ageing.	●
3.5	The design should intentionally incorporate elements of visual imperfection to enhance character and user acceptance of wear.	●
3.6	The design should embrace irregularities and variation as part of the design.	●
3.7	The design should express the appreciation of the material used.	●
3.8	The design should embrace graceful ageing.	●
3.9	The design adds a sense of newness.	●
3.13	The design must foster for authentic wear only; artificial wear affects must be avoided.	●
3.14		
3.15	The design should aim for gradual and predictable changes to allow users to emotionally adapt to the aesthetic changes.	●
3.16	The design should embrace abrupt aesthetic changes.	●
4.6	The design should provide a narrative or function that gives meaning to localised wear, if visible.	●
4.7		

● None
 ● Partially
 ● Full

7.10 CONCEPT EVALUATION ON THE PROBLEM AREAS

The requirements within each strategy differ because the takeaways were translated into requirements for each strategy (Chapter 6.5). This subchapter compares each concept on the three problem areas identified in the observational study on headphones (Chapter 5). The results are shown in Table 15. All concepts focus on only one or two problem areas, which means that further improvements can be made in later steps. However, the aim is to create a coherent concept with a clear focus. Chapter 8 focuses on refining the chosen concept into a final concept by combining the strategies, aiming for a cohesive story. Based on the concept evaluation of the requirements and personal preferences, Scratch Art was selected for further refinement. This final concept serves as a showcase for the toolkit.

7.11 REFLECTION ON THE TOOLKIT

The concepts were developed prior to the formulation of the toolkit. To reflect on the toolkit, this subchapter examines the toolkit in light of these concepts.

- **Prevent**

The examples of current products within the strategy Prevent (Chapter 6.4), such as bumper feet on laptops, initially appeared functional, conventional and conservative in their approach. This is especially in contrast to Show, which presented more outspoken and statement examples. However, the concept Harm or Be Harmed, which uses provocation as a means of behavioural change, and the concept Layered, which applies an existing principle in a novel context, demonstrate that Prevent can foster

innovative outcomes as well.

- **Heal**

Gracefully ageing products is not solely achieved by using materials that age beautifully; they need care and maintenance to do so. Healing focuses on caring for and maintaining the materials of a product. Integrated Kit allows the user, for example, to heal back accumulated dirt or cushions with ablation. Functionality and repair are outside the scope of this study. Heal operates in a grey area between maintaining the materials of a product and functionality, and repair. DIY-Healing operates more on the material side of Heal. Therefore, including Heal within the framework remains essential to support designs that recover the cosmetic aesthetics of a product.

- **Hide**

Hide accepts that materials inevitably accumulate traces of use but aims to visually conceal these signs rather than prevent them. This approach is effective to a degree; however, just as with Heal and Show, it does not attempt to eliminate wear. For example, while Grains effectively masks superficial scratches, deeper deterioration would ultimately require restorative techniques similar to Heal to maintain longevity. Likewise, patterned bus seats hide dirt to some extent but still need regular cleaning. This demonstrates that the toolkit serves as inspiration and guidance, but the strategies could be part of a spectrum where combining methods might further extend the cosmetic lifespan of products.

Table 15: Each concept evaluated on the three problem areas within headphones, identified in Chapter 5

Concept	Problem area 1	Problem area 2	Problem area 3
	Abrasion on housing	Dirt on connection	Ablation and dirt on cushion
Layered	●	●	●
Harm or Be Harmed	●	●	●
DIY-Healing	●	●	●
Integrated Kit	●	●	●
Grains	●	●	●
Brushed	●	●	●
Kinkizu	●	●	●
Scratch Art	●	●	●

- **Show**

Show operates closer to artistic expression, often creating more provocative or statement-driven designs. As Chapman (2017) said, “... *provocative design concepts must emerge that challenge our social desire for a scratch-free and box-fresh world*”. While this strategy offers potential for emotional connection and storytelling, it may not align with the preferences or comfort zones of all designers, users or brands. This highlights that Show is particularly suited for contexts where expressive ageing is embraced, but may be less applicable where subtlety is preferred.

7.12 CONCLUSION: THE CONCEPTS

This chapter explored eight design concepts aimed at engaging with material ageing and enhancing long-term product retention. This was done to answer RQ4: “*How can a headphone be designed to engage with material ageing and enhance long-term product retention?*” By assigning a role to wear in the product’s narrative, each toolkit strategy addresses enhancing product retention in a different way. Prevent does so with a more conservative mindset by keeping a product pristine; however, the outcome can be novel. Heal seeks to achieve this via active user involvement. Hide aims to enhance product retention through passive camouflage. Show aims to do so through visible storytelling. Different strategies for enhancing product retention suit different contexts. The designer can select a toolkit strategy that best fits their specific situation.

DELIVER

Phase 4

This last phase of the project includes the final design proposal (Chapter 8), its validation (Chapter 9), and a discussion (Chapter 10). The discussion reflects on both the concept and the toolkit, addressing limitations and suggesting possible recommendations for future development.

8. FINAL CONCEPT

This chapter describes the Scratch Art concept chosen in the previous chapter. This chapter aimed to showcase the final concept as an example of what you can achieve by using the toolkit. It will begin by introducing the concept and further exploration (Chapter 8.1). It then presents each part that has been further designed in Chapters 8.2 to 8.5. After that, Chapters 8.6 and 8.7 present the possibility of combining the strategies by providing design suggestions for problem areas two and three. The chapter is concluded in 8.8.

8.1 INTRODUCTION OF SCRATCH ART AND FURTHER EXPLORATION

Figure 75 presents the final concept, Scratch Art. It builds upon the strengths of the earlier concept while adding some elements. The underlying idea remains unchanged: wear is revealed as coloured scratches, reframing synthetic wear as a positive transformation. Like the previous version, Scratch Art uses coloured plastic beneath a black coating. Whereas the earlier concept was primarily exploratory, this version reflects a more

detailed concept. Revisions include the coating, the embossed detail on the cup, the production method, and the advertising. Suggestions are given for the cushions and the cup-to-housing connection. The coating was further developed through material testing, the embossing was introduced as an additional communicative element, and the problem areas (cushions and the connection) were addressed through iterative solution generation. Chapters 8.2 to 8.7 explain the further exploration of the parts.



Figure 75: The final concept, Scratch Art as new, 5 years old and 10 years old (indications)

8.2 COATING

As identified in Chapter 7.9, further exploration of the coating was necessary to ensure it could reveal wear through scratches without compromising product longevity. The goal was to find a coating that scratches rather than flakes, durable enough to withstand at least ten years of regular use. A coating expert was consulted to achieve this (Appendix E). It was recommended to compare two coating types, waterborne and solvent-borne, due to the hydrophobic nature of plastic. Waterborne coatings were expected to scratch more easily, but also risk ablation. Solvent-borne coatings were anticipated to offer greater durability, but not scratch easily with regular use.

Based on the consultation, an abrasion test was set up and executed. Sixteen 3D-printed samples were prepared: eight coated with waterborne paint and eight with solvent-borne paint (Figure 76). For each paint type, four coating configurations were tested: (1) single layer, (2) single layer with embossing, (3) double layer, and (4) double layer with embossing. Each configuration was tested twice, once as the main sample and once as a control. Following the expert's suggestion, the abrasion test involved placing the samples in a bag with sharp objects (key, coin, and pen), shaking them for ten minutes, and rubbing them on the table for 100 passes. Visual documentation of the results is shown in Figure 76.

The test results indicated that waterborne coatings flaked and rubbed off, making them unsuitable for this concept (Figure 77). In contrast, solvent-borne coatings demonstrated controlled abrasion, aligning with the concept's intent. Thus, the concept is made from plastic and sprayed with a solvent-borne coating. The embossing results are discussed in Chapter 8.3, and the production method and plastic are discussed in Chapter 8.4.

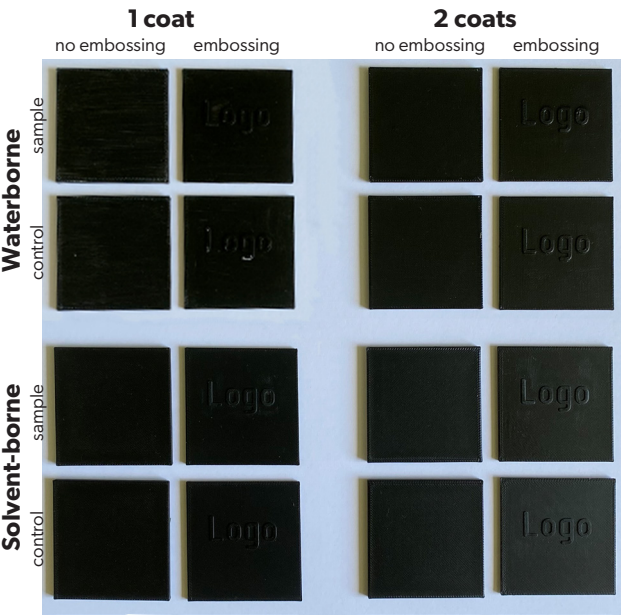


Figure 76: Setup for the abrasion test comparing waterborne and solvent-borne coatings across four sample configurations (1 or two layers, and with or without embossing)

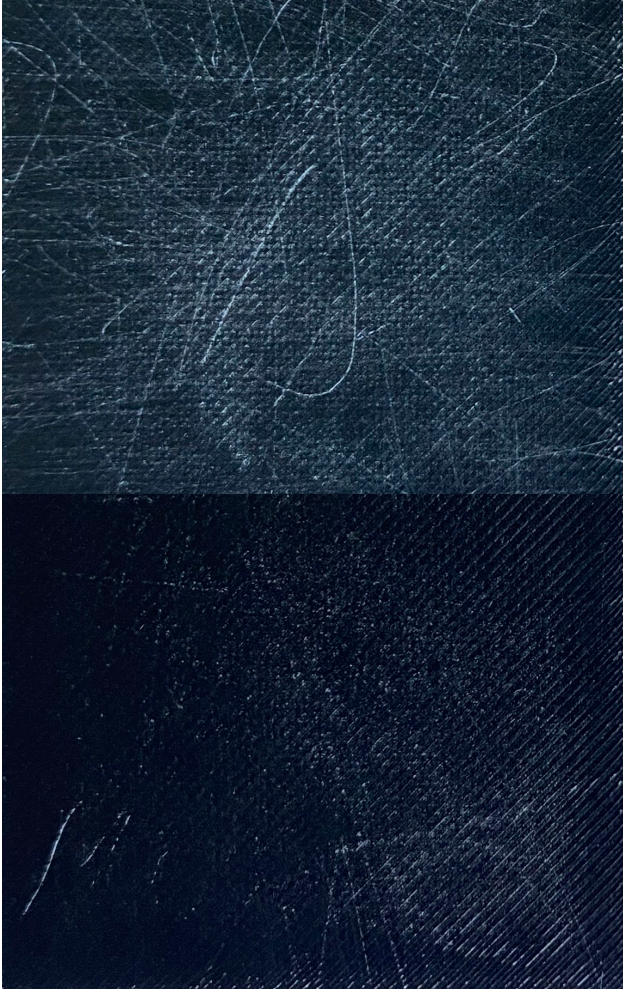


Figure 77: Results of the abrasion test for waterborne (above) and solvent-borne (below)

8.3 EMBOSSING

Due to the height differences in the imperfect prototype (Figure 78), there was an interplay of fast and slow abrasion. The embossed letters in the abrasion test (Chapter 8.2) yielded similar results to embossed letters from the observational study (Chapter 5). Figure 79 shows examples of the letters with abrasion, and Figure 80 shows the accelerated abrasion. This form of abrasion is usually perceived negatively because it was not meant to happen. However, the interplay of fast and slow abrasion presented an opportunity for Scratch Art, as the aim of Scratch Art is to make abrasion meaningful in plastics. These insights led to the inclusion of embossing in the final concept (Figure 81) to further enhance the Scratch Art concept.



Figure 78: Height imperfections due to the prototype method used



Figure 79: Examples of observed embossing with abrasion



Figure 80: Abrasion test result on the sample with embossing and two layers of solvent-borne paint



Figure 81: Embossing in the final concept

8.4 PRODUCTION

The plastic housing of the headphones is produced using coloured granulates through injection moulding. This method is chosen for its suitability for mass production, the creation of random-coloured speckles, and the added benefit of using recycled plastics. Figure 82 displays the result of injection moulding Scratch Art headphones with recycled granulates before applying the black coating. Precious Plastics is an example of an organisation demonstrating how to create products with recycled plastic that have a terrazzo-like appearance (Figure 83). Using recycled granulates is uncommon in mass production because brands prefer consistent colour and appearance, and controlling the randomness in standard injection moulding is difficult. However, for Scratch Art, the randomness of colours is desired, and the headphones are coated in black (Figure 84), which reduces the importance of easy colour management.



Figure 83: Examples of products made from recycled plastic by Precious Plastics (2025).



Figure 84: The process of spraying the headphones black with a solvent-borne coating.



Figure 82: Injection moulded headphone with recycled granulates without black coating

8.5 ADVERTISING

Requirement 3,2 in the previous concept was not met; the design did not inform the user of how it would look after extended use. Lee West Objects (2025) sells a brass watering can that “will develop a beautiful patina with time and use”. However, it does not show the user what the patina will look like after prolonged use. This causes the consumer to wonder about its appearance, potentially leading to disappointment if it does not meet their expectations (Oliver, 1980). Additionally, informing the user is important for Scratch Art, as the coloured abrasion is a key selling point. Therefore, the final concept communicates how the headphones will look after extended use. Figure 85 visualises how the final concept is advertised in-store, and Figure 86 shows the online version. Both advertising methods demonstrate that the headphones will develop coloured scratches over time, making visible wear an intentional and aesthetic feature of the design. By addressing the only missing requirement, Scratch Art now addresses all the requirements for the Show direction. Predicting the appearance of wear is challenging because each interaction with a product is unique. The advertisement, however, gives an impression of what the headphones could look like.



Figure 85: Advertising the Scratch Art headphones

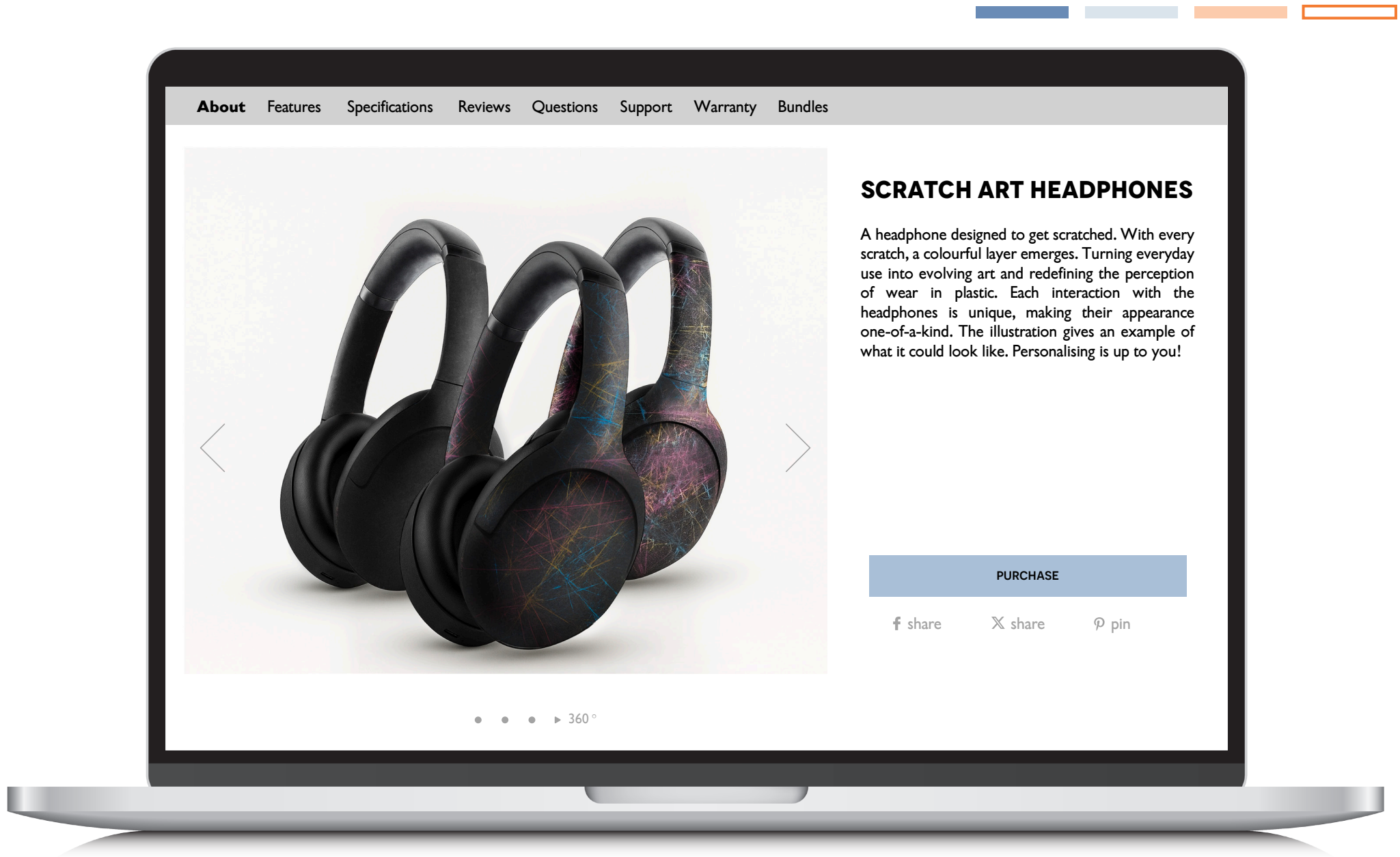


Figure 86: Advertising the Scratch Art headphones online

8.6 PROBLEM AREA 2 SUGGESTION: DIRT IN CONNECTION POINT

As discussed in Chapter 7.10, Scratch Art addresses only the first problem area: abrasion in the housing. This remains the central feature of the concept and should not be overshadowed. However, problem areas two (dirt in the connection point) and three (ablation and dirt in the cushions) remain unaddressed. These offer an opportunity to integrate additional toolkit strategies. This chapter proposes a solution for problem area two, dirt accumulation in the cup-headband connection, based on the design strategies from the toolkit. The Prevent strategy was selected over Show, Heal, or Hide to avoid distracting from the main feature. Additionally, preventing dirt was presumed to be more effective than hiding or reversing it in this context. This is because the dirt is often already partly hidden in the crevice of the connection point, making showcasing more difficult and healing more of a statement. The suggestion for the problem area aims to demonstrate that combining strategies within a single concept is feasible.

A common connection mechanism in headphones is the U-shaped yoke connection (Figure 87).

However, the observational study (Chapter 5) showed that this connection is a hotspot for accumulated dirt. To propose an alternative, a taxonomy (Figure 88) of cup-headband connections was created based on an internet search and in-store observations at MediaMarkt:

- **Fixed:** The cup is directly mounted to the headband.
- **Hinge:** Includes a foldable mechanism in one direction, sometimes offers a tilt in the cup for a better fit.
- **Swivel:** The cup can swivel for flat storage and tilt for a better fit.
- **Swivel and hinge:** The cup can swivel flat and fold in for optimal storage, and the cup also tilts for a better fit.



Figure 87: The U-shaped yoke connection in headphones

The observed headphones from Chapter 5 were then categorised using the four connection mechanisms: fixed, hinge, swivel, and swivel-hinge. To identify a cleaner alternative without compromising comfort and fit, the search was filtered for swivel and swivel-hinge connections that do not accumulate dirt. This led to three connection types that offer similar comfort but less attraction to dirt (Figure 89). Adopting one of the following three connection mechanisms reduces dirt accumulation without diverting attention from the core aesthetic concept of embracing abrasion in plastic.



Figure 89: Three connection types that accumulate less dirt than a yoke connection



Figure 88: Cup-headband connection mechanisms, structured by joint type and freedom of motion

8.7 PROBLEM AREA 3 SUGGESTION: ABLATION AND DIRT IN CUSHION

This section focuses on problem area three (T5.3): ablation and dirt accumulation in the cushion. Cushion ablation typically occurs through the gradual degradation of material, resulting in flaking and surface wear over time. As mentioned in Chapter 5, the cushions were often in worse condition than the rest of the headphones, which worsened the overall appearance. Ablation, combined with accumulated dirt, reduces the tactile and visual quality of the product, contributing to cosmetic obsolescence. In response, a one-on-one brainstorming session was conducted to solve this problem (Figure 90). Solutions were brainstormed using the toolkit; Figure 91 visualises the results.

The final concept's aim was to showcase the toolkit. The aim of Chapters 8.6 and 8.7 was to show that the toolkit's strategies can be combined to create a cohesive product that ages gracefully. The toolkit strategy for Scratch Art is Show, by embracing abrasion in the plastic housing. Instead of using faux leather, which is prone to ablation, choosing a washable mesh fabric (Figure 92) offers a viable option. It Heals dirt by washing it, and Hides dirt with a mesh pattern. By addressing cushion ablation and dirt (problem area three), the concept aims to reduce one of the headphones' most visually prominent signs of degradation. Addressing this problem area showcases the toolkit; demonstrating that the strategies, Show (ablation in the housing), Prevent (dirt in the connection point), Heal and Hide (ablation and dirt in the cushion) can be combined into a cohesive design.



Figure 90: One-on-one brainstorming session for the cushion problem



Figure 91: Overview of the results for the one-on-one brainstorming session

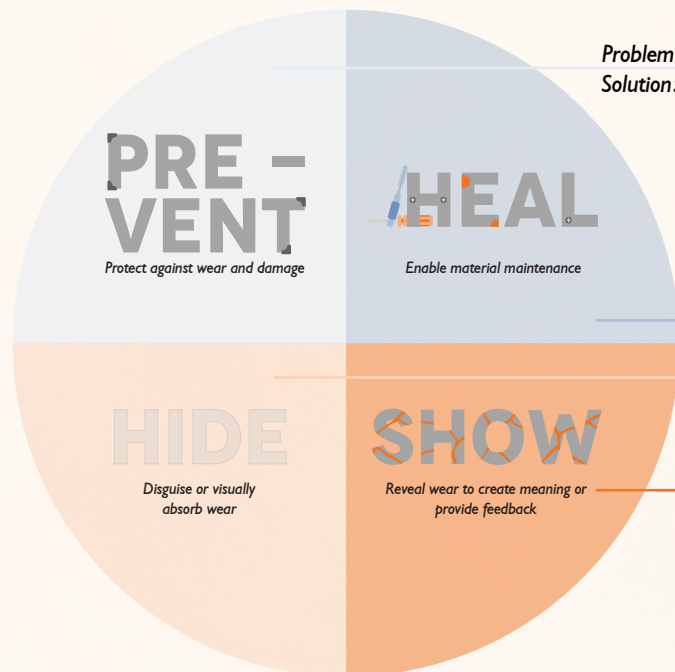


Figure 92: Headphone ear cushion made from a washable (Heal) mesh (Hide) fabric

8.8 CONCLUSION: FINAL CONCEPT

The final concept of Scratch Art is a design that integrates multiple strategies from the Design Toolkit for Gracefully Ageing Products. It demonstrates that multiple toolkit strategies can be integrated into a cohesive design. The first problem area, abrasion in the housing, remains the central feature of the concept. Scratch Art uses the strategy of Show to fight the mindset that wear means a loss of value. The concept embraces signs of use by revealing the colour underneath as scratches.

Scratch Art integrates the strategies Prevent, Heal, and Hide by addressing the two other problem areas. The issue of dirt accumulation in the cup-headband connection is reduced by selecting alternative joint types that collect less dirt, following the Prevent strategy. The third issue, cushion ablation and dirt build-up, is approached through the Heal and Hide strategies by introducing washable mesh cushions that heal wear and hides dirt. Scratch Art aims to stimulate product retention by designing with wear in mind using the Design Toolkit for Gracefully Ageing Products. The Scratch Art headphones are summarised in Figure 93.



Problem area 1: dirt in connection between cup and band
*Solution: **prevent** dirt with a less prone to dirt connection*

Problem area 2: ablation and dirt in cushions
*Solution: **heal** wear with washable cushions*
*Solution: **hide** dirt with mesh pattern*

Problem area 3: abrasion on housing
*Solution: **show** wear with coloured scratches*

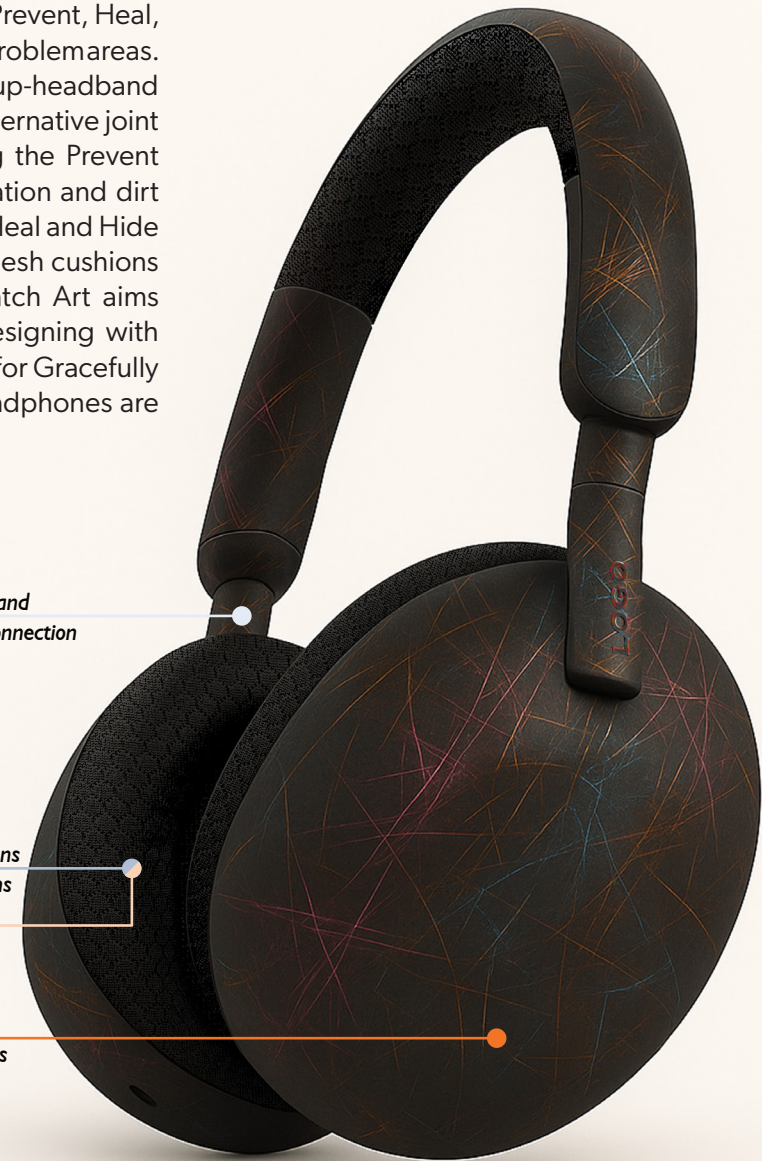


Figure 93: Scratch Art headphones summarised

9. USER STUDY ON PERCEPTION OF CONCEPT

This chapter presents the consumer study to validate the final concept (Chapter 8). It starts by introducing the goal (Chapter 9.1). Next, the research method (Chapter 9.2) and results (Chapter 9.3) are discussed. The chapter is concluded in Chapter 9.4.

9.1 INTRODUCTION: USER PERCEPTION OF THE CONCEPT

A consumer study was conducted to understand the consumer perception of Scratch Art. The main goal was to validate whether the concept enhances long-term product retention. This study validates Scratch Art (Chapter 8) by addressing RQ4, *“How can a headphone be designed to engage with material ageing and enhance long-term product retention?”*.

9.2 METHOD: USER PERCEPTION OF THE CONCEPT

A questionnaire was used as the research tool for this study. This was done so a larger sample size could be achieved in a short period of time compared to an interview or observation. Figure 94 shows the demographics of the 45 participants (19 male, aged 18–83, Dutch). The recruitment method used was convenience sampling through personal WhatsApp groups (e.g., friends, family, sports, school). Additionally, snowball sampling occurred as initial participants shared the survey within their own networks. The language used in the questionnaire was Dutch, as this was the used language in the WhatsApp groups. A pilot test was conducted with a fellow TU Delft student to check for typos, usability issues, and to estimate the length of the questionnaire.

At the start of the questionnaire, participants were informed that the study aimed to assess how the appearance of a headphone changes over time. It was explicitly stated that functionality was out of scope, and participants were asked to base their answers solely on the product’s visual appearance.

The questionnaire required approximately five to ten minutes and consisted of multiple Likert scale and open-ended questions. Participation was voluntary, and respondents could withdraw at any point..

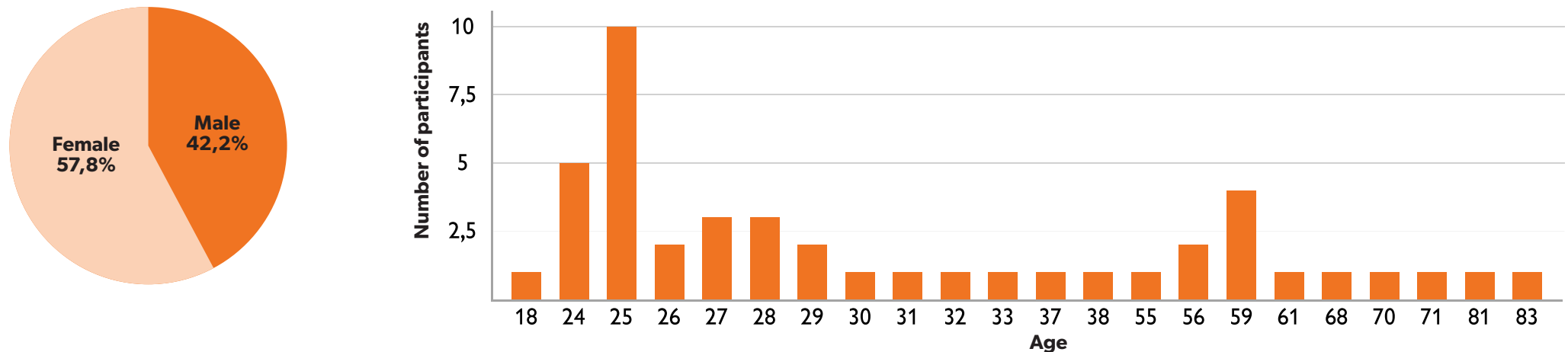


Figure 94: Participant demographics (gender and age distribution) for this study

The questionnaire had three sections:

- **Aesthetic evaluation over time**

This section assessed participants' perception of the headphone's appearance at three moments in its lifespan: before buying, after moderate wear, and after extensive wear. To ensure valid comparisons in the analysis, the wording of the questions was kept the same: "What do you think of the appearance of these headphones?". The different time contexts (new, after 5 years, after 10 years) were communicated through the introductory text before each question rather than altering the question itself. This approach ensured that participants evaluated the same question frame while considering different ageing scenarios presented visually (Figure 95).

- **Perception of wear**

This section focused on participants' subjective perceptions of wear. Specifically, it asked whether scratches were perceived as disruptive (T4.6) and whether the wear was perceived as natural (T4.7). The characteristics disruptiveness and naturalness were found in Chapter 4 and were added to the questionnaire to link back to the literature.

- **Influence of colour use on retention**

The final section explored whether the colourful appearance of the headphone influenced the willingness to keep wearing the product for longer. This approach aimed to assess whether Scratch Art enhances aesthetic appreciation over time and whether it positively affects product retention compared to a non-coloured version (Figure 96). Additional questionnaire materials, including the questions, can be found in Appendix F.



Figure 95: Visuals used to evaluate the aesthetic evaluation over time. The left shows the headphone when purchased, the middle after moderate wear (5 years), and the right after extensive wear (10 years).



Figure 96: Visual used to evaluate the influence of colour use on product retention

9.3 RESULTS: USER PERCEPTION OF THE CONCEPT

• Aesthetic evaluation over time

A Friedman test was conducted to compare the effect of the three concepts on appearance. The Friedman test is a non-parametric alternative to the repeated-measures ANOVA and is appropriate for ordinal data or when the assumption of normality is violated. A Shapiro-Wilk test confirmed that the ratings were not normally distributed for any of the headphone versions ($p = .002$, $p = .003$, and $p = .002$), suggesting variability in how participants perceived the appearance of wear. The Friedman test revealed a significant difference in participants' aesthetic evaluations between the new headphone, the headphone with five years of wear, and the headphone with ten years of wear ($\chi^2(2) = 17.657$, $p < .001$). Median ratings were 5 for the new headphone, 4 for the five-year version, and 4 for the ten-year version. Pairwise Wilcoxon signed-rank tests with Bonferroni correction ($\alpha = 0.017$) revealed that the new headphone was rated significantly higher than the five-year version ($Z = -2.512$, $p = .012$) and the ten-year version ($Z = -3.604$, $p < .001$).

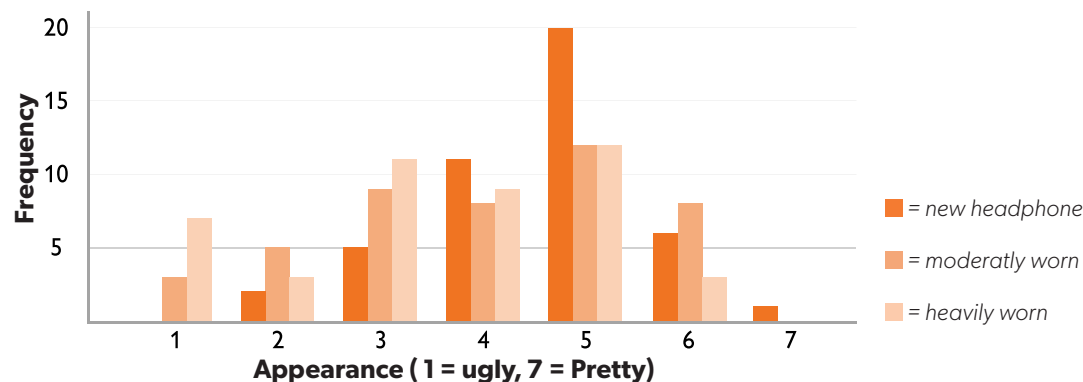


Figure 97: Appearance ratings for the new, moderately worn (5 years), and heavily worn (10 years) headphones

Moreover, the five-year headphone was also rated significantly higher than the ten-year headphone ($Z = -3.275$, $p = .001$). These results indicate that the aesthetic appreciation of the headphones declines progressively with increasing wear. Figure 97 shows the decline and the spread in ratings. The spread in the quantitative results aligns with the qualitative data, which revealed variation in user attitudes towards material ageing. While some respondents appreciated the added character of scratches, others perceived the same traces of use as signals of neglect or disorder. Four themes were identified from the open-ended responses to understand this variation better.

1. Appreciation for uniqueness and added character

Some participants felt that light wear introduced a sense of uniqueness and personality, especially with the five-year version. As one participant noted, *"The new one was a bit boring but nicely sleek in shape. The scratches actually added some colour."* For this group, wear contributed positively by making the product feel less generic.

2. Boundaries of acceptable wear

Despite the moderate appreciation for wear, there was a tipping point. The decline in positive ratings between the five- and ten-year versions reflects this. One participant explained, *"The ratio between scratches and black on the last one is less appealing,"* while another commented, *"After 10 years, it looks kind of grimy, a bit too much."* These remarks suggest that for some people, the abrasion becomes undesirable when it dominates the product's appearance.

3. Loss of perceived cleanliness, professionalism, and neutrality

Many participants expressed discomfort with how the scratches disrupted the product's clean and professional appearance. This was evident among those who preferred neutral and simplistic designs. One participant remarked, *"It does not look well-maintained, almost as if you do not take care of your stuff,"* while another stated, *"I bought a black headphone because I like the colour. The random colours from the scratches do not look good with it."* For these users, colourful wear conflicted with their aesthetic preferences and how they want to perceive themselves.

4. Functionality outweighs aesthetics for some users

For a subset of participants, the appearance of wear had little impact on product acceptance as long as functionality remained intact. One participant stated, *"Honestly, I do not care that much. It's not a showpiece or something to make a statement with."* This reflects a purely functional mindset in which visual ageing is secondary to performance.

- **Perception of wear**

The scatter plot (Figure 98) displays the relationship between perceived disruptiveness and naturalness of scratches. Each point represents an individual respondent. A Spearman's rank-order correlation was conducted to assess the strength and direction of the relationship between these two ordinal variables. This non-parametric test is appropriate when the assumptions of normality are not met or when dealing with ordinal scales, as is the case in this study. The Spearman's rank-order correlation revealed a moderate, statistically significant positive correlation between perceived disruptiveness and naturalness ($r_s = .423$, $p = .004$). This suggests that participants who perceive scratches as non-disruptive also tend to perceive them as more natural, and vice versa. However, the low correlation coefficient indicates that opinions vary considerably, which aligns with the spread visible in the scatter plot (Figure 98).

This spread is reflected in the open responses. Participants who rated the scratches as disruptive often mentioned concerns about the product looking damaged, unintentional, or visually cluttered (e.g., *"It looks broken or damaged"* or *"A headphone should be sleek, and this one is not"*). Similarly, low naturalness scores were associated with comments about the colours feeling unnatural or unintended (*"You would not expect completely different colours to appear"* or *"The colours do not look realistic to me"*). Conversely, participants who rated the scratches as less disruptive and more natural referred to the added character, uniqueness, and acceptance of wear over time (*"It gives more character to the design"* and *"Use leads to damage"*). One respondent noted, *"It is clear that*

the scratches are intentionally part of the design," which made the wear feel natural. This variety in responses aligns with the widespread scatter in the scatter plot (Figure 98), indicating polarised but explainable perceptions of the scratched aesthetic.

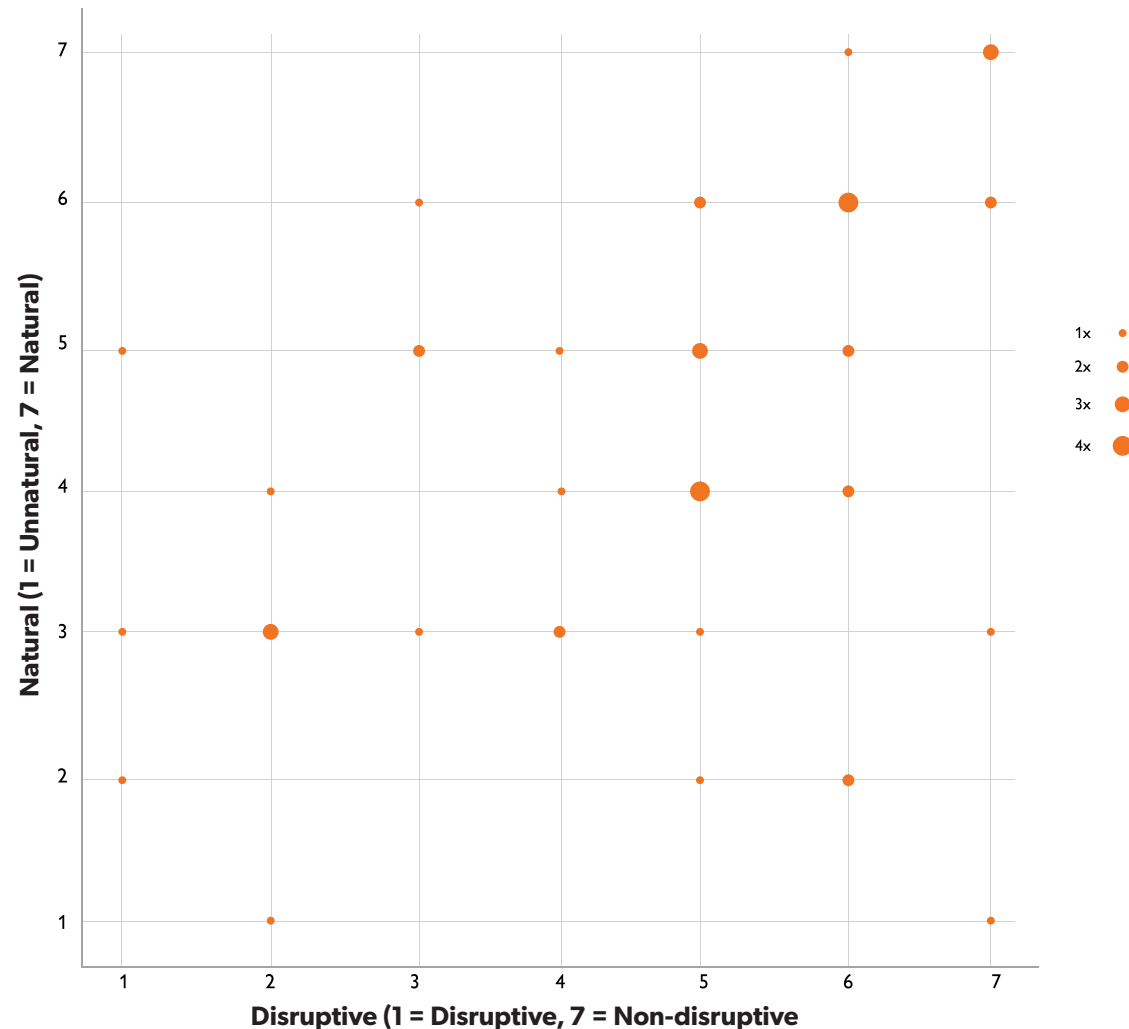


Figure 98: Relationship between perceived disruptiveness and naturalness of the scratches

- **Influence of colour use on retention**

The use of coloured scratches has a positive influence on product retention compared to plain scratches. A one-sample Wilcoxon signed-rank test was conducted to determine whether participants' ratings of the coloured scratches differed significantly from the neutral midpoint value of 4. This is a non-parametric alternative to the one-sample t-test, suitable for ordinal or non-normally distributed data. The test revealed that participants rated the coloured scratches as significantly increasing their willingness to continue wearing the headphone compared to the neutral midpoint of 4 ($Z = 3.08$, $p = .002$, $r = .46$). The median score ($Mdn = 5.00$) was significantly higher than neutral, indicating that the colourful appearance moderately enhances product retention despite wear. The distribution was moderately negatively skewed (skewness = -0.70), suggesting more participants leaned toward positive ratings. The distribution was also platykurtic (kurtosis = -0.48), indicating a relatively flat distribution with varied opinions. Figure 99 visualises the retention ratings for the coloured scratches compared to a headphone with plain scratches.

This tendency is reflected in the open responses. Participants who responded positively mentioned that the colours made the scratches appear intentional, more artistic, or part of the design (e.g., *"It looks more like it's meant to be"* or *"The wear pattern is more artistic and interesting"*). Others noted that the colours reduced the perception of the product being worn out (*"The coloured scratches make it look less like neglected or broken"*). However, several participants expressed a clear preference for minimalism or neutral tones,

describing the colours as *"Too chaotic"*, *"Too RGB gamer vibes"*, or *"Harder to match with outfits"*. This aligns with the variance seen in the distribution, indicating that while the coloured appearance positively influences retention for many, it remains polarising.

9.4 CONCLUSION: USER PERCEPTION OF THE CONCEPT

The consumer study on Scratch art demonstrated that aesthetic appreciation decreases as the headphone accumulates wear. At the same time, the use of colour in the wear patterns positively influences the willingness to retain the product, compared to non-coloured scratches. However, responses were highly diverse, with both positive and negative perceptions. This indicates that the visual statement made by Scratch Art does not appeal to everyone. For some users, it enhances the acceptance and appreciation of wear, while others maintain a preference for an undamaged or more neutral appearance. Nevertheless, the findings demonstrate that Scratch Art can support product retention by helping a subset of users perceive wear as something positive.

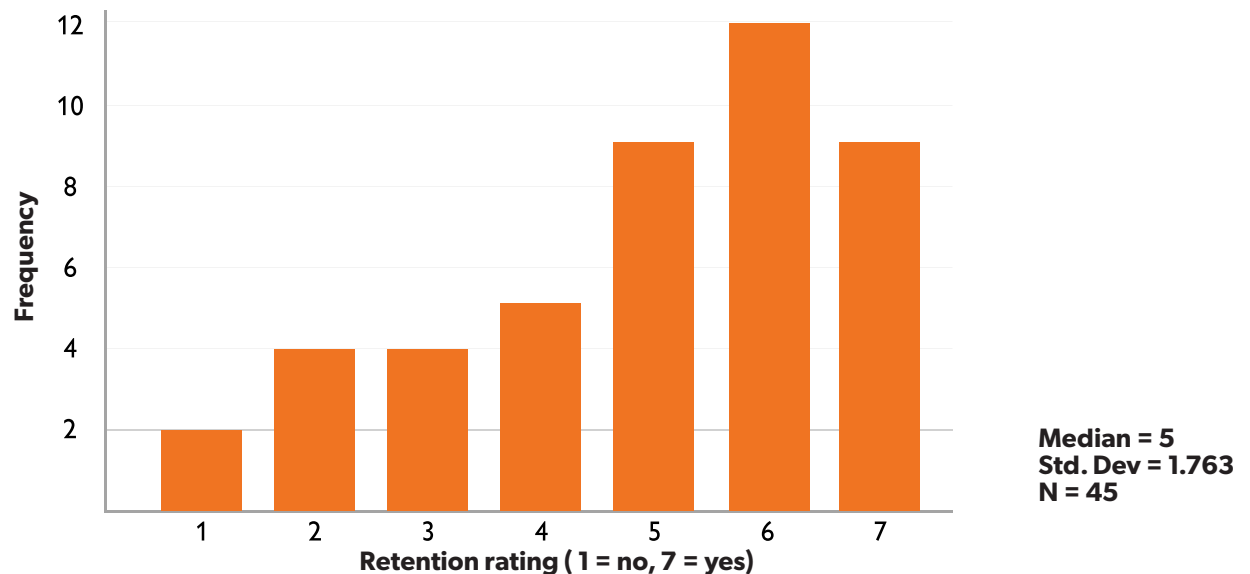


Figure 99: Retention ratings for coloured vs. non-coloured headphone appearance

10. DISCUSSION

This chapter reflects on the research results and discusses the recommendations for future research.

Stakeholder validation

It is necessary to conduct a more in-depth validation of the final toolkit. The strategies within the toolkit, Prevent, Heal, Hide, and Show, were validated in an early stage through a creative session (Chapter 6.3). The creative session aimed to determine whether the strategies effectively guided design students through the ideation process of ideating gracefully ageing headphones. The early validation of the toolkit was successful. However, a final validation of the toolkit would help to fully understand whether the tool successfully guides designers towards gracefully ageing products. The future validation should at least include the descriptions of the strategies, the examples of existing products that fit within the toolkit, and the design requirements.

Usability of the toolkit

The previous discussion point leads to the recommendation of improving the usability of the toolkit. If the toolkit's contents prove successful in guiding designers, future research should investigate whether the toolkit is easy to use. The current toolkit is presented as a flyer, which explains the four strategies and provides examples of existing products that align with these strategies. Validation with designers could determine whether the toolkit requires additional features or information to be developed as a design method. Various formats could be tested, such as a lecture, a video, or a more step-by-step guide similar to the design methods found in the Delft Design Guide (Boeijen et al., 2014).

Broader validation

To evaluate the toolkit's effectiveness and identify any missing strategies, future research should apply it within new design processes across diverse product contexts. One alternative context could be the product class, such as up-to-date, workhorse, and investment products (Cox et al., 2013). This toolkit was formed using an up-to-date product, headphones, which are discarded not only due to functional issues but also because of fashion, image, or novelty factors. For these products, cosmetic wear is especially undesirable and closely linked to perceived obsolescence. The toolkit provides examples of existing products that align with the strategies (Chapter 6.4), such as bus seat patterns to hide dirt or toothbrush heads that show colour when worn down. These are examples of workhorse products. The user research (Chapter 4) indicated that cosmetic wear is more tolerated in workhorse products, which are valued for their functionality rather than their appearance. Investment products, prioritising longevity and quality, are typically well-maintained, making aesthetic degradation less significant. A more comprehensive validation across these product classes could determine the toolkit's generalisability.

Broader spectrum than cosmetic obsolescence

The previous discussion point mentions a broader validation within the context of cosmetic obsolescence. However, cosmetic obsolescence is a subset of relative obsolescence. Relative obsolescence occurs when the user no longer finds the product appealing, or when newer, more attractive, or more advanced products emerge, even if the product still functions properly. This

raises the question of whether the toolkit could be applied beyond cosmetic ageing to address a broader range of problems. Or even for absolute obsolescence, such as improving functionality. For instance, preventing a product from breaking, healing a product by supporting reparability, hiding broken functionality with backup hardware, or even showing the broken headphones off by repurposing them into ear warmers. Future research should explore whether the toolkit's strategies, Prevent, Heal, Hide, and Show, could be extended to other forms of obsolescence to support longer product attachment and retention.

Judgement on product retention

Chapter 9 validates the final concept, Scratch Art. Results indicate a decline in aesthetic appreciation as coloured abrasion increases. The key limitation of this study was the simulation of long-term wear. A version with fewer fuzzy scratches for the ten-year headphones, for example, could have caused different outcomes. It remains unclear whether users responded negatively to the specific wear design or to the abrasion in general. Future research should explore improved methods for simulating and evaluating long-term wear.

The use of colour in wear patterns did show a more positive effect on willingness to retain than the non-coloured scratches. However, responses varied, suggesting that the strategy Show is not for everyone. While coloured abrasion was generally preferred over non-coloured, it remains uncertain how much product retention would actually be achieved by the strategy Show. Furthermore, future research should assess whether all four strategies contribute equally to prolonged product use.

CONCLUSION

This research explored how designers can use ageing and changing materials to stimulate product retention. The main question of this research was: *"How can designers use ageing and changing materials to stimulate product retention?"* This was examined through the lens of cosmetic obsolescence, which refers to the replacement of products due to visible wear, despite continued functionality. Based on the executed headphone design process, it can be concluded that there is no single way to address cosmetic obsolescence. The outcome is a Design Toolkit for Gracefully Ageing Products (Figure 100), which offers four strategies: Prevent, Heal, Hide, and Show. Prevent aims to keep products pristine by protecting against wear. Heal enables users to maintain a product's aesthetics over time. Hide camouflages visible wear. Lastly, Show embraces or uses wear to inform users.

The toolkit was developed through a research-through-design process using headphones as the context. Literature, user research, and headphone observations were translated into key takeaways that guided the design process, from which the four strategies emerged. These were tested in an early-stage creative session, where participants reported that the strategies offered useful structure without constraining creativity. The final concept, Scratch Art, focuses on the strategy Show and demonstrates the possibility of integrating the other directions into a cohesive design. Scratch Art is a headphone design that reveals coloured plastic beneath a black surface as it wears down. Although user responses to the concept were mixed, the project challenged perceptions of wear, illustrating how it can be reframed as a meaningful element of product use.

This research contributes to the sustainable aesthetics strategy by offering a practical toolkit that guides designers in addressing material ageing. Rather than ignoring it, these four strategies include material ageing into the product's full lifecycle, starting from the design process.

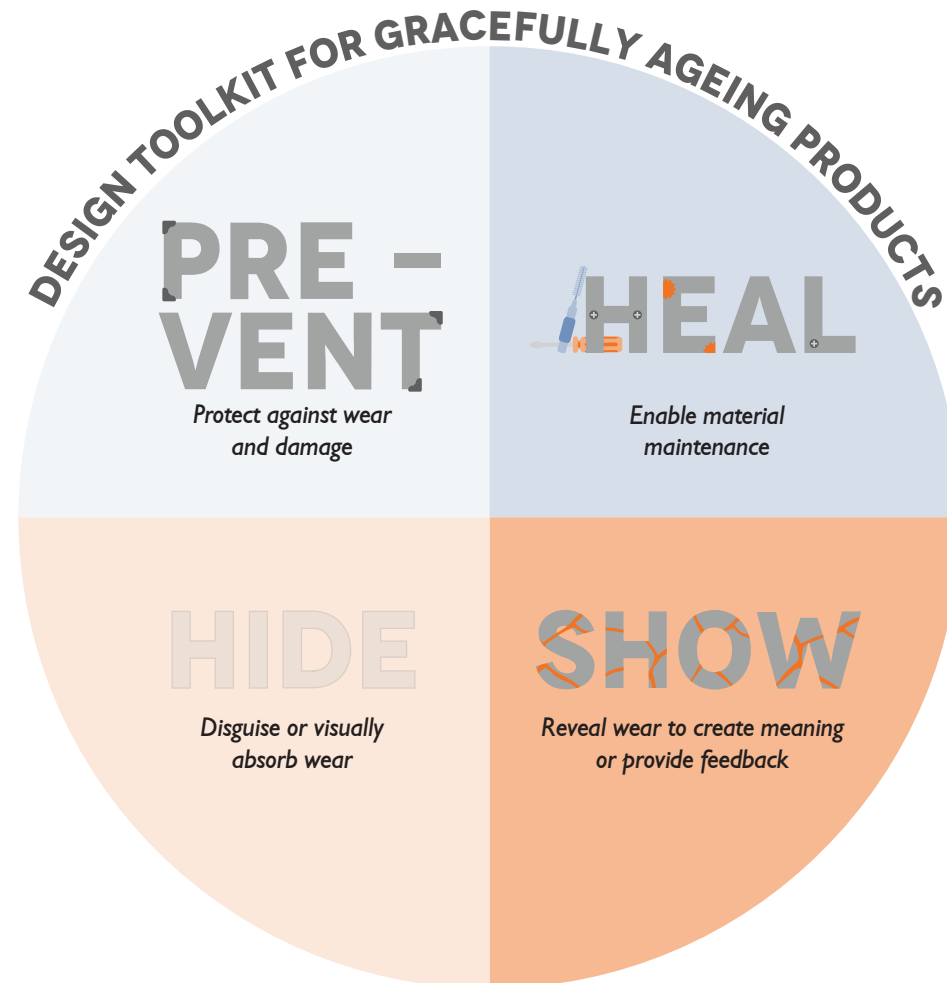
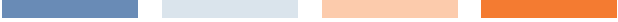


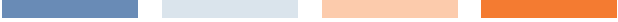
Figure 100: The Design Toolkit for Gracefully Ageing Products

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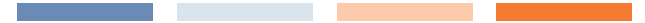
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APPENDICES

The following appendices are included:

- A. Project brief
- B. Case study product selection
- C. User perception study: aged products
- D. Creative session: validating the toolkit strategies
- E. Coating expert consultation
- F. User study: perception of the concept



A. PROJECT BRIEF

The attached document is the project brief, which marks the official start of the graduation thesis after it was approved in the kick-off meeting.



Name student J.N.A. Polderman

Student number 4,873,971

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Designing for longevity: implementation of the sustaining aesthetic value strategy to tackle premature obsolescence in product X

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

We live in a consumer society where products are cheap, easy to obtain, and quickly replaceable. This has led to people attaching less value to products and discarding them prematurely. Premature obsolescence is a global issue that affects a wide range of electronic products. It can result from manufacturers designing items prone to failure, as well as from consumers choosing to replace functional products or neglecting to repair faulty ones (Magnier & Mugge, 2022).

From an environmental perspective, such early replacement is highly undesirable. Prolonging the lifetimes and use times of products is considered a key strategy for increasing resource efficiency (UNEP 2011; Cooper 2010; Reuter and van Schaik, 2008). This approach is also one of the core principles of the circular economy concept (Cooper 2020) (Jaeger-Erben et al., 2020).

The decision to replace a product is not solely based on rational considerations. Emotional, functional, epistemic, social, and conditional values all influence the trade-off between keeping an existing product or replacing it with a new one (Van Den Berge et al., 2020). While significant attention has been given to functional value—such as enabling upgradability through Product Service Systems or promoting care and maintenance via the right-to-repair movement—less focus has been placed on supporting emotional value, particularly in sustaining aesthetic value.

This graduation project aims to contribute to existing research by further exploring and testing the strategy of sustaining aesthetic value (Van Den Berge et al., 2020). Products provide emotional value through their aesthetics, but wear and changing trends can diminish this appeal, often leading to early replacement. To address this, timeless designs (Figure 1)—characterized by simplicity, balance, and harmony—are less influenced by fashion changes and broadly appreciated across social groups. Additionally, using materials like leather or wood that age gracefully can promote product retention. These materials develop a pleasing patina over time, preserving or even enhancing their aesthetic value despite signs of wear (Figure 2) (Van Den Berge et al., 2020).

introduction (continued): space for images



image / figure 1 Timeless chair



image / figure 2 Old camera with a patina




Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Problem to Solve

This project addresses the premature replacement of products caused by diminished aesthetic and emotional value. While functional value often remains, products are discarded when wear or changing trends reduce their appeal. As Magnier and Mugge (2022) note, "replacement decisions are frequently driven by emotional and symbolic considerations rather than functional utility." This highlights the need to sustain aesthetic value to delay replacement.

Van den Berge et al. (2020) emphasize that timeless designs and materials that age gracefully can help preserve emotional value, yet more research is needed on how to implement this strategy for a specific product and context. Additionally, as Jaeger-Erben et al. (2020) suggest, shifting consumer perceptions of wear from defect to desirable can encourage retention.

Opportunities to Create Value

By focusing on timeless designs and resilient materials, this project explores the mentioned sustaining aesthetic value strategy (Van Den Berge et al., 2020). Providing actionable insights (e.g. types of upgrades) for designers and manufacturers. This approach fosters emotional attachment, prolonging the product lifetime, and support sustainability goals. Jaeger-Erben et al. (2020) argue this aligns with circular economy principles, where "extending product lifetimes is critical for increasing resource efficiency."

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Redesign a product X using the sustain aesthetic value strategy to combat premature obsolescence

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

The approach is divided into five phases: Literature Research, Testing, Concepts, Redesign, and Validation. The Literature Research phase focuses on understanding consumer replacement behaviour and the components of the sustaining aesthetic strategy. This involves identifying a product category with high replacement rates and applying methods from the Aesthetic Durability & Repair project (Nr. 4508805, 2024), alongside researching timeless designs, gracefully aging materials, and examples of products that maintain aesthetic value. In the Testing phase, the goal is to verify if my perception of gracefully aging and timeless designs aligns with consumers' views, using co-creation sessions, interviews, and questionnaires. The Concepts phase involves ideating, prototyping, testing, and evaluating iteratively to develop concepts for technical components, materials, and aesthetics based on insights from the Literature and Testing phases. In the Redesign phase, insights from the previous phases are combined into a single redesign. The Validating phase tests whether the implementation of the strategy fosters emotional attachment, extends product lifetime, and supports sustainability goals. Activities include aesthetic value testing (interviews/questionnaires) and evaluating.

The planning is straightforward, with 40 hours per week reserved. I anticipate a break in week 17, with some deviations due to national holidays.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a kick-off meeting, mid-term evaluation meeting, green light meeting and graduation ceremony. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).

Make sure to attach the full plan to this project brief. The four key moment dates must be filled in below

Kick off meeting 27 jan 2025

Mid-term evaluation 20 mrt 2025

Green light meeting 27 mei 2025

Graduation ceremony 7 juli 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	☐
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five. (200 words max)

I want to become a more confident designer, someone who dares to make my own decisions and can use critical feedback constructively without taking it personally. During my time as a board member at my rowing club, I have already taken significant steps in this direction. I've asked fewer small questions that I could solve myself and have become more confident in my decisions. The next steps for me are to truly trust my choices and not take feedback personally. After all, my mentors are there to guide me and offer help when needed.

I also want to keep enjoying the process, as there will undoubtedly be moments when graduating feels challenging. During my ACD project, I tackled this well by continuing to engage in activities that excite me about Industrial Design, such as conducting small tests and prototyping. I want to be able to do this even in the parts of my graduation process that I'm less enthusiastic about, such as documentation. My goal is to keep documenting the process while still enjoying tasks like prototyping.

B. CASE STUDY PRODUCT SELECTION

A headphone was chosen based on specific criteria derived from the literature and consumer relevance. The aim was to find a product for this project that would best explore ageing and changing materials. This scope helps to test and explore effectively and to uncover broader insights that may apply to other products. This appendic shows the process of selecting the case study product.

Introduction

The research was scoped to focus on electronic products because of the significant environmental impact associated with electronic waste. Over 50 million tonnes of electronic waste are generated annually, with the Netherlands alone averaging more than 20 kg per capita (Compendium voor de Leefomgeving, 2024). Household appliances, in particular, present challenges regarding premature obsolescence (Hennies & Stamminger, 2016) and retaining their aesthetic value over time (van den Berge et al., 2021). According to the Global E-waste Monitor (Michelle Wagner et al., 2024) , small equipment is the most discarded electronic and electrical equipment (Figure 101).

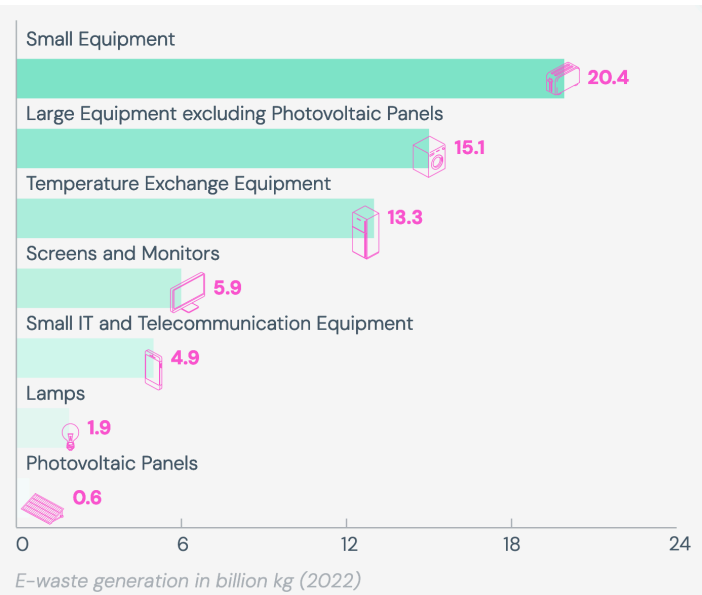


Figure 101: Total E-waste Generated by electronic and electrical equipment (Michelle Wagner et al., 2024).

Method

The product was selected using an elimination process inspired by the project Aesthetic Durability & Repairability (Vooren, 2024). The initial pool of 56 household appliances used by Vooren (2024) was expanded to 70 (Figure 102) to better reflect the 74 electrical products typically found in EU households (Michelle Wagner et al., 2024).



Figure 102: The initial pool of household appliances

The elimination process (shown on next page) was based on feasibility, viability, and desirability to fit the scope of this graduation project. Feasibility ensures the product can be redesigned within the 100-day timeframe. Large appliances such as ovens and washing machines are excluded for this reason. Viability ensures that investment pieces, which are already well-maintained and less affected by aesthetic degradation (Cox et al., 2013), are not selected. This excludes products such as sewing machines and stereo speakers. Desirability considers both the target audience and my personal preferences. Since one of my goals (Appendix A) is to keep enjoying the project, the product should align with my interests. As a result, products like a gaming console and a humidifier are excluded.

Through the process of elimination, 10 appliances were left; these were then ranked based on the following four weighted (5,3,3,4) criteria, because the criteria differ in their importance (Boeijen et al., 2014). The criteria are further explained on page 104.

- **Product class:** Prioritises products discarded due to aesthetics rather than functionality, as these offer greater potential for aesthetic durability strategies.
- **Market penetration rate:** Focuses on widely owned products, where even minor improvements in longevity can significantly reduce waste.
- **Visibility and emotional interaction:** Prefers frequently seen and emotionally engaging products, making their aesthetic condition more relevant to consumers.
- **Sensitivity to signs of use:** Selects products prone to visible wear and tear, as maintaining their aesthetic appeal can extend their lifespan.

											
Criteria	Weight	Alarm clock	Blender	Hair clipper	Hairdryer	Hand mixer	Headphone	Hand blender	Iron	Kettle	Vacuum cleaner
Product class	5	3	1	2	3	1	4	1	3	1	3
Market penetration rate	3	2	3	2	4	3	2	3	3	4	4
Visibility and emotional interaction	3	4	1	4	3	1	4	1	2	4	2
Sensitivity to signs of use	4	1	3	3	2	3	4	2	3	2	4
	Without weight	10	8	11	12	8	14	7	11	11	13
	With weight	37	29	40	44	29	54	25	42	37	49

Figure 103: Overview of how the products score on the weighted criteria

Results

Figure 103 shows how the ten remaining appliances scored on the weighted criteria mentioned above. Headphones score the highest on the weighted criteria. The argumentation for each ranking is as follows:

- **Product class**

Headphones fall under the “up-to-date” product category, as headphones are frequently updated with new models and technology, making older versions prone to being replaced due to technological advancements or aesthetic trends (Manley, 2018).

- **Market penetration rate**

Second, headphones are sensitive to signs of use, with visible wear such as scratches or cracked faux leather impacting their perceived value.

- **Visibility and emotional interaction**

Headphones are a visible product, worn on the head, often serving as a fashion accessory. This enhances the concerns about aesthetic wear.

- **Sensitivity to signs of use**

Although interventions to prevent cosmetic obsolescence exist, their uptake among users is limited. An internet search showed that while some higher-end models come with a travel case, such protective accessories are generally absent from lower-priced products. Even when a case is included, only 18% of users use it regularly (Philipson & Wallner, 2018). These low adoption rates for preventative measures call for other ways to prevent cosmetic obsolescence.

Conclusion

The headphone was chosen as the product case for this study based on its alignment with the following criteria: product class, market penetration rate, visibility and emotional interaction, and sensitivity to signs of use.

Elimination process

The following images show the elimination process that led to the 10 remaining products.

1. Everyday appliances



2. Feasibility

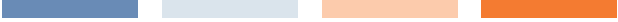


3. Viability



4. Desirability





Detailed explanation of the weighted criteria

1. Product class (Weight: 5)

A product's category influences why and when it is discarded. "Many products are thrown out not because they are broken but because they are no longer wanted" (Cox et al., 2013). A key selection criterion was whether a product falls under Cox et al.'s (2013) typology classification, specifically *Workhorse* or *Up-to-date* products.

Investment products were excluded since they are already well-maintained, making aesthetic degradation less significant.

Up-to-date products, frequently replaced due to aesthetics or technological trends rather than functionality, are the most relevant for exploring the strategy Sustaining Aesthetic Value. These products are closely aligned with *dynamic products* (Mugge et al., 2017), which are affected by technological advancements and are often discarded due to (planned) obsolescence. Examples include smartphones and laptops, which consumers replace not because they no longer function, but because newer models offer more features or improved design.

In contrast, Workhorse products, valued for reliability, are mainly discarded when broken, making aesthetic factors less relevant. These products are similar to *static products* (Mugge et al., 2017), which maintain their functionality over time and are less vulnerable to technological obsolescence. Products like irons and kettles, which serve their utilitarian function for many years without significant technological advancement, fall into this category.

For this study, prioritising Up-to-date and dynamic products provides the best opportunity to explore how aesthetic durability can extend the lifespan of products typically discarded due to trends or technological changes.

2. Market penetration rate (Weight: 3)

The penetration rate of a product refers to the percentage of the population that owns or uses the product (Cambridge University Press & Assessment, 2025a). For example, the penetration rate of a vacuum cleaner is generally higher than that of a humidifier, as vacuum cleaners are more common household appliances. Products with high penetration rates are owned by a larger percentage of households, meaning that even minor improvements in longevity and desirability can lead to significant waste reduction. For this project, finding the exact market penetration rate for the ten remaining products is challenging due to limited publicly available data. However, based on available information, (Teschke & Riedel, 2004) an estimation was made for all products.

3. Visibility and emotional interaction (Weight: 3)

People may also replace frequently used, visible products due to aesthetic boredom or desire something new to express their style (Mugge, Schoormans, et al., 2005) (Desmet & Hekkert, 2007). Visible products, such as watches or kitchen appliances, are regularly seen by others and often serve an expressive function, making their aesthetic condition crucial (Mugge et al., 2017). In contrast, hidden products, such as vacuum cleaners or drills, serve a utilitarian role and are stored out of sight, reducing concerns about aesthetic wear (Park, 2009). Selecting a visible product ensures a stronger focus on aesthetic durability, as these products are more likely to be replaced for aesthetic reasons rather than functional failure.

4. Sensitivity to signs of use (Weight: 4)

This criterion is essential for selecting a product that aligns with the overall strategy. Signs of wear, such as scratches or marks, can significantly reduce a product's aesthetic appeal and lead to premature disposal (van den Berge et al., 2021). When choosing a product, it is important to consider materials more susceptible to these visible signs of use and deterioration, as these products are more likely to be discarded due to their perceived loss of aesthetic value (Mugge, Schifferstein, et al., 2005, 2005; van den Berge et al., 2021). The focus was on identifying products that likely have materials prone to quickly losing their visual appeal. This increases the opportunity to investigate ways to maintain aesthetic durability. My selection process relied on intuition and prior knowledge to assess the potential for visible wear and the materials' tendency to degrade aesthetically over time.

C. USER PERCEPTION STUDY: AGED PRODUCTS

The attached documents are the materials and results from the semi-structured interview about the user perception of ages products.

Consentform

Toestemmingsformulier

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd **Tijdloos of trendy & mooi of slecht verouderd**. Dit onderzoek wordt uitgevoerd door Jet Polderman van de TU Delft.

Het doel van dit onderzoek is inhoudelijke inzichten verzamelen over wat een design tijdloos of trendy maakt en wanneer mensen materialen mooi en wanneer slecht vinden verouderen en zal ongeveer 30 minuten in beslag nemen. De data zal gebruikt worden voor mijn afstudeerproject aan de TU Delft. U wordt gevraagd om een aantal producten en materialen te beoordelen op een schaal van 1-7 om vervolgens een aantal inhoudelijke vragen over de producten te beantwoorden.

Uw deelname aan dit onderzoek is volledig vrijwillig, en **u kunt zich elk moment terugtrekken zonder reden op te geven**. U bent vrij om vragen niet te beantwoorden. Het is eventueel ook mogelijk om data na verzameling te laten verwijderen binnen twee weken, doe dit door mij een berichtje te sturen.

Doorgaan met de survey betekent dat u het eens bent bent de bovenstaande informatie.

Ondersteunende informatie voor de vragen
Mooi/slecht verouderd

Geef je mening over de leeftijd en staat van het materiaal. Als de functie of andere andere aspecten je mening beïnvloeden, mag je die ook benoemen.

- 1 = slecht verouderd, 7 = mooi verouderd.

Toestemmingsformulier

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICIPANT TASKS AND VOLUNTARY PARTICIPATION		
1. Ik heb de informatie over het onderzoek gedateerd april 2025 gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	☐	☐
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	☐	☐
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent - Foto met prioriteiten lijst. Deze foto kan ten alle tijden vervaagd gemaakt worden als dat de voorkeur heeft. Ik geef aan als ik dit wil en weet dat dit tot 30 mei 2025 aangegeven kan worden. - Audio-opname interview. De audio-opname wordt gebruikt om de antwoorden van de open vragen te kunnen samenvatten, de opname wordt aan het einde van de studie (sept 2025) verwijderd en de antwoorden worden voor publicatie verstuurd om gecontroleerd te worden door de deelnemer. - Deelnemer vult score in 1-7, onderzoeker noteert open vragen	☐	☐
4. Ik begrijp dat de studie na 30 minuten eindigt.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
5. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden. Zoals persoonlijke mening over tijdloos/trendy designs en meningen over materialen.	☐	☐
6. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk: de audio opname wordt verwijderd op 1 september 2025, als gewenst worden bij eventuele ondersteunende foto's gezichten vervaagd	☐	☐
7. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals (bijvoorbeeld naam en woonplaats) niet gedeeld worden.	☐	☐
8. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt op 1 september 2025.	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
9. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor: - gemiddelde score (1-7) van materialen voor materiaalkeuze - gemiddelde score (1-7) van producten voor inzichten over wat consumenten tijdloos/trendy vinden - toelichting op de vragen kunnen als quotes in mijn rapport komen - alle toelichtingen worden samengevat in mijn rapport - mijn rapport wordt gepubliceerd op de archief website van de TU Delft	☐	☐
10. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
11. Ik geef toestemming om de geanonimiseerde data (foto, quotes, samengevatte inzichten) die over mij verzameld worden gearchiveerd worden in de archief website opdat deze gebruikt kunnen worden voor toekomstig onderzoek en onderwijs.	☐	☐
12. Ik begrijp dat de toegang tot deze archief website (repository) open is.	☐	☐

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

Jet Polderman

Naam onderzoeker

Handtekening

Datum

Naam deelnemer

Handtekening

Datum

Materials

Rank the following 13 materials from aged badly (1) to aged well (7)
Beoordeel de volgende materialen van slecht (1) tot mooi verouderd (7)

	Aged badly							Aged well						
	Slecht verouderd							Mooi verouderd						
	1	2	3	4	5	6	7							
1. 6 years old polyester-plastic	☐	☐	☐	☐	☐	☐	☐							
2. 5 years old aluminium	☐	☐	☐	☐	☐	☐	☐							
3. 40 years old wood (hout)	☐	☐	☐	☐	☐	☐	☐							
4. 5 years old TPU-plastic	☐	☐	☐	☐	☐	☐	☐							
5. 20 years old steel (staal)	☐	☐	☐	☐	☐	☐	☐							
6. 7 years old leather (leer)	☐	☐	☐	☐	☐	☐	☐							
7. 3 years old cork (kurk)	☐	☐	☐	☐	☐	☐	☐							
8. 40 years old leather (leer)	☐	☐	☐	☐	☐	☐	☐							
9. 30 years old steel (staal)	☐	☐	☐	☐	☐	☐	☐							
10. 5 years old bamboo	☐	☐	☐	☐	☐	☐	☐							
11. 7 years old plastic	☐	☐	☐	☐	☐	☐	☐							
12. Own product aged well	☐	☐	☐	☐	☐	☐	☐							
13. Own product aged badly	☐	☐	☐	☐	☐	☐	☐							

1. 6 year old polyester-plastic



2. 5 year old aluminium



3. 40 year old wood (hout)



4. 5 year old TPU-plastic



5. 20 year old steel (staal)



6. 7 year old leather (leer)



7. 3 year old cork (kurk)



8. 40 year old leather (leer)



9. 30 year old steel (staal)



10. 5 year old bamboo



11. 7 year old plastic



12. Can you find an object that has aged well around your home/surroundings. Rate its aging quality on the scale.

b. Can you explain your answer? What do you like/dislike?

13. Repeat question 12 but for an object that has aged badly

b. Can you explain your answer? What do you like/dislike?

Answers

Aged badly

Pilot 3 year old fabric



P1 1 year old plastic



P2 7+ year old laminated wood



Aged badly

P3 20 year old coloured metal



P4 Unknown age painted steel



P5 9 year old wood veneer on plastic



P6 2 year old plastic



P7 13 year old painted wood



P8 Unknown age painted wood



Aged well

Pilot 3 year old fabric



P1 30+ year old wood



P2 100 year old bronze



P3 50 year old ceramic



P4 Unknown age wool



P5 80 year old leather and aluminium



Aged well

P6 1 year old leather



P7 20 year old wood



P8 70 year old wood



D. CREATIVE SESSION: VALIDATING THE TOOLKIT STRATEGIES

The Scratch Art concept was developed using the newly developed Graceful Ageing Toolkit. While the toolkit was based on literature and user research, validation was needed to assess whether it also functions effectively to guide designers. This chapter presents the creative session to validate the toolkit's usability and effectiveness, including the introduction with aim, method, results, and conclusion of the session.

Introduction

This chapter presents a creative session to validate the toolkit's strategies. The aim was to test whether the strategies were successful for generating ideas and if they encompass the complete topic of gracefully ageing. The same context of headphones was used to help generate concepts and keep the research consistent.

The main question was used to form a problem statement to guide the creative session: *"Consumers discard headphones while they are functionally sound, disgraceful ageing is one reason for that"*.

Method

Three fellow students (1 male, aged 24-25, Dutch) engaged in a two-hour creative session. The participants were recruited through convenience sampling. The session was held in Dutch, as this was the native language of all participants. Products with different materials were placed on the table so the participants could use them for inspiration. These products were made from wood, bamboo, aluminium, plastic and silicon. They were first introduced to the topic and problem statement and performed rapid ideation to challenge their preconceptions. After that, the participants explored the problem through different “How Can We” (HCW) questions:

- Make wear fun (in headphones)?
- Camouflage wear (in headphones)?
- Heal wear (in headphones)
- Prevent wear (in headphones)?
- Stimulate ugly ageing (in headphones)?
- Stimulate the maintenance of materials?
- Let nature inspire us?

The first four HCW questions, based on the Graceful Ageing Toolkit, were addressed using a 'brain sketching' activity. Participants rapidly visualised and built on each other's ideas through sketches. Afterwards, ideas were evaluated using a 'hits and dots' method, where participants placed coloured stickers to indicate ideas they found impactful, enjoyable, or original. A reflection was done to see if anything was missing. The set-up for the brainsketching activity is shown in Figure 104.

The ugly ageing question was added to change things around and stimulate absurd ideas. The final two HCW questions were added to see whether the toolkit was comprehensive or missing elements. The questions were explored through post-it brainstorming. The resulting ideas were thematically clustered and assessed using the 'hits and dots' approach. The set-up for this part is shown in Figure 105.



Figure 104: Brainsketching set-up for the creative session



Figure 105: Post-it brainstorming set-up during the creative session

Results and reflection

The creative session demonstrated that the toolkit's strategies effectively supported idea generation. Participants produced diverse ideas across all HCW questions, balancing conceptual and practical outcomes.

HCW questions

- HCW embrace wear?

Ideas focused on transforming wear into either an artistic or communicative function. The brainstorm resulted in statements and art-like results.

- HCW hide wear?

Two distinct strategies emerged: camouflaging wear with patterns or textures, and physically covering worn areas with replaceable or modular elements. This directly links to the Layered Concept presented in Chapter 7.

- HCW heal wear?

This strategy led to solutions involving self-healing materials and modular components that users could easily replace or repair. Although fewer in quantity, the ideas were convenient and directly applicable.

- HCW prevent wear?

This question generated ideas focusing on material properties, such as hard and soft materials, and unconventional ideas, including a trampoline add-on and changing the mindset to treat it like a child.

- HCW stimulate ugly ageing?

This question created a playful, humorous atmosphere. Ideas became increasingly extreme, intentionally reversing desired wear created a nice, creative break from the more commercially viable options. The overall result was that the grosser the product, the uglier they felt they were aged.

- HCW stimulate the maintenance of materials?

The answers generated to this question were the more practical solutions from the heal question. It stimulated many implementable ideas. Participants proposed integrated maintenance tools and rituals that encourage care, directly leading to the Integrated Kit (Chapter 7.5) concept used to improve the Take Care of Me prototype.

- HCW let nature inspire us?

Participants drew inspiration from how nature ages, such as shedding, growth rings, and wrinkles. While not always directly transferable to headphones, it was an elevating question.

Strategies

The four toolkit strategies, then Embrace, Hide, Heal, and Prevent, functioned effectively as prompts for idea generation. Embrace led to expressive concepts that embraced wear as a meaningful feature, often through storytelling or aesthetic enhancement. However, it also generated more informative ideas about wear, such as the hidden message to be careful. This resulted in refining Embrace to Show. Hide generated ideas such as patterns, textures, or modular covers to disguise wear, directly linked to the Layered Concept in Chapter 7.2. Heal focused on repairability through filling, repurposing, or modular replacement. The additional Stimulate Maintenance question complemented Heal by producing the highest number of implementable ideas, emphasising the importance of supporting users in maintaining products. This directly led to the development of the Integrated Kit. Prevent resulted in a mix of practical solutions—such as wear-resistant materials—and more unconventional ideas, including behavioural changes like replacing headphone use with singing.

Conclusion

The participants mentioned that the four strategies provided a good balance between freedom of brainstorming and guidance for the problem statement. The strategy Embrace was refined to Show to better align with Show's two sides: informing and embracing. The insights from this session improved the concept Take care of me.

Materials used for the creative session

CREATIVE SESSION

Gracefully aging and changing materials

ONDERWERP VAN VANDAAG

Het mooi oud worden van materialen
In koptelefoons

9-4-2025

IDEEËN VINDEN

- Stel het oordeel uit
 - We zijn niet kritisch nu, maar ik later
- Er zijn wat regels
 - Quantity breeds quality: Hoe meer ideeën, hoe beter!
 - Hitchhike: Bouw voort op elkaars ideeën
 - Freewheel: Geen enkel idee is te wild of te gek

VIES



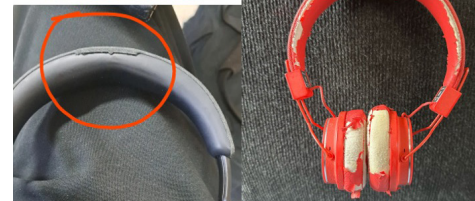
KAPOT



AGENDA

- 16:45– Start sessie & Introductie
- 16:55– Ideeën vinden
- 17:45– Pauze
- 18:00– Ideeën vinden
- 18:35– Reflectie & afronden
- 18:45– Samen eten)

AFBLADDEREN



INTRODUCTION

Kunnen jullie voorbeelden noemen van materialen
of producten die mooi zijn verouderd?

KRASSEN



UITGEKEKEN

“Toe aan iets nieuws”

“Vriend van me heeft net de
nieuwste gekocht, die wil ik
ook”

“Deze heeft betere noise
cancelling”

CHALLENGE

Consumenten danken koptelefoons af terwijl ze
functioneel nog goed zijn, onder andere doordat
het materiaal ‘lelijke’ slijtage heeft en doordat ze zijn
uitgekeken op het product

Opdracht:
Schrijf in 2 minuten zoveel mogelijk dingen op
over dit onderwerp

Tips:
• Gebruik je blaadje en stiften
• Er zijn geen foute antwoorden
• Omhoud: Hitchhike, freewheel en Quantity
breeds Quality

CHALLENGE 1

Deze ‘opportunity statement’ heeft mij ook aan
het denken gezet...

CHALLENGE 1

Deze ‘opportunity statement’ heeft mij ook aan
het denken gezet...

Er zijn ook manieren om slijtage leuk en
mooi te maken, zodat mensen niet
uitgekeken raken



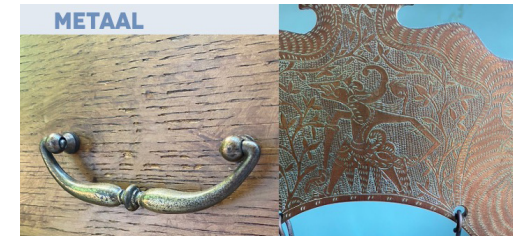
Slijtage positief zien
Embrace

HKJ 1

Hoe kunnen we slijtage in een koptelefoon leuk
maken?

15 MIN

METAAL



HOUT



LEER



INTRODUCTION

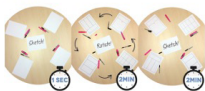
Kunnen jullie voorbeelden noemen van materialen
of producten die lelijk zijn verouderd?

KUNSTSTOF

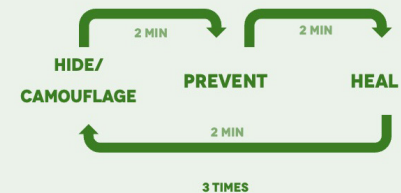


BRAINSKETCHING – 18 MIN

- "Brainsketching" 18 min
- Op basis van mijn gevonden clusters
- Er zijn 3 rondes
- **Stap 1:** Pak allemaal een A3 en een pen, elke ronde is 2 min
- **Stap 2:** Schrijf je zoveel mogelijk oplossingen op
 - Gebruik woorden, tekeningen, pijlen
- **Stap 3:** Na 2 minuten, geef het papiertje door naar links
 - Bouw voort op elkaars ideeën



BRAINSKETCHING – 18 MIN



BRAINSKETCHING – 18 MIN



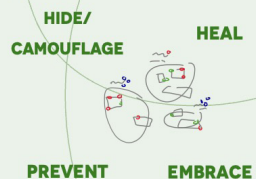
VRAAG

Zijn er naast 'Embrace', 'Heal', 'Hide', 'Protect' nog meer clusters die ik heb gemist?

5 MIN

HITS OR DOTS – 5 MIN

- Impactvol
- Goed/ leuk
- Origineel / vernieuwend
- Gemist / nieuwe cluster



PAUZE

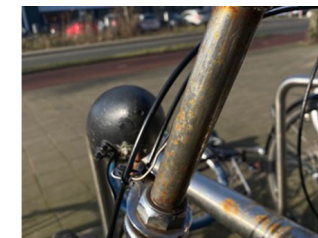
Pauze!

15 minuten om wat snacks en drinken te pakken!

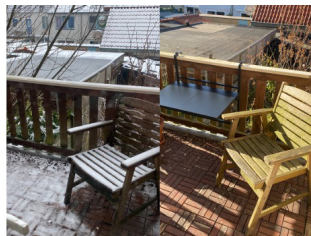
OPPORTUNITY STATEMENT

Consumenten zijn lui en zorgen niet goed voor materialen die normaal wel 'gracefully agen'

METAAL



HOUT



LEER



HKJ 4

Hoe kunnen we onderhouden van materialen stimuleren

12 MIN

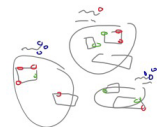
HKJ 4 - CLUSTERTIJD!

Hoe kunnen we onderhouden van materialen stimuleren

5 MIN

HKJ 4 - HITS OR DOTS

- "Hits or Dots" 5 min
- **Stap 1:** Pak allemaal een stickervel
- **Stap 2:** Blauwe sticker
 - Welke clusters zijn volgens jou het 'meest impactvol'?
- **Stap 3:** Rode sticker
 - Kies welke ideeën volgens jou 'goed' of 'leuk' zijn
- **Stap 3:** Groene sticker
 - Welke ideeën zijn volgens jou het meest 'origineel' of 'vernieuwend'?



HKJ 5

Hoe kunnen we lelijk oud wordende producten stimuleren?

15 MIN

HKJ 6

Hoe kan de natuur ons inspireren voor mooi oud wordende producten?

15 MIN

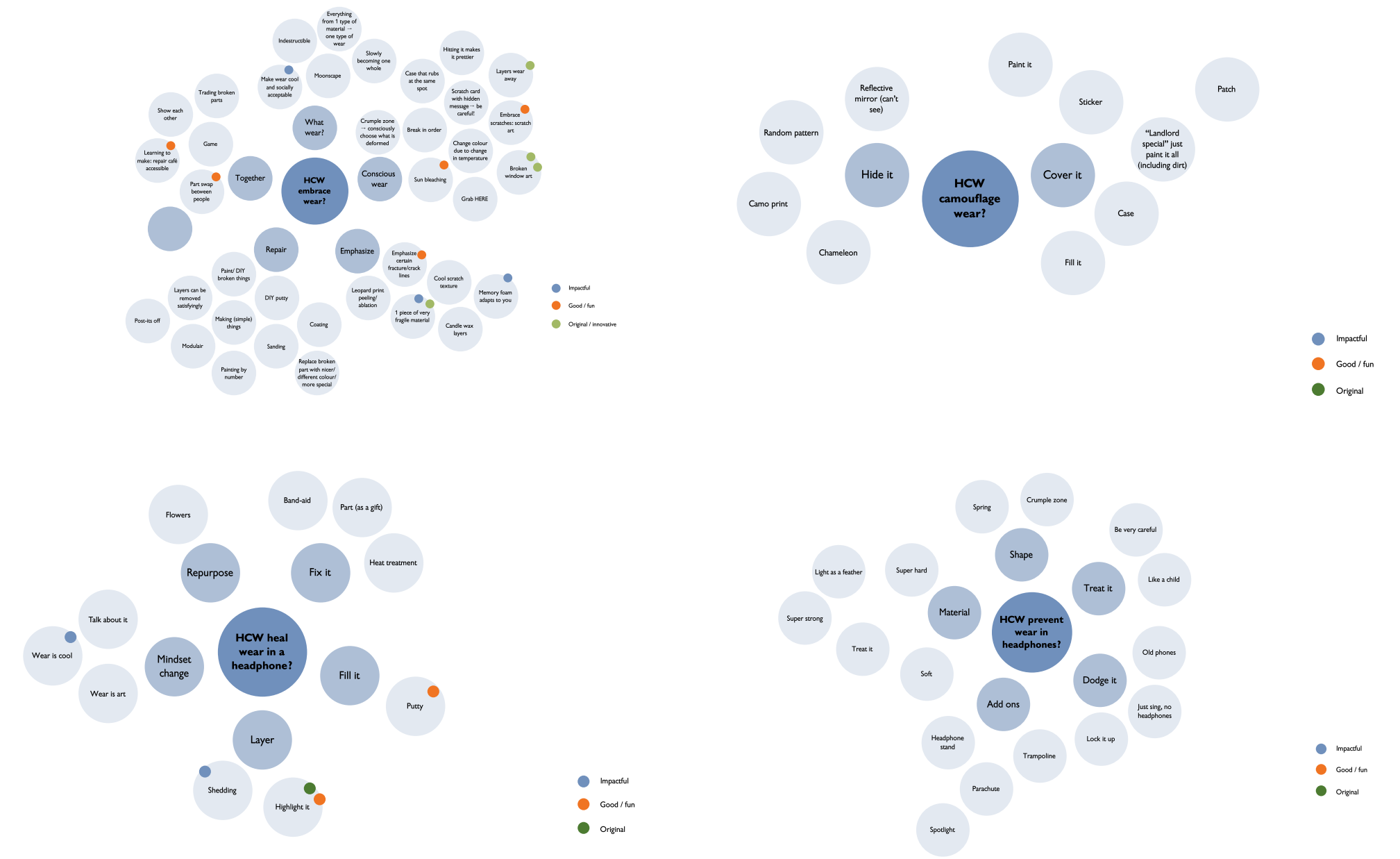
REFLECTIE EN AFRONDEN

- Ben je tevreden met de uitkomsten?
- Zijn er topics die we niet besproken hebben?
- Wat is volgens jou het 'beste' idee?

EINDE

Bedankt voor het mee doen <3!!!

Results from the creative session





- Impactful
- Good / fun
- Original innovative



E. COATING EXPERT CONSULTATION

AkzoNobel Research and Development director

Het idee achter mijn koptelefoon is slijtage laten zien op een leuke manier. Nu houden mensen gemiddeld koptelefoons 1 jaar aan en verwachten mensen dat ze niet langer dan 5 jaar mee gaan. Ik wil deze mindset tegengaan door een koptelefoon te ontwerpen die mensen veel langer aan willen houden, misschien wel 15 jaar. Ik wil dit doen door een kleurrijke plastic koptelefoon te coaten met een dunne zwarte laag. Zodra er krassen op komen, komt de kleurrijke laag naar boven. Dit concept is geïnspireerd op 'scratch art' van vroeger en de 'gobstopper shoe'. Dus doordat je hem gebruikt, wordt hij steeds kleurrijker. Qua productie zal de koptelefoon waarschijnlijk worden spuitgegoten met gekleurd plastic. Later zal hij dus moeten worden gecoat met zwart. Het is dus een gekleurde plastic koptelefoon met daaroverheen een coating die krasbaar is. Ik denk dat jij vooral weet hoe coating heel goed blijven zitten, maar mijn vraag was dus of jij een coating in gedachte had die een aantal jaar kan blijven zitten maar wel wegkrast bij intensief gebruik.

Dus je bent eigenlijk opzoek naar iets wat door mechanische belasting vanaf gaat. Yes, dus als je het in je tas vervoerd, er krassen op komen die de onderste laag onthult.

Welk plastic materiaal gaat het worden?

Nog niet besloten, mag een best hard plastic zijn. Ik weet alleen dat PETG sneller krast dan PLA, de rest heb ik nog niet onderzocht. PP, ABS, en PE zijn gebruikelijkere plastics die waarschijnlijk ook goed zullen werken voor mijn doeleinde.

Je zal op zoek moeten naar een coating die een relatief slechte hechting geeft, het goede nieuws is dat deze plastics relatief hydrofoob zijn. Dus dat je daar in zijn algemeen een slechte hechting op krijgt. Vaak is het dus ook een uitdaging om een goede hechting te krijgen. Terpetinebasis, een organisch oplosbare basis, zorgt voor verweking en zorgt voor relatief gezien een goede hechting. Dus een coating op een terpetinebasis zou beter moeten hechten dan een watergedragen basis. Ik zou dan dus voor een relatief goedkope watergedragen verf gaan, die in zijn algemeen al geldt dat een goede hechting krijgen een uitdaging is. Latex muurverf is een goedkope optie, maar dan denk ik dat het te hard gaat, dat je eerder afbladdering dan mooie krassen krijgt. Je zou naar een watergedragen

acrylaatverf kunnen gaan, die zijn minder hoog gepigmenteerd. Die heb je eventueel ook kleurloos. Wil je de kleur halen uit het plastic?

Het is een gekleurd plastic met een zwarte coating die snel krast, zodat het contrast goed zichtbaar is. Het idee is dat je na een jaar al wel leuke krasjes ziet, maar dat hij na een hele lange tijd, bijvoorbeeld 15 jaar, de volledige coating heeft verloren. Zodat de koptelefoon de gehele 15 jaar interessant blijft om te houden.

Wat dan grappig zou zijn om te doen, ik weet niet hoe dat kwa effect gaat uitwerken, maar is om naar een gekleurde maar wel transparante en dus niet dekkende laag gaat. Dan moet je bijna denken aan een transparante watergedragen beits, die je ook in het zwart kunt krijgen. Voor ebony hout bijvoorbeeld.

Denk je met zo'n watergedragen beits dat het ook 10 jaar best goed mee kan gaan?

Dat is wel relatief lang. Vaak worden ze voorbehandeld met vlambewerking, of specifieke hechtprimers. Maar dat wil je juist niet, maar je wil ook niet dat het er meteen af komt zetten. Verf is het ultieme zoeken naar de compomis.

Wat als je dan de standaard coating techniek van plastic gebruikt maar dan zonder het vlammen of de hechtprimer, zou dat kunnen werken? Voor specifieke verven die je gebruikt om plastic oppervlaktes te coaten zou ik dan even voor je moeten kijken. Die zitten niet standaard in mijn assortiment moet ik zeggen. Daar kom ik bij je op terug. Dan zou ik ook iets moeten kijken wat ik je in Nederland kunt krijgen.

Ik weet nog niet helemaal hoe ver ik de coating wil testen. Ik zou kunnen zeggen dat een bepaalde coating gebruikelijk is, en dat jij dat als expert ook aanraadt. Maar ik zou ook een aantal kunnen testen. Is maar net welk detail ik van mijn concept nog verder moet en wil uitwerken voor het beste resultaat. Er zijn namelijk nog veel andere aspecten die ik uit kan werken, dus misschien is een aanbeveling al goed maar dat weet ik nog niet. Ik kan je in ieder geval wat opties geven waarmee je een soort mini proef opzet mee kan doen zonder dat dat heel veel tijd hoeft te kosten. Hoe wij het zouden aanpakken, is een klein paneeltje of sampeltje coaten, hoeft niet een mooi gevormde koptelefoon te zijn, dat je die met een X aantal beitsen/coatings gaat coaten, en ze dan kunstmatig die

mechanische abrasie test. Dit kan bij wijze bij elkaar in een zak, vaak met een steen erbij. Dat zijn typische manieren waarop wij ook praktisch testen doen. Dat hoeft geen zeeën van tijd te kosten.

Ik denk dat dan dan zeker wel een sterk verhaal is om te doen. Waarschijnlijk test ik dan een paar coatings, doe ik een aanbeveling van dit is de beste maar wordt het nog een aanbeveling om verder te ontwikkelen voordat het op de markt gebracht kan worden.

Duurtesten passen niet in je scope, maar dan lijkt het me niet meer dan normaal om een aanbeveling voor verder onderzoek te doen.

De spuitlak die ik al heb gebruikt is op terpetinebasis, dus die zou een betere hechting moeten hebben dan watergedragen toch?

Bij een proefopzet zou ik die zeker meenemen. Maar mijn hypothese is goede hechting, is minste krassen.

Ik had nu een super dun laagje gedaan, dat kan natuurlijk ook nog uitmaken, hoe dik je die doet. Zeker. Deze kant heb ik met een schuurpapiertje gedaan, en aan deze kant heb ik niks gedaan en hem alleen in mijn tas vervoerd. Dus hij slijt al na twee weken. Dus misschien kan een goed hechtende laag maar dan een dunne laag. Je wil wel voorkomen dat het echt afbladderd. Ja precies, dat zou het nadeel van een echt slechte hechting kunnen zijn. Zo'n blader effect is het laatste wat je wil doen. Ik zou wel eens het verschil willen zien tussen een dekkende laag en een transparante laag. Dus een beits/olie op kleur waar je nog doorheen kunt zien versus een gepigmenteerd systeem (dus grotere pigment deeltjes waardoor je dekkracht krijgt). Bij houtbewerking ga je voor transparante lagen, daardoor kun je ook goed met de glansgraad spelen. Bij een auto zet je eerst de kleurlaag erover en vervolgens ga je er met een transparante laag overheen die ook hardheid maar ook glanskracht. Goed als ik jou later een aantal suggesties geef? Is natuurlijk wel even een uitdaging om ook te vinden wat je als consument gewoon kan kopen. Als je ook dingen bedenkt waar ik als consument niet snel aan kom maar wat wel een goede oplossing zou zijn mag je dat ook sturen. Dan kan ik dat altijd als aanbeveling noemen.

Ik hoop dat je iets aan onderstaande lijstje hebt. De eerste zijn geen goedkope oplossingen. Het geeft je wel wat technologische verschillen.

- Cetabeveer Tuinbeits Schuur & Tuinhuis Dekkend Zwart (=watergedragen)
- Cetabeveer Douglas Beits Zwart (=transparant, watergedragen)
- Gamma Extra Dekkend lak zwart zijdeglans (=terpetinegedragen).

Ik heb de beitsen gekozen zodat je ook de transparante opties kunt testen. Een beits is eigenlijk alleen voor hout, een beits zorgt dat hij goed in het hout penetreert en het hout beschermt. Jouw Gamma kleurtester binnenlak zijdeglans (watergedragen) zou je kunnen vervangen met de eerste optie dekkend zwart.

Goedkopere opties om eventueel ook esthetisch effect van glans vs mat vs metallic te bekijken:

- Gamma OK Spuitlak hoogglans zwart 400 mL, €3,29 (=terpetinegedragen, dekkend)
- Gamma OK Spuitlak mat zwart 400 mL, €3,29 (=terpetinegedragen, dekkend)
- Gamma OK Spuitlak metallic zwart 400 mL, €3,29 (=terpetinegedragen, dekkend)

Laat me weten of je iets van het beoogde effect gaat zien, en of er verschillen zijn tussen de opties. Afhankelijk daarvan kunnen we dan in ieder geval nog wat aanbevelingen voor toekomstig onderzoek geven, mocht er voor jou niet meer voldoende tijd zijn om nog meer te testen.

Ik heb ook wel gekeken naar allerlei specifieke coatings voor kunststoffen, maar dan krijg je dat je eerst een primer laag aanbrengt, en daarna een andere laag erover heen. Voor jou werkt dat niet want dan moet je door twee lagen heen krassen. Voor consumenten heb je wel zwarte primers, maar dan betaal je 60 euro per liter.

Het gaat dus vooral om de technologie: watergedragen tegen terpetine gedragen (oplosmiddel). Terpetine gedragen is oplosmiddel gedragen. In het engels praat je over solvent-borne en water-borne. Solvent born is alles wat een organisch oplosmiddel, terpetine is een organisch oplosmiddel. De hypothese is dat je met watergedragen een minder goede hechting hebt, maar je loopt risico op afbladderen dus daardoor kun je die het beste vergelijken. Die transparante beits is meer voor het effect, of het zou heel mooi kunnen zijn of het is helemaal niks.

F. USER STUDY: PERCEPTION OF THE CONCEPT

The developed final concept was validated using an user study. This Chapter includes the materials and raw data from the questionnaire.

Materials

Uiterlijk van een koptelefoon over de tijd

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd *Uiterlijk van een koptelefoon over de tijd*, uitgevoerd door Jet Polderman aan de TU Delft. Het doel is om inzicht te krijgen in hoe mensen het verouderingsproces van een koptelefoonontwerp ervaren. Het invullen van deze vragenlijst duurt ongeveer 10 minuten. De verzamelde gegevens worden gebruikt voor mijn afstudeerproject aan de TU Delft.

U wordt gevraagd om de koptelefoon te beoordelen over de tijd. Dit gebeurt aan de hand van vragen met een schaal van 1 tot 7, aangevuld met enkele open vragen over uw mening. **Belangrijk om te weten is dat de functionaliteit van de koptelefoon in dit onderzoek geen rol speelt; het gaat puur om het uiterlijk.**

Deelname is volledig vrijwillig. U kunt op elk moment stoppen zonder opgave van reden en bent vrij om vragen over te slaan. Indien gewenst, kunt u uw gegevens een week na deelname laten verwijderen. Neem hiervoor contact op via j

Door verder te gaan met de vragenlijst, gaat u akkoord met bovenstaande informatie.

Achtergrond informatie

1. Wat is uw gender?

Markeer slechts één ovaal.

- ☐ Vrouw
☐ Man
☐ Non-binair
☐ Anders
☐ Zeg ik liever niet

2. Wat is uw leeftijd?

Uiterlijk van een koptelefoon

Voor het beste resultaat: **zet uw helderheid op maximaal**

3. Stel u bent op zoek naar een nieuwe koptelefoon en ziet deze in de winkel. Wat vindt u van het **uiterlijk** van deze koptelefoon?



Markeer slechts één ovaal.

1 2 3 4 5 6 7
Lelij ☐ ☐ ☐ ☐ ☐ ☐ ☐ Mooi

4. Stel dat u heeft besloten om deze koptelefoon te kopen. Na 5 jaar werkt de koptelefoon nog naar behoren maar zijn er wel diverse gebruikssporen zichtbaar. Deze zijn hieronder visueel weergegeven. Wat vindt u van het uiterlijk van deze koptelefoon?



Markeer slechts één ovaal.

1	2	3	4	5	6	7	
Lelij	☐	☐	☐	☐	☐	☐	Mooi

5. Na 10 jaar werkt de koptelefoon nog steeds naar behoren maar de gebruikssporen zijn toegenomen door het gebruik. Deze zijn hieronder visueel weergegeven. Wat vindt u van het uiterlijk van deze koptelefoon?



Markeer slechts één ovaal.

1	2	3	4	5	6	7	
Lelij	☐	☐	☐	☐	☐	☐	Mooi

6. Kunt u toelichten waarom u deze beoordelingen heeft gegeven? Wat vindt u van het uiterlijk en waardoor komt dat, denkt u?

7. De krassen in de koptelefoon zijn voor mij:

Markeer slechts één ovaal.

1	2	3	4	5	6	7	
Stor	☐	☐	☐	☐	☐	☐	Niet-storend

8. Kunt u toelichten waarom u deze beoordeling heeft gegeven?

9. De krassen in de koptelefoon zijn voor mij:

Markeer slechts één ovaal.

1

2

3

4

5

6

7

OnnNatuurlijk

10. Kunt u toelichten waarom u deze beoordeling heeft gegeven?

11. Zorgt het uiterlijk van de kleuren koptelefoon ervoor dat u hem langer zou aanhouden dan wanneer deze geen kleur had (zie voorbeeld)?

(Ervan uitgaande dat ze functioneel blijven werken)



Markeer slechts één ovaal.

1

2

3

4

5

6

7

ZekerZeker wel

12. Kunt u toelichten waarom u deze beoordeling heeft gegeven?

13. Heeft u nog op- of aanmerkingen over deze koptelefoon of het onderzoek?

