3D-Printed Jewelry - A new era for online jewelry customization

(Exploring consumer perceptions, consumption drivers and barriers for the Portuguese online market)

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Abstract

The jewelry industry has been forever re-shaped by the introduction of 3D printing technology. When compared to the centuries-old production methods still in use, 3D printing allows the creation of previously "impossible" designs, fully customized and at a fraction of the cost and time.

Driven by the international growth of this business and the increasing trend for online purchases among Portuguese consumers, this research aims to determine their perceptions of this disruptive product, as well as the drivers and barriers for its adoption/purchase. Following a thorough review of the literature, this study has adopted the Technology Acceptance Model (TAM) and expanded it to incorporate additional variables relevant to the research subject.

For this study, 10 in-depth interviews were conducted, followed by an online questionnaire that generated 115 valid responses. From the data analysis, it was possible to conclude that despite the low levels of awareness and purchase of 3D-printed jewelry in the Portuguese market, a significant percentage of consumers demonstrated strong indicators toward the adoption and acquisition of this product.

Moreover, the perceived ease of use, usefulness, compatibility, customization level, along with the aesthetic features of the jewelry, the tech optimism of the consumer and his/her attitude toward the use of the product, were identified as the key purchase drivers, influencing the behavioral usage intention of 3D-printed jewelry. In contrast, the perceived cost, the lack of awareness along with the problems and concerns associated to the online jewelry shopping were identified as the main barriers for consumers' purchase.

Keywords: 3D printing, 3D-printed Jewelry, Online jewelry shopping, Drivers, Barriers, Consumer perceptions, Ease of use, Usefulness, Compatibility, Customization level, Cost, Aesthetic, Tech optimism, Attitude toward use, Behavioral usage intention, Lack of awareness.

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Resumo

A indústria da joalharia foi para sempre modificada com a introdução da tecnologia de impressão 3D. Comparada com os métodos de produção, com séculos de existência, ainda em uso, a impressão 3D permite a criação de designs anteriormente "impossíveis", totalmente personalizados e a uma fração do custo e tempo.

Impulsionado pelo crescimento deste negócio a nível internacional e pelo progressivo aumento do volume de compras online entre os consumidores portugueses, o presente estudo visa determinar as perceções sobre este produto, bem como os impulsionadores e barreiras para a sua adoção/compra. Após uma revisão da literatura, o Modelo de Aceitação de Tecnologia foi adotado e expandido de modo a incorporar novas variáveis, relevantes para o tema em estudo.

Para a recolha dos dados foram realizadas 10 entrevistas, seguidas de um questionário online do qual resultaram 115 respostas válidas. Foi possível verificar que apesar dos baixos níveis de consciência e de compra relativo às jóias impressas em 3D no mercado português, uma percentagem significativa de consumidores demonstrava fortes indicadores no sentido da sua adoção e aquisição.

Adicionalmente, a perceção da facilidade de utilização, utilidade, compatibilidade, nível de personalização, características estéticas das jóias, o otimismo tecnológico do consumidor e a atitude em relação à utilização do produto foram considerados impulsionadores ao consumo, visto influenciarem positivamente a intenção de usar jóias impressas em 3D. Por outro lado, o custo, a falta de consciência e os problemas associados à compra de jóias online foram identificados como principais obstáculos à adoção por parte dos consumidores.

Palavras-chave: Impressão 3D, Jóias impressas em 3D, Compra online de jóias, Impulsionadores, Barreiras, Perceções dos consumidores, Facilidade de uso, Utilidade, Compatibilidade, Nível de customização, Preço, Caraterísticas estéticas, Otimismo tecnológico, Atitude em relação à utilização, Intenção comportamental de uso, Consciência.

Título: Joalharia impressa em 3D – Uma nova era para a customização online de jóias: Explorando as perceções dos consumidores, impulsionadores e barreiras ao consumo no mercado online português.

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Table of Contents

List of Figures

List of Graphics

List of Tables

List of Abbreviations

Aes – Aesthetic Features

AR – Augmented Reality

ATU – Attitude Toward Using

BUI – Behavioral Usage Intention

CAD – Computer-Aided Design

CAGR – Compound Annual Growth Rate

H_n – Hypothesis n

NMIRI – Nagoya Municipal Industrial Research Institute

PC – Perceived Compatibility

PCL – Perceived Customization Level

PEOU – Perceived Ease of Use

PU – Perceived Usefulness

RQ_n – Research Question n

SLA – Stereolithography

SPSS – Statistical Package for the Social Sciences

TAM – Technology Acceptance Model

TO – Tech Optimism

WTP – Willingness to Pay

Chapter I – Introduction

1.1 Contextualization

In an era in which global online shopping sales were projected to reach $4,2 trillion by the end of 2021, representing 2,14 billion unique online shoppers around the globe, e-commerce has become one of the biggest industries in the world. And, with forecasts of surpassing the $5,4 trillion mark in 2022, it is one of the fastest growing industries worldwide (Statista, 2021).

E-commerce was growing fast before the Covid-19 crisis, but the pandemic has exponentially increased its growth in the last two years, since it "forced" many consumers, due to lockdowns and store closures, to embrace online shopping, and led many others to increase their online expenditures (Fryer, 2021).

However, all this growth has also resulted in the emergence of new market trends, such as the demand increase for customized products, which presented a new set of challenges to the industry (Abraham et al., 2021).

According to Deloitte (2015), consumers, empowered by digital services and social networks, are becoming more aware of what the global market has to offer, increasing their expectations and demanding a more personalized service and the opportunity to shape the products they consume.

However, despite this new market trends, traditional manufacturing methods still present several limitations when trying to pursue mass customization. And a great example of that can be found in the jewelry industry.

Although the manufacture of jewelry has been around for millennia, it has not changed a lot through time, despite several technological advancements. Jewelry design and production are still time-consuming and labor-intensive procedures requiring a highly skilled worker both to draft and manufacture each piece. However, even highly skilled workers sometimes fail to create intricate designs due to technological limitations (Fatma et al., 2021).

As a result, mass customization is almost impossible to achieve using traditional methods only, so that consumers struggle to get jewelry fully customized to their needs, at reasonable prices, and end up buying pieces which do not fully satisfy them or end up spending high amounts of money to do so.

However, through the use of digital manufacturing technology, such as 3D printing, these limitations are easily surpassed, since the process allows these intricate designs to be printed, one layer at a time, in a matter of minutes, reducing manufacturing time, energy and labor costs (Ong, 2020)

Despite its potential, the 3D printing adoption in manufacturing is still rather low, since although fantastic for producing custom products, it still struggles when it comes to production on larger scales (AMFG Corp., 2020).

Nevertheless, as the technology continues improving, its ability to enhance product performance is expected to increase, so that 3D printing is likely to go from a niche to a more predominantly used technology (Deloitte, 2015).

1.2 Problem Statement

In the last years, jewelry retailers and designers have been using 3D printing technology to create prototypes and customized pieces (Vanderploeg et al., 2016). From necklaces and earrings to customized wedding rings, 3D-printed jewelry is expected to be the future of the jewelry industry, by allowing the exploration of previously unavailable techniques and designs, giving consumers a more customized final product and overall experience (Fatma et al., 2021).

Despite this potential impact in the industry, the number of studies investigating how consumers perceive and accept 3D-printed jewelry is still relatively low.

Previous studies have focused on the application of 3D printing technologies to the fashion and jewelry (e.g., Cooper, 2016; Vanderploeg et al., 2016) or on the relation between 3D printing and mass customization (Fuenmayor et al., 2019), failing to understand consumers perceptions, although it is one of the most crucial objectives of all markets (Limbu et al., 2011).

Due to the limited amount of research on this topic, there are still many doubts concerning how consumers perceive 3D-printed jewelry, its advantages, and disadvantages, and how these affect its adoption and purchase (Perry, 2017b).

Therefore, the aim of this research is to study consumers' adoption of 3D-printed jewelry, focusing on three main topics: (1) consumer perceptions, (2) consumption drivers, and (3) consumption barriers.

Finally, the study will be limited to the Portuguese online jewelry market, allowing for a more in-depth analysis of the research topic. In addition, in order to achieve the above-mentioned goal, the following questions will be addressed:

RQ_1: What are the main drivers of the purchase intention for 3D-printed jewelry?

RQ_2: What are the main barriers of the purchase intention for 3D-printed jewelry?

1.3 Academic Relevance

Despite the exponential increase in the number of studies and articles related to 3D printing in the last couple of decades, the available research concerning 3D-printed jewelry is still scarce, and the number is even lower when we focus on the ones concerning the Portuguese market, so that it is easy to conclude that it is still an underexplored topic.

As a result, exploratory qualitative research is required, in addition to the development of new research questions and hypotheses based upon the literature review, in order to ultimately serve as foundation for future research.

1.4 Managerial Relevance

In terms of managerial relevance, this study can have a significant importance for companies operating in the Portuguese jewelry market, that intend to adopt this new technology, 3D printing, into their manufacturing process, or simply to learn more about it and to access valuable insights on consumers' drivers and barriers, regarding its purchase.

This knowledge will also help jewelry businesses to better understand consumers' perceptions and needs regarding 3D printing and the online commerce and will ultimately represent a major competitive advantage for sellers, not only for the ones that already sell 3D-printed jewelry through the online market, but also for those, more traditional, which still strictly operate in a brick-and-mortar business and are looking for extending their presence into the online business.

1.5 Dissertation Structure

This dissertation is composed of 6 chapters. Chapter I includes a contextualization of the research topic, the problem statement and research questions, as well as the academic and managerial relevance of the study. Chapter II covers the initial literature review on jewelry, 3D

printing technology, mass customization and 3D-printed jewelry, in addition to multiple industry analysis. Chapter III continues the literature review, this time focusing on the technology acceptance, and presents both the developed hypotheses and proposed research model. Chapter IV provides a detailed description on the methodology and data collection methods. Chapter V is dedicated to the presentation and analysis of the results from the previous chapter. And finally, on Chapter VI the main findings and conclusions of the study will be presented, in addition to its limitations along with some suggestions for future research.

Chapter II – Initial Literature Review

More in detail, this second chapter is divided into four major topics:

- The first one contemplates an overview of the global jewelry market, focusing on its history, current and forecasted market values, as well as an analysis to the global online jewelry market, and a brief study to the covid-19 impact to both;

- The second topic regards the Portuguese jewelry market, again with a current and forecasted market analyses in addition to a SWOT analysis;

- Following these, the third one focuses on 3D printing technology, addressing its definition, history, used materials and current applications;

- The fourth topic analyzes the subject of mass customization from its definition to its relationship with 3D printing technology;

- Finally, the fifth topic examines the Global 3D-printed jewelry market, addressing the technology implementation in the industry and providing an overall market overview.

2.1 Global Jewelry Market Overview:

2.1.1 The History of the Traditional Jewelry Market

Jewelry is one of the oldest of the decorative arts. The earliest traces of jewelry go back to Mediterranean civilizations, at what is nowadays called Iran, around 3000 to 400 BC (LeGrand, D. 2003).

From stone and bones to diamonds and gold, millenniums of evolution have shaped the materials and techniques used to create jewelry, making it perfect examples of human mastery.

However, despite these changes, its meaning has remained untouched:

> Jewelry answers to the deep human love of intrinsically beautiful materials, to the deep human wish for bodily beautification, and to the superstitious need for reinforcing human powers by adornments that seem to a savage more lasting and more mysterious than man. (Evans, J. 1989)

From pharaohs in the ancient Egypt to emperors in Rome and Kings and Queens throughout history, jewelry has always been at the vanguard for symbolizing people's status and wealth.

However, in today's world, "jewelry plays a greater role than it ever did in the past." (Untracht, O. 2011)

> No more is its use only the privilege of the wealthy, for the broadening of the social structure of contemporary society and the burgeoning concepts of what a jewel is or can be, have made its use universal. (Untracht, O. 2011)

And since the basic appeal for the use of jewelry lies in the satisfaction of primitive needs, imbedded in the core of human existence, it is safe to assume that it will persist, for as long as humanity survives (Untracht, O. 2011).

2.1.2 Global Jewelry Market Overview and Forecasts

Moving now from the past history to the present detailed analyzes of the global jewelry market.

According to the market research report elaborated by EMR (2021), the global jewelry market is expected to grow from 228 billion dollars in 2020 to 307 billion by 2026, representing a 5.1% annual CAGR growth during this period.

The evolving lifestyles and increasing disposable income, combined with aggressive advertising and branding techniques performed by the key players in the market are the main drivers increasing its growth (EMR, 2021).

Concerning the end-user, the market is segmented as men and woman, being the latter one still estimated as the largest segment, due to many factors, such as a wider variety of options and cultural habits. However, the male segment is also experiencing, in the last decades, a positive growth, and it's expected to continue this trajectory for the following years (FBI, 2020).

Regional wise, the Asia-Pacific market is still dominating the global market with a market share of 130.49 billion dollars in 2019, followed by North America, and Europe (FBI, 2020).

Finally, the report elaborated by FBI (2020) analyzed the key companies in this market and pointed up: LVMH, Tiffany, Signet Jewelers, Cho Tai Fook, among others, as the most relevant ones.

2.1.3 Global Online Jewelry Market Overview and Forecasts

After having analyzed the global jewelry market in all its magnitude, the next logical step is to analyze, the global online jewelry market.

As reported by Technavio (2021), this market is expected to grow at an annual CAGR of over 15%, reaching USD 19.88 billion, during the forecasted period of 2020-2024.

Revenues from the global online jewelry market are expected to grow at an accelerated rate over the forecast period, mostly driven by the innovations in jewelry design and technology, the enhanced quality of online jewelry platforms and items, and most importantly, due to the busy schedules of consumers, which ultimately result in less time to go out and shop at brick-and-mortar stores, making online shopping a more accessible path for the purchase (Reports and Data, 2021).

According to Reports and Data (2021), this market can be segmented into two types: Fine Jewelry, pieces strictly made from precious metals and precious stones, and Fashion Jewelry, made with less expensive materials such as brass, bronze, and base metal. Between the two categories, the latter represents the largest revenues share in the global online market, due to several factors such as the easy accessibility, higher cost efficiency, and overall durability of the materials used.

However, despite the growth of the global online jewelry market, there are still several challenges to overcome, especially for the fashion jewelry category. Some examples of these are: the high delivery fees for inexpensive jewelry items, which many times discourage the purchase; late delivery; poor quality of jewelry items, in many cases; and finally, less availability of affordable customized jewelry pieces (Reports and Data, 2021).

In accordance with the same report, the Asia-Pacific market accounts for the largest revenue share in the global online jewelry market, with India as the country most contributing to it, especially due to cultural and religious beliefs resulting in a higher demand for jewelry among women in the region (Reports and Data, 2021).

Finally, the report focused on the key players operating in the market, and highlighted: Chow Tai Fook Jewelry, LVMH, Rajesh Exports, Signet Jewelers, along with others.

2.1.4 Covid-19 Impact in the Global Jewelry Markets

Now that the jewelry history as well as the global jewelry market and the global online jewelry market have been analyzed, it is important to understand how the current pandemic situation, caused by Covid-19, is affecting both markets, and what impact will it leave for the upcoming years.

The Covid-19 pandemic has created an unprecedented crisis, reshaping the world we live in, and forcing both industries and consumers to adapt to a new reality. One of the major consequences for the jewelry market was the fact that consumers were forced to reduce their short-term and medium-term spending in nonessential categories, in which jewelry is included (McKinsey, 2020).

Subsequentially this resulted in the closure of thousands of stores and the cancellation of events and trade shows, across the globe. Despite all the downfalls that it caused to the jewelry industry, the physical distancing and the lockdown orders have also forced consumers to change their consumption habits and to embrace, more than ever, online shopping.

According to McKinsey (2020), the number of consumers that expect to make a portion of their jewelry purchases online has increased 10%, when we compare the data before the covid-19 (54%) and the current one (64%). This means that the pandemic situation has led consumers to become more comfortable shopping jewelry online, steering the jewelry industry into a new digital era. Jewelry brands that previously lacked an online presence, were “pressured” into start investing in it, and the others, that already had an online presence, to strengthen it in favor of a better position in the market.

2.2. Portuguese Jewelry Market Overview

Moving now from a global analysis of the jewelry markets to a more in-depth study focused on the Portuguese market.

2.2.1 Portuguese Jewelry Market Overview and Forecasts

Portugal is a country with vast traditions in the art of jewelry. Since the XV century, with the great amount of gold and other precious metals coming from Brazil, that Portugal has placed itself in a prominent position in the market of the European jewelry production (Alma e Coração, 2021).

However, as the years went by, the Portuguese jewelry market failed to grow and to adapt to the new international trends, and stagnated. Despite this past performance, in these last few years, a shift in direction can be noticed in the Portuguese industry, with a higher focus on the internalization process. This is already showing results, and according to Santos (2019), the internationalization process, although recent, has a fast growth rate, and has already shown positive results: 100 million euros in 2017 and 150 million in 2020.

Additionally, the current revenue in the Portuguese jewelry market amounts to 280 million euros in 2021, and the market is expected to grow annually at a CAGR of 2.21% in the forecasted period of 2021-2026 (Statista, 2021).

2.2.2 Portuguese Jewelry Market - SWOT Analysis

To better explore the Portuguese jewelry industry's competitive position, potential and risks, and inspired by the research of Rodrigues (2020), I will start by conducting a SWOT analyzes, in order to identify its main strengths, weaknesses, opportunities, and threats.

- **Strengths**

Tradition is the core strength of the Portuguese jewelry industry. Portuguese jewelers' values and techniques passed on and improved throughout generations, concede Portuguese jewelry a cultural value imbedded in each piece, which must be considered a major strength of the industry (Rodrigues, 2020).

- **Weaknesses**

On the other hand, one of the utmost weaknesses of it is its dimension. According to Santos (2019) the Portuguese industry has only 4237 companies and less than 11 thousand workers, resulting in an average lower than 3 workers per company (Pinto, 2018).

In addition to this, by not having established, over the years, a strong and stable position in the international markets, it is much harder for Portuguese companies to promote internationalization and to gain new market share.

Finally, there is a major weakness in the Portuguese jewelry industry in terms of the growing importance of e-commerce, since despite being one of the most important trends in today's global market, the majority of Portuguese companies have yet to adapt their strategies and market approaches to it (Rodrigues, 2020).

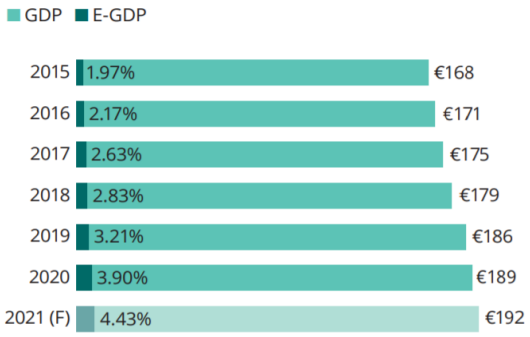
- **Opportunities**

As already mentioned, e-commerce and online channels are the major trends in the current international jewelry market, constituting a key opportunity for the Portuguese market, both to develop indoors but also internationally.

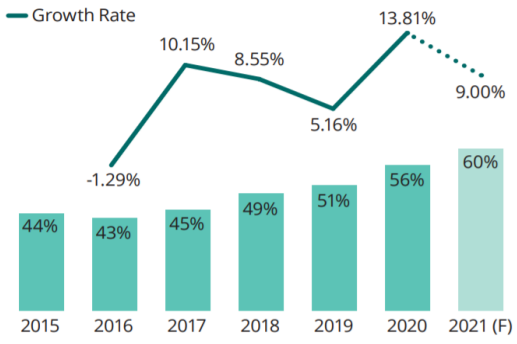
Portuguese consumers are no exception regarding the worldwide trend to use digital platforms to shop online. According to the report from EuroCommerce (2021), at the end of this year, at least 60% of internet users will have bought goods or services online, which represents a 9% increase, when compared to the previous year.

Also, according to this report, the turnover growth rate for e-commerce in Europe was 10% for 2020 and the forecast for 2021 is 12%, which is also representative of the market's growing trend.

The Gross Domestic Product (GDP) and the percentage of it used for e-commerce sales was also analyzed, and it was concluded that from 2015 to 2021 (forecasted values), the GDP has increased 14.3%, from €168 to €192 billion. And the % of GDP used for e-commerce sales, has risen from 1.97% to 4.43% (EuroCommerce, 2021).



Graphic 2: Portuguese Gross Domestic Product (GDP) in Billions of €, and its percentage used for e-commerce sales
Source: EuroCommerce, 2021



Graphic 1: Percentage of Portuguese internet users that bought goods or services online
Source: EuroCommerce, 2021

These results, graphically represented above, are clear evidence of the increasing importance off e-commerce for the Portuguese GDP and its relevance for the Portuguese jewelry market.

- **Threats**

The major threat for the Portuguese jewelry industry resides in the lack of qualified labor force (Rodrigues, 2020). This results in an urgent need to form or "import" new professionals so that the industry can flourish and develop to its full potential, otherwise, taking the risk of stagnating once again.

2.3 Introduction to the 3D printing Technology

Introducing now the technology that serves as the innovative base for the current study: 3D printing.

2.3.1 3D Printing Definition

"3D printing is a disruptive technology that promises to change the way we consume, create, and maybe even live in the world." (Prince, 2014)

3D printing, also known as "addictive manufacturing", is a term used to describe a manufacturing procedure that consists of building objects one layer at a time. As each layer sets, the next is then printed on top, till it ultimately forms the desired product.

Before the printing process begins, a 3D design of the desired object is created using computer-aided design (CAD) tools. This file is a virtual 3D model in which the user can see exactly what will then be printed, and modify it as needed for its ultimate use. After the file examination, it is sent to a 3D printer and so the printing process begins (Mikolajczyk et al., 2019).

2.3.2 The Evolution of 3D Printing Technology

Originally from the 1980s, "rapid prototyping", a printing technique using a single laser beam, was developed by the Japanese doctor Hideo Kodama at the NMIRI, in Japan. His invention is considered the foundation of 3D printing technology (Al'Aref et al., 2018).

Although his work was revolutionary, Hideo Kodama's failure in patenting the design, opened the door for others to use it and to incorporate it into their own work.

Consequently, years later, in 1984, Charles Hull, an American engineer, developed a method named stereolithography (SLA), which used digital data and computer-controlled beam of light to create each material layer. Subsequently founded 3D Systems and developed the world's first commercial SLA printer (Al'Aref et al., 2018).

All this was only possible since Hull applied for a U.S. patent for the technology (issued in 2016) and that is the main reason why several researchers entitle Hull as the father of 3D printing, instead of Kodama (Wohlers et al., 2016).

With the evolution of times, there has been a huge development concerning 3D printer's technology, making them not only, more advanced, and capable of production at an industrial scale, but also cheaper to produce, thereby expanding its range of application.

Nowadays, 3D printing is more present than ever in our industries and society and is seen as a technology with endless possibilities, capable of reshaping the world we live in.

2.3.3 3D Printing Materials and Applications

From plastics to metals, food and even living cells, 3D printing technology is flexible enough to allow manufacturers to determine the design, texture, and strength of a product, according to its specific requirements (Sharretts Plating Company, 2021).

Despite its creation in the 80s, only in the last decade has 3D printing technology seen real breakthroughs in the markets, starting to being fully utilized in multiple industries from prototypes to products. Part of this, explained by the technological developments, already mentioned, and the price decrease, not only for 3D printers, but for the raw materials as well. Other part, explained by the realization from the market, of 3D printing's potential and broad range of new production opportunities.

From aerospace to medicine, construction, and jewelry, among several others, 3D printing technology allows for higher design flexibility, rapid prototyping, waste minimization and higher cost and time efficiency (Mehrpouya et al., 2019).

All these advantages compared to traditional manufacturing processes have contributed to the proliferation of the technology throughout entire industries, and as direct consequence, through society as a whole.

However, despite these advantages, one of the major drivers for this huge and rapid proliferation of 3D printing technology was the emergence of new market trends, like the growing demand for customized goods, thus increasing the need of adoption of new production processes, such as mass customization.

2.4 Mass Customization

According to Bharadwaj et al. (2009), a great number of consumers are now demonstrating a higher propensity to buy customized products, rather than standardized, mass-produced ones.

At the same time, recent studies point up consumers' increasing need to take part in the creation process of the products and services they consume, as a way of customizing them to fit their personal needs and taste (Fenech and Perkins, 2015). As a result, mass customization grows as a central trend in the global market (AMFG Corp., 2020):

> Mass-customization is the manufacture of custom products that match the needs of individual consumers, but which are produced at the low unit cost associated with high-volume production. (Fuenmayor et al., 2019)

Consequently, as the number of consumers demanding customized products grows, technologies such as 3D printing become crucial in helping companies to keep up with this market trend, by allowing them to produce high quantities of customized products, with relatively low costs (AMFG Corp., 2020).

2.5 3D-Printed Jewelry Market Overview

The variety of materials and applications of 3D printing technology has exponentially increased in the last decades, as seen in the point 2.3.3. This resulted in the emergence of new innovative products, such as 3D-printed jewelry, which are the primary research subject of this work.

2.5.1 3D Printing Applied to Jewelry Production: The process

Traditional methods of jewelry production require either handcrafting or wax casting, being the later the most commonly used (Formlabs, 2019). With traditional lost-wax casting methods, jewelers start by hand-carving jewelry designs in wax, which are then covered in a heat-resistant material, usually plaster, and then placed in a hoven, melting the wax and leaving only the hardened mold (AMFG Corp., 2020). This gives place to the pouring of precious metals such as gold or silver, or other less expensive ones such as bronze, into the mold cavity. Afterwards,

for the piece to achieve its final appearance, any imperfections are filed, creating most of the times, a significant amount of waste, and finally, the piece is polished to shine (AMFG Corp., 2020).

With the use of digital methods, jewelers use CAD software tools to create a 3D model of the jewelry from scratch, or to scan an existing piece, which is then sent to a high-resolution 3D printer to produce the 3D-printed designs (Formlabs, 2019).

At the printing stage, there are two methods used for 3D-printed jewelry production: Direct and Indirect 3D printing. The former is exactly what it sounds like, a 3D printer uses metal powder to directly print the jewelry piece. However, despite sounding like the fastest and cheapest way of doing it, it is not! This method requires the use of high-end 3D printers, which may cost over €100k, the printing process itself is much slower and creates more waste, although less than with traditional methods, but still enough to making it a far less popular method (Ye, 2019).

Comparatively, indirect 3D printing does not directly print the final product. Instead, it is used to print an exact copy of the final piece, in a much cheaper material, usually wax, which is then casted into a mold, and from this moment on, the process follows the same path as in the previous, traditional wax casting method (Yap & Yeong, 2014).

This process is explained in the figure below:

Figure 1: Production process of 3D-printed jewelry
Source: Formlabs, 2019

A great advantage of this method, compared to direct 3D printing, and to traditional methods, is the waste reduction. Since the final piece is complete once it leaves the mold, nothing needs to be filed away, and this allows a great amount of cost saving, especially in an industry that works with precious metals such as gold and silver, making the waste costs very significant (Sun and Lu, 2015).

Additionally, by adopting 3D printing technology to the jewelry production this allows the producers to, apart from reducing waste, decrease the number of hours spent performing time-intensive manual labor, and to easily modify, preserve, and recreate jewelry designs, making it a far better alternative than traditional methods. (Formlabs, 2019).

2.5.2 3D-Printed Jewelry Online Market Overview and Forecasts

Moving now from the technicalities of 3D printing processes to the actual impact it generates in the world's market economy.

From the report elaborated by Technavio (2021), concerning the Global 3D-Printed Jewelry Market, we can observe a forecasted growth of USD 2.51 billion during 2021-2025, at an annual CAGR growth of 22.14%.

According to the same report, 42% of the market's growth will originate from North America, surpassing Asia and Europe. The main reasons appointed to justify this growth in North America are the rising technological innovations in the online retail channel throughout the last decades, combined with the latest cultural trends which point toward a demand increase for customized designer jewelry in the US.

At a global scale, growing fashion consciousness and changing consumer preferences cause a demand increase for innovative jewelry designs, resulting in a higher adoption of CAD software and 3D printing manufacturing technologies by manufacturers (Technavio, 2021).

In addition, the introduction of augmented reality (AR) is highlighted as the critical trend which will positively impact 3D-printed jewelry market's growth for the upcoming years.

Following this idea, big jewelry brands such as De Beers and Tacori have already incorporated AR technology on their websites, allowing customers to virtually try jewelry and get a better sense of how it will look on them (Technavio, 2021).

Finally, the key 3D-printed jewelry market vendors were identified, as in the previously analyzed reports, with Imaginarium Ltd, Arlette Gold Ltd, and Shapeways Inc emerging as the most prominent.

Chapter III – Technology Acceptance, Hypothesis and Research Model

Now that the existing literature on jewelry, 3D printing technology, mass customization and 3D-printed jewelry has been analyzed in addition to the presentation of the results from multiple market analyses, this third chapter, will present a continuation of the literature review, exploring the Technology Acceptance Model (TAM). From this, several hypotheses will be developed and finally, a theoretical model will be proposed for the study of Portuguese consumers' adoption of 3D-printed jewelry.

3.1 Technology Acceptance Model (TAM)

The acceptance of a new innovation or technology in a market is crucial to its successful application (Chang & Chen, 2016). Following this idea, the Technology Acceptance Model (TAM) (Davis et al., 1989) is one of the most recognized and widely accepted theoretical models to investigate consumers' perceptions, acceptance, and adoption intentions toward technology (Kim and Shin, 2015).

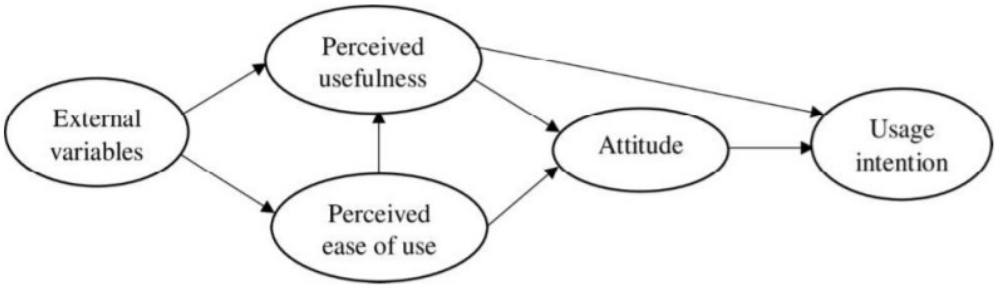


Figure 2: The original TAM model
Source: Davis et al., 1989

In the original TAM, an individual's acceptance of a new technology is determined by his intention to use it, which is itself influenced by the individual's attitude toward the technology, in addition to his perception of its usefulness and ease of use (Sousa, 2015).

In his work, Davis et al., (1989) defined perceived ease of use (PEOU) as "the degree to which the prospective user expects the target system to be free of effort." (p. 985) and perceived usefulness (PU) as "the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organizational context" (p. 985).

In the subsequent years, multiple studies, such as the ones elaborated by Kim et al., (2007) and Kim & Shin (2015) have confirmed and demonstrated that PEOU and PU indeed determine

users' acceptance of a certain technology. Additionally, further research by Venkatesh & Davis (2000) has also revealed that PU influences the relationship between PEOU and the behavioral intention to adopt a technology (Bozhen, 2021).

In this context, by anticipating that the results mentioned in the previous studies will also be valid in this study on consumers' adoption of 3D-printed jewelry, the following hypothesis are proposed:

H_1: Attitude toward using positively affects the usage intention of 3D-printed jewelry.

H_2: Perceived usefulness of 3D-printed jewelry is positively related to the attitude toward using it.

H_3: Perceived usefulness of 3D-printed jewelry is positively related to the usage intention.

H_4: Perceived ease of use of 3D-printed jewelry is positively related to the attitude toward using it.

H_5: Perceived ease of use of 3D-printed jewelry is positively related to its perceived usefulness.

3.2 TAM Extension – Application to 3D-Printed Jewelry

In the following years, a substantial number of studies has accumulated in favor of the TAM (Venkatesh, 2000). At the same time, numerous researchers have proposed several external variables in an attempt to extend the TAM and to study consumers' perceptions, attitudes, or adoption of technology in a vast range of industries (Perry, 2017a).

Despite the effort, no study, prior to Perry (2016), had extensively investigated the influence of these external factors toward the adoption of a 3D-printed product, more specifically, 3D-printed apparel. In her research, Perry (2016, 2017a and 2017b) identified several external variables, three of which being the most relevant for this current study: tech optimism, aesthetic features, and perceived compatibility.

Their influence in addition to the appropriate justifications and hypotheses developed are described below.

3.2.1 Tech Optimism

As stated by Parasuraman (2000), tech optimism refers to a "positive view of technology and a belief that it offers people increased control, flexibility, and efficiency in their lives." (p. 311).

As a result, optimists tend to be less concerned about potential negative outcomes and so, more likely to address technology more openly (Walczuch et al., 2007).

Perry (2016) concluded that tech optimism positively influenced the attitude toward using 3D-printed apparel, and as also identified a direct and positive influence of tech optimism, regarding the perceived ease of use. These observations were also supported by several recent studies, from which Godoe & Johansen (2012).

Consequently, the following hypotheses are proposed:

H_6: Tech optimism is positively related to the attitude toward using 3D-printed jewelry.

H_7: Tech optimism is positively related to the perceived ease of use of 3D-printed jewelry.

3.2.2 Aesthetic Features

According to Lamb & Kallal (1992), aesthetic features concern the extent to which a products observable characteristics and overall appearance are perceived as pleasant by consumers.

Several quantitative researchers focused on the study of aesthetic features and its relation to the TAM have identified a direct and positive link between this variable and three variables from the original model: perceived usefulness, attitude, and usage intention. Some examples of these are Wang et al., (2010) research on online shopping, and Perry (2016), research on 3D-printed apparel.

Finally, as a result of this literature findings, the succeeding hypotheses will be included in the study:

H_8: Aesthetic features of 3D-printed jewelry are positively related to its perceived usefulness.

H_9: Aesthetic features of 3D-printed jewelry are positively related to the attitude toward using it.

H_{10}: Aesthetic features of 3D-printed jewelry are positively related to the usage intention.

3.2.3 Perceived Compatibility

Perceived compatibility is defined as the "degree to which the innovation is perceived as consistent with the existing values, needs, and past experiences of a potential adopter." (Ko et al., 2009, p. 261). Applied to this study, this variable measures 3D-printed jewelry "consistency with one's existing wardrobe and appropriateness for one's current needs and lifestyles." (Ko et al., 2009, p. 261)

Jewelry is already deeply emerged into people's culture and lifestyle, at a global scale. However, to date no research has yet been done to see if this relationship holds true for 3D-printed jewelry, and if it is compatible with consumer's existing jewelry, clothing styles and cultural values (Perry, 2016).

Although fulfilling an identical purpose, 3D-printed jewelry and "normal" jewelry are quite different, both in style, materials, and production process. And as stated by Perry (2016), these differences may result in different perceived compatibilities for each consumer, since, for example, while some may be concerned about the comfort and durability of the new materials, others may overlook these aspects, in order to have quicker access to newer and unique styles.

Moreover, several empirical studies have connected perceived compatibility to the TAM, observing a positive relationship between the aforementioned variable and two variables from the original model: attitude and usage intention (Vijayasarathy, 2004).

Additionally, by narrowing this literature to the 3D-printed apparel and accessories segment, Perry (2016) has also founded statistical evidence supporting these results, leading to the inclusion of the following hypotheses in this study:

H_{11}: Perceived compatibility of 3D-printed jewelry is positively related to the attitude toward using it.

H_{12}: Perceived compatibility of 3D-printed jewelry is positively related to the usage intention.

3.2.4 Perceived Cost

In this study, the influence of price on consumers' attitude toward using and usage intention of 3D-printed jewelry will be analyzed under the variable "perceived cost". Perceived cost refers to the "monetary cost required to adopt technology or to use a service" (Chen et al., 2017).

Since the beginning of business that price has been seen as a crucial factor influencing consumers purchase behavior (Kusumah, 2015). So that it is not surprising a large number of studies, over the decades, have highlighted it as one of the most important variables toward consumers' adoption and purchase intention of technology (Sujata et al., 2017).

As an example, Kim et al., (2009) has explored this variable's influence on consumers' behavior toward mobile data services and found clear evidence that perceived cost had a negative correlation with consumers' attitude, and usage intention toward the technology.

Finally, these results support the inclusion of the following hypotheses in this study:

H_{13}: Perceived cost of 3D-printed jewelry is negatively related to the attitude toward using it.

H_{14}: Perceived cost of 3D-printed jewelry is negatively related to the usage intention.

3.3 Proposed Theoretical Model

Considering the literature review and all the variables mentioned in the previous points 3.1 and 3.2, a theoretical framework (Figure 3) was elaborated as a way of illustrating all the relevant variables that affect consumers' perceptions, attitude, and usage intention toward 3D-printed jewelry, along with all the proposed hypotheses.

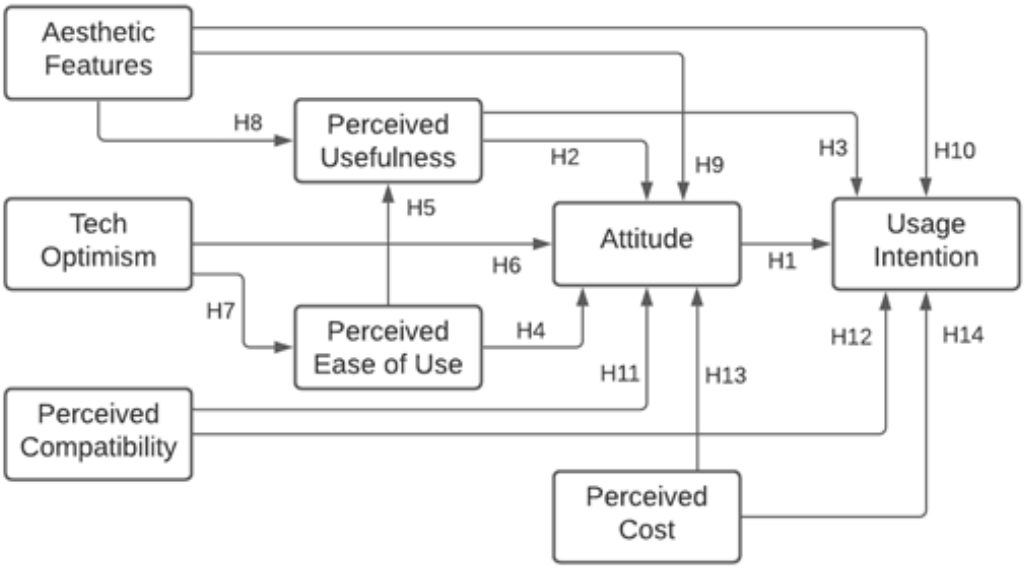


Figure 3: Proposed Theoretical Model
Source: Adapted from Perry (2016 & 2017a)

Chapter IV – Research Methodology and Data Collection

4.1 Research Method

The objective of this research is to explore consumers' perceptions, drivers and barriers toward the adoption/purchase of a rather innovative product such as 3D-printed jewelry, focused on the Portuguese online market.

In order to achieve this purpose, the first stage of the research was the collection of secondary data, through an exploratory review of the most relevant literature concerning the research subject, which was then followed by a primary data collection. For this second stage, qualitative research was conducted using in-depth interviews (Appendix 1) as a way of collecting first-hand information on consumers' perceptions, purchase drivers and barriers regarding 3D-printed jewelry, as well as to perform an initial test of the validity of the previously established hypotheses. After this, and with the introduction of new hypotheses, quantitative research was also developed, through the use of an online questionnaire (Appendix 2), performing a more in-depth analysis of these results.

This combination of approaches within a single study is known as mixed methods research and has gained widespread acceptance among researchers for exploratory and evaluative research, as a way to find different insights on the same subject (Bazeley, 2003).

4.2. Secondary Data Collection

Secondary data, collected throughout the literature review stage, included academic articles, books, company reports, journals, and websites covering a broad range of subjects relevant to the research topic, which served as the foundation for the hypotheses' development.

4.3 Primary Data Qualitative Research

Individual in-depth interviews were the chosen research method to gather qualitative primary data, since "they provide much more detailed information than what is available through other data collection methods" (Boyce & Neale, 2006, p. 3).

This method was also chosen since it allows participants to free themselves from the social pressure to conform with the group opinion, which is usually the downfall of other collection methods such as focus groups (Boyce & Neale, 2006).

By removing the participant from the group pressure, it empowers him/her to express his/her personal, and unbiased, thoughts and believes, which is of the upmost importance, especially in the context of analyzing the adoption of a rather new and disruptive product such as 3D-printed jewelry, which can generate a great number of controversial opinions.

Finally, this method also has the advantage of allowing the collection of an unlimitedly vast number of data, as a result of participants not being restricted to closed-ended questions. This promotes the obtention of valuable complementary inputs, which can ultimately result in the development of new research hypotheses (Books, 1997).

4.3.1 Qualitative Research – Results

In an attempt to acquire a preliminary understanding of consumers' perceptions of 3D-printed jewelry, as well as their purchasing drivers and barriers toward it, 10 participants were interviewed. The interviews ranged from 20 to 30 minutes, and from the 10 interviewees, 5 were male and 5 were female. They were all Portuguese and currently resided in Portugal, making them representative of the target market studied in this research. There ages ranged from 18 to 80 years, with an average age of 36 years old. Four of them were students and six of them were non-students. The non-student's occupations included a bank manager, a waiter, a telecommunications technician, an IT technician, a consultant, and a former dressmaker, currently retired. From the students, two were completing a bachelor's degree in international relations and sociocultural animation, respectively, while two were completing a master's degree in Management.

The structure of the interview (Appendix 1) was as follows:

I - General attitudes toward online jewelry shopping;
II - General perceptions, purchase drivers and barriers toward 3D-printed jewelry:
    A - Awareness about 3D-printed jewelry and its previous purchase;
    B - Perceived benefits and consumption drivers regarding 3D-printed jewelry;
    C - Perceived risks and consumption barriers regarding 3D-printed jewelry;

4.3.1.1 General Attitudes Toward Online Jewelry Shopping

Initially, participants were asked about their general attitudes toward online jewelry shopping, focusing on their shopping habits for this type of product. At this stage, eight of the ten stated

to have already purchased at least one piece of jewelry online, with an impressive number of seven, claiming it to be their preferential channel for jewelry shopping.

From this information, a new hypothesis was formulated in order to understand if this behavior evidenced by the participants, regarding their preferential jewelry purchase channel, could be generalized to the majority of the jewelry consumers for the Portuguese market:

H_{15}: More consumers prefer to shop for jewelry online than in physical stores.

Furthermore, participants were questioned about the regularity of their online jewelry purchases, which resulted in an average of 5 to 10 times per year. Additionally, the preferential purchased type of jewelry was also inquired, resulting in a clear preference for rings (7 out of 8).

Moreover, interviewees' level of satisfaction toward the current offer in the Portuguese online jewelry market was also addressed, with seven out of the ten participants giving positive feedback to the question, in addition to two who had never purchased jewelry online, and another who had a single purchase, and stated not to know enough about the market to give a conclusive answer.

Finally, interviewees were asked to enumerate their perceived major advantages and disadvantages of purchasing jewelry online, compared to in-store, and these results are presented in the table below:

	Online jewelry shopping compared to In-store jewelry shopping
Advantages	- More convenient (n = 6) - Higher product variety (n = 5) - Cheaper prices (n = 4) - Time saving (n = 4)
Disadvantages	- Less customer interaction (n = 4) - Problematic return policies (n = 3) - Problems with "product size" (n = 3)

Table 1: Online jewelry shopping advantages and disadvantages, compared to in-store jewelry shopping

With this table, it is possible to conclude that the most important advantages, perceived by the participants were the higher convenience and the higher product variety, which contrasted with the lower customer interaction and the problematic return policies, recognized as the main disadvantages of online jewelry shopping compared to in-store.

4.3.1.2 General Perceptions, Purchase Drivers and Barriers Toward 3D-Printed Jewelry

For this second part of the interviews, a detailed description on both 3D printing technology and 3D-printed jewelry was presented to the participants combined with the presentation of two explanatory videos, giving them a better understanding of the concepts. Afterwards participants were questioned about their previous knowledge of 3D-printed jewelry and its purchase.

- **Awareness About 3D-Printed Jewelry and its Previous Purchase:**

From the 10 participants interviewed, five stated to know about the product and indeed had already purchased at least one 3D-printed jewelry piece, while the remaining five stated to had never purchased it before. When questioned on the reasons for never having purchased this type of product before, all 5 participants said they had never heard about it before, being this the main reason for never having purchased it. Moreover, from this five, three stated they would be interested in purchasing this product in the future, with only two saying they would not be interested in it.

Considering that three out of five participants, who had never purchased 3D-printed jewelry before, were interest in its purchase after knowing about it, a new hypothesis was proposed in order to analyze the impact of lack of awareness on consumers' purchase intention.

H_{16}: The lack of awareness regarding the available 3D-printed jewelry options in the market prevents consumers from purchasing it.

Additionally, a question was made regarding the participants' level of acceptance toward the use of new technologies, in a scale from 1 to 10, being 1 the lowest and 10 the highest. This question, demonstrated that the participants who had never tried 3D-printed jewelry before and did not intend to do so in the future, were the ones with the lowest levels of acceptance toward new technologies, while the current consumers and the ones who had never purchased it but intended to do so in the future, showed higher levels of acceptance. This result demonstrated that participants with higher levels of acceptance toward new technologies were more likely to purchase 3D-printed jewelry, supporting H_6.

Having observed some of the potential negative impacts of the lack of awareness on consumers' purchase of 3D-printed jewelry, a decision was made to segment the participants in two distinct groups: Group 1, participants who had never purchased 3D-printed jewelry, and Group 2, participants who had already purchased at least one piece. This differentiation enabled a better

segmentation of subsequent questions based on the respondents' characteristics and product knowledge, resulting in a better understanding of each participant's unique inputs.

- **Perceived Benefits and Consumption Drivers Regarding 3D-Printed Jewelry**

Moving on to the next point, both groups were asked to express their perceptions of 3D-printed jewelry's advantages over traditional jewelry, which they saw as drivers for purchasing 3D-printed jewelry pieces.

This was done with the purpose of understanding their general perceptions toward 3D-printed jewelry and its purchase, as well as to assess if the participants from the two distinct groups shared similar perceptions, or on contrary, quite different ones.

These results are summarized in the table below:

Benefits and consumption drivers of 3D-printed jewelry	
Group 1	**Group 2**
Customization (n = 5) Uniqueness (n = 3) Aesthetic features (n = 3) Compatibilty (n = 1)	Customization (n = 5) Aesthetic features (n = 4) Uniqueness (n = 3) Compatibilty (n = 2) Sustainability (n = 1)

Table 3: Benefits and consumption drivers of 3D-printed jewelry – comparison between Group 1 and Group 2

Here we can observe that customization is the key benefit and consumption driver perceived by the participants from both groups. This variable is then followed by uniqueness and aesthetic features, with three mentions each and finally a mention for compatibility, with regard to Group 1. Concerning Group 2, aesthetic features and uniqueness were also the advantages mentioned after customization, with 4 and 3 mentions respectively, which were then followed by compatibility (2), and finally by a new advantage, sustainability (1).

From these results it is possible to understand that H_9, H_{10}, H_{11} and H_{12}, are supported by the participants, due to the demonstrated relevance of the variables: aesthetic features and compatibility, as drivers of their purchase intention for 3D-printed jewelry.

Furthermore, customization has also emerged from these results as a key driver for the usage/purchase intention, such that two new hypotheses must be established to represent this reality:

H_{17}: Perceived customization level of 3D-printed jewelry positively influences the attitude toward using it.

H_{18}: Perceived customization level of 3D-printed jewelry positively influences the usage intention.

- **Perceived Risks and Consumption Barriers Regarding 3D-Printed Jewelry**

After assessing participants perceived benefits and consumption drivers toward 3D-printed jewelry, the next logical step was to assess their perceived risks seen as consumptions barriers toward this product.

Bellow, the results from this analysis:

Risks and consumption barriers of 3D-printed jewelry	
Group 1	**Group 2**
Expensiveness (n = 4) Materials' quality (n = 2) Durability (n = 2)	Expensiveness (n = 4)

Table 5: Risks and consumption barriers of 3D-printed jewelry – comparison between Group 1 and Group 2

With these results we can conclude that the perceived cost, in this case, expressed by the word expensiveness, is the major consumption barrier perceived by both groups, supporting H_{13} and H_{14}. Additionally, concern regarding the material's quality and durability was also evidenced by the participants of Group 1, the ones who had never purchased a 3D-printed jewelry piece before. However, since all the participants from this group have previously mentioned a lack of awareness of its existence, this might justify these uncertainties regarding the jewelries' materials and durability, as a result of a lower knowledge of the product.

4.4 Primary Data Quantitative Research

As previously mentioned, following the qualitative data research, an online questionnaire (Appendix 2) was developed in order to acquire primary quantitative data for this thesis's aim. This was the chosen research method since it enables the collection of data from a large number of respondents, in a rather short period of time, and with a relatively low financial cost (Wright, 2005).

The questionnaire was developed using Qualtrics software and was pretested by 8 participants, which did not participate in the final study, in order to analyze their feedback and to avoid any

possible problems that could jeopardize the final results. After this pretest, no problems were identified, so that the questionnaire was made available to participants through social networks such as WhatsApp, Facebook, Instagram, and LinkedIn. This dispersion through the social media networks, allowed reaching a higher number of respondents, which ultimately resulted in a significant increase in the number of data collected.

The questionnaire was composed of 26 questions, and targeted jewelry consumers who currently or regularly live in Portugal, with a focus on their experience regarding the online jewelry market, and more specifically, their knowledge and previous purchase habits regarding 3D-printed jewelry.

In order to ensure the responses collected were from participants respecting the study's target market, the initial question was a filter question, in which respondents were asked if they were currently/usually living in Portugal or not. If the respondents did not meet the aforementioned condition, they were automatically excluded from the research. Otherwise, they would proceed to the following questions.

From this initial screening, the remaining questions were developed in accordance with the guidelines previously followed by the in-depth interviews:

- Initially, general shopping habits and attitudes toward online jewelry shopping were addressed. At this stage, participants were initially asked about the frequency of their jewelry purchases, as well as regarding the type of pieces they usually bought. Additionally, were also questioned on their online jewelry shopping habits, if any. Concerning the respondents who had never purchased jewelry online, they were then asked about the reasons for this behavior, and whether or not they would be interested in doing so in the future. The ones who stated not to be interested in purchasing jewelry online in the future were directed to the final stage of the questionnaire, demographics, after which their participation would be over, since they did not represent the type of consumer suitable for testing the adoption of 3D-printed jewelry. The remaining ones, who either already had an experience purchasing jewelry online, or were interested in having in the future, were inquired about their perceived advantages and disadvantages of the online jewelry market, compared to the in-store, and finally, on their preference, again, if any, regarding both markets, in order to test H_{15}.

- Furthermore, the concept of 3D-printed jewelry was introduced to the participants with the visual help off an explanatory video, demonstrating the production process of 3D-printed jewelry in addition to two images of 3D-printed jewelry pieces, giving participants a better

understanding on both the process and the final product. After the video, participants were inquired about their awareness of the concept and, for the participants who were not aware of its existence, their first impressions toward it were also analyzed.

- This study on participants knowledge of 3D-printed jewelry was then followed by an assessment on previous purchase behavior regarding this product, from which 3 different participants' groups have emerged: 1 – participants who had already purchased 3D-printed jewelry in the past; 2 – participants who had never purchased but were interested in purchasing in the future; 3 – participants who had never purchased and were also not interested in doing so in the future.

- For the participants who had never purchased 3D-printed jewelry before, the reasons for this behavior were then studied, after which, the ones who stated not to be interested in a future purchase (group 3) were forwarded to the final, demographic stage, of the survey. Regarding the ones from the first two groups, a new set of questions were introduced, as a way of understanding their perceived advantages and disadvantages of 3D-printed jewelry versus "traditional" jewelry, as well as to study their individual opinions and perceptions toward multiple variables related to the attitude toward using 3D-printed jewelry and its usage intention. The purpose of this was to assess the validity of the previously stated hypothesis, H_1 to H_{18}, excluding H_{15}, which had already been analyzed in previous questions.

- After this step, participants were questioned about their willingness to pay for 3D-printed jewelry compared to "traditional" jewelry, and finally, at the end of the questionnaire, demographic questions were also introduced.

Chapter V – Results and Analyses

The purpose of this chapter is to describe the findings of the conducted analyses and to connect them to the findings of the literature review.

5.1. Data Collection

All data was collected between the 8th and the 13th of December 2021. A total of 140 online questionnaires were started, of which 125 were fully completed, resulting in an 89% completion rate. From these, 10 were still excluded from the analysis, with 5 respondents not respecting the study's target market, in addition to 5 other who failed to correctly answer the two control

questions in Q20. Finally, after eliminating these answers that failed to meet the required parameters of this study, a total of 115 valid responses were then analyzed using the IBM SPSS software in addition to the Microsoft Excel (Cleff, 2019).

5.2 Sample Characterization

This sample of 115 valid answers included 64 female respondents (55,65%) and 51 males (44,35%). The majority of respondents were aged between 18 and 24 years old (41,74%) followed by 21,74% aged between 25 and 34. Regarding their highest level of education, most participants had completed high school (41,74%) or a bachelor's degree (31,3%). As for the current occupation, the majority was currently employed (49,56%) and 38,26% were still students. Finally, concerning their gross monthly income, the majority claimed to receive less than 500 euros a month (35,65%), while 30,44% stated to receive between 1000€ and 1499€.

Additionally, these results can be consulted and analyzed with a higher level of detail in the Table 4 (Appendix 3).

5.3 Descriptive Statistics

5.3.1 General Shopping Habits and Attitudes Toward Online Jewelry Shopping

After the initial screening question, participants were questioned on their jewelry purchase frequency, on a yearly basis (Table 5, Appendix 3), with 39,13% stating to purchase new pieces of jewelry "2 or less times per year", followed by 20,87% who claimed to purchase between "3 to 6 new jewelry pieces per year".

Following this analysis on purchase frequency, participants were asked about the type of jewelry they usually purchase (Table 6, Appendix 3), from which, earrings (28,86%), necklaces (24,14%) and rings (23,71%) have emerged as the most mentioned items. These results contradict the ones from the report elaborated by FBI (2020), in which the ring was the leading product in the global jewelry market. However, this can be justified either by the small number of respondents and their low representativity of the global market demand, or by the specific cultural characteristics of the Portuguese consumers, which would have to be further analyzed in future studies, to better understand this potential causal relationship.

Additionally, participants were questioned regarding their previous online jewelry purchase behavior (Table 7, Appendix 3), from which 53,91% answered to had never purchased jewelry online before, and the remaining 46,09% stated to have already purchased at least one piece of jewelry online.

Furthermore, the non-consumers' reasons for never having purchased jewelry online before were also assed (Table 8, Appendix 3), with the majority (51,61%) expressing that "It just never happened" followed by 32,26% who expressed their preference for in-store jewelry purchases as the main reason.

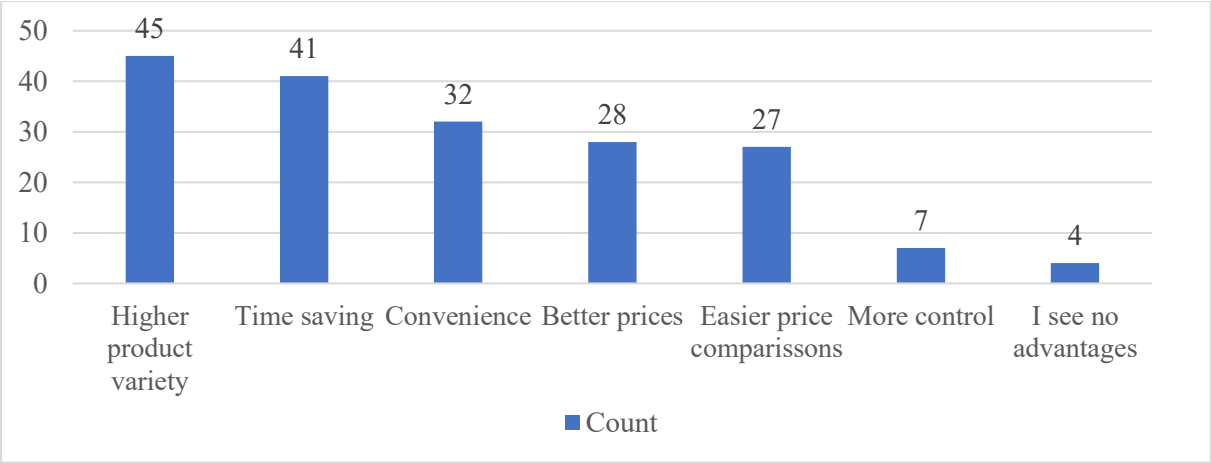
Additionally, these participants were also asked if they would be interested in purchasing jewelry online in the future (Table 9, Appendix 3), from which only 35,48% answered affirmatively, while the remaining 64,52% stated not to be interested.

These participants who had never purchased jewelry online nor were interested in doing so in the future where not indicated to answer the remaining questions, by not meeting the required characteristics to do so, such that this resulted in a decrease in the number of participants for the subsequent questions, from 115 to a total of 75 answers.

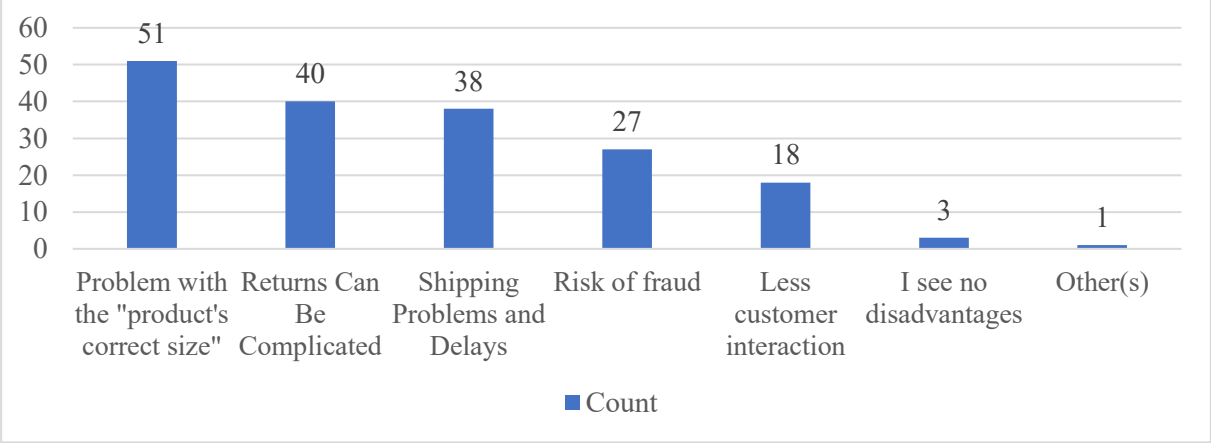
Furthermore, this group of participants, not interested in a future purchase, was also studied in order to understand if there were any demographic patterns that stood up from these respondents, and indeed there was. The majority of this answers were given by female participants (60%), aged between 18 and 24 years old (67,5%), currently students (57,5%), with high school as their highest level of education (47,5%), and earning a gross monthly allowance of less than 500 euros (52,5%).

Regarding the participants who stated to have already purchased at least one piece of jewelry online, were then questioned about the frequency of their online jewelry purchases, with the answer "more than half" of all their jewelry purchases emerging as the central trend (49,06%). This question was then followed by an inquiry on their satisfaction level toward the current offer in the Portuguese online jewelry market, with the results demonstrating high levels of satisfaction, with more than 64% of the participants answering to be at least moderately satisfied with it.

Additionally, the remaining 75 participants were asked to express their perceived advantages and disadvantages of purchasing jewelry online compared to in-store, and the results were as follows:



Graphic 3: Perceived advantages of purchasing jewelry online compared to in-store



Graphic 4: Perceived disadvantages of purchasing jewelry online compared to in-store

From the graphics above it is possible to conclude that the key perceived advantages of online jewelry purchase compared to in-store were: Higher product variety, time saving and convenience, which is consistent with the results from the qualitative analysis. Moreover, regarding the key disadvantages: Problems with the products' correct size and complications with return policies were mentioned as the primary problems, which again is consistent with the qualitative results.

Finally, in order to conclude this chapter concerning respondents' general shopping habits and attitudes toward online jewelry shopping, participants' preference, if any, regarding both markets was analyzed and the results (Table 10, Appendix 3) show that the majority (50,67%) preferred to buy their jewelry in-store. And if to these, we add the results from table 7 (Appendix 3), the conclusion is that from the total of 115 valid answers given by participants only 26 (22,61%) stated to prefer to buy jewelry online, such that H_{15} is therefore rejected.

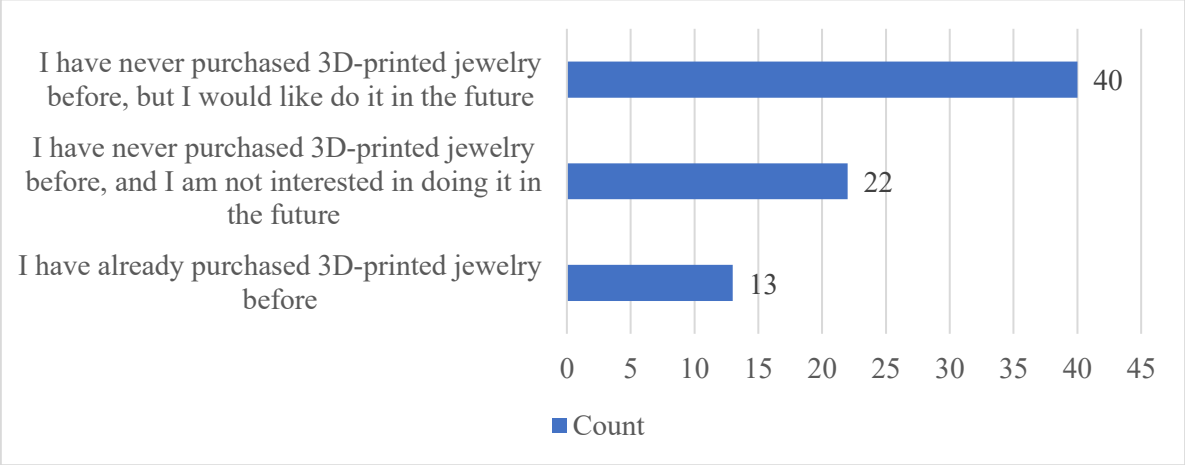
5.3.2 Awareness, Previous Purchase, and Attitudes Toward 3D-Printed Jewelry

At this point, respondents were introduced to the concept of 3D-printed jewelry, as previously explained on point 4.4, and their awareness of the product in addition to their previous purchase behavior and perceived advantages and disadvantages toward it were also assessed.

From the 75 participants who met the requirements to answer to this questionnaire's chapter, 47 (62,67%) stated not to know about the concept, while the remaining 28 (37,33%) have stated to know about it (Table 11, Appendix 3).

Additionally, for those who manifested their lack of awareness regarding 3D-printed jewelry, their first impressions were also studied, with more than 50% (55,31%) expressing a "positive" or even "very positive" impression toward the concept.

Furthermore, the respondents were questioned about their previous purchase of 3D-printed jewelry, from which the following results have emerged:



Graphic 5: Participants' previous purchase behavior regarding 3D-printed jewelry

With these results it is possible to observe that the majority of participants (62) have never purchased 3D-printed jewelry before (82,67%). However, at the same time, it is also observable that most participants who had never purchased, are interested in do so in the future (40), constituting 53,3% of the analyzed group.

Additionally, for the respondents who stated to had never purchased 3D-printed jewelry before, the reasons for this behavior were also studied (Table 12, Appendix 3), and was found that 72,58% of these participants have expressed "lack of awareness of product existence" as the main reason for never having purchased this product before. These results proved that the lack

of awareness regarding the available 3D-printed jewelry options in the market prevented the majority of participants from purchasing this product, therefore validating H_{16}.

Moreover, for the ones who were not interested in acquiring 3D-printed jewelry in the future, the majority (59,26%) have expressed "the preference for the purchase of other jewelry types" as the main reason, while 25,93% have expressed "not to like 3D-printed jewelry" (Table 13, Appendix 3).

After this screening on respondents' previous purchase of 3D-printed jewelry, the respondents who answered to have already purchased it, in addition to the ones who stated to be interested in purchasing it in the future, without having already purchased it, were questioned on their perceived advantages and disadvantages of 3D-printed jewelry when compared to "traditional" jewelry. The remaining respondents were redirected to the final, demographic, stage of the questionnaire. This was done in order to further segment and analyze the study's target market, of participants who would be willing to adopt and purchase 3D-printed jewelry and, as a result of it, more valid and less unbiased answers were obtained for the study's purpose.

These participants expressed "allowing more complex designs" and "level of customization" as the main advantages of 3D-printed jewelry (Graphic 6, Appendix 3) and "durability" and "materials' quality" as the main disadvantages (Graphic 7, Appendix 3), with a substantial amount also stating not to see any disadvantages (30,56%). These results were again consistent with the ones found on the qualitative research.

5.3.3 Willingness To Pay

At this point, respondents' willingness to pay for 3D-printed jewelry was also assessed (Table 14, appendix 3) with the majority (43,40%) answering to be willing to pay a lower price for it, when compared to "traditional" jewelry, followed by 30,19% how said to be willing to pay a similar price for both products.

However, if we look at these results with a higher level of detail, and analyze them according to participants' previous purchase behavior (Table 15, Appendix 3), we can observe that from the participants who had already purchased 3D-printed jewelry in the past, the majority (76,92%) would be willing to pay a higher price, while for the participants who stated to have never purchased 3D-printed jewelry before, the results are the totally opposite, with the majority (52,5%) only willing to pay a lower price for the 3D-printed jewelry.

This is a clear evidence that consumers who have never purchased this type of product before have more uncertainties, for example, regarding the quality and durability of the jewelries, as previously mentioned. Consequentially, this makes them more cautious toward the amount expended for it, while the ones who have already purchased it in previous occasions, no longer have these concerns, making them willing to spend higher amounts for its acquisition.

5.3.4 Measurements Reliability, Validity, and Hypotheses Testing

Finally, in order to test the remaining hypotheses previously established in Chapter III, question Q20 of the online questionnaire asked 3D-printed jewelry consumers and non-consumers who were interested in purchasing this product to rate their level of agreement toward a set of 20 different scales, including 2 control ones (to ensure the validity of results).

The majority of the scales utilized in the research were adapted from previous literature focused on the study of variables that affect the adoption of new technologies, and to which the respective references can be found in (Table 19, Appendix 4).

Additionally, and in accordance with previous studies (Cho et al., 2014; Gao et al., 2015), a five-point Likert scale, ranging from 1 "strongly disagree" to 5 "strongly agree", was used to measure all items.

Moreover, in order to ensure the quality and suitability of the results, the reliability and validity of the used scales were initially assessed (Masrom, 2007). For this purpose, and according to Hair et al. (2014), a Cronbach alpha's test in addition to a composite reliability test and an item-total correlation test were used to analyze the constructs' reliability, followed by the assessment of the construct' validity through the use of both convergent validity and discriminant validity tests.

5.3.4.1 Reliability Assessment

The Cronbach's alpha coefficient is the most commonly used criteria to measure the Internal Consistency Reliability (Sideridis et al., 2018).

> It calculates the intercorrelations between the observed indicator variables and thus estimates the reliability. (Dzimiera, 2017)

According to Waljee et al. (2010) the Cronbach alpha's value should be between 0.6 and 0.8 in order to be considered acceptable. An alpha of more than 0.8 indicates that within the scale

there is a higher redundancy of items, while an alpha lower than 0.6 implies a higher heterogeneity among the scale's items (Waljee et al.,2010).

In addition to the Cronbach's alpha, also the composite reliability, "which takes the outer loadings of the indicator variables into account" (Dzimiera, 2017) was used to measure the internal reliability of the measurement. This, must follow the same value range as the Cronbach's alpha (Hair et al., 2010).

Moreover, also the item-total correlation was used at this point, as it "indicates the correlation of an item with the total scale when that item is omitted" (Matta et al., 2016). And as stated by Sreiner & Norman (2003), a good level of correlation can be achieved for values over 0.2, giving the construct a solid level of internal reliability.

- **Results**

By analyzing the results from Table 16 (Appendix 3), all parameters for the referred tests were within the desirable ranges, with all the Cronbach alpha's as well as the composite reliability's values between 0,6 and 0,8, and the item-total correlations all over 0,2, demonstrating the good internal reliability of all used scales (Hair et al., 2010).

5.3.4.2 Validity Assessment – Convergent Validity

Convergent validity is "the assessment to measure the level of correlation of multiple indicators of the same construct that are in agreement". (Ab et al., 2017, p.2)

In order to analyze it, two different criteria were applied: Extracted Average Variance (EAV) and Indicator reliability.

The first "measures the level of variance captured by a construct versus the level due to measurement error" (Alarcón et al., 2015) and must achieve a value of at least 0.5 to be acceptable, while the second "describes the commonalities shared by the indicators of a construct" (Dzimiera, 2017), and is measured by the factor loadings' values which must exceed 0,5.

- **Results**

Through the analysis of the results from Table 16 (Appendix 3), we can again conclude that all parameters are within the desirable range, with the factor loadings as well as the AVEs all above 0,5.

5.3.4.3 Validity Assessment – Discriminant Validity

Discriminant validity refers to the degree to which a construct is actually differentiated compared to the other constructs (Hair et al., 2014).

According to Hair et al., (2014) a usual approach to assess it is the Fornell-Larcker criterion, which compares the square root of the AVEs with the correlation of the remaining constructs and is fulfilled only when the square root of the AVE of each construct is higher than any other correlation with the remaining constructs.

- **Results**

Since for each variable, two scales were defined, in order to analyze these results, the mean of each scale was computed and then aggregated into a single variable.

With the results from table 17 (Appendix 3), we perceive that the scales used has a good discriminant validity since the AVEs of all constructs had square roots bigger than the correlations (Hair et al., 2010).

5.3.4.4 Hypotheses Testing

All these results have confirmed the reliability and validity of all the used scales such that the remaining hypotheses can now be tested with higher levels of confidence.

First, a correlation test was conducted in order to quantify the relation between variables. Due to the ordinal nature of the data resulting from the five-point Likert scales, the Spearman's Correlation Test, also known as non-Parametric test, was the chosen method used to analyze the data, instead of the Pearson's Correlation which is more suitable for the analysis of continuous variables (Schober et al., 2018)

The results from this test are presented in Table 18 (Appendix 3), from which the following results can be observed:

- The ATU was directly influenced by the PU (r_s = 0,382, p-value = 0,005), PEU (r_s = 0,480, p-value < 0,001), TOpt (r_s = 0,591, p-value < 0,001), Aes (r_s = 0,536, p-value < 0,001), PC (r_s = 0,584, p-value < 0,001), Cost (r_s = 0,476, p-value < 0,001), and PCL (r_s = 0,416, p-value < 0,001), respectively validating H_2, H_4, H_6, H_9, H_{11}, H_{13}, H_{17}.

- The BUI was influenced by the ATU (r_s = 0,521, p-value < 0,001), PU (r_s = 0,572, p-value < 0,001), Aes (r_s = 0,578, p-value < 0,001), PC (r_s = 0,624, p-value < 0,001), Cost (r_s = 0,348, p-value = 0,011), and PCL (r_s = 0,538, p-value < 0,001), supporting H_1, H_3, H_{10}, H_{12}, H_{14}, H_{18}, respectively.

- The PU was directly affected by the PEU (r_s = 0,360, p-value = 0,008), as well as by the Aes (r_s = 0,581, p-value < 0,001), validating H_5 and H_8.

- Finally, the TOpt also had a direct impact on the PEU (r_s = 0,416, p-value = 0,002), supporting H_7.

Chapter VI – Main conclusions, Limitations and Future research

6.1 Main Conclusions

This dissertation proposed to study the perceptions, drivers and barriers that influence jewelry consumers' adoption of 3D-printed jewelry, limited to the Portuguese online jewelry market.

For this purpose, two research questions were developed:

- *"What are the main drivers of the purchase intention for 3D-printed jewelry?"*

- *"What are the main barriers of the purchase intention for 3D-printed jewelry?"*

In order to address these questions, this research started by an extensive literature review on some relevant topics namely jewelry, 3D printing technology, mass customization and 3D-printed jewelry, in addition to the presentation of the findings of several market analyses.

This data was then presented and followed by a new literature review concerning consumers' adoption of innovative technological products such as 3D-printed jewelry, from which the technology acceptance model (TAM) has emerged as the most widely accepted and appropriate model for this purpose.

From this, several were the examined studies, with specific focus on the extension of the TAM for a wide range of products and industries, with a special relevance for the ones elaborated by Perry (2016; 2017a; 2017b) regarding the adoption of 3D-printed apparel.

Inspired by these works, several hypotheses were then proposed in order to study the variables influencing consumers' adoption of 3D-printed jewelry for the Portuguese online jewelry market, and ultimately a theoretical model was also developed to quantify this impact. This model was a result of a combination between existing variables from previous studies (Perry, 2016; 2017a) with new ones found to be relevant during the literature review process.

Throughout the qualitative and quantitative analyses, the data substantially supported the proposed hypotheses and confirmed the influence of all variables on consumers' intention to adopt 3D-printed jewelry, in addition to revealing the most important factors influencing their perceptions and purchase intention toward the product.

It proved that participants placed a lot of importance on the 3D-printed jewelries' perceived compatibility, such that the higher they perceived it as compatible with their fashion style the more likely they were to use it and to purchase it. At a similar level, also the aesthetic features and the perceived customization level have shown their positive influence both on the attitude toward 3D-printed jewelry as well as on its usage and purchase intention, demonstrating the importance that consumers place both on the designs and overall style of the jewelries, as well as on how well do these designs fit their specific requirements. Moreover, the results have also demonstrated that consumers who have a more positive view toward technology are more inclined to adopt and use 3D-printed jewelry. It was also proven that the adoption and purchase was positively influenced by a good perception from consumers of its ease of use and of its usefulness in their lives. And finally, also the attitude toward the use of 3D-printed jewelry was demonstrated to have a significant positive influence on its usage intention.

By analyzing these results, and in order to answer the first proposed research question, this study has concluded that the key drivers found to positively influence the purchase intention of 3D-printed jewelry (analyzed in this study by the variable BUI) are: Perceived usefulness; Perceived ease of use; Aesthetics; Perceived compatibility; Perceived customization level; Tech optimism; and the Attitude toward using, all directly or indirectly influencing the aforementioned BUI variable.

On the other hand, and contrasting with the previously mentioned drivers, the perceived cost has been demonstrated to negatively influence both the attitude and the usage intention, as

expected by the normal relationship between price and demand, in the majority of markets. In addition to this, also the lack of awareness regarding 3D-printed jewelry and its available options in the market was found to be one of the main barriers preventing a higher adoption of this product in the Portuguese market. Moreover, in addition to these two, also the typical problems and concerns associated to the online shopping, and more specifically to the online jewelry shopping, were found to prevent participants from adopting and purchasing 3D-printed jewelry. Problems such as "product's correct size discrepancies" or "problematic return policies" and "delays" were some of the main obstacles discovered preventing a greater number of jewelry consumers from purchasing jewelry online, and ultimately resulting in a higher preference for the in-store purchasing channel.

In conclusion, and in order to answer to the second proposed research question, three were the identified barriers preventing consumers from purchasing 3D-printed jewelry: Perceived cost; Lack of awareness; and Problems and concerns associated to the online jewelry shopping.

Moreover, and as a final remark of this study, it has been demonstrated through the presentation of all these results and conclusions that despite consumers' low levels of adoption of 3D-printed jewelry for the Portuguese online jewelry market so far, there are some positive indications of consumers' interest and purchase intention for this type of innovative product such that this should be a subject of interest to be studied in the close future due to its propensity to reshape the Portuguese online jewelry market.

6.2 Limitations and Future Research

Despite the relevant results provided by this research, some limitations need to be considered upon their interpretation.

The scarcity of academic literature concerning the research topic is the first constraint of this study. The fact that 3D-printed jewelry is a relatively new and novel concept, especially for the Portuguese market, makes it a very underexplored topic, even more, if we focus on the research of consumers' perceptions, attitudes, and purchase behaviors toward it.

The second major limitation of the research regards the small sample size, composed of 115 valid participations. As a result of this reduced number of observations, the sample cannot be considered entirely representative of the Portuguese consumers, such that the results might be prone to sampling errors (Lin, 2018).

Moreover, the high levels of unawareness evidenced by the majority of participants regarding 3D-printed jewelry may have also increased the propensity for the existence of biased results. Since most of the answers to the online questionnaire came from participants who had their first contact with the concept through a rather explanative but still diminutive video description of the product's process and final appearance, without having the chance to explore more about it or even to try it, their answers were merely based upon perceptions rather than experiences, which might have influenced their accuracy.

In the future, studies focused on similar research topics should try to collect a larger, and more representative sample of the jewelry consumers, in order to avoid the previously mentioned limitations. In addition, it would also be beneficial to ensure that participants are more familiarized with the product, and, if not, to provide some exemplars of 3D-printed jewelry during the interviews, giving them a better notion of the product, which will ultimately result in the collection of more meaningful conclusions.

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Appendices

Appendix 1 – In-depth interview guidelines

Introduction

Hello [Name] and thank you in advance for agreeing to be interviewed. My name is Alfredo Soares, and I am currently finishing my master's in Management with specialization in Strategy and Entrepreneurship at Católica Lisbon School of Business and Economics and, for the final stage of the master's, I am developing a dissertation about consumers perceptions, consumption drivers and barriers toward 3D-printed jewelry focusing on the Portuguese online market. To better understand the perceptions of Portuguese consumers and the buying habits in this industry about this type of product, I am conducting some interviews to gather some valuable insights on the topic. I have some general questions to ask you, but this is supposed to be an open conversation, so feel free to add anything important that you think is missing, and please keep in mind that there are no right or wrong answers, and that what matters is your true and open opinion about the subject. The interview will last, approximately, 20/30 minutes, and it will be recorded for later in-depth analysis of your answers. Moreover, all your answers will remain anonymous, and you will not be contacted further past this interview.
Thank you and let's begin:

Consumers interviewed:

A.B.: 22 years old, Female, Bachelor's student (International Relations)
L.F.: 54 years old, Male, Bank manager
M.A.: 23 years old, Female, Master's student (Management)
B.G.: 33 years old, Male, Waiter
A.S.: 57 years old Male, Telecommunications technician
B.S.: 18 years old, Female, Bachelor's student (sociocultural animation)
C.E.: 22 years old, Female, Master's student (Management)
J.M.: 22 years old, Male, IT technician
M.L.: 80 years old, Female, Retired
D.V.: 30 years old, Male, Consultant

I - General attitudes toward online jewelry shopping:

1. Initial question: Tell me about how you usually shop for jewelry (where, when, how, how often...)

A.B. Usually I buy them online, only on important days (anniversaries, …) or when there are special sales (lower prices).

L.F.: I tend to buy my jewelry online. I only buy them in a store when I am worried about the size, and when I do it, I first search what I want online. I tend to buy them on a regular base, like once a month, and also on special occasions, like anniversaries, or similar.

M.A.: Usually I do it online. I do it like once every two months or at special occasions.

B.G.: Most of the times, I do it in a physical store. I only purchase it as a gift so, only on special occasions.

A.S.: I always do it in-store. Usually, to offer as a gift.

B.S.: I buy it online almost every time. I buy them regularly for myself and sometimes as gifts.

C.E.: Normally, I buy my jewelry online. Almost always for myself when I want to try something new.

J.M.: I buy it online most of the times.

M.L.: I always buy my jewelry in-store. Not very often, more as a gift for special dates.

D.V.: I usually buy them online. I buy them for me but also to offer to my family and friends.

2. Do you shop for jewelry online? (If the answer is negative, move to question 8 of this point)

A.B.: Yes

L.F.: Yes

M.A.: Yes

B.G.: Yes

A.S.: No

B.S.: Yes

C.E.: Yes

J.M.: Yes

M.L.: No

D.V.: Yes

3. How many times did you shop for jewelry products online in the last year?

A.B.: Maybe between 5 and 10 times.

L.F.: Between 15 and 20 times.

M.A.: Between 5 and 10 times.

B.G.: Only 1 time.

A.S.: Not applicable.

B.S.: Between 15 and 20 times.

C.E.: Maybe between 5 and 10 times.

J.M.: Maybe like 5 times.

M.L.: Not applicable.

D.V.: Between 5 and 10 times.

4. What kinds of jewelry products do you usually buy online? (e.g., rings, necklaces, earrings, bracelets, etc.)

A.B.: earrings, necklaces, and bracelets.

L.F.: earrings, necklaces, and cheaper rings.

M.A.: rings, earrings, and necklaces.

B.G.: a necklace.

A.S.: Not applicable.

B.S.: rings, necklaces, earrings

C.E.: earrings, bracelets, and rings.

J.M.: rings and necklaces.

M.L.: Not applicable

D.V.: Rings, necklaces, and cufflinks.

5. What is your level of satisfaction toward the current offer in Portuguese online jewelry market? What aspects do you value the most? What aspects do you think can be improved?

A.B.: Overall I am quite satisfied. There is a lot of variety, and the prices are usually cheaper compared to in-store. However, sometimes it is hard to know the exact size for the pieces ("ring size that fits me"), however "if I did, I would buy it online".

L.F.: I am happy with it! There are a lot of products to choose from, more than in stores! However, sometimes I tend to buy them in-store, since if I have to return them, it is much easier than online. And I also had some troubles with return policies in the past, but if it was easier, I would always buy it online.

M.A.: I am very satisfied. Great variety and usually at cheaper prices. I only have good things to say about it.

B.G.: I think it has a lot of variety and a good quality, but I don't know enough about it to give a proper description.
A.S.: Not applicable.
B.S.: I really like it. There are a lot of products to choose from, and they are usually cheaper than in-store. I really like how fast the deliveries are. I can't remember any aspects to improve.
C.E.: I like it a lot. There is a lot of variety. However, I find it hard to return some pieces.
J.M.: I think it has a lot of products at very good prices. I can't remember any negative aspects.
M.L.: Not applicable
D.V.: I am really satisfied. The prices are accessible and there is a lot of variety. I can't think of any relevant negative aspects.

6. What are, in your opinion, the main advantages of purchasing jewelry online, compared to in a store?
A.B.: It is much easier and faster to shop online. Besides that, the higher product variety, more discounts, and good return policies, makes me "love it".
L.F.: It is more convenient, the variety is much higher, and I can do it while at home and on my phone, without having to go to several different stores.
M.A.: Way easier, and much more convenient.
B.G.: Saves more time and has more products available
A.S.: Not applicable.
B.S.: Much more convenient and has more variety of products.
C.E.: More variety, and I can see all the products at the same place.
J.M.: I can be at home while doing it, so it saves me a lot of time.
M.L.: Not applicable
D.V.: It's way more convenient and it save me a lot of time.

7. And what are the main disadvantages of purchasing jewelry online, compared to in-store?
A.B.: Some problems with some return policies, but not very frequently.
L.F.: Some problems with jewelry sizes, and with return policies.
M.A.: Maybe the lack of interaction.
B.G.: Less customer interaction.
A.S.: Not applicable.
B.S.: Probably some problems "knowing my size" and with a lower customer interaction.
C.E.: Some problems with some return policies.

J.M.: Less interaction.

M.L.: Not applicable

D.V.: Probably some problems when I am not really sure about the correct size.

8. Do you prefer to buy jewelry online or in-store? Why?

A.B.: I prefer to buy jewelry online, because it is faster and more accessible, and because of the variety and higher price discounts. However, I still think that the in-store experience is very important.

L.F.: I definitely prefer to buy jewelry online, because it is easier, I can do it while I am at home, there is more product variety, and I can see all the products at the same place.

M.A.: Online for sure. It saves me a lot of time and I can see all I want at the same place.

B.G.: I prefer to buy it in-store. I prefer the in-store experience

A.S.: I prefer to buy it in-store. Because that is what I am used to

B.S.: Definitely online. It saves me a lot of time.

C.E.: I prefer to buy it online. It saves me a lot of valuable time.

J.M.: I rather buy online. I prefer to have more variety to choose from.

M.L.: I prefer in-store. I don't really know how to purchase online, and I am used to do it in-store.

D.V.: I prefer to buy it online. I like the online experience and the variety of products.

II - General perceptions, purchase drivers and barriers toward 3D-printed jewelry

Introduction to the 3D printing technology and to 3D-printed jewelry products:

At this point, I will provide a brief introduction on the topics and will show to the interviewee two explanatory videos, both on the technology https://www.youtube.com/watch?v=Vx0Z6LplaMU and on its application to jewelry making https://www.youtube.com/watch?v=Ig8lBnRUC0k.

1 - Awareness about 3D-printed jewelry and its previous purchase

1. Did you know about 3D-printed jewelry? If the answer is yes, can you tell me where did you hear about it?

A.B.: No, I had never heard about it before today.

L.F.: No, I did not know about it.

M.A.: Yes, I heard about it through social media, Instagram.

B.G.: No.

A.S.: No.

B.S.: Yes, through someone I follow on Instagram.

C.E.: Yes, a friend of mine had a 3D-printed ring and she showed it to me.

J.M.: Yes, I knew about it through social media.

M.L.: No, I have not.

D.V.: Yes. I saw a random advertise online and got interested in it.

2. More specifically, have you ever purchased or tried any 3D-printed jewelry piece before? (If the answer is negative, move to question 3. If positive, move to the next topic)

A.B.: No

L.F.: No

M.A.: Yes

B.G.: No

A.S.: No

B.S.: Yes

C.E.: Yes

J.M.: Yes

M.L.: No

D.V.: Yes

3. Would you be interested in purchasing this product in the future?

A.B.: Yes

L.F.: Yes

B.G.: Yes

A.S.: No

M.L.: No

4. How would you describe your level of acceptance toward the use of new technologies? (High, medium, low, not sure, …) and in a scale from 1 to 10, being 1 the lowest and 10 the highest?

A.B.: Very high, maybe a 9.

L.F.: High, like an 8.

M.A.: Very high, a 9 for sure.

B.G.: Medium, like a 6.

A.S.: Low, like a 4.

B.S.: High, an 8.

C.E.: High, like a 9.

J.M.: Really high, probably a 10.

M.L.: Low, maybe a 2.

D.V.: Medium, like a 6.

Target 1: Consumers who never purchased 3D-printed jewelry

A – Perceived benefits and consumption drivers regarding 3D-printed jewelry

1. What do you think are the key drivers to buy a 3D-printed jewelry piece?

A.B.: Its unique designs and aesthetics, the fact that I can customize it as I want to

L.F.: Higher customization and better looking designs;

B.G.: Customized products, which I can combine with my current ones

A.S.: Unique customized products, with better designs.

M.L.: Customized and unique jewelry

B – Perceived risks and consumption barriers regarding 3D-printed jewelry

1. Can you mention some possible barriers toward the purchase this type of product?

A.B.: Uncertainty regarding the materials and the long-term quality of the jewels, and maybe some lower technology acceptance.

L.F.: Probably if the price is too high, compared to "normal" jewelry.

B.G.: If the price is too high, I would not buy it, because I am not really sure about the quality.

A.S.: If the customer does not know about the overall quality or if it is too expensive.

M.L.: Probably if the price is too high and if I am not sure about the quality.

2. Can you mention some reasons why you have never tried this type of product before?

A.B.: I had never heard about it before, neither on TV nor on social media.

L.F.: I didn't know about it.

B.G.: Never heard about it, and I usually buy jewelry in-store

A.S.: I didn't know it and I usually don't buy jewelry online.

M.L.: Used to the "traditional". Never heard about it.

Target 2: Consumers who have already tried a 3D-printed product

A – Perceived benefits and consumption drivers regarding 3D-printed jewelry

1. What do you think are the key drivers to buy a 3D-printed jewelry piece?

M.A.: It is a customized and unique piece of jewelry with beautiful designs that match with all my other jewelry.

B.S.: More sustainable, customized and with prettier designs.

C.E.: We can get more complex and beautiful designs, that we can customize to our taste.

J.M.: Customized, unique, and compatible with my jewelry, at lower prices

D.V.: Customized, unique, with better designs, with better prices

B - Perceived risks and consumption barriers regarding 3D-printed jewelry:

1. Can you mention some possible barriers to purchase this type of product?

M.A.: Maybe if the price is too high

B.S.: I see no barriers for the purchase of 3D-printed jewelry

C.E.: If the price is too high

J.M.: Maybe if the price is much higher compared to a "traditional" alternative.

D.V.: Probably if it isn't cheaper than "traditional" ones.

Appendix 2 – Online questionnaire

Start of Block: Introduction

Dear Participant,

Thank you for taking time to answer this survey.

This questionnaire is a crucial part of the research for my thesis in my MSc in Management with Specialization in Strategy and Entrepreneurship and its goal is to study consumers' perceptions and purchasing drivers and barriers concerning 3D-printed jewelry.

All your answers will be kept completely anonymous, and I also want to remind you that there are no right or wrong answers and that all opinions are valid and important. This way, I ask you to give an honest answer to all questions. The survey will take approximately 15 minutes to be completed. If you have any questions or feedback about the survey or the study, feel free to contact me at: 152120232 @alunos.lisboa.ucp.pt

Thank you for your help,

Alfredo Soares

End of Block: Introduction

Start of Block: Screening question

Q1 Do you currently/regularly live in Portugal?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey if: Q1 = "No"

End of Block: Screening question

Start of Block: Jewelry buying habits - Part 1

Q2 How often do you buy new pieces of jewelry?

- ○ 2 or more times per month (1)
- ○ Once a month (2)
- ○ 3 to 11 times per year (3)
- ○ 3 to 6 times per year (4)
- ○ 2 or less times per year (5)
- ○ Never (6)

Q3 What kinds of jewelry products do you usually buy? (Multiple answers allowed)

- ○ Earrings (1)
- ○ Necklaces (2)
- ○ Rings (3)
- ○ Bracelets (4)
- ○ Cufflinks (5)
- ○ Other (6) _____

Q4 Have you ever purchased jewelry online?

- ○ Yes (1)
- ○ No (2)

Skip To: Q7 if: Q4 = "Yes"

End of Block: Jewelry buying habits - Part 1

Start of Block: Reasons for never purchasing jewelry online before

Q5 What is the main reason why you have never purchased jewelry online?

- ○ It just never happened (8)
- ○ I prefer to buy jewelry in a physical store (9)
- ○ I don't trust online shopping (10)
- ○ I don't know how to purchase jewelry online (11)
- ○ Other (12) _____

Q6 Would you be interested in purchasing jewelry online in the future?

- ○ Yes (1)
- ○ No (2)

Skip To: Q22 if: Q6 = "No"

End of Block: For consumers who have never purchased jewelry online before

Start of Block: For consumers who have purchased jewelry online before

Q7 When you buy jewelry, how many of those purchases are online?

- ○ All of them (1)
- ○ More than half (2)
- ○ Half (3)
- ○ Less than half (4)
- ○ None (5)

Q8 Overall, what is your level of satisfaction toward the current offer in Portuguese online jewelry market?

- ○ Extremely satisfied (1)
- ○ Moderately satisfied (2)
- ○ Slightly satisfied (3)
- ○ Neither satisfied nor dissatisfied (4)
- ○ Slightly dissatisfied (5)
- ○ Moderately dissatisfied (6)
- ○ Extremely dissatisfied (7)

End of Block: For consumers who have purchased jewelry online before

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Start of Block: Jewelry buying habits - Part 2

Q9 What are, in your opinion, the main advantages of purchasing jewelry online, compared to in a store? (Multiple answers allowed)

- ○ Better prices (1)
- ○ Time saving (2)
- ○ Convenience (3)
- ○ Higher product variety (4)
- ○ Easier price comparisons (5)
- ○ More control (6)
- ○ I see no advantages (7)
- ○ Other(s) (8) _____

Q10 And what are, in your opinion, the main disadvantages of purchasing jewelry online, compared to in a store? (Multiple answers allowed)

- ○ Shipping Problems and Delays (1)
- ○ Less customer interaction (2)
- ○ Returns Can Be Complicated (3)
- ○ Problem with the "product's correct size" (4)
- ○ Risk of fraud (5)
- ○ I see no disadvantages (6)
- ○ Other(s) (7) _____

Q11 Overall, do you prefer to buy jewelry online or in-store?

- ○ Online (1)
- ○ In-store (2)
- ○ I have no preference (3)

End of Block: Jewelry buying habits - Part 2

Start of Block: Introduction to 3D-printed jewelry

At this point I want to introduce you to the concept of 3D-printed jewelry:

As the name suggests it is the result of the application of 3D printing technology, which you probably have already heard about, to the production of jewelries.

In order to give you a better understanding of this process, I ask you to view the video below. It takes around a minute and a half and it is very interesting

Additionally, there are two pictures of 3D-printed jewelry pieces, to give you an idea of their final looks.

End of Block: Introduction to 3D-printed jewelry

Start of Block: 3D-printed jewelry - Previous knowledge

Q12 Did you know about 3D-printed jewelry?

- ○ Yes (1)
- ○ No (2)

Skip To: Q14 if: Q12 = "Yes"

End of Block: 3D-printed jewelry - previous knowledge

Start of Block: 3D-printed jewelry - first impression

Q13 How would you evaluate your first impression of this product?

- ○ Very positive (1)
- ○ Positive (2)
- ○ Neutral (3)
- ○ Negative (4)
- ○ Very negative (5)

End of Block: 3D-printed jewelry - first impression

Start of Block: 3D-printed jewelry - previous purchase behavior

Q14 Which of the following situations do you identify more with?

- ○ I have already purchased 3D-printed jewelry before (1)
- ○ I have never purchased 3D-printed jewelry before, but I would like do it in the future (2)
- ○ I have never purchased 3D-printed jewelry before, and I am not interested in doing it in the future (3)

Skip To: Q18 if: Q14 = "I have already purchased 3D-printed jewelry before""

Skip To: Q17 if: Q14 = "I have never purchased 3D-printed jewelry before, but I would like do it in the future""

End of Block: 3D-printed jewelry - previous purchase behavior

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Start of Block: Non-consumers who would not like to purchase 3D-printed jewelry in the future

Q15 What is the main reason why you have never purchased 3D-printed jewelry before?

- ○ I was not aware of its existence (1)
- ○ I prefered to purchase other types of jewelry (2)
- ○ I don't like 3d-printed jewelry (3)
- ○ Other (4) _____

Q16 Why aren't you interested in purchasing it in the future? (Multiple answers allowed)

- ○ I don't like 3D-printed products in general (1)
- ○ I prefer to purchase other types of jewelry (2)
- ○ I specifically don't like 3D-printed jewelry (3)
- ○ Other (4) _____

Skip To: Q22

End of Block: Non-consumers who would not like to purchase 3D-printed jewelry in the future

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Start of Block: Non-consumers who would like to purchase 3D-printed jewelry in the future

Q17 What is the main reason why you have never purchased 3D-printed jewelry before?

- ○ I was not aware of its existence (1)
- ○ I preferred to purchase other types of jewelry (2)
- ○ I don't like 3D-printed jewelry (3)
- ○ Other (4) _____

End of Block: Non-consumers who would like to purchase 3D-printed jewelry in the future

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Start of Block: 3D-printed jewelry - Perceived advantages and disadvantages

Q18 What do you think are the main advantages of 3D-printed jewelry when compared to traditional (handmade ones) ones? (Multiple answers allowed)

- ○ Price (1)
- ○ Level of customization (2)
- ○ Allowing more complex designs (not possible with traditional methods) (3)
- ○ Faster production (5)
- ○ Detailed precision (6)
- ○ Other (7) _____
- ○ I see no advantages (8)

Q19 What do you think are the main disadvantages of 3D-printed jewelry when compared to traditional (handmade ones) ones? (Multiple answers allowed)

- ○ I see no disadvantages (6)
- ○ Lower amount of handmade work (7)
- ○ Materials' quality (8)
- ○ Durability (9)
- ○ Other (10) _____

End of Block: 3D-printed jewelry - Perceived advantages and disadvantages

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Start of Block: 3D-printed jewelry - Consumer behavior

Q20 Please rate the following statements according to your opinion on a scale ranging from 1 (strongly disagree) to 5 (strongly agree). In case you have never used or purchased 3D-printed jewelry please rate according to your general perception/ expectation.

	Strongly disagree (1)	Somewhat disagree (2)	Neither agree nor disagree (3)	Somewhat agree (4)	Strongly agree (5)
Technology gives me more control over your daily live. (1)	○	○	○	○	○
I find new technologies to be mentally stimulating. (2)	○	○	○	○	○
The designs of the 3D-printed jewelry are aesthetically appealing to me. (3)	○	○	○	○	○
The overall style of 3D-printed apparel is appealing to me. (4)	○	○	○	○	○
This product would match well with other pieces of jewelry I own. (5)	○	○	○	○	○
Wearing this product would be appropriate for my fashion style (6)	○	○	○	○	○
Please select "strongly disagree" (7)	○	○	○	○	○
I find 3D-printed jewelry to be a highly customized product (8)	○	○	○	○	○
Overall, I prefer to buy customized products rather than standardized ones. (9)	○	○	○	○	○
The use of 3D-printed jewelry is clear and understandable. (10)	○	○	○	○	○
Overall, I find 3D-printed apparel easy to use. (11)	○	○	○	○	○
Overall, 3D-printed jewelry addresses my needs (12)	○	○	○	○	○
Overall, I would find 3D-printed jewelry to be useful in my life. (13)	○	○	○	○	○

Please select " Strongly agree" (14)	○	○	○	○	○
I intend to use 3D-printed jewelry regardless of the price (15)	○	○	○	○	○
I intend to use 3D-printed jewelry if it is cheap (16)	○	○	○	○	○
3D-printed jewelry seems like an interesting product (17)	○	○	○	○	○
Overall, I have a favorable reaction to 3D-printed jewelry (18)	○	○	○	○	○
I intend to try the 3D-printed jewelry (19)	○	○	○	○	○
Assuming I have access to 3D-printed jewelry, I intend to use it (20)	○	○	○	○	○

End of Block: 3D-printed jewelry - Consumer behavior

Start of Block: Willingness to pay

Q21 What price would you be willing to pay for a 3D-printed jewelry piece, compared to a “traditional” one?

- ○ A higher price for the 3D-printed jewelry (1)
- ○ The same price as the "traditional" one (2)
- ○ A lower price for the 3D-printed jewelry (3)

End of Block: Willingness to pay

Start of Block: Demographic Data

Q22 What is your gender?

- Male (1)
- Female (2)
- Non-binary / third gender (3)
- Prefer not to say (4)

Q23 How old are you?

- Less than 18 (1)
- 18 - 24 (2)
- 25 - 34 (3)
- 35 - 44 (4)
- 45 - 54 (5)
- 55 - 64 (6)
- 65 or older (7)

Q24 Which is the highest level of education you have completed?

- Less than high school (1)
- Highschool (2)
- Professional degree (3)
- Bachelor's degree (4)
- Masters' degree (5)
- Doctoral degree (6)

Q25 What is your current occupation?

- Student (1)
- Student-worker (2)
- Employed (3)

- ○ Unemployed (4)
- ○ Retired (5)
- ○ Disabled (6)

Q26 What is your gross monthly income/allowance?

- ○ Less than 500€ (1)
- ○ 500€ - 999€ (2)
- ○ 1000€ - 1499€ (3)
- ○ 1500€ - 2499€ (4)
- ○ More than 2500€ (5)

End of Block: Demographic Data

Appendix 3 – SPSS Descriptive statistics outputs

		Frequency	Percentage
Gender	Male	51	44,35%
	Female	64	55,65%
Age	Less than 18	10	8,70%
	18 – 24	48	41,74%
	25 – 34	25	21,74%
	35 – 44	19	16,52%
	45 – 54	11	9,56%
	55 – 64	2	1,74%
	65 or older	0	0%
Education	Less than high school	8	6,96%
	High school	48	41,74%
	Professional degree	12	10,43%
	Bachelor's degree	36	31,3%
	Masters' degree	10	8,7%
	Doctoral degree	1	0,87%
Occupation	Student	44	38,26%
	Student-worker	9	7,83%
	Employed	57	49,56%
	Unemployed	4	3,48%
	Retired	1	0,87%
	Disabled	0	0%
Gross Monthly Income	Less than 500€	41	35,65%
	500€ - 999€	22	19,13%
	1000€ - 1499€	35	30,44%
	1500€ - 2499€	11	9,56%
	More than 2500€	6	5,22%
	Total respondents	115	100%

Table 7: Sample characterization (N = 115)

Answer	Frequency	Percentage
2 or more times per month	5	4,35%
Once a month	6	5,22%
3 to 11 times per year	14	12,17%
3 to 6 times per year	24	20,87%
2 or less times per year	45	39,13%
Never	21	18,26%
Total	115	100%

Table 8: Descriptive statistics for jewelry purchase frequency

Answer	Frequency	Percentage
Earrings	60	25,86%
Necklaces	56	24,14%
Rings	55	23,71%
Bracelets	42	18,10%
Cufflinks	4	1,72%
Other	15	6,47%
Total	232	100%

Table 9: Descriptive statistics for purchased jewelry type

Answer	Frequency	Percentage (%)
Yes	53	46,09%
No	62	53,91%
Total	115	100%

Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	2	1,54	0,50	0,25	115

Table 10: Descriptive statistic for previous online jewelry purchase behavior

Answer	Frequency	Percentage
It just never happened	32	51,61%
I prefer to buy jewelry in a physical store	20	32,26%
I don't trust online shopping	5	8,06%
I don't know how to purchase jewelry online	1	1,61%
Other	4	6,45%
Total	62	100%

Table 11: Descriptive statistic on the reasons for never having purchased jewelry online

Answer	Frequency	Percentage
Yes	22	35,48%
No	40	64,52%
Total	62	100%

Table 12: Descriptive statistic on non-consumers' interest in purchasing jewelry online

Answer	Frequency	Percentage
Online	26	34,67%
In-store	38	50,67%
I have no preference	11	14,67%
Total	75	100%

Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	3	1,80	0,67	0,45	75

Table 13: Descriptive statistic on respondents' market preference

Answer	Frequency	Percentage
Yes	28	37,33%
No	47	62,67%
Total	75	100%

Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	3	1,80	0,67	0,45	75

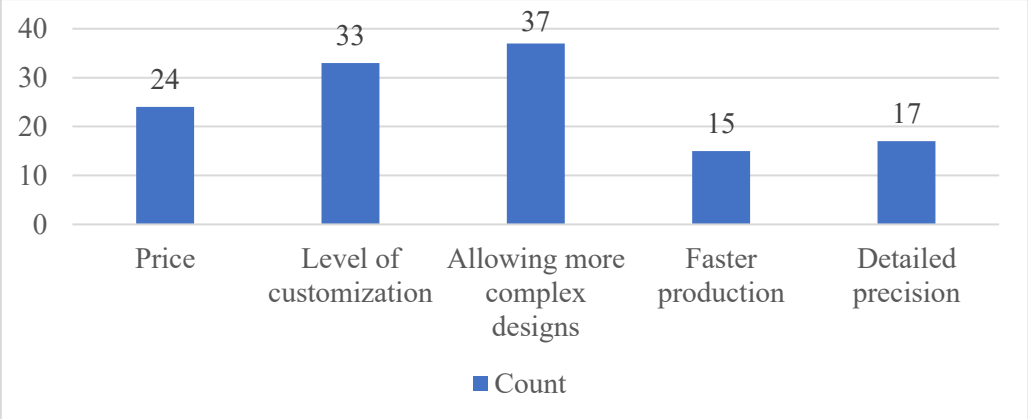
Table 14: Descriptive statistic on respondents' awareness of 3D-printed jewelry

Answer	Frequency	Percentage
I was not aware of its existence	45	72,58%
I preferred to purchase other types of jewelry	10	16,13%
I don't like 3d-printed jewelry	4	6,45%
Other	3	4,84%
Total	62	100%

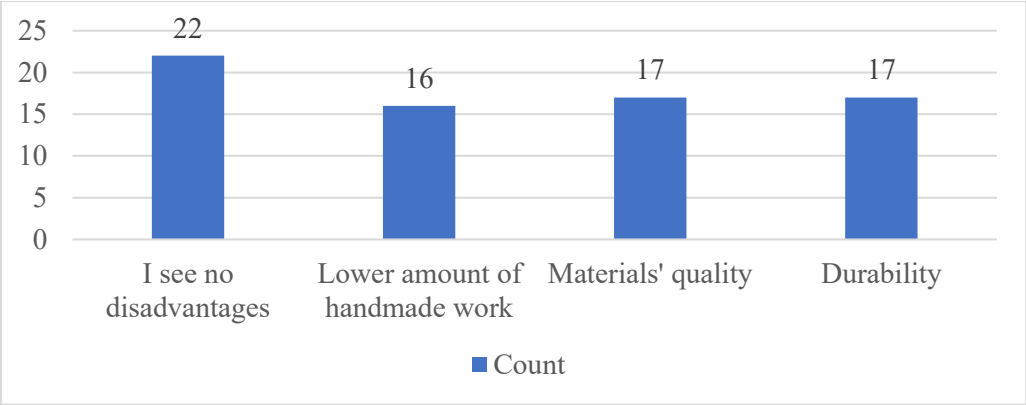
Table 15: Descriptive statistic on respondents' key reasons for not having purchased 3D-printed jewelry before

Answer	Frequency	Percentage
I don't like 3D-printed products in general	4	14,81%
I prefer to purchase other types of jewelry	16	59,26%
I specifically don't like 3D-printed jewelry	7	25,93%
Other	0	0%
Total	27	100%

Table 16: Descriptive statistic on non-consumers' reasons for not being interested in purchasing 3D-printed jewelry in the future



Graphic 6: Respondents' perceived main advantages of 3D-printed jewelry compared to traditional one



Graphic 7: Respondents' perceived main disadvantages of 3D-printed jewelry compared to traditional one

Answer	Frequency	Percentage
A higher price for the 3D-printed jewelry	14	26,42%
The same price as the "traditional" one	16	30,19%
A lower price for the 3D-printed jewelry	23	43,40%
Total	53	100%

Table 17: Descriptive statistic on respondents' willingness to pay for 3D-printed jewelry

	3D-printed jewelry Consumers		3D-printed jewelry Non-consumers	
Answer	**Frequency**	**Percentage**	**Frequency**	**Percentage**
A higher price for the 3D-printed jewelry	10	76,92%	4	10%
The same price as the "traditional" one	1	7,69%	15	37,50%
A lower price for the 3D-printed jewelry	2	15,39%	21	52,5%
Total	13	100%	40	100%

Table 18: Descriptive statistic on respondents' willingness to pay for 3D-printed jewelry according to their previous purchase behavior

Variable	Item name	Cronbach's alpha	Item-total correlation	Loading	Composite Reliability	Average variance extracted	*M*	SD
Tech Optimism	TOpt1	0,792	0,763	0,704	0,718	0,561	4,406	0,605
	TOpt2		0,539	0,792				
Aesthetics	Aes1	0,795	0,447	0,816	0,835	0,718	3,972	0,660
	Aes2		0,412	0,877				
Perceived Compatibility	PC1	0,796	0,492	0,768	0,748	0,597	3,868	0,821
	PC2		0,537	0,777				
Perceived Customization Level	PCL1	0,799	0,309	0,917	0,868	0,768	4,17	0,657
	PCL2		0,458	0,834				
Perceived Ease of Use	PEU1	0,727	0,469	0,593	0,706	0,554	4,208	0,737
	PEU2		0,528	0,870				
Perceived Usefulness	PU1	0,793	0,518	0,714	0,726	0,571	3,755	0,847
	PU2		0,381	0,795				
Perceived Cost	Cost1	0,643	0,237	0,872	0,808	0,679	4,104	0,549
	Cost2		0,346	0,773				
Attitude Toward Using	ATU1	0,713	0,566	0,707	0,796	0,664	4,387	0,543
	ATU2		0,254	0,911				
Behavioral Usage Intention	BUI1	0,673	0,262	0,871	0,823	0,7	4,321	0,666
	BUI2		0,378	0,801				

Table 19: Internal reliability and convergent validity
Source: Adapted from Perry (2016)

	TOpt	Aes	PC	PCL	PEU	PU	Cost	ATU	BUI
TOpt	0,749								
Aes	0,510	0,847							
PC	0,429	0,622	0,777						
PCL	0,331	0,554	0,559	0,876					
PEU	0,390	0,565	0,412	0,452	0,744				
PU	0,301	0,589	0,747	0,672	0,361	0,756			
Cost	0,218	0,565	0,404	0,363	0,445	0,314	0,824		
ATU	0,494	0,527	0,548	0,392	0,553	0,357	0,508	0,815	
BUI	0,506	0,557	0,651	0,510	0,489	0,560	0,394	0,515	0,837

Table 20: Fornell-Larcker Criterion

Hypotheses		r_s	p-value	Results
H_1	ATU → BUI	0,521**	< 0,001	Supported
H_2	PU → ATU	0,382**	0,005	Supported
H_3	PU → BUI	0,572**	< 0,001	Supported
H_4	PEU → ATU	0,480**	< 0,001	Supported
H_5	PEU → PU	0,360**	0,008	Supported
H_6	TOpt → ATU	0,591**	< 0,001	Supported
H_7	TOpt → PEU	0,416**	0,002	Supported
H_8	Aes → PU	0,581**	< 0,001	Supported
H_9	Aes → ATU	0,536**	< 0,001	Supported
H_{10}	Aes → BUI	0,578**	< 0,001	Supported
H_{11}	PC → ATU	0,584**	< 0,001	Supported
H_{12}	PC → BUI	0,624**	< 0,001	Supported
H_{13}	Cost → ATU	0,476**	< 0,001	Supported
H_{14}	Cost → BUI	0,348*	0,011	Supported
H_{17}	PCL → ATU	0,416**	< 0,001	Supported
H_{18}	PCL → BUI	0,538**	< 0,001	Supported

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 21: Hypotheses results
Source: Adapted from Perry (2017a)

Appendix 4 - Literature references for the online questionnaire - Q20

Variable	Adapted from:
Tech Optimism	
TO1: Technology gives me more control over my daily live.	Parasuraman, 2000
TO3: I find new technologies to be mentally stimulating.	Parasuraman, 2000
Aesthetics	
Aes1: The designs of the 3D-printed jewelry are aesthetically appealing to me.	Hwang, 2014
Aes2: The overall style of 3D-printed apparel is appealing to me.	Hwang, 2014
Perceived Compatibility	
PC1: This product would match well with other pieces of jewelry I own.	Moore and Benbasat, 1991
PC2: Wearing this product would be appropriate for my fashion style	Moore and Benbasat, 1991
Perceived Customization Level	
PCL1: I find 3D-printed jewelry to be a highly customized product	Komiak & Benbasat, 2006
PCL2: Overall, I prefer to buy customized products rather than standardized ones.	Komiak & Benbasat, 2006
Perceived Ease of Use	
PEU1: The use of 3D-printed jewelry is clear and understandable.	Davis et al., 1989
PEU2: Overall, I find 3D-printed apparel easy to use.	Davis et al., 1989
Perceived Usefulness	
PU1: Overall, 3D-printed jewelry addresses my needs	Davis et al., 1989
PU2: Overall, I would find 3D-printed jewelry to be useful in my life.	Sun et al., 2013
Perceived Cost	
Cost1: I intend to use 3D-printed jewelry regardless of the price (*)	Garg & Garg, 2013
Cost2: I intend to use 3D-printed jewelry if it is cheap	Garg & Garg, 2013
Attitude Towards Using	
ATU1: 3D-printed jewelry seems like an interesting product	Mackenzie et al., 1986
ATU2: Overall, I have a favorable reaction to 3D-printed jewelry	Mackenzie et al., 1986
Behavioral Usage Intention	
BUI1: I intend to try the 3D-printed jewelry	Venkatesh et al., 2003
BUI2: Assuming I have access to 3D-printed jewelry, I intend to use it	Perry, 2017a

* This scale results were reversed upon the analysis

Table 22: Literature references for the online questionnaire Q20's scales

Source: Adapted from Dzimiera (2017)