The Impact of Digital Product Passports on Consumer Behavior in the Electronics Industry

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Digital Product Passports (DPPs) are digital datasets containing comprehensive information about a product, more specifically its origins, materials, production details, and performance characteristics. Although as of now, DPPs are mostly theoretical, they are envisioned as a driver for fostering a circular economy and allowing for more transparency within supply chains. Consumers play an important role in the circular economy as they decide on the fate of products through their consumption and purchasing practices. This study provides insight into the (hypothetical) impact DPPs would have on consumers' perception of security, awareness of environmental sustainability, and purchasing habits in the electronics industry through a literature study and the true experimental research method. The first serves as a theoretical starting point for how DPPs are thought to impact consumer behavior. The second, however, is intended to test the effects of DPPs on the consumer purchasing process in a real-life setting. This research is expected to give valuable insight into the theoretical positive impacts of DPPs on consumer behavior in the electronics industry.

Additional Key Words and Phrases: Digital Product Passport, consumer behavior, security, environment, sustainability, purchase decisions, experiment, electronics, information exchange

1 INTRODUCTION

The Digital Product Passport (DPP) is a novel concept for digitalizing product life cycles [1]. As of December 2023, the time of conducting this study, DPPs are theoretical for the most part and do not exist in the real world yet. DPPs would contain information about products' origins, journeys across the supply chain, ownership records, and manufacturing materials and processes. It is thought that implementing DPPs would present an opportunity for circular economy adoption (an economic system that aims to minimize waste and maximize/promote the continual use of resources) and scaling [2]. While manufacturers, retailers, and other supply chain actors play a large part in DPP implementation success or failure, consumers have the biggest responsibility and influence over a functioning circular economy, from making sustainable purchasing decisions to extending product lifetimes and exploring end-of-life trajectories for products and materials to be circulated at their highest utility [3]. Thus, it is important to gain insight into to what extent and how would DPPs impact consumer purchasing decisions.

Since Europe ranks first in the world for the amount of electronic waste generated per capita [4] and the world is becoming more digital by the day, this study focuses on DPPs' impact on consumer behavior specifically in the electronics industry. To add to that, the European Commission declared electronics to be one of the more prioritized ones for the DPP implementation. Moreover, electronic

waste has a notoriously low recycling rate of 17.4% [5]. As price is an important deciding factor when it comes to purchasing electronics, many consumers turn to second-hand retailers and remanufacturers to get better deals or more value for money. Such deals may come with the risk of getting a faulty product or a replica, which due to its inferior software and hardware could be prone to unstable performance [6] like malfunctioning or causal of physical or intellectual harm. DPPs would provide the consumers with verified information about a product's authenticity and previous ownership, as these are among the requirements by the EU for DPP systems [7]. This research also explores the impact of such a sense of security. As of December 2023, to the best of our knowledge, there have been no studies done about the impact of DPPs on consumer behavior. There are hypotheses that DPPs will guide consumers in the direction of making more sustainable purchasing decisions and adapting more environmentally friendly usage practices[3][8][9]. To best understand how this concept of the future could influence the people of today, this research utilizes the literature review method (see section 5.1) to get a deep understanding of the current hypotheses and theories in place regarding consumer behavior changes as a result of providing them with DPPs. Additionally, this research uses the method of true experimental study design to gain some more relevant and actual information on how the DPPs might influence present-day consumers. A detailed description of the experimental study design and the experiment are discussed in Chapter 4.

2 PROBLEM STATEMENT

Although there has been research done on the requirements and potential positive impact of implementing and using DPPs on a large scale on the environment, security, and supply chain transparency ([7][10][11][12]), there is no dedicated study that focuses on one of the primary stakeholders in the DPP project, the consumer. This research explores the consumers' theoretical purchasing process of products if products had DPPs attached to them.

3 RESEARCH QUESTION

The problem statement in mind, the research question could be formulated:

"How do Digital Product Passports influence consumer security perceptions, environmental sustainability considerations, and purchasing decisions in the electronics industry?"

This research question can be split up into three distinct sub-questions, that each help answer the main research question:

(1) SUB RQ1: In what way do Digital Product Passports influence the perception of security for consumers of electronic devices?

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(2) SUB RQ2: How do Digital Product Passports influence consumer awareness of environmentally sustainable practices in the electronics industry?

(3) SUB RQ3: How does the availability of detailed product information provided by Digital Product Passports affect consumers' purchasing decision-making process in the electronics industry?

4 RELATED WORK

For finding related papers, search engines such as Scopus, Google Scholar, FindUT, and Semantic Scholar were used. The keywords used in the search were Circular Economy, Consumer, Digital Product Passport, Environment, Habits, Purchases, Requirements, Security, Traceability, and Transparency. Using these search terms, various documents were found, however, none were directly related to the topic of this research.

In the field of DPPs, there has been research done on data governance related to DPPs [13], the requirements of DPPs [7][10], guiding principles for DPPs [14][15], DPPs with regard to transparency, verifiability and accountability [16] and communicating traceability information to consumers [17]. From these papers, this research could use knowledge about information flow and DPPs in general, but none of the papers touch on the topic of DPPs shaping the purchasing decisions of consumers or how the DPPs might influence consumers' sense of security and environmental sustainability awareness. Thus, for this research, these aforementioned papers were used to gain a deeper understanding of DPPs, the requirements for what data DPPs should include, and how the data would have to be verified. Based on that knowledge, demo DPPs could be constructed that were used for the second part of this research- the experimental study.

5 METHODS OF RESEARCH

This research consists of three parts. The following sub-sections explain the process behind the research.

5.1 Literature Review

First, a literature review was done to identify the current understanding of how DPPs should function, what they should consist of, and how the information would flow between different actors in the supply chain. Moreover, through the literature review, it was possible to find insight into how DPPs are speculated to affect consumers' environmental sustainability awareness and perceptions of security due to the increased information access DPPs provide.

5.2 Experimental Study

The second part consisted of the construction of demo DPPs, creating an appropriate questionnaire, choosing the research population for the experiment, and then, conducting the experimental study. The study followed a True Experimental Design methodology. Subjects were split into two groups based on the coin toss method- the control group just had to go through a product purchasing simulation and select between two products, and the experimental group went through an identical process but with a slight extra addition-

the experimental group had also demo DPPs accompanying the two products. Additionally, both groups had to answer a questionnaire consisting of three parts: 1) their perceptions of security, 2) their environmental sustainability awareness, and 3) their thought process while purchasing a certain item. Each part provided information to assist with answering one of the research sub-questions, and ultimately the research question.

5.3 Analysis

The third part of the research was a qualitative and quantitative analysis. The questionnaire contained both open-text questions (qualitative) and Likert Scale questions (quantitative). Open questions allowed the research subjects to describe how they feel when choosing one product over the other, either without DPPs present or by making a thought-through decision with DPPs in play. The differences in questionnaire answers between the two randomly selected groups gave trustworthy insight into how much DPPs influenced their behavior and thought processes. Based on the data, graphs were created made using Tableau and compared with literature findings to see if the predictions of existing studies align with the experiment results.

6 LITERATURE REVIEW

This section provides background about DPPs and the Circular Economy and brings out the theoretical aspects DPPs would benefit consumers with. Moreover, the identified requirements of DPPs are discussed which were used to construct the Demo DPPs utilized in the second part of this research.

6.1 Circular Economy and Digital Product Passports

As the population of the world is growing and the world is becoming more digital, an increased amount of electronic devices are being manufactured, sold, and thrown away at the end of their life cycles. Today's traditional economic system is often referred to as a linear "Take-Make-Dispose" economy [18]. As the name suggests, it means "taking" raw materials to "make" products, and then selling them to consumers for them to throw away or "dispose" them when they reach the end-of-use stage or the end of the products' life cycles. However, with the increasing population, this system is not sustainable, as it leads to more pressure on finite resources and generates a significant amount of waste and emissions [18]. To find an alternative to this lacking economic system of today, more attention has been on the future concept of the Circular Economy. It aims to decouple global economic development from the consumption and use of finite resources and to find utility in waste. The Circular Economy business models extend product life, maximize asset utilization, and create multiple value loops in supply chains [2]. An important factor of this concept is digitalization, and DPPs are speculated to play an important role in this process. A Digital Product Passport is a future concept of a document accompanying a product that specifies product information like its origins, journey, components, materials, and chemical substances as well as repairability, spare parts, and proper disposal of products which should capture environmental and social sustainability data in a standardized, comparable format

to enable all actors in the value and supply chain to work together towards a circular economy [1].

6.2 DPPs and Consumers

Consumers play an important role in the theoretical functioning and success of DPPs. Electronic products most often reach their end of life in the hands of consumers. It also comes down to consumers to influence the supply and demand of products. DPPs could shift consumers' purchasing decisions towards sustainable development [19] making sure that electronic products that are manufactured in a way that is transparent and environmentally sustainable would be more popular and in demand among consumers.

6.3 Requirements for DPPs

For DPP systems, there have been seven main data categories that have been identified in various reports and academic studies: (1) usage and maintenance, (2) product identification, (3) products and materials, (4) guidelines and manuals, (5) supply chain and reverse logistics, (6) environmental data and (7) compliance [3]. However, it is important to distinguish between DPP systems and DPPs. The DPP system is the IT/software system that allows for the consolidation of the data required for DPPs by facilitating the interaction between the various actors along a product's value chain, as well as the assignment of a physical product to the DPP [7]. Since for this research, there is a need for identified requirements of DPPs, not DPP systems, the focus is shifted to only DPP requirements. By analyzing various pieces of existing studies and reports [7][10][15][20][21], the information a DPP should contain is the following:

- **Manufacturing and Production Information**
  Information about the product's manufacturing process, composition and materials used, durability, and component removeability and replaceability. This provides the consumer with information that allows them to extend the product's life expectancy and enable optimal product use [20].
- **Usage Information**
  Information about changes to the products during their life cycles, repairs and switched parts, damages to the product, and previous ownership(s). [20]
- **End-of-Life Information**
  Information and documentation about collection, sorting, and treatment during the product's End-of-Life phase. These data fragments, when combined with user input, can help improve waste management and make sure that the product ends up in an appropriate waste collection point for it to be recycled/reused. [20]
- **Lifecycle Information**
  Information about sales volume, proper storage and usage of the product, in addition to the environmental impact of the product (emissions during production, movement between supply and value chain actors, and the environmental impact of materials used in manufacturing). [20]

6.4 Design of DPPs

With the main requirements for DPPs identified, it was necessary to structure them in a way that would be intuitive and easy to use for the consumer (in the context of this research, the research participant) for the demo DPPs that were used in the second part of this research, the experiment. There is not a lot of information on the designs of DPPs, more specifically those of the electronics industry, as they are still a concept of the future, and requirements are bound to change with new ideas and visions. However, for the design of DPPs for electronic products, a common ground for designs could be identified. A product should have a Quick Response (QR) code or a Near Field Communication (NFC) tag attached, which allows an actor to scan the code/tag and access purpose-driven, non-corruptible, decentralized data about the product in the form of a DPP. To achieve that, blockchain technology could be used [12]. The aforementioned two access points for DPPs apply to physical products at retail stores. For e-commerce stores online there is another access point for DPPs that was identified. A Uniform Resource Locator (URL) [20]. For the experiment in this research, a URL is used as an access point to the demo DPPs. The level of aggregation or granularity of the included information can differ for DPP approaches and there is no trend currently visible besides the vast majority of DPPs going beyond the product level and towards the component and material level [12]. DPPs would need to follow a design that allows for their widespread use in different sectors and maximizes their impact. Additionally, DPPs would need to assume a decentralized architecture and enable the self-sovereign identification of supply and value chain actors to provide and access data without the need for intermediaries [14]. According to this, the consumers should have the same DPP interface view as other actors in the supply/value chain and a DPP should be able to identify a consumer as a consumer.

As mentioned before, there have been no official DPP designs made that the researcher could draw inspiration from for this study. However, two unofficial designs were found online which seemingly ticked all the identified requirements boxes, Figure 1 [22] and Figure 2 [5]. These designs, alongside the requirements identified in Section 5.3 acted as cornerstones for the demo DPP designs. As can be seen from Figure 1 and Figure 2, the challenge with DPPs is fitting a large amount of data on a small screen in a presentable and universal easy-to-use way. The demo DPPs are accessed from a mock URL. Although responsiveness (how the webpage acts and looks on different screen sizes) is an important aspect of a DPP design, for the mock DPPs responsiveness was neglected for the sake of time conservation and simplicity. For this research the goal was not to test different design solutions for potential DPPs, it was to understand how DPPs affect the customer while making a purchasing decision between two electronic products. Therefore, the demo DPPs for this research experiment were designed for desktop resolution.

7 EXPERIMENT

This chapter describes the conducted experiment in-depth and describes the background behind the creation of the demo DPPs, demo e-commerce webpage, and questionnaire.
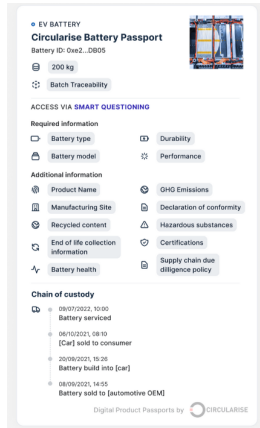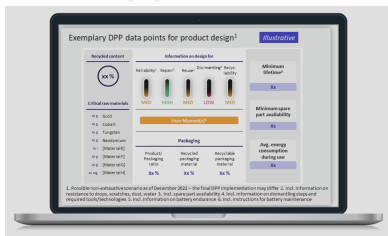
Fig. 1. DPP design. Circularise. [22]

Fig. 2. DPP design. BCG. [5]

7.1 Structure and Population

To identify the cause and effect relationships between variables, this experiment utilized the True Experimental design, meaning there was:

- **a Subject and a Control Group**
  The subject group was subjected to the experiment and underwent changes (Group one - Participants made the purchasing decision with access to DPPs), and the control group did not undergo any changes (Group two - Participants made the purchasing decision without any access to DPPs).
- **an Independent Variable**
  The independent variable in this experiment was a binary boolean value: True(1) if the DPPs were included and False(0) if they were not.
- **Random Assignment to Groups**
  The assignment to groups was a random distribution based on a toss of a coin. Every participant had an equal chance of being positioned in either one of the groups.

The structure of the experiment was as follows: Participants were individually randomly assigned to groups, and each experiment session had only one participant. An informed consent form was presented to participants with an information letter that stated the proceedings of the experiment and all the relevant information about the experiment and the study. If a participant decided to proceed with the experiment and their questions (if there were any)

were answered, they were presented with a demo e-commerce webpage (see Section 6.2.2) with two products. If they were assigned to the Subject Group, participants had additional DPP access points (URLs) attached to the products that the participants were able to inspect. Participants then had to make the decision about which product they would choose to buy while answering questions in an accompanying questionnaire (see Section 6.3). If the questionnaire questions were answered (and the purchase decision had been made), they were let know by the researcher that the experiment had ended and the individual experiment session was concluded.

The research population for this experiment was the students of the University of Twente (mainly technical students), between the ages of 18 and 30 (inclusive), regardless of their gender, religious beliefs, or any other factors. It is important to note that due to not including a more diverse population in the sense of ages less than 18 and more than 30, the results might differ for other age groups and may not be generalizable.

7.2 Demo Digital Product Passports and E-Commerce Site

All of the designs presented below have been created using Figma designing and prototyping software on Figma.com, a free UI/UX prototyping software owned by Adobe. The pictures of headphones have been generated by AI, more specifically DALL·E 2, GPT-3.

7.2.1 Demo E-Commerce Site. Since the experiment had data subjects compare two products and decide which one of the two to buy, a demo website had to be created to list the two products alongside access points to their DPPs. For the demo E-commerce website design (see Appendix A), since the experiment's context is the purchasing of electronic products, inspiration was drawn from MediaMarkt's website [23] which is a popular consumer electronics retailer in Germany and the Netherlands. While constructing the designs it was important to ensure that the page would look authentic and believable, as the purchasing process would need to be lifelike and familiar for the consumer, the experiment's participant, to make them feel like they are comparing two real existing products that they will start to use regularly.

7.2.2 Demo Digital Product Passports. To ensure the most accurate and truthful responses from the data subjects, it is important to present them with demo DPPs that would be easy to use and understand and additionally contain all the relevant and required information (requirements listed in Section 5.3). As there have been no DPPs made for electronic products, novel hypothetical designs were required and constructed. The demo DPP designs for this experiment (see Appendix B) have been created by drawing inspiration from the two DPP designs discussed in Section 5.4.

7.3 Questionnaire

The questionnaire was divided into three parts, which all contributed to answering the research sub-questions and ultimately the main research question. The first part of the questionnaire gathered information about participants' perception of security about either one of the products. Additionally, participants were asked to express how much they thought security influenced their making of

the decision. The second part of the questionnaire focused on the topic of environmental sustainability. Participants were asked how much environmental sustainability matters to them while buying electronic products, as well as if some aspect of environmental sustainability influenced their purchasing decisions. The third part of the questionnaire collected information about what the participants thought influenced their purchasing decisions the most. The complete questionnaire can be seen in Appendix B.

8 RESULTS

This section presents the results and findings from the questionnaire accompanying the conducted experiment. This is done in three parts, each part representing one research sub-question.

8.1 Security

The following questions (1-4) range on a 4-point Likert scale from 'Strongly Disagree' to 'Strongly Agree'. Question 5 is an open question.

Multiple-choice question 1: When choosing and buying electronic products either from online or physical retail stores, products' security and authenticity play an important role in making my purchasing decisions.
The data shows that 47% of all respondents selected 4, 'Strongly Agree', 40% indicated that they agree with the statement by selecting 3, and just 13% selected 2 or 'Disagree'. Therefore, it is apparent that for the most part, security plays an important role in participants' purchasing decisions.

Multiple-choice questions 2 and 3: When inspecting product 1 (Pear SpacePods)/product 2 (Deaffer Rythmers), I had a sense of security that I would be getting an authentic, secure and properly functioning product.

It can be seen from figure 3 that for the group with no access to DPPs, there was no noticeable difference in their sense of security between the two products. However, for the group with DPPs, product 1 (Pear SpacePods) scored marginally higher than product 2 (Deaffer Rythmers) in sense of security. It indicates that by having had DPPs available, the participants were able to see more detailed information about both products and therefore see that product 2 has some security concerns.

Multiple-choice question 4: I feel like my perception of security (or the lack of it) influenced or even led to my purchase decision.

Although not enormous, the difference between the two experiment groups is noticeable. As can be seen from figure 4, on average, the participants who had access to DPPs answered number three (meaning they agreed with the statement), whereas those who did not answered approximately two (meaning they disagreed with the statement). Therefore, based on the data, participants with access to DPPs felt like their sense of security (or the lack of it) influenced their decision, while the other group did not due to seeing two practically identical products with no additional information about
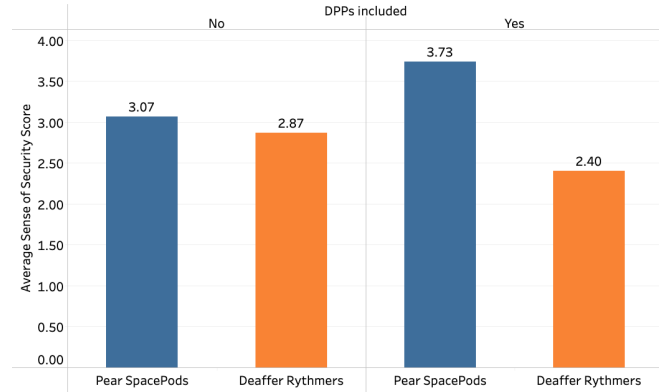

Fig. 3. Sense of Security Regarding Both Products. With distinction between the group with DPPs and the group without.

their technical states or product journeys.

follow-up open question: Please briefly explain why you answered to the previous question the way you did.

Among the group with access to DPPs, common answers were about the SpacePods (product 1) being a safer purchase due to the fact that the pair has not been previously returned by a customer, and it because has a higher repairability score. One respondent mentioned the reputation of a retailer being more important than the information about the products. In general, although some said the price was the more decisive factor, it was clear that the information from the DPPs of both products raised some concerns about the Deaffer Rythmer (product 2) headphones and made the SpacePods (product 1) more appealing.
Answers from the respondents in the group without DPPs were noticeably different. A frequently appearing remark was that both products had the same specifications and the same amount of information available, therefore they both felt secure to buy. According to one response, both products felt safe to purchase due to the "available information on the website including the overall looks of the web page.". Another respondent mentioned their decision not being affected by security concerns as they did not know anything about either one of the products anyway.

8.2 Environmental Sustainability

The following questions (1-3) range on a 4-point Likert scale from 'Strongly Disagree' to 'Strongly Agree'. Question 4 is an open question.

Multiple-choice question 1: When choosing and buying electronic products either from online or physical retail stores, I have some environmental sustainability aspects in mind that are important to me (materials used, manufacturing and supply chain transportation greenhouse gas emissions, repairability & recyclability).
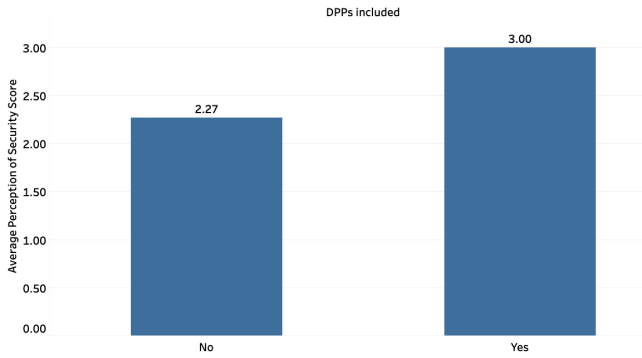
Fig. 4. Influence of the sense of security on making the purchasing decision. With distinction between the group with DPPs and the group without.

According to the data, only 10% of participants answered 4 or 'Strongly Agree', 30% answered 3 or 'Agree', and the leftover 60% of participants did not agree with the statement. According to this, for the students at the UT between the ages of 17-30, environmental sustainability does not matter much when shopping for electronic products. An interesting finding is that by splitting up the age group 17-30 to 17-23 and 23-30, the average answer differs noticeably (2.0 or 'Disagree' for ages 17-23, 3.14 or 'Agree' for ages 23-30), which can indicate that for older students/adults, environmental sustainability plays a bigger role when doing electronics shopping.

Multiple-choice question 2: When inspecting the two products on the ElectronicsRetailer site, information like the products' production and transportation CO2 emissions, recyclability, and other environmental sustainability factors were available and clearly presented to me.

Data indicates that the group with access to DPPs answered 3.7 on average (or almost 'Strongly Agree'), while the group without DPPs answered 1.6 or 'Disagree'. This was expected as the group without DPPs had no sustainability or manufacturing information accompanying the products. The designs of the DPPs achieved their goal of making information accessible and understandable, according to the results.

Multiple-choice question 3: I feel like environmental sustainability awareness made me choose one product over another (e.g. I chose the more sustainable option out of the two).

As can be seen from figure 5, on average, the group with DPPs answered 2.4 ('Disagree') and the group without DPPs 1.2 ('Strongly Disagree'). This would make it clear that environmental sustainability, whether the participants had access to DPPs or not, did not influence the purchase decision. In question 1 it was discovered that for the older age group, environmental sustainability was more meaningful. The same pattern is present here. From figure 6 one can see how for the older age group that had access to DPPs, the average answer is 3.25 ('Agree'), whereas for the younger age group, it is 2.09 ('Disagree'). As there was no information about environmental sustainability present for the group without DPPs, the scores in that

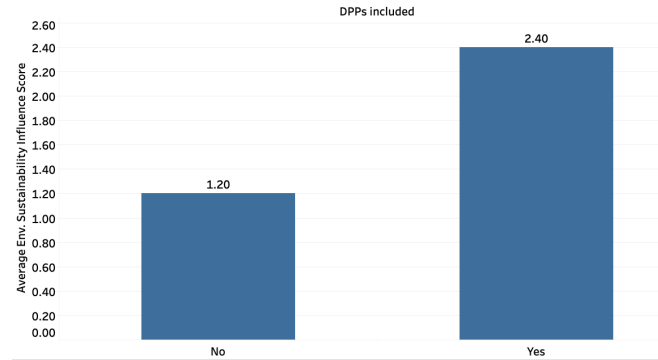group remained low, regardless of age.

Fig. 5. Influence of environmental sustainability considerations on making the purchasing decision. With distinction between the group with DPPs and the group without.
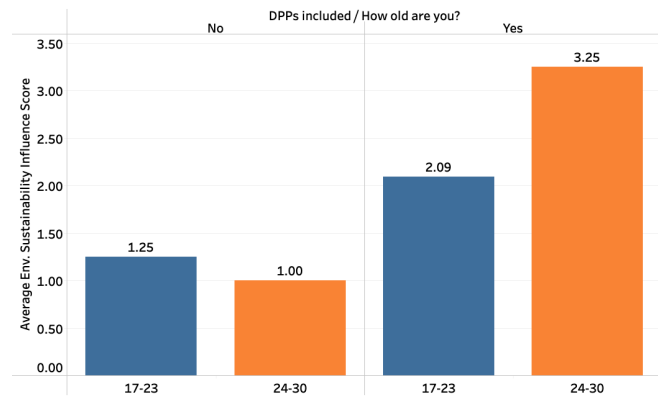

Fig. 6. Influence of environmental sustainability considerations on making the purchasing decision. With the distinction between the group with DPPs and the group without as well as two different age groups.

follow-up open question: Please briefly explain why you answered the previous question the way you did.

In the group with DPPs, although some answers mentioned CO2 emissions and recyclability playing an important part in the decision-making process, the majority of answers noted the insignificance of the environmental sustainability side. "I do care about sustainability, but as a student, I pay more attention to price and the overall specs," one participant said. Another participant mentioned that eco-friendliness was a nice addition, but not the most important thing for them. The group without access to DPPs mainly remarked that there was no information about environmental sustainability, therefore naturally it was not a factor at play when deciding which product to go for. A common theme that emerged from the answers was that the price and the quality of the specs were what influenced the decision.

8.3 Purchasing Decision

When it comes to which pair of headphones was more popular, the statistics show that among the group of participants with access to DPPs, the more popular choice was product 1, Pear Spacepods (73.3%). In the group without access to DPPs, the more popular choice was product 2, Deaffer Rythmers (66.7%).

The participants were asked to choose their preferred product first without seeing product images, only product information (the images were blurred), and then choose again seeing the images as well as the information. The data indicates that both in the group with and without access to DPPs, the percentage of people who changed their decision after seeing the products was 20%. This does not mean, however, that designs did not have any influence on participants' decision-making process. For the most part, the designs simply did not matter to the participants enough for them to change their minds after choosing one pair over another based on product information of both headphones.

The following question asked the participants to select the options that they felt influenced their decision the most. The options were: 1) The price 2) Security 3) Environmental Sustainability 4) All of the above 5) None of the above 6) Other. By choosing either one of the last three options, the participants were asked to specify their answer in an open question.

Multiple-choice question 3: My purchase decision was mainly influenced by:

The results show that the group with access to DPPs considered the perception of security (33.3%) and the combination of price, security, and environmental sustainability (33.3%) to be the most influential factors when deciding between the two products. 20% of the participants in this group marked the price as the sole influencer and 13.3% answered 'Other'. When asked to explain their answer ('Other'), the most frequent answer was that it was the combination of the price and either security or environmental sustainability that played an important role in making up their minds.

The group without access to DPPs showed a different trend. More than half, 53.3% of the respondents perceived the price to have been their most significant purchasing decision influencer, with 40% answering 'Other' and 6.7% 'None of the above'. A noticeable contrast can be seen between the answers of the group with access to DPPs and the group without. Unfortunately, none of the participants wished to elaborate on answering 'None of the above'. For the option 'Other', however, the bulk of the answers were either about liking the appearance of one product more than the other, or the combination of both the price and design making them choose one pair over another. A few answers also mentioned that the higher price tag of product 1, made them feel like it would have better build quality, therefore going for that pair.

9 DISCUSSION

In this section, each sub-question is individually addressed leading up to the answering of the primary research question. Additionally, the limitations of this research are discussed.

9.1 DPPs' influence on consumers' perception of security (SQ1)

Based on the results of the experiment, it can be said that DPPs do influence consumers' perception of security. However, it is important to note that the results do not suggest that consumers feel less secure about their purchases when not being able to access and utilize DPPs. The participants in the experiment who were in the group without access to DPPs did not express their distrust in either of the two products and did not have any notable security concerns. Instead, the effect of DPPs on the participants' sense of security was seen in the group that had access to DPPs. By seeing both products' journeys and verification statuses, for many, security concerns arose around product 2 (Deaffer Rythmers) as they had been returned and not re-verified. The results show a considerable difference (27,7%) between the group with and without access to DPPs where some aspect of security influenced participants' purchasing decisions. Therefore, based on the findings, DPPs make consumers more aware of what they are buying. And, DPPs have the potential to increase (seeing a product is verified, functioning, and has all the accompanying manufacturing information) and also decrease the sense of security (as seen in the case of product 2, wherein the group without access to DPPs the product did not raise any red flags, but in the group with access to DPPs it did) of consumers.

9.2 DPPs' influence on consumers' environmental sustainability awareness (SQ2)

Although environmental sustainability is a topic that is discussed frequently in media and politics, it was interesting to see that for the participants of this experiment, the environmental sustainability aspect when purchasing electronic products was not too important. Still, it could be seen that in the group that had access to DPPs (and therefore information about various environmental sustainability attributes like production and supply chain CO2 emissions, as well as recyclability and a list of raw materials) there were consumers for whom some aspect of environmental sustainability was important enough to influence their purchasing decision. Furthermore, environmental sustainability seemed to have had more weight in the older age group (24-30). The reason behind this could be that for young students, the only factor that matters when purchasing electronic products online is getting the best deal for one's money, whereas older students that might have well-paying jobs have the freedom to pay more attention to production practices and long term impacts of products on the environment It is also safe to say that DPPs make consumers notably more aware of the impact the manufacturing and shipping of the products they are eyeing have had or might have on the environment. By doing that, implementing DPPs on a large scale could have vast effects on the global manufacturing and logistics landscape.

9.3 DPPs' influence on consumers' purchasing decision-making process (SQ3)

As discussed in section 8.3, the contrast between the group with access to DPPs and the group without was clear. The group without access to DPPs mainly considered the price of a product being the main influencer of their purchasing decision, while in the group with access to DPPs the main influencer was either some aspect of security, or environmental sustainability. In the group without access to DPPs, however, price came on top as the most important influencer of their purchasing decision. Moreover, in the aforementioned first group, the majority of the participants opted for product 1 (Pear SpacePods), while in the second group, product 2 (Deaffer Rythmers) came out on top. Based on that knowledge, it is fair to assume that the available product information that DPPs offer has a significant impact on what the consumer decides to buy and what to leave on the shelves. It makes consumers more aware of what is behind products' specifications, appearances, and prices and allows them to make more thought-through and knowledgeable purchasing decisions while promoting sustainability offering security to themselves that what they are purchasing is authentic and is going to function properly.

9.4 Research Question

Based on the discussion of sub-questions in sections 9.1-9.3, DPPs have the potential to both increase and decrease consumer security perceptions, both being beneficial for the consumer. DPPs allow consumers to be less oblivious and more informed about the electronic devices they are buying. DPPs, thanks to readily available environmental sustainability information, also make consumers think more about sustainability and therefore contribute to a greener, more environmentally sustainable economy. Lastly, DPPs have the potential to shift the sole focus of consumers away from price, specifications and appearance, and make them think more about every individual purchase (if the product they would be getting seems to be safe, if by purchasing the product they would support unsustainable manufacturing practices). Moreover, by having more thought-provoking information available, DPPs could reduce reckless impulse buying and, therefore generation of electronic waste.

9.5 Limitations

Since the experiment had only 32 participants, and all of them were students of the University of Twente, aged between 17-33, the results do not have strong generalizability, as the effect DPPs have on consumer behavior has the potential of being considerably different for other (older and younger) age groups. Additionally, due to all respondents being students, the results lack the perspective of full-time working adults, as well as seniors, who are all consumers of electronic products. Lastly, the designs of the DPPs used have not been confirmed and the actual DPPs launched in the future may differ drastically.

10 CONCLUSION AND FUTURE WORK

This paper has explored the potential impacts Digital Product Passports could have on consumer behavior in the electronics industry. The requirements, both for content and design, of DPPs were identified through a process of literature review. Using the information collected from the sources, demo Digital Product Passports were constructed, which then were used in an experiment with 32 participants (individual sessions) alongside a demo Figma e-commerce website prototype and a questionnaire that collected their thoughts while choosing between two pairs of headphones on said e-commerce site. The results indicated a strong positive effect DPPs had on consumers' security perceptions, environmental sustainability awareness, and thought processes when deciding between the products. It is important to mention that the answer to the research question this experiment led to in this research is only a speculation, as non-official demo Digital Product Passports were used, which have in no way been reviewed nor confirmed by any authorities. However, as the DPPs were constructed by utilizing the information attained from numerous studies, they should give valuable information about the potential impact DPP could have on consumer behavior in the electronics industry in the future.

Due to this research only having 32 experiment participants and digital product passports being in the concept stage, future research has to be done on a bigger scale with a significantly larger and more diverse pool of data subjects to gain a better understanding of the potential effects of Digital Product Passports on consumer behavior. More mockup Digital Product Passport designs need to be created and to ensure their legitimacy, they would have to be confirmed with specialists globally who are developing said passports. Further studies should also be done to understand how DPPs would contribute to customers' relation to products' end-of-life scenarios as one of the identified requirements in this research for digital product passports was the need to have end-of-life and recyclability information included in them. Additionally, the research should be expanded to not just be limited to the electronics sector.

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A FIGMA DESIGNS

Here are presented all of the Figma Designs (website, digital product passports) created and utilized for this research.

A.1 Appendix A.1
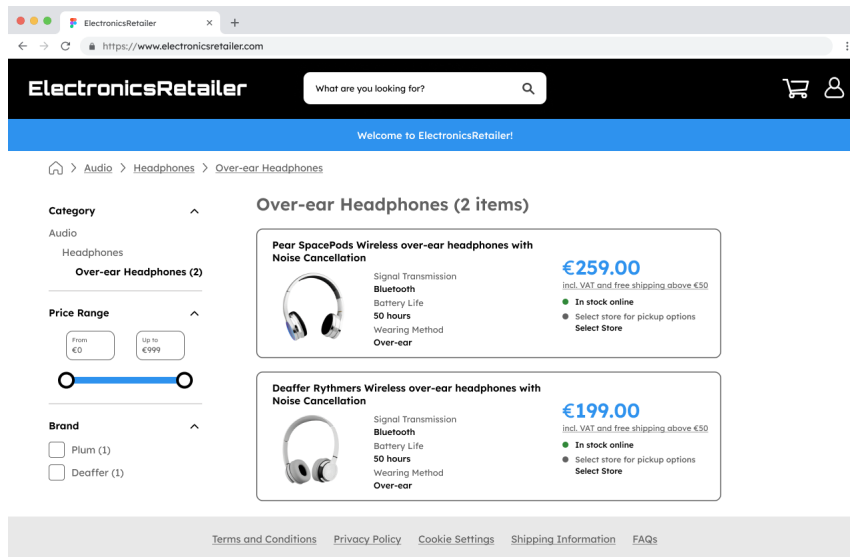
Demo e-commerce website
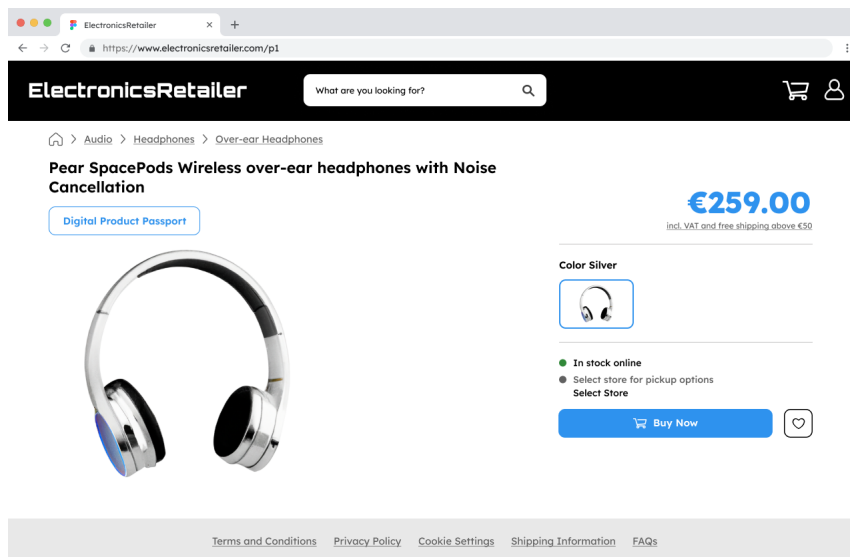

Fig. 7. Demo e-commerce site. List of products.

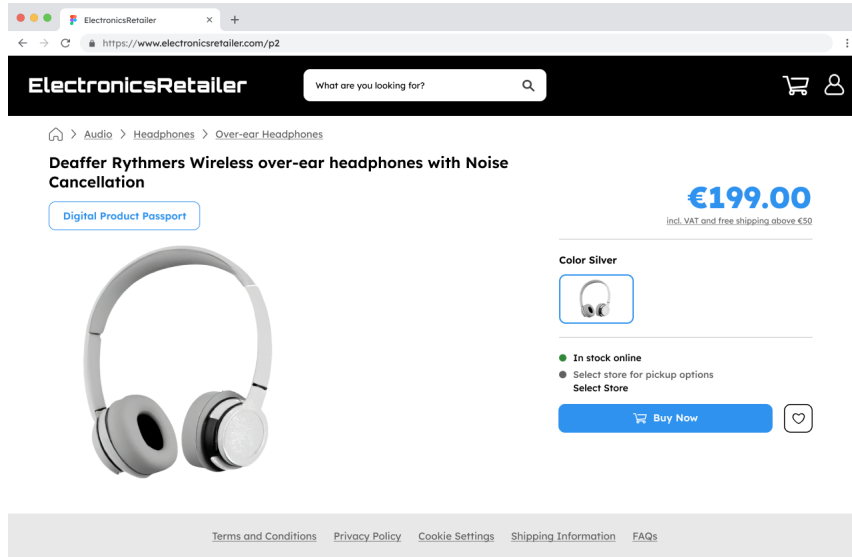Fig. 8. Demo e-commerce site. Product 1 (Pear SpacePods) product page.

Fig. 9. Demo e-commerce site. Product 2 (Deaffer Rythmers) product page.

Fig. 10. Demo e-commerce site. Product specifications when scrolling down.

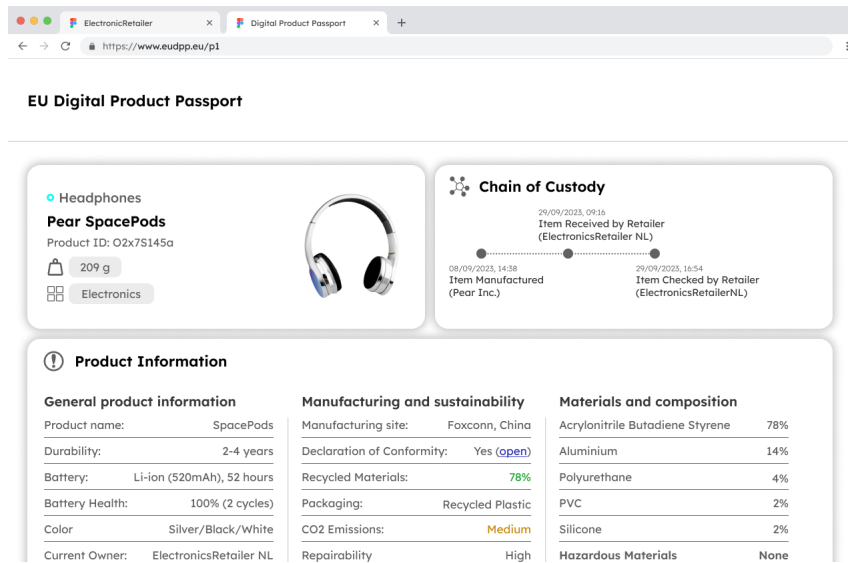## A.2   Appendix A.2

Demo Digital Product Passports

Fig. 11. Demo Digital Product Passport. Product 1 (Pear SpacePods). Desktop view.
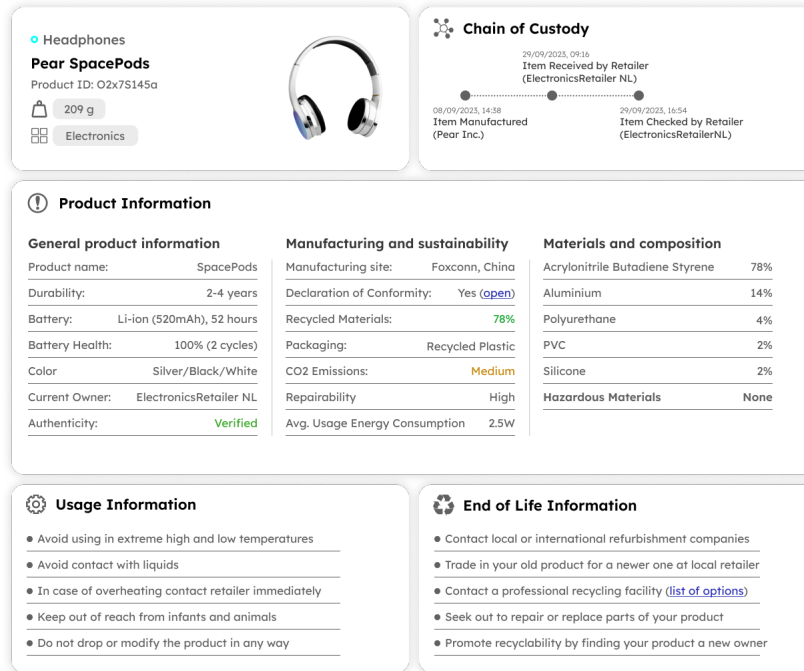

Fig. 12. Demo Digital Product Passport. Product 1 (Pear SpacePods). All information.
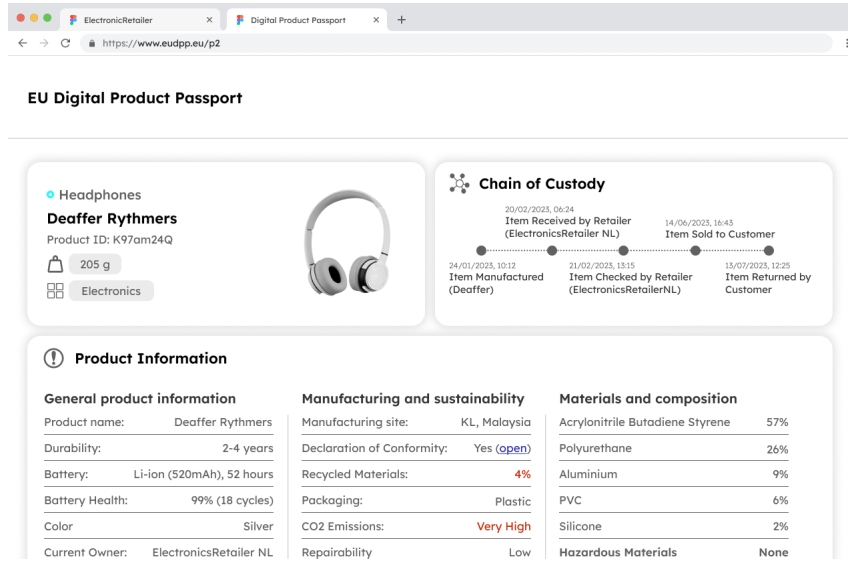
Fig. 13. Demo Digital Product Passport. Product 2 (Deaffer Rythmers). Desktop view.
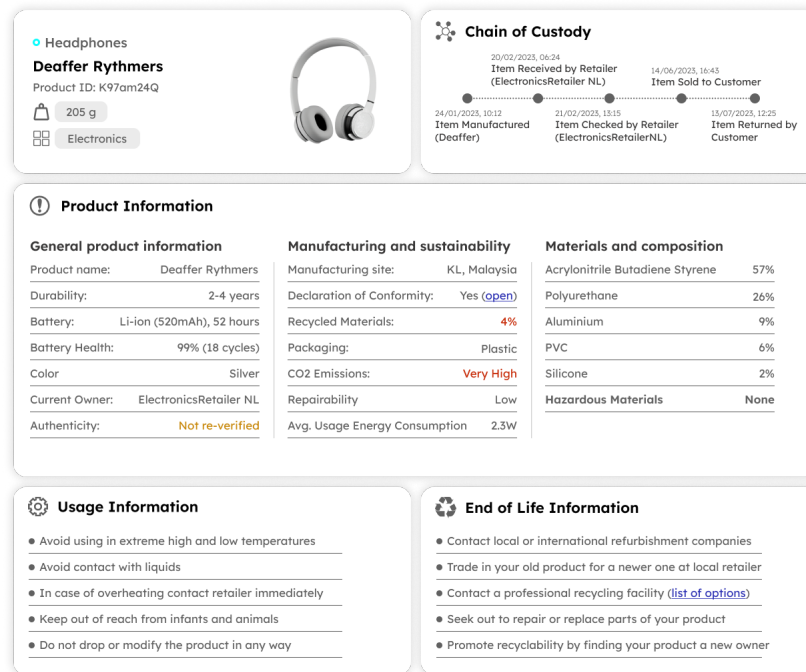

Fig. 14. Demo Digital Product Passport. Product 2 (Deaffer Rythmers). All information.

B   QUESTIONNAIRE

Here is presented the questionnaire created and utilized for this research.

B.1   Appendix B.1

Introduction

- How old are you? (Multiple Choice)
  - 17-23
  - 14-30
  - 31+
- What gender do you identify as? (Multiple Choice)
  - Male
  - Female
  - Prefer not to say
- Headphones you have decided to purchase from ElectronicsRetailer (Multiple Choice)
  - Pear SpacePods
  - Deaffer Rythmers
- Headphones you have decided to purchase from ElectronicsRetailer (Multiple Choice)
  - Pear SpacePods
  - Deaffer Rythmers

B.2   Appendix B.2

Part 1: Perception of Security

- When choosing and buying electronic products either from online or physical retail stores, products' security and authenticity play an important role in making my purchasing decisions. (Likert)
  - 1 (Strongly Disagree)
  - 2 (Disagree)
  - 3 (Agree)
  - 4 (Strongly Agree)
- When inspecting product 1 (Pear SpacePods), I had a sense of security that I would be getting an authentic, secure, and properly functioning product. (Likert)
  - 1 (Strongly Disagree)
  - 2 (Disagree)
  - 3 (Agree)
  - 4 (Strongly Agree)
- When inspecting product 2 (Deaffer Rythmers), I had a sense of security that I would be getting an authentic, secure, and properly functioning product. (Likert)
  - 1 (Strongly Disagree)
  - 2 (Disagree)
  - 3 (Agree)
  - 4 (Strongly Agree)
- I feel like my perception of security (or the lack of it) influenced or even led to my purchase decision. (Likert)
  - 1 (Strongly Disagree)
  - 2 (Disagree)
  - 3 (Agree)
  - 4 (Strongly Agree)
- Please briefly explain why you answered the previous question the way you did. (Optional) (Open Question)

B.3   Appendix B.3

Part 2: Environmental Sustainability Awareness

- When choosing and buying electronic products either from online or physical retail stores, I have some environmental sustainability aspects in mind that are important to me (materials used, manufacturing and supply chain transportation greenhouse gas emissions, repairability & recyclability). (Likert)
  - 1 (Strongly Disagree)
  - 2 (Disagree)
  - 3 (Agree)

  – 4 (Strongly Agree)
- When inspecting the two products on the ElectronicsRetailer site, information like the products' production and transportation CO_2 emissions, recyclability, and other environmental sustainability factors were available and clearly presented to me. (Likert)
  – 1 (Strongly Disagree)
  – 2 (Disagree)
  – 3 (Agree)
  – 4 (Strongly Agree)
- I feel like environmental sustainability awareness made me choose one product over another (e.g. I chose the more sustainable option out of the two). (Likert)
  – 1 (Strongly Disagree)
  – 2 (Disagree)
  – 3 (Agree)
  – 4 (Strongly Agree)
- I feel like my perception of security (or the lack of it) influenced or even led to my purchase decision.
- Please briefly explain why you answered the previous question the way you did. (Optional) (Open)

B.4 Appendix B.4

Part 3: Purchasing Decision (Influential Aspects)
- My purchase decision was mainly influenced by: (Multiple Choice)
  – The Price
  – Security (I felt like the product was authentic, safe to use and I would get a functioning product)
  – Environmental sustainability (I felt like the product was sustainably manufactured, and could be easily recycled and/or repaired at the end of its lifecycle)
  – All of the above
  – None of the above
  – Other
- If you answered "All of the above" to the previous question, please briefly explain your answer (Open)
- If you answered "None of the above" to the previous question, please briefly explain your answer (Open)
- If you answered "Other" to the previous question, please briefly explain your answer (Open)