Enhancing Augmented Reality with Audio: When and why it boosts online purchase intention

Forough Sharifihosseini

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Goodman School of Business, Brock University
St. Catharines, Ontario

Abstract

Augmented reality (AR) can be considered an appealing tool for product evaluation in an online shopping context where the product is unavailable. Although this technology provides a tangible environment for product evaluation, it is mainly based on the visual aspect of product presentation. Vision is a dominant sense, and humans mostly rely on sight to comprehend an event. Nevertheless, it is only from a combination of senses that one can gain an extensive understanding of it. Auditory sensory is the second crucial human sense. The literature documenting AR's impact on customers' decision-making and behavioural intentions has overlooked the role of audio in this environment. This study investigates the role of audio through product sounds in an AR experience, and by using active inference theory, it demonstrates how enhancing AR environments with sound can influence behavioural intentions in customers. Moreover, it presents two important auditory factors (i.e., sound pleasantness and sound controllability), each of which can have impactful roles in different online shopping steps. Using data obtained from the Zappar AR platform, this research examines two products with their related sounds to demonstrate the performance of multisensory AR experience on behavioural intentions of customers who use AR apps for shopping online. The results indicate that enhancing AR with sound has both direct and indirect influence on behavioural intentions of the customers, through customer engagement and decision comfort. Additionally, we show the moderating role of sound controllability on the relationship between audio-enhanced AR and customer engagement.

Keywords: Augmented Reality, Auditory Sensory, Behavioural Intentions, AR audio-enhancement, Multisensory AR environment, Sound Pleasantness, Sound Controllability

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1. Introduction

Technological advances in computer science are often used to improve performance in other industries, and their intelligent use can make a superior difference between rivals. Extended realities are one such type of advances, which refers to environments in that real and virtual components are mixed in different levels. Virtual reality and augmented reality have become more famous, as they have been industrialized in different domains such as the gaming industry and e-commerce. Augmented reality (AR) is distinguishable above all, as we still have our physical world as our surroundings, enhanced through super-imposed digital content. As Rauschnabel et al. (2017) indicate, we are moving toward a future where individuals will operate in an enhanced reality, in that the physical environment is enriched with computer-generated content. In this era, the marketplace also needs to keep pace with the technological improvements and stay appealing in customers' eyes. Therefore, there is a need for adaptation and implementation of such technology on behalf of industries. One such industry is e-commerce, in which AR works as an appealing tool for evaluating products prior to purchase.

Many brands and retailers are now trying to take advantage of AR technology in their online services. E-commerce apps featuring augmented reality are primarily famous in domains like home furnishing, fashion, and beauty. In furnishing apps, virtual holograms of home appliances are projected in the customers' environment, and leading brands like IKEA and Home Depot have gained much attention with their AR apps. Virtual try-on apps are recognized in the fashion industry, ranging from trying shoes and dresses to eyeglasses and watches, with brands like Lacoste, Topshop, and Timberland. Furthermore, the beauty industry has offered virtual makeup try-on, and well-known brands like L'Oréal and Sephora help customers try different makeup items before shopping through their AR apps. These apps enhance the shopping experience by allowing customers to virtually evaluate products in their physical environment or try them on and gain a better perception of the products. In other words, through AR-based retail apps, customers can gain better sensory feedback from a product through observing its digital hologram and gaining control over it by customizing (e.g., changing the colour of a dress while virtually trying it) or reforming it (e.g., resizing or rotating the hologram of furniture).

As Heller et al. (2019b) discussed, customers' experiences are shaped upon sensory inputs from various resources. To make a purchasing decision in a physical shopping situation, customers try to shape a mental representation of the product by acquiring sensory information. For instance, they try to hold it, look at it through different angles, touch it, if applicable, listen to its sound, etc. In online shopping environments, nevertheless, one has a limited chance to exploit the above means of sensory inputs, even though AR has already bridged this gap to a considerable extent. For example, one of the sensory modalities that consumers almost lack in AR environment is sound, in the sense that it is either totally absent or, in most cases, its quality, controllability, and informativeness is overlooked. For instance, the AR feature on the Home Depot shopping app does not include any sound in its AR environment for the products who have sound. On the other hand, IKEA's shopping app does include sound for some products in its AR feature. However, the feature is so limited and is not offered for a variety of different products. This is not limited to the shopping apps, and it goes beyond that, including most existing AR apps. The Google's AR feature can be named as an example, which shows AR holograms of animals in their realistic sizes. This feature includes a mixture of environmental sound and the animal's sound; however, users do not have any control over the sound. Surprisingly, to the best of our knowledge, there is even a research void investigating sound and its attributes in AR environments, mostly in the retail-related studies, where sound becomes an important characteristic of the products (Ho et al., 2013; Petit et al., 2019; Heller et al., 2019a; Lavoye & Tarkainen, 2021).

Despite the importance of sound in the process of decision-making, the marketing and e-commerce literature about augmented reality has focused primarily on the visual aspects of such technology compared to other sensory modalities (e.g., Javornik et al., 2021; Yim et al., 2017; Hilken et al., 2017). However, researchers have emphasized the importance of sensory modalities other than vision in the AR environment. For example, Lavoye and Tarkainen (2021) indicate that although AR sensory marketing is primarily visual, other senses (e.g., sound) can have a great impact on the acquisition of cognitive information and influence consumer behavior. Moreover, Heller et al. (2019a) state that sensory modalities other than visual may be offloaded on AR devices and address further research in this regard. Hence, despite the call for further study on multisensory AR, the literature in this domain is sparse and requires more research (Ho et al., 2013; Petit et al., 2019; Lavoye & Tarkainen, 2021).

There are a few exceptions (Gatter et al., 2021; Barhorst et al., 2021; Heller et al., 2019b; Ho et al., 2013; Huang & Liao, 2017; Huang and Tseng, 2015) who have focused on multisensory AR in the context of marketing and retailing. For instance, the study by Heller et al. (2019b) is one of the leading multisensory studies that investigates the influence of sensory control modality (touch vs. voice) on customers' willingness to pay. Another study focused on multisensory AR is by Ho et al. (2013) who have investigated enhancing the virtual experience of trying on new clothing while hearing its congruent auditory feedback. They demonstrated that online shoppers spent significantly longer time using the system and were willing to pay more for the products in the presence of sound during the virtual trying of a winter clothing item, compared to the silent situation. This research, however, does not offer any conceptual model to explain the underlying effects of such results or any boundary condition. Furthermore, few studies have integrated audio and visual senses in AR experience (e.g., Barhorst et al., 2021) to induce a more realistic and engaging atmosphere. Therefore, although there has been growing attention in scholarly research on augmented reality in the past few years, we still have limited understanding regarding the multisensory effects of AR in the marketing domain.

To gain a comprehensive understanding of multisensory AR, it is necessary to investigate inclusion of each of the senses individually. Hence, this study exclusively looks into enhancing AR experience with sounds. We try to investigate enhancing AR with audio and its influence on online shoppers who interact with AR apps during their shopping. Various studies have focused on the effects of audio-visual interaction on individuals' attention, perception, and intentions in the marketing literature. In line with these studies, the current research aims to investigate the influence of enhancing AR shopping apps with sounds on customers' behavioural intentions. Precisely, the main goal is to see whether the integration of AR hologram of products with audio (i.e., product sounds) during the product evaluation increases the customer's behavioural intentions (i.e., their intention to buy the product, to use the AR app again, and to suggest the AR experience to their family and friends). Moreover, we investigate the role of two sound features (i.e., sound pleasantness and sound controllability) and how they may affect the main relationship.

This research takes advantage of active inference theory (Heller et al. 2019b, Friston, 2018) to investigate its primary effect. According to this theory, customers rely on sensory control and feedback loops while evaluating a product to decide upon a choice. This loop happens during every pre-purchase product evaluation in a physical shop, in that individuals gain control over the product (e.g., handling, moving, and rotating the object), receive sensory feedback from it (e.g., gaining information about its size, material, and functionalities), and update their mental representation about the product. This loop repeats until the customer feels that he/she knows enough about the product to make a decision. In an online shopping condition, AR tries to facilitate this loop for the customer by improving sensory control and feedback. However, this loop will not be complete, unless a combination of sensory modalities is used to gain sensory control and feedback, one of which is audition.

The present study contributes to the augment reality literature as well as the marketing and e-commerce literature. First, this research addresses the importance of multisensory experience in e-commerce and its influence on customers' buying intentions. The human brain is a multi-dimensional body organ, which operates through receiving multiple sensory cues from the environment. In other words, at every moment, the brain receives and analyzes a combination of multiple senses to create a robust perception of the human's surroundings (Chandrasekaran, 2017). This brain functionality indicates the way with which individuals behave to gain a good understanding of their surroundings. It is important to note that the brain does not analyze senses individually but rather as an integrated entity (Schifferstein & Spence, 2008). Additionally, as Friston (2018) indicates, everything we do as human beings, is in line with minimizing surprise and maximizing evidence to infer the hidden states of the world and understand our surrounding (i.e., referring to active inference). Shopping is one of these situations, whereby individuals need to make use of their multiple senses to minimize their uncertainty and ambiguity in their decision and maximize their understating of the product through gaining evidence. Previous literature (e.g., Mishra et al., 2020, Gatter et al., 2022, Huang & Liao, 2017) have pointed out the importance of touch sense in the context of augmented reality. In our research, following Ho et al. (2013), we also point out the importance of auditory sensory and show why adding sound to AR shopping experience is necessary and can lead to higher behavioural intentions in customers to buy the product, use the shopping app again, and to introduce the AR experience to others.

Second, this research demonstrates the underlying mechanism of how sounds enhance customers' AR experience of online product evaluation. We show that AR audio-enhancement brings a higher level of customer engagement in the shopping experience and strengthens the sense of comfort in decision-making by enriching affective and informative aspects of the online shopping procedure. Differently said, sound of products contains details about the product, which is worth considering while viewing the item for purchase (Spence and Zampini 2006), or it can convey or accentuate the features of a product (Petit et al., 2019, Zampini & Spence, 2004, Spence & Zampini, 2006).

Moreover, sounds also influence our moods and feelings, and adding product sounds to an AR environment can alter our mood during the shopping experience or our feeling toward the product. This is where pleasantness of the product sound becomes an important factor, which can significantly influence the shopping experience. Hence, our third contribution is regarding the sound pleasantness and the way with which it can influence the relation between enhancing AR with sound and behavioural intentions of the customers. our research shows the effect of sound pleasantness on the process of decision making and decision comfort, in that pleasant sounds induce a better feeling toward the product, and less pleasant sounds provide an uncomfortable experience.

Third, the current research calls attention to the ability to control the sound in an AR experience. In our research we propose and demonstrate that having sound controllability leads to higher customer engagement in the AR environment, as customer also try to modify the sound as well as the AR hologram. Additionally, we highlight that adding sound controllability in the AR app helps the immersive flow of the user, and also increases the app's usability through providing easy and rapid product evaluation.

The remainder of the current research proposal looks into the literature of augmented reality, its characteristics, and how it has affected the online retail industry. Then by looking into sound and audio-visual senses, it explains how audio-enhanced AR can influence online commerce.

2. Literature Review

2.1 Augmented Reality

Augmented reality can be defined as a technology, which enables displaying virtual (or computer-mediated) objects in the physical environment through digital devices such as smartphones, digital glasses, head mounted displays (HMD), or contact lenses (Poushneh, 2018). AR is one of the sub-categories of technology-mediated realities, also known as extended reality (XR) (Flavián et al., 2019). XR encompasses a wide variety of virtuality-reality concepts, including augmented reality, virtual reality, mixed reality, and augmented virtuality. Many researchers have tried to identify specific characteristics of these realities and demarcate them upon the degree to which they are integrated into the virtual world. One of the first efforts to put forth such taxonomy was by Milgram and Kishino (1994), who offered a virtuality continuum ranging from pure reality to a completely virtual environment (Figure 1) (Flavián et al., 2019; L. Turchet et al., 2021). In Milgram and Kishino's continuum, the concept of MR (i.e., mixed reality) refers to a reality where virtual and real elements are displayed together, in which it can be hard to delineate the boundaries between virtual and reality. Hence, this continuum expects augmented reality and augmented virtuality as part of mixed reality (Flavián et al., 2019).

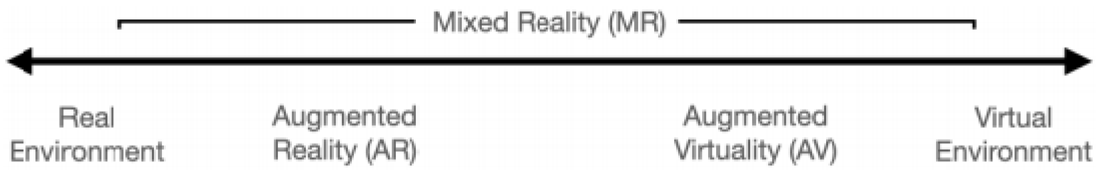

Figure 1: Reality-virtuality continuum 1 (Flavián et al., 2019)

Moreover, in another effort, Flavián et al. (2019) offered a more specific continuum, based on the previously discussed one, and argued that in the new continuum, mixed reality should be considered as an independent dimension, in that there is a "total blend of virtual holograms with the real world". The new dimension, also regarded as pure mixed reality (PMR), is a reality in which virtual contents are rendered in the real world in a way that is indistinguishable from the physical environment (Figure 2). Flavián et al. (2019) further discuss that reality and virtual environments are the two extremes in this continuum, and the other technology-mediated realities are distributed throughout this continuum according to the level of integrity between virtual and real worlds. In this research, our focus is mostly on augmented reality, which is a dimension between the real environment and PMR. In this dimension, virtuality overlaps reality, meaning that the digital contents are "superimposed on the users' real surroundings" (Flavián et al., 2019).

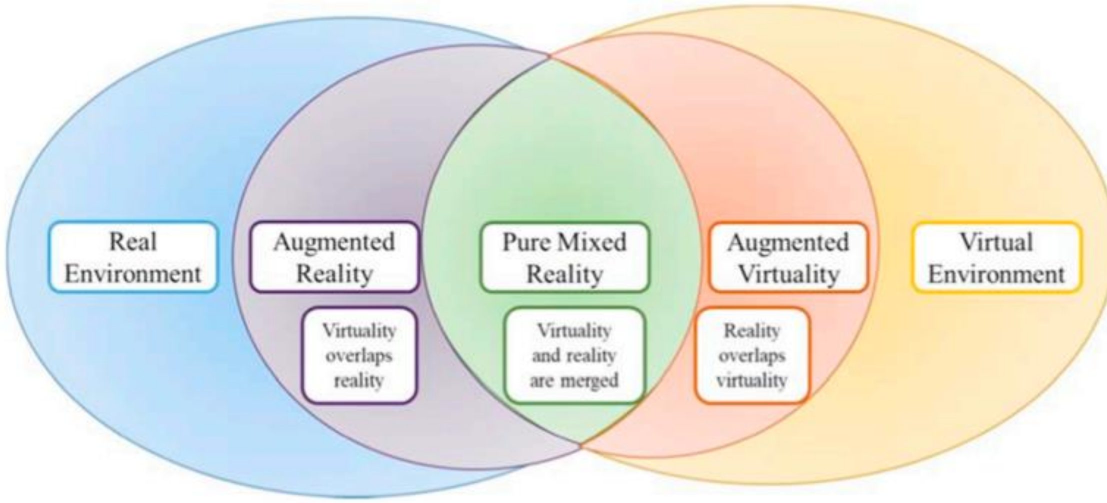

Figure 2: Reality-virtuality continuum 2 (Flavián et al., 2019)

Many marketing related studies in the context of augmented reality take advantage of mental imagery to explain the concept and advantages of such technology. For instance, Heller et al. (2019a) explain that when making decisions, individuals usually try to imagine using the product to anticipate different aspects of product usage before buying it. However, such mental imagination is vulnerable and can rapidly disappear. They further discuss that AR can digitally generate the mental image of customers while also helping them transform it and inspect it from different dimensions. Therefore, AR allows us to offload our imagery generation and transformation, meaning that it digitally visualizes our imagination of the products and transforms it to see its different aspects.

The literature on augmented reality provides two specific characteristics for such technology (Dacko, 2017). First, augmented reality combines real and virtual imagery, in that computer-generated information or objects are included in the physical environment. This characteristic is also referred to as the embedding aspect of AR (Heller et al., 2019a; Hilken et al., 2017). Second, it is interactive in real-time, meaning that it has simulated physical control (i.e., the ability to control, move, or rotate the virtual object) (Hilken et al., 2017; Dacko, 2017).

Similar to many other technological advances, augmented reality can highly influence industries and the way with which they offer value to their customers. In the next section, we further explain AR's potential in online retail section and how it works as a proper marketing tool for e-commerce industries.

2.2 Augmented Reality in Marketing and E-commerce

Augmented reality (AR) can be regarded as a relatively new technology, which has recently gained attention from marketing scholars and practitioners due to its benefits and applications in the marketing domain. Using this technology, individuals can now virtually try on dresses, shoes, and makeup products; they can redesign their rooms or recolor their walls; and they can even virtually visit a zoo or a stadium. Stubhub, an American ticket seller company, has developed a mobile AR app that allows ticket buyers to view the stadium in an AR format prior to purchasing a ticket. Other brands are also taking advantage of AR for their creative marketing strategies. For instance, using AMC app from AMC theatres, an American movie theatre chain, individuals can scan movie posters, receive relevant AR content about the movies, and if interested, buy a ticket.

This technology has also grown in many aspects of marketing literature, such as in retail (both online and offline setting) (e.g., Hilken et al., 2017; Yim et al., 2017), advertising (e.g., Yang et al., 2020; Sung, 2021) and brand management (e.g., Scholz & Duffy, 2018). Above all the marketing related topics, retail, and more specifically e-commerce, has mostly emphasized augmented reality and its usage, due to its ability to provide exceptional customer experience (e.g., Poushneh & Vasquez-Parraga, 2017) and assist through decision-making (Dacko 2016).

Many authors have emphasized the need for a better understanding of AR-supported decision-making, and the way such technology can affect customers' perception of products and behavioural intentions. For example, using the mental imagery theory, Heller et al. (2019a) explain how AR in retail can help customers to offload their mental imagination through AR generation and transformation. Moreover, they show how AR generation and transformation can imply a sense of ease in product processing and provide positive behavioural intentions. Most of the studies that investigate AR as a tool to improve decision-making have primarily focused on visual aspects of product presentation through AR. However, decision-making does not always depend on visual aspects of the products. In a physical situation, customers try to gain information through their other senses to make purchasing decisions.

2.3 Multisensory Experience in Augmented Reality

Humans have multisensory perceptions of events and objects, and the perception resulted from multiple senses creates better recognition, enhances learning, and improves detection and discrimination (Chandrasekaran, 2017). Despite the importance of multisensory experiences, online retailers have been mostly focusing on visual sensory interactions, mainly due to the lack of limited advances in technology.

Augmented reality is a technology that although has had a significant impact on the customers' experience in e-commerce, it is still mostly vision-based and does not resolve the need for multisensory experience. Scholar research in this domain has also mainly focused on AR's visual aspects and the way these aspects affect customers' intentions when buying online (table 1). Nonetheless, few studies have investigated multisensory augmented reality.

As the product is not present during an online shopping situation, customers try to imagine the product and the consumption experience. According to Schifferstein (2009), vivid mental images occur in all sensory modalities and the quality of mental images tend to be better for vision and audition than other senses. His study also show that the quality of visual and auditory images does not have a significant difference. These results show the importance of auditory sensory modality as well as visual senses, and indicate that in situations in which humans heavily depend on mental imagery for decision-making, having audio is as essential as offering visual presentations. Moreover, when combined with vision, audiovisual experiences can create the most realistic and influential experiences. Hence, this study tries to focus on audition as an important human sense and tries to demonstrate how combining AR environment with audio can create a multisensory experience for customers who try to shop online.

Table 1: Selected literature on Augmented Reality in Retail which have mostly focused on vision

Study	**Sample**	**Context**	**Theory**	**Independent variables**	**Boundary Condition**	**Outcome Variables**	**Involved senses**
Carrozzi et al. (2019)	Undergraduate students	Customizing and sharing AR	Socially situated cognition theory	Customization	–	Psychological Ownership	Vision
Javornik (2016)	University students and alumni	Media characteristics of AR apps and customer's response	Theory of Interactive Media Effects	Perceived augmentation	–	Affective responses, Cognitive responses, Behavioural responses	Vision
Hilken et al. (2019)	Young customers, Students, Mturk participants	Social augmented reality	Socially situated cognition theory	POV sharing (static vs. dynamic)	Recommender's impression management concerns, Recommender's persuasion goal	Recommendation Comfort, Desire for product, Usage and WOM Intentions (for the Recommender), Choice (for the Decision maker)	Vision

Hilken et al. (2017)	Undergraduate students	Potential of AR for online retail	Situated cognition theory	Simulated physical control, Environmental embedding	Style of information processing, privacy concerns	Value perceptions of online service experience, Decision comfort	Vision
Heller et al. (2019a)	Students, MTurk participants	functionality of AR in retail context	Mental imagery theory	AR Configuration AR Transformation	Processing type, Product contextuality	Behavioural intentions (WOM, Choice)	Vision
Bonnin (2020)	French individuals	Benefits of AR of online retailers	–	Presence/absence of AR	Familiarity with AR	Patronage intention	Vision
Poushneh & Vasquez-Parraga (2017)	Young consumers at a U.S. Southern Metropolitan City	Impact of AR on retail user experience	Equity theory	Augmented reality (AR)	Trade-off between price and value, User information privacy control	User willingness to buy, User satisfaction	Vision
Poushneh (2018)	Young adults in a metropolitan area of the American Southwest	Impact of AR on retail user experience	Equity theory	Augmented reality experience	Augmentation quality, User's control of access to personal information	User satisfaction	Vision
Park & Yoo (2020)	Female online consumers in South Korea	Influence of AR characteristics on mental imagery	Cognitive consistency theory, Theory of reasoned action	Perceived interactivity (Controllability, Playfulness, Responsiveness)	Product involvement	Attitude, Behavioural intentions	Vision
Jessen et al. (2020)	University students	The use of AR in the early stages of purchase journey	Regulatory mode theory	Use of AR	Assessment orientation	Anticipated satisfaction	Vision
Javornik et al. (2021)	Female university students	Augmented self	Theory of plasticity	AR mirror	Appearance self-esteem	Ideal-actual attractiveness gap, Variaty seeking	Vision
Smink et al. (2020)	Students recruited by an online student subject pool	Persuasiveness of AR apps	Reactance theory	AR app (vs non-AR app)	–	App responses, Brand responses	Vision

Kowalczuk et al. (2021)	Undergraduate students	Advantage of AR-based over web-based product presentations	Feelings-as-information theory	Interactivity, System quality, Product Informativeness, Reality congruence	–	Reuse intention, Purchase intention	Vision

Few studies have examined the effect of multisensory experiences in augmented reality (Table 2). For example, Ho et al. (2013) have investigated enhancing the virtual experience of trying on new clothing while hearing its congruent auditory feedback. In their research, they have found that online shoppers were willing to pay more for the product in the presence of sound during the virtual trying of a winter clothing item, compared to the silent situation (Petit et al., 2018). Moreover, Heller et al. (2019b) introduce multisensory AR (m-AR) as a great solution for customer's mental intangibility barrier, while making decisions in online shopping. According to them, m-AR enables sensory control for customers and generates sensory feedback through controlling holograms in the physical environment. They show that offering touch controls for holographic products is much more effective than voice controls in increasing customers' willingness to pay, as it provides a simulation of touching experience in a physical situation. In addition, they demonstrated that providing auditory feedback in the AR experience positively influences the effect of touch control on decision comfort. Another research by Huang and Liao (2017) examines factors that create a multisensory flow experience in the online shopping context while using AR tools. Few studies have also integrated audio and visual senses in AR experience (e.g., Barhorst et al., 2021) to induce a more realistic and engaging atmosphere.

Offering multisensory experiences, mostly through combining audio and visual senses, can have several positive consequences. For example, adding sounds to games can increase the feeling of presence in the player in a virtual world. It can further bring engagement with the game and players while also intensifying their feelings. Similar to video games, sound can have a substantial influence on augmented reality. Studies in computer science have investigated such a combination of sensory modalities in humans while interacting with computer-mediated realities. However, this has been overlooked in marketing literature and there is a gap of research in how sound can change augmented reality usage in online retail settings.

The current study aims to investigate the influence of sound in an AR experience. More specifically, it explores how enhancing AR services in retail apps with the sound of objects (i.e., product sounds) can influence customers' experiences and decision-making. AR audio-enhancement may have impressive influences on shoppers' experience on retail apps, which can lead to higher levels of intention to buy. Therefore, in the next section of the literature review, sound as a sensory factor in marketing study will be explored.

Table 2: Literature on multisensory Augmented Reality

Study	**Theory**	**Independent variables**	**Outcome Variables**	**Involved senses**	**Key Findings**
Heller et al. (2019b)	Active inference theory	Sensory control modalities (touch vs voice)	Willingness to pay	Vision, Audition, Touch	Touch control (vs voice control) increases customers' willingness to pay through the partial mediating effect of mental intangibility and decision comfort.
Ho et al. (2013)	_	Adding auditory feedback to virtual try-ons	Willingness to pay	Vision, Audition	Enhancing virtual try-ons with realistic clothing sounds can create an immersive experience for the customers, and they were willing to pay more for clothes experienced with auditory feedback.
Javornik (2016)	_	_	_	Vision, Audition	A review and research agenda for unexplored research areas in AR and consumer responses this technology can potentially have.
Mishra et al., (2020)	Vividness theory	Technological interfaces (AR/VR/mobile apps)	Ease of use, Responsiveness, WOM, Visual and emotional appeal, Purchase intentions	Vision, Touch	These is a more customer engagement when customers use haptic interfaces, and it positively affects their purchase intentions.
Barhorst et al. (2021)	Flow theory	Interactivity, Vividness, Novelty	Satisfaction with AR experience	Vision, Audition	AR characteristics (vividness, interactivity, and novelty) can significantly create an immersive state of flow, resulting in a more engrossing experience.

Gatter et al. (2022)	Uses and gratification theory (UGT)	AR feature in shopping app	(a) app evaluation, (b) brand attitude, (c) product attitude, and (d) purchase intention	Vision, Touch	AR satisfies customers' need for touch and it provides a particular benefit for customers who have higher need for touch, because the ones with higher need for touch have stronger imagery.
Huang and Tseng (2015)	Self-referencing theory	Sense of ownership, Vivid memories	Concentration, exploratory behavior, playfulness, and time distortion	Vision, Touch	In an AR context, consumers' sense of ownership control and autotelic need for touch has a significant influence on the relation between vivid memories and the four types of exploratory consumption behavior
Huang & Liao (2017)	Virtual liminoid theory, Flow theory	Perceived sense of self-location, Haptic imagery	Consumer willingness to invest more time using ARIT, Satisfaction derived from using ARIT	Vision, Touch	Haptic imagery and sense of self-location have positive influence on perceived sense of body ownership, perceived ownership control, and self-explorative engagement.

2.4 Sound

Sounds play an essential role in our lives. Some sounds increase our attention to an urgent matter (e.g., ambulance siren), some distract us (e.g., surrounding noises), some attract us (e.g., attractive voice of a person), and others may provoke us to do some types of activities (e.g., hearing a sound of water increases the willingness for drinking water) (Fraedrich & King, 1998). Fraedrich and King (1998) define sound as a tone resulting from vibrations of an elastic metal and further explain that the sound waves corresponding to such vibrations cause human eardrum vibration, resulting in a tone to be heard.

Sounds surround us. They are a ubiquitous element in our lives and can positively and negatively affect our lives (Alegre, 2017). For example, noises are unwanted and unpleasant sounds, which according to Dalton and Behm (2007), can negatively affect an individual's health and performance. For example, people who live in polluted urban areas report poor sleep quality, and their performance the following day is also negatively affected (Dalton & Behm, 2007). On the other hand, pleasant sounds (e.g., musical sounds) can positively affect us psychologically and physiologically. For instance, music literature has shown that background music positively influences performance, and such influence is due to an increase in motivation, arousal, and energy (Dalton & Behm, 2007). Moreover, pleasant sounds, more specifically music, can affect our mood (Alpert & Alpert, 1990; Bruner, 1990). For example, previous studies have shown that fast music induces happiness and slow tempo music evokes sentimental and tranquil moods (Bruner, 1990). Also, studies have found that high-pitch music is associated with excitement and happiness, whereas low-pitch music is perceived as sad.

Many industries use music and sound in order to attract individuals. One such industry is cinema, in that music and sound are used to induce certain emotions. Sounds can induce fear in horror movies so that the movie becomes much more realistic and terrifying in the eyes of the viewers. They can induce worries, happiness, sadness, and even doubt. As UKEssays (2018) indicate, sound enhances the quality of the movie. It is the sound in movies that creates suspension and makes the audience thrilled about what happens next. Hence, filmmakers use sounds to induce and intensify emotions and make the movie more realistic by engaging the auditory and visual senses of individuals.

Another industry that uses sound and music is the gaming industry. Music causes thrill in the gaming industry. Moreover, some games can be regarded as augmented virtuality, in that players have individual characters in the world of the game and tend to do specific actions with that character. In such worlds, sounds such as auxiliary and environmental sounds make the game world much more realistic by engaging auditory and visual senses in players. Engagement of these senses also brings attention to the player to stay more focused and feel thrilled for a longer time.

2.4.1 Sound as a Marketing Component

Due to the influence of sound and music on humans, marketers have tried to use it as a means for triggering moods and behaviors of customers both in the retail setting and advertisements on television and radio (Bruner, 1990). For example, various studies have illustrated the influence of different types of sounds and music on customers' choice and purchase intention. Wilson (2003) investigated the influence of musical styles on purchase intentions in a restaurant and found that individuals exposed to classical, jazz, and popular music were willing to spend the most on their main course. Andersson et al. (2012) explored the effect of music in retail stores and found that music positively influences arousal and purchase intention in shoppers and such effect is moderated by gender, in that female shoppers preferred slow tempo music, whereas males preferred the opposite. Another recent research by Biswas et al. (2019) studied the influence of ambient music volume on customer's food choices and found that low-volume music increases the individual's intention to consume healthy food, and high-volume music enhances excitement levels, which, in turn, increases unhealthy food choices.

Other marketing research has investigated cross-modal effects of sound and audio with other human senses. Concerning audio and visual senses, Hagtvedt and Brasel (2016) have studied the cross-modal communication of sound frequency and colour lightness and have found that high-frequency sounds attract individuals' attention toward objects with light color. In contrast, low-frequency sounds attract attention toward dark color, and such effect happens automatically in individuals. Another study by Knoeferle et al. (2014) investigated whether individuals associate sound with gustatory attributes. More specifically, they tested the cross-modal correspondence between parameters of music (e.g., pitch, roughness, and sharpness) and the verbal representations of basic tastes (e.g., sweet, sour, and salty) and showed that specific musical compositions match certain tastes. For example, the bitter taste was mapped to rough, slow, and low-pitched sounds, and sweet tastes were mapped to high-pitched, smooth, and continuous sounds.

2.4.2 Classification for Sounds

Sounds can be classified in many ways. They can be categorized as audible and inaudible sounds. Although vibrations of air molecules can create sound waves, the human ear cannot hear all ranges of sound waves and is only able to hear the frequencies between 20 Hz and 20,000 Hz (Veerendra, 2020). Hence, inaudible sounds refer to sound frequencies below 20 Hz and above 20,000 Hz, which are also called infrasonic and ultrasonic (Veerendra, 2020). Moreover, sounds can be classified as musical and nonmusical. According to Thomson (2010), musical sounds refer to any tone or sound with a controlled pitch and timbre. Pitch is a characteristic of musical tones that refers to a subjective sensation of high or low tones, and timbre, also regarded as tone color, is a characteristic that distinct sounds from each other (Hagtvedt & Brasel, 2016). Thomson further explains that such classification may be oversimplified, as any sound (e.g., the tinkle of bell or slam of door) can be organized in a way that produces a combination called music. Therefore, we can conclude that musical sound is a combination of sounds that produce rhythm and may have controlled pitch and timbre. Any sound without rhythm and controlled pitch and timbre can be regarded as nonmusical sounds.

Nonmusical sounds can also be categorized into vocal and non-vocal sounds. Vocal sounds are related to words and the human voice. According to Graakjær and Bonde (2018), vocal or verbal sounds include "the prosody of the human voice (i.e., speech intonation, speed of delivery and accent) as well as phonetic symbolism (i.e., associational meaning caused by the phonological structure and fluency)". Nonverbal sounds can include auxiliary sounds and environmental sounds.

The current research aims to focus on product sounds. As mentioned before, many products produce sounds, either by themselves or by using and touching them. Such sounds convey potentially useful information about the nature of the product with which we are interacting (Spence & Zampini, 2006). Product sounds can have different types and objectives. Some of them are intentionally added to the product, have informatory purposes, whereas some others do not have any purpose, and are the result of working motors and gears. Moreover, sounds differ our perceptions of a product. It can add to a product's quality by intensifying strength, or it may show a product's cuteness by showing it as flimsy and amusing. In literature, several studies by Zampini and colleagues (Zampini, Guest, & Spence, 2003; Zampini & Spence, 2004), reveal that sound influences people's perceptions of products. For example, by manipulating sounds through amplifying high frequencies, an electronic toothbrush was perceived as rougher and unpleasant and potato chips were crisper and fresher. The current study highlights the importance of product sounds in an online shopping situation and looks into how enhancing augmented reality with sound of products can result in better product evaluation leading to higher product knowledge and increase in behavioural intentions.

3. Hypotheses Development

3.1 Enhancing AR with sound

AR positively affects sales, allowing retailers to present direct product experiences via virtual products to facilitate product evaluation (Tan et al., 2021). However, this tool does not fulfill the objective of product evaluation in a complete manner, as it lacks senses other than vision in the experience. The current study emphasizes on audition as the second important sense in sensory modalities and presents enhancement of AR with audio as a way to strengthen product evaluation experience, leading to higher behavioural intentions.

In AR-related literature, customers' attitudes and intentions are widely investigated. Poushneh and Vasquez-Parraga (2017) found that usage of AR increases user experience, leading to higher user satisfaction and intention to buy. Poncin and Ben Mimoun (2014) showed that AR has positive effects on store atmosphere, and perceived store atmosphere leads to enhanced satisfaction and customer patronage intention. In studies relating to multisensory augmented reality, Heller et al. (2019b) demonstrated that having touch control over AR holograms (vs voice control) increases customers' behavioural intentions.

I draw upon active inference theory (Friston, 2018, Heller et al., 2019b) to discuss the influence of sound on AR. This theory suggests that to make a decision for a product, individuals rely on sensory control and feedback deduced from interacting with the object. In other words, when evaluating a product, customers physically handle, move, and try the product to get sensory feedback and update their mental representations. Heller et al. (2019b) explain that in active inference theory, sensory control concentrates on reducing an inconsistency between sensory feedback and mental representation. When deciding to buy a chair, the customer may expect that the chair fit under the desk. Then, by trying to move it toward the desk, he/she realizes that the chair does not fit. In this product evaluation, by moving the chair, the customer gets sensory feedback about the object and then updates his/her mental representation of the product (Heller et al., 2019b). This theory points out the importance of experiencing the product prior to purchase.

In the online retail setting, the absence of physical product limits our sensory feedback and aggregates physical and mental intangibility, as we cannot receive sensory information from the product (Laroche et al. 2005) Therefore, online shoppers will only have the chance to experience the product after their purchase. However, AR gives us the necessary means to evaluate the product and it stimulates the experience of using the product by letting the customer manipulate and control the product's hologram through hand gestures, moving, clicking, and resizing the product. Therefore, AR lets us to see the product in our own environment (vision) and allows us to touch and manipulate in to gain sensory information (touch). Nonetheless, this experience still lacks auditory sense to make a more realistic shopping experience. The combination of audio and visual senses creates a more realistic product experience prior to purchase and resolves customers' concerns about the product.

On the other hand, customers may need to hear a product's sound to make better decisions. The absence of audio for objects with sounds works as a barrier to have sensory feedback and have a clearer mental representation about a product. Hence, presence of sound during the AR experience increases customers' ability to gain more sensory feedback during product evaluation, leading to a better mental representation of the product. The product sounds are not limited to the ones who actually have sound (e.g., microphone, speaker, musical instruments, toys) and it can encompass a wide range of products. For example, Ho et al. (2013) combined the virtual try-ons with their relevant clothing sound. For the purpose of this study, we are just focusing on products who have sound as their main feature (i.e., core product).

In this research, we suggest that adding sound to an AR shopping experience increases customers' behavioural intentions (i.e., reusing the AR app, purchase intention, WOM intentions). Behavioural intentions can be defined as the behaviors created by motivational factors and show what a person intends or is willing to do. Behavioural intentions are mainly investigated in marketing research due to the importance of customers' intentions when exposed to motivational factors such as an advertisement. Behavioural intentions can broadly be identified as favorable and unfavorable behaviors. The former refers to signaling creating bonds with the company, and the latter explains signals of leaving the company or spending less time with it (Zeithamal et al., 1996).

In augmented reality literature, Park and Yoo (2020) measure behavioural intentions of female customers who use the AR function of a mobile app for cosmetic products and demonstrate that controllability and playfulness of the AR function increase customers' mental imagery, which in turn influence their attitude toward the product and induce positive behavioural intentions. Their research investigates behavioural intentions through revisiting the mobile app, willingness to purchase a product, and positive word-of-mouth. Moreover, Heller et al. (2019a) study choice and WOM intentions in users who have interacted with AR and discuss that augmented reality allows imagery generation and transformation, which in turn increases their WOM intentions and improves their choice through the mediating role of processing ease and decision comfort.

The current study argues that enhancing AR function in an e-commerce platform increases customers' behavioural intentions. We study this variable through three factors (i.e., reusing the AR app, purchase intention, WOM intentions) and believe that these factors will experience an increase when the AR technology is enhanced with audio. Audio-enhanced AR is a sensory-rich experience, which allows a virtual product trial closely resembling a real situation, and customers perceive it as if they have tried the actual product. Having such experience can positively influence behavioural intentions in them.

Thus:

H1: *Customers searching for products through audio-enhanced AR will have higher behavioural intentions ctompared to the silent mode.*

3.2 Mediating Role of Decision Comfort

Next, the current research posits that decision comfort mediates the positive relationship between Audio-enhanced AR and behavioural intentions, such that customers who experience the AR environment with a sound will have higher decision comfort compared to the mute condition. Decision comfort relates to the psychological ease individuals feel in the process of making a decision (Parker et al., 2016). Individuals feel happy about their decision and although they may know that their decision is not the best, they are comfortable with it and do not feel pressure and uneasiness while choosing it. Any factor which helps individuals in lowering the anxiety and concern with regard to a decision, can have positive influence on their decision comfort (Parker et al., 2016).

Decision comfort is an important element in a retail setting, and both researchers and practitioners always seek to find ways and offer tools to facilitate decision-making in customers. AR is one of such tools, which helps customer’s imagery of the product and offers additional information about the product to make his/her decision-making process easier. Moreover, AR resolves anxiety and concern about the product fit, as it aids customers to visualize the product in their own consumption context and hence bring more comfort at the time of decision.

Heller et al. (2019a) show in their research that decision comfort mediates the relationship between mental imagery generation and transformation AR and WOM intentions. They further explain that AR presentation of products provides a processing style more similar to the final consumption experience and increases decision comfort due to higher realism and lower cognitive cost. Moreover, Hilken et al. (2017) show how spatial presence of objects resulted from simulated physical control and environmental embedding (i.e., AR characteristics) positively influences decision comfort. However, many of these studies neglect the role of sound as an auditory sensory modality.

According to Parker et al. (2016), decision comfort reflects the mood an individual has in a post-decision situation. Sound is an element that can significantly influence mood and affections. In an AR environment, hearing a sound can differ one's feeling about the AR hologram. Hence, the sound of a product in an AR environment influences decision comfort in customers. Above that, decision comfort is provided through reducing anxiety and mitigating one's concern in a shopping environment. Here, we propose that sound can mitigate users' concern about a product by providing relevant information about it (Spence & Zampini, 2006). Customers can now make better decisions as they have more information at the time of purchase. Therefore:

H2: *Decision comfort mediates the relationship between AR audio-enhancement and behavioural intentions.*

3.3 Parallel Mediating Role of Spatial Presence and Customer Engagement

Next, this study argues that AR audio-enhancement is a process of parallel sequential mediation, in that audio-enhanced AR affects spatial presence and customer engagement, which leads to decision comfort, resulting in higher levels of behavioral intentions (Figure 3). Enhancing AR with the sound of objects can increase spatial presence and customer engagement in customers while interacting with the augmented representation of the object. Spatial presence can be defined as a subjective perception in which individuals fail to accurately identify the role of technology in an experience and feel the presence of digitally mediated objects (Hilken et al., 2017; Lombard & Snyder-Duch. 2001). Spatial presence also referred to as "physical presence" or "perceptual immersion" (e.g., Lombard and Snyder-Duch, 2001), has been the subject of research for many years and more recently, it has been investigated in augmented reality and virtual reality research. This concept becomes even more important in retail industry, as it can influence how customers experience the products while evaluating them. Feeling the existence of an object makes an AR experience closer to the real consumption context, while also resolving uncertainties regarding product fit.

In their research, Smink et al. (2020) discuss that using AR technology in retail allows customers to interact with virtual products through adding and modifying them in their physical environment, thus feeling the presence of products in their environment and have more direct product experience. In their research, they also examined the mediating role of spatial presence and showed that AR apps improve the sense of spatial presence in customers, leading to more positive app and brand responses. In addition, in another study, Hilken et al. (2017) investigated the mediating role of spatial presence and found that participants who experienced heightened spatial in an AR environment, had higher hedonic and utilitarian value perceptions of the online service experience.

According to Smink et al. (2020), the level of spatial presence customers feel depends on the number of senses, which are engaged through the experience. Although most current AR apps involve visual and haptic senses in their experience (viewing the AR hologram and being able to touch and modify it), they still miss auditory senses in their experience. Sound enhances the vividness of mental imagery when combined with visual sensory. Many studies have shown the importance of combining audio-visual senses (e.g., Lewis, 2010 & Naumer et al., 2011) and how it can improve the sense of presence in users who interact with virtual environments (Davis et al., 1999; Nam et al., 2008; Larsson et al., 2007; Larsson et al., 2010). For example, Davis et al. (1999) investigated the influence of audio on the presence and subjective quality of virtual displays and found that enhancing visual display with audio increases the sense of presence, and perceived quality of visual display significantly. In their study, participants reported a higher feeling of perceived realness in the presence of audio, although there was no difference in characteristics of visual display in both presence and absence of audio.

Moreover, Larsson et al. (2007) state that across all sensory modalities, matching audio with visual displays has a vital role in increasing the sense of presence in a virtual environment. Further, in their research, participants also indicated a significantly higher feeling of presence in situations where both audio and visual senses were present, compared with visual-only situations. In the present study, when enhancing AR with product sounds, customers feel a higher sense of presence for the product they are interacting and evaluating in the AR environment compared with the no-sound environment.

On the other hand, sense of presence has positive influence on decision comfort, as it reduces purchase uncertainty, which is highly valued by the shoppers (Dacko, 2017). Moreover, following Schubert (2009) suggestion that having a sense of presence creates assurance for customers as they regard the attribute of AR hologram as real attributes, Hilken et al. (2017) propose and demonstrate the positive effect of spatial presence on decision comfort. In the current research we propose that having a sense of presence resulted from audio-enhanced AR leads to decision comfort for customers, as they will be having more sensory input, which creates more assurance for them:

H3a: *The relation between AR audio-enhancement and behavioural intentions is sequentially mediated by spatial presence and decision comfort.*

Next, audio-enhanced AR increases customer's engagement with the AR experience. When it comes to mobile retail apps and websites, customer (or user) engagement becomes an important factor. Customer engagement refers to the psychological interaction experience between an object or a concept and customer as an engaged subject (Algharabat, 2018). Scholz and Smith (2016) define customer engagement as a process in which customers get involved with an interactive experience or object, which leads to better customer relationships. Customer engagement can happen in many domains such as brand engagement, social media engagement, and mobile app engagement (Harrigan et al., 2018; Lim et al. 2015; McLean, 2018). In the context of AR technologies, customer engagement can be defined as the levels of psychological interaction individuals experience with the AR environment. Customer engagement is a progressive process, meaning that it initiates by some reactions to the technology, followed by more absorption with the content in the mediated environment (Algharabat, 2018). Jessen et al. (2020) study creative customer engagement in the AR context and show that heightened levels of customer engagement results in AR-enabled customer creativity, which, in turn, presents a source of customer satisfaction.

The present study proposes that audio-enhanced AR creates heightened levels of customer engagement, compared to non-audio AR. Multisensory experience increases brain engagement (as opposed to uni-sensory experience) and consequently, customers feel more involved with the experience (Stein et al., 2014). Human's brain tends to process events and form perceptions using multiple sensory inputs and combining them. Such process is also called multisensory integration, in that the brain is more involved with the sensory stimuli and forms a better perception of the events and objects (Chandrasekaran, 2017). Customers who interact with AR holograms of an object use their visual and haptic senses to observe the hologram and modify it through enlarging and rotating with their hands. Adding sound to such experience creates multisensory experience, which brings brain engagement and consequently more customer engagement. On the other hand, customer engagement enhances decision comfort, as customers perceive a better understanding of the product. Brain engagement is caused by receiving multiple sensory inputs from the product evaluation process. These sensory inputs help users gain more information and have a better perception of the product. Therefore, they would feel comfortable when making a purchase decision as they have had a fruitful product evaluation. Thus:

H3b: *The relation between AR audio-enhancement and behavioural intentions is sequentially mediated by customer engagement and decision comfort.*

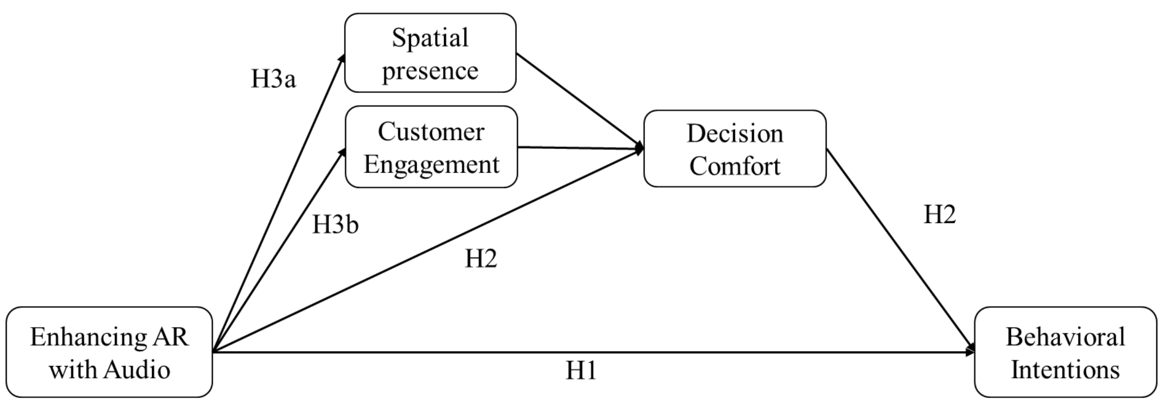

Figure 3: Research Model 1

3.4 Sound Pleasantness

In this study, we propose that pleasantness of the sound may have positive or negative influences on customer engagement, decision comfort, and behavioural intentions. From a general perspective, sounds can be perceived as pleasant or unpleasant. Pleasant sound refers to a sound that generates good and agreeable feelings and unpleasant sound refers to an annoying sound that causes discomfort. Most product sounds result from how a product operates (e.g., hairdryer, epilator, and shaver). In addition, they can be intentionally added sounds for informatory purposes (e.g., ringing of a phone, beeping of alarm), also called intentional sounds (Özcan & van Egmond, 2012). These product sounds are generally loud, sharp and noisy, which have unfavorable judgment when evaluated independently, and they create an unpleasant experience with the product (Özcan Vieira & Schifferstein, 2014). On the other hand, some product sounds are generally considered pleasant and induce a good feeling. For example, the sound of a musical instrument, a musical box, or a musical toy can be regarded as pleasant sounds.

Users are now showing more attention to the pleasantness of product sounds and the sense of pleasantness has become a significant factor in evaluating quality sound which is part of product evaluation process (Jurc et al., 2010). Literature on the pleasantness of product sounds show that products with a more pleasant sound bring more positive emotions for the customers. For example, Van Balken (2002) showed that through some mechanical changes in coffee machines and improving its auditory quality, customers will have more positive feelings toward the product. Spence and Zampini (2006) also showed that brushing teeth with electronic brush becomes more pleasant if the sound level is reduced or the high frequency of the sound is lessened. Additionally, Fenko et al. (2011) demonstrate that the noisiness of product sound has negative effect on the overall pleasantness of the product, and they suggest that the product designers need to pay more attention to the auditory properties of the products in the design procedure.

Özcan Vieira and Schifferstein, (2014) investigate the influence of sound pleasantness on the visual and overall pleasantness of the product. They manipulate pleasantness of the product sounds according to their loudness and sharpness and the products they investigate include common products used on a daily basis (e.g., epilator, hairdryer, and shaver). The auditory pleasantness is investigated through four conditions: control condition (no sound), original sound, pleasant sound, and less pleasant sound. Their results indicate that in the control condition (i.e., no sound condition) people have the same level of visual and overall pleasantness. However, in the existence of sound, there was a decrease of overall pleasantness and increase of visual pleasantness. In this research, we propose that sound pleasantness effects behavioral intentions in customers who are interacting with audio-enhanced AR. As discussed earlier, sound pleasantness is one of the important factors for customers to evaluate the quality of products. Customers are getting more and more sensitive about product sounds, and they pay higher attention to sound quality at the time of purchase (Jurc et al., 2010). Therefore, viewing a product with a less pleasant sound can result in lower intention to purchase the product. Moreover, sound is a factor that can considerably affect human's mood (Quarto et al., 2017; Kujala & Brattico, 2009; Lesiuk, 2010; Chanda & Levitin, 2013; Basner et al., 2014). Viewing a product in an AR environment with a less pleasant sound can result is a negative effect on mood and can lead into lower intentions to reuse the AR app and recommend the experience to their family and friends.

Hence:

H4a: *Pleasantness of the sound in an audio-enhanced AR environment has a direct effect on behavioural intentions of the customers.*

In this study, we further propose that the effect of sound pleasantness on behavioural intentions is a sequential mediating effect, such that for products with less pleasant sounds, customers will be less engaged and consequently feel less decision comfort while making their decision, which can result in lower behavioural intentions (Figure 4). Conversely, for those products with pleasant sound, customers can feel more engaged with the environment, and experience higher levels of decision comfort, leading to strengthened behavioural intentions in them. As discussed earlier, enhancing AR with sound can lead to higher brain engagement due to the multisensory effect of events on brain. However, the pleasantness of the sounds can also play an important role. A less pleasant sound can weaken brain engagement, as it creates interruptions in further involvement with the AR environment and creates a discomfort in decision-making. Less pleasant sounds prevent customers from further engaging with the hologram as they provide irritating situation for them and limit further concentration on product evaluation. On the other hand, a pleasant sound can help better engagement with the hologram and prepare a comforting atmosphere for decision-making, as customers will experience a good mood and will have a feeling of joy. Hence, although adding sound to an AR environment leads to higher customer engagement, we expect that for products with (un)pleasant sounds users experience (lower) higher engagement.

Next, we argue that the users who are less engaged due to the pleasantness of the sound will experience lower decision comfort, whereas those who are more engaged dues to sound pleasantness will feel higher levels of decision comfort. As Parker et al. (2016) state, decision comfort is about the good feeling that one has after making a decision. As discussed in H2, associating an object with their sounds in an AR environment increases decision comfort, due to the affective influence of sound on one's mood. According to Palazzi et al. (2018), human decisions are mostly related to their emotions and moods. Therefore, having an AR experience with a pleasant sound makes the overall experience more agreeable and customers feel good after their decision. However, less pleasant sound creates an uncomfortable experience, which makes the decision-making much harder to the customer. Users who are more engaged as a result of the pleasant sound will have a positive feeling and will consequently experience more comfort in their decision, leading to higher behavioural intentions:

H4b: *The effect of sound pleasantness on behavioural intentions is sequentially mediated by customer engagement and decision comfort.*

One may propose to use sound pleasantness as a moderator in the first model, in that the relationship between AR audio-enhancement, customer engagement and decision comfort is moderated by sound pleasantness. However, this may not be possible as AR audio-enhancement is a categorical variable, in that we have mute condition versus with-sound condition and there will be no moderating effect sound pleasantness on the mute condition because there is no sound.

3.5 Moderating Role of Sound Controllability

One of the important questions in equipping AR with sound is whether it will be necessary to provide control over the sound for AR users. Many apps who offer augmented reality services do not include volume control in the AR environment. For instance, with the AR service in the Google search, it is now possible to discover animals through projecting three-dimensional holograms of them in the physical space. Such service is equipped with a sound, and while interacting with the hologram of an animal, users can hear the sound of that animal, combined with the environmental sound. This service does not include any sound manipulation option in the AR environment, and it is possible to control volume only through the device itself. In this research, the aim is to investigate the importance of providing volume control in the AR environment and the way it can influence customers' experience in this environment.

The current research argues that the ability to control the sound in an AR experience has a moderating role on the effect of sound pleasantness on customer engagement. According to the augmented reality literature, simulated physical control is one of the important characteristics of AR, in that it allows customers to evaluate and playfully interact with the holographic presentation of the product (Fan et al., 2020; Hilken et al., 2017). The ability to control the sound which is played during the AR experience (i.e., auditory or volume control) influences simulated physical control such that it adds an aspect of controllability other than routine functionality of AR environments (e.g., rotating and resizing the hologram). While evaluating the product through its AR hologram, customers will have the ability to control the sound they hear by controlling its volume.

Sound controllability may influence the positive impact of sound pleasantness on customer engagement (Figure 4). This effect can be discussed through brain engagement. Human's brain has the ability to use signals from various senses in harmony to gain a perception from external world. Such ability maximizes the brain's use of the information, and it improves the level of perception from different events (Stein et al., 2014). Each human sense carries a unique perspective from the events and combining information from these senses has several advantages that cannot be achieved through cues from a single sense. In presence of several senses (multisensory experience), brain uses more of its capacity to analyze a combination of senses to gain a better perception of events, resulting in more brain engagement. In the current proposition, we argue that other than auditory sensory cues originating from product sounds, adding control to the sound influences touch sensory modality, as users touch the screen to modify the product's sound. In this regard, Dulabh et al. (2017) refer to the touch experience in the shopping process and state that having more frequent touch results in more engagement of customers with the product. In the context of this study, we are having control over the product sound, which increases the touch experience in the AR environment and results in more customer engagement (due to the effect of simulated physical control over the product in the AR environments). Hence, sound controllability results in heightened levels of touch experience, which increases the levels of senses engaged in an experience, leading to more brain engagement (Stein et al., 2014). Thus, through auditory control, users feel more engaged with the AR environment.

H5: *Positive effect of sound pleasantness on customer engagement is strengthened by sound controllability.*

One may question the necessity of investigating sound controllability, as all our electronic devices provide tools to control sound from the device itself. Here, we highlight two important issues, which can address this matter. First, augmented reality provides an immersive environment in that individuals neglect their surroundings and feel as if virtual holograms exist in their environment (Park & Yoo, 2020). They are able to handle the hologram, customize it, and hear its sound, which represents a real situation and makes the environment more immersive. However, without the possibility to control the sound from inside the virtual environment, users need to manipulate sound from their devices, and this makes an interruption in the immersive experience, with which users do not feel as immersed as before. Such incidence can have negative influences on their experience with the AR app.

We can also look at this matter from a user experience perspective. Usability is a vital factor in user experience and is defined as the ease of access and use in a product, a website, or an app. Differently said, usability describes the easiness and rapidness of achieving a goal using a product or an app. In an AR environment of a retail app, the goal is to evaluate the product in an improved and rapid way. Thus, when designing an app, the objective is to provide necessary tools in this environment to achieve the desired goal, and sound controllability can be regarded as one of them. Without manipulating sound within the AR environment, users do not find appropriate tools for product evaluation, and the user experience will deteriorate. The two issues above highlight the importance of sound controllability in two aspects of theoretical and practical.

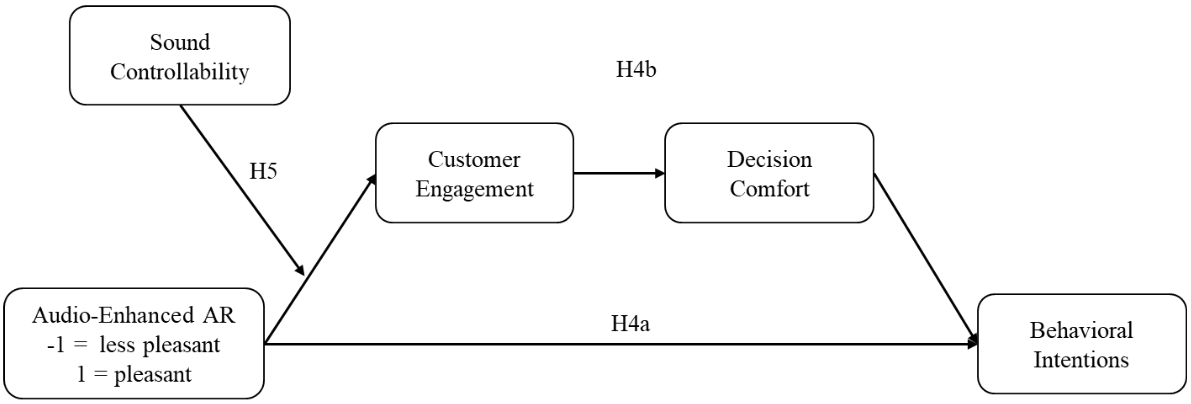

Figure 4: Research Model 2

A question may be raised for the reason why this study proposes two different research models. Moreover, one may propose to use sound pleasantness and sound controllability as moderators for the first research model. We have to have in mind that the first research model mainly investigates the effect of enhancing AR environment with sound and it compares the mute AR environment with the sound-equipped AR environment. Investigating the role of sound-related factors (i.e., sound pleasantness and sound controllability) as moderators for this model means that both mute and sound-equipped conditions will be altered in the existence of these moderators. However, there will be no sound pleasantness and controllability in the mute condition and such moderating effects are redundant. Hence, it is necessary that we propose a second research model, in that we explore the effect of sound pleasantness and sound controllability in audio-enhanced AR.

4. Methodology

An experiment tests the hypothesized sequence of effects in AR audio-enhancement (H1, H2, H3a, and H3b), the effect of sound pleasantness (H4), and the moderating role of sound controllability (H5a, H5b). The AR platform is developed using ZapWorks Studio. ZapWorks Studio is a software developed by Zappar Company which allows creating fully customizable AR experiences without any scripting knowledge. Moreover, Zappar app is used as the tool to observe AR content created through ZapWorks Studio. Users can access AR content on Zappar app by scanning the Zap code. AR experiences include a various range of experiences such as image tracking, face tracking, and world tracking. The current study will use world tracking experience as the AR retail experience requires projecting AR holograms into the physical world.

4.1 Research Design and Procedure

Two products will be used for this study. Each product will have 5 scenarios {[1 mute] + [2 Sound pleasantness] × [2 Sound controllability]}, which makes a total of 10 study groups (2 products × 5 study groups for each product). This experiment is done through smartphone and the survey is also filled out on the smartphone, as we want to make the transition between survey and the AR app easier. In the first step, the participants are informed about the experiment and that they are going to work with an AR environment. They are given a chance to exit the experiment if they do not prefer to participate, as they will have to download the Zappar app and give access to their camera for projecting AR holograms. Then they are provided with a guideline of how to download the Zappar app and how to work with it using the different functionalities. Then, the participants are asked to download the Zappar app (exists in both App Store and Google Play) on their phone.

In the second step, an online shopping situation is described for them, and they are asked to evaluate the product in the AR environment and make a purchasing decision. The shopping situation is as follows: "Imagine that you want to buy a [product], and you are searching for it through an online shopping platform. You find a good [product] and would like to further consider it for purchase. The website/app offers you an Augmented reality tool for product evaluation.

Please evaluate this product and decide if you would like to purchase it" (heller et al., 2019b). A link is embedded in this section of the survey which opens the AR environment on Zappar app.

Next, users are presented with an AR hologram of a product, and they are able to embed the hologram into their physical environment and manipulate it (resize and rotation). The experiment starts when the users project the hologram in their own physical space and start engaging with it. They can exit the platform by choosing the exit button. The exit button leads them to the next part of the survey.

For further analysis about the participants' activities on the app, Zappar website provides an Analytics section, in that there is a comprehensive analysis of all the activities participants do during their time in the AR environment. Following information is available in this section: total number of views, number of unique users, average time spent in the AR environment, total amount of time all users have spent in the AR environment, dates and hours users have visited the AR environment, and their type of devices (iOS or android).

4.1.1 Sound Pleasantness Stimuli

In the mute condition, participants do not hear any sounds, but they are able to fully interact with the hologram. In the condition where sound is present, participants view the hologram of a product and hear the sound of that specific product. The product sounds have different levels of sound pleasantness (pleasant, and less pleasant). To create product sounds with different ranges of pleasantness, the sharpness and loudness of the real product sound is manipulated. For example, a real piano sound is used and by changing its loudness and sharpness, two new audios (pleasant and less pleasant) are created. Loudness and sharpness are two acoustical dimensions of product sounds and are factors that can also indicate the pleasantness of the sound (Özcan & van Egmond, 2012, Özcan Vieira & Schifferstein, 2014). Therefore, any type of sound can be manipulated through its loudness or sharpness to induce pleasantness (Özcan Vieira & Schifferstein, 2014). For example, sharpness or loudness of a sound of blender can be reduced to create a more pleasant sound compared to the original sound. In contrast, sharpness or loudness of a sound of musical box can be increased in order to create an unpleasant sound, compared to its original sound.

In the experiment, participants visually see a hologram of a product and they hear the sound of that product while they are working with the AR app. The sound they hear can differ in the level of pleasantness (e.g., they may hear a sound of a digital piano in one of the levels of sound pleasantness). Each participant evaluates one product in one of the sound pleasantness conditions (no participant evaluates two products or one product with two different sound pleasantness levels at the same time). The sound starts to play as soon as the hologram is projected in the environment, and it will be stopped when users decide to exit the AR environment.

4.1.2 Sound Controllability Stimuli

The study groups who hear a sound while working with AR app experience two different situations. In the first situation sound controllability is not present, meaning that users are not able to control the sound (there is no tool in the AR environment to manipulate the sound). For instance, they visually see a hologram of a digital piano, hear the sound of that piano in the duration of their interaction with AR app, and they cannot stop the sound. In the condition where controlling sound is enabled, participants have access to a volume button, with which they can start and stop the sound. Looking at the example of piano, this time participants are able to start and stop the sound, as they prefer. Users can interact with the AR environment for as long as they like, and when finished, they will close the app and continue to fill out the main survey on their computer.

Participants will be omitted from further analysis, if they have not used the AR environment in the experiment, have experienced technical difficulties, did not completely answer the survey questions, and did not understand the instructions.

4.2 Measures

4.2.1 Independent Variable

In the first model, the stimulus material for independent variable is two different versions of AR environment, one of which is equipped with audio and users will hear sound of the product they are observing in AR environment. The other version is identical to the first version, and the difference is that it is not equipped with audio, and users will not hear any sound during their interaction with the hologram. This study also investigates pleasantness of the sound added to the AR environment. Sound pleasantness is going to be studied to investigate if products with pleasant sound can influence users' decision-making in the AR environments. In this study, the focus is on product sounds. Hence, using the method tested by Özcan Vieira and Schifferstein, (2014) the original product sounds are manipulated to achieve two level of pleasantness in the sounds: pleasant and less pleasant sounds for each product.

4.2.2 Dependent Variable

Behavioural intentions serve as the dependent variable in this study, which is going to be rated through a three-items measure adopted from Yoo and Kim (2014) with some modifications to fit this study ("I would purchase the product that I evaluated.", "I would recommend the AR shopping experience to my friends and family.", "I would use the AR tool again for my shopping purposes."). This variable is measured on a nine-point Likert scale (1 = "strongly disagree" and 9= "strongly agree").

4.2.3 Mediating Variables

To measure decision comfort, a five-item scale by Parker et al. (2016) is adapted to fit the context of this study. For example, the original item “I am comfortable with choosing X” is converted to “I am comfortable with the decision I made” and “I am experiencing positive emotions about X” to “I am experiencing positive emotions about my decision.” Spatial presence will be measured by eight items adopting from Hilken et al. (2017), such as “I felt like the [product] was actually there in the real world” and “I felt like the [product] meshed with the real-world surroundings.”

To measure customer engagement, a five-item measure is adopted from Hollebeek et al. (2014) and changed to fit this study. Two items take a cognitive perspective (e.g., “I think about my experience a lot when I’m using AR”), and two item aims to measure affective aspects of engagement (“I feel very positive when I shop online using AR.”), and one item measures activation (“If a shopping app offers AR tool, I use it whenever I want to shop online.”). Participants rate decision comfort and spatial presence and customer engagement through a nine-point Likert scale ranging from 1= “Strongly disagree” to 9 = “Strongly agree”.

4.2.4 Moderating Variables

4.2.4.1 Sound Controllability

The last moderator is sound controllability, which investigates if controlling sounds in the AR environments is necessary to help further user engagement, provide a comfortable decision-making situation, and create higher spatial presence by resembling the action of turning the product on and off. This variable in manipulated through a volume button in the AR environment, with that customer can turn the sound on and off and replay and increase or decrease the volume while interacting with the product's hologram. In situations where sound is controllable, the volume buttons exist in the AR environment and in other situations where sound is not controllable, customers will not see the volume button and will not be able to manipulate the sound from inside the AR environment.

4.2.5 Control Variables

This research controls for several variables to reduce the impact of other factors and provide robustness in the results. In the first step, the number of clicks and the time spent on the AR platform will be observed and controlled, to remove participants who have not engaged enough with the hologram, have not used volume button, or have spent little time in the AR platform. The average amount of time will be 45 seconds to one minute, which will be spent on getting to know the AR environment, projecting the hologram in the participants' physical place and engaging with the hologram. Participants who spend less that one minute will be removed from the study.

In the next step, technology innovativeness will be controlled to rule out participants' characteristics in facing a new technology. To measure technology innovativeness, a measure scale adopted from Parasuraman (2000) will be used (e.g., "I enjoy the challenge of figuring out new technologies").

Next, this study controls for variables which can result from the products and participants' feeling toward them. First, we control form visual pleasantness of the product, using measurement items adopted from Kim et al. (1996) with a small change to fit the context of visual pleasantness. This variable will be measured through a 9-point semantic differential scale. Moreover, we control for product involvement, to make sure that participants' involvement with the proposed products does not influence their desire for purchase. This variable will be measured with items adopted from Zaichkowsky (1985).

5 Data analysis

This chapter contains analysis and results of the data obtained from conducting the studies presented in the previous chapter. First, results from the sound pleasantness manipulation check are reported and two products are chosen to be used in the main study. Next, the result from the main study is presented, including the results of the hypothesized research framework.

5.1 Sound Pleasantness Manipulation Check

A total of four products were chosen for the sound pleasantness manipulation check: acoustic guitar, portable speaker, music box, and karaoke microphone. Each product was represented with one corresponding product sound without any visual presentation (Özcan Vieira & Schifferstein, 2014). However, the name of the products was indicated for clarification.

5.1.1 Auditory Stimuli

Each product was presented with one corresponding product sound and the sound of each product was a recording of the main functioning of that specific product which lasted for fifteen seconds. The pleasantness of the original sounds was manipulated to achieve two level of pleasantness, resulting in a total of 8 soundtracks (four products × two sound conditions). The more pleasant and less pleasant product sounds were created using a sound editor program (Audacity, free digital open-source audio editor). For less pleasant sound, the original sound was filtered through a high-pass filter (which passes sound waves with higher frequencies or shorter wavelengths), and the amplitude of the sound was increased. In addition, the more pleasant sound was produced through filtering the original sound with low-pass filter (which passes sound waves with lower frequencies or longer wavelengths), and the amplitude of the sound was decreased (Özcan Vieira & Schifferstein, 2014). During the manipulations, we tried to keep the spectral-temporal composition of the pleasant and less pleasant sounds close to each other (Özcan Vieira & Schifferstein, 2014).

5.1.2 Procedure

The pleasantness of four manipulated product sounds was tested using 146 participants recruited through Amazon Mturk (73 female, average age = 37.308). The pleasant and less pleasant audio tracks were randomly distributed meaning that each participant would only hear either pleasant or less pleasant sound of each single product. Participants were asked to rate the pleasantness of each product sound independently and also in comparison to the sound they may generally hear from that specific product on 9-point semantic differential scale.

Independent-samples T test was run to analyze the data for sound pleasantness manipulation check. Among the four products, three products showed significant difference among more pleasant and less pleasant groups [acoustic guitar ($t(144) = 3.37$, $p < .001$), portable speaker ($t(144) = 2.64$, $p = .009$), and music box ($t(144) = 2.80$, $p = .006$)]. We ran the test again to choose the final products for the main study.

In the second test, 181 participants filled out the survey for pleasantness of manipulated product sounds for five products (88 female, average age = 37.31). Among the three products in this test, two have shown significant results (i.e., acoustic guitar and portable speaker). As for acoustic guitar, there was a significant difference among the level of pleasantness ($t(179) = 6.70$, $p < .001$) and pleasant guitar sound ($M_{pguitar} = 7.79$, $SD = 1.03$) demonstrated significantly better pleasantness scores compared to less pleasant guitar sound ($M_{unpguitar}$ = 6.17, *SD* = 2.07). As for portable speaker, the pleasant group ($M_{pspeaker}$ = 7.55, *SD* = 1.24) showed significantly higher difference (t (179) = 6.70, $p < .001$) in comparison with the less pleasant group ($M_{unpspeaker}$ = 6.33, *SD* = 2.06).

5.2 Main Study Participants and Manipulation Checks

5.2.1 Sample Analysis

A total of 1100 participants were recruited from Amazon Mturk restricted to US participants with a HIT approval rate higher than 95% to participate in this study. This study included two attention checks using Instructional Manipulation Check Method (Oppenheimer et al., 2009). Following the removal of invalid responses according to the manipulation checks, a total of 926 usable responses were collected and analyzed. 469 of the participants were female, 19.3 percent were 26-30 years old. 88.3 percent of the participants have post-secondary studies, 51.5 percent of which has undergraduate/bachelor's degree. In terms of income level, 33.9 percent of the respondents reported an annual income of $50,000 to $74,999.

Table 3: Summary of Sample Demographic Profile

Age	Frequency	Percent
19 - 25	207	22.4
26 - 30	179	19.3
31 - 35	182	19.7
36 - 40	109	11.8
41 - 45	77	8.3
46 - 50	65	7
51 - 55	46	5
56 - 60	36	3.9
61 - 65	18	1.9
66 - 70	6	0.6

71 - 75	1	0.1
Total	926	100

Education Level	Frequency	Percent
High School/ College Degree	108	11.7
Undergraduate - Bachelor's Degree	477	51.5
Graduate - Master's Degree	324	35
PhD.D. or Terminal Degrees	17	1.8
Total	926	100

Income Level	Frequency	Percent
Less than $20,000	65	7
$20,000 to $34,999	120	13
$35,000 to $49,999	206	22.2
$50,000 to $74,999	314	33.9
$75,000 to $99,999	184	19.9
Over $100,000	37	4
Total	926	100

5.2.2 Manipulation Checks

Prior to testing the hypotheses, the manipulations of sound pleasantness was checked. To assess the ‘sound pleasantness’ manipulations, participants rated a four-item measure (e.g., “I heard an agreeable sound from the [product]”). Participants responded to these measures on a nine-point Likert scale ranging from 1 = “Strongly disagree” to 9 = “Strongly agree”. The manipulation check revealed a significant difference between pleasant ($M_{pleasant}$ = 7.04, SD = 1.27) and less pleasant ($M_{lesspleasant}$ = 5.70, SD = 1.96) conditions; (t (628) = 10.27, $p < .001$).

To see whether all participants were able to project the AR holograms in their physical environment and modify them, they rated a three-item measures (e.g., “I successfully projected the augmented reality hologram of product in my space” and “The hologram was visible to me from all angles”) some of them adopted from Heller et al. (2019b). participants who failed to project the hologram or failed in modifying the hologram were removed from the data.

5.3 Main Study Results

5.3.1 Measurement Model Examination

Before assessing the models, the quality of the measurement items is evaluated (Hair et al., 2017). As for the first model, after calculation of psychometric properties for each variable, one item from spatial presence, two items from decision comfort and one item from customer engagement that did not meet the criteria were removed from further analysis. As it can be seen from the measurement items table, all items have factor loading higher than .70 which is the recommended loading. To measure the internal consistency reliability, Cronbach’s Alpha and composite reliability (CR) were measured. The Cronbach’s Alphas range from .815 to .920, showing good levels of reliability and internal consistency, in that it shows how well the items of a construct reflect the corresponding construct. Composite reliability of the constructs ranges from .715 to .821 evidencing for good reliability of composite index, all of which are above the critical value of .70.

The average variance extracted (AVE) that measures convergent validities (i.e., the adequacy of instruments to measure each construct), ranges from .547 to .675. Compared to the critical value of .50, the results evidence that the items adequately and convergently capture the corresponding constructs (Hair et al., 2017).

Table 4: Constructs and Measurement Items

Constructs and Measurement Items	Factor Loading	t-Value
Behavioural Intentions (α = 0.815; CR = 0.717; AVE = 0.547)		
I would purchase the product that I evaluated. (1)	0.726[a]	---
I would recommend the AR shopping experience to my friends and family. (2)	0.809	18.096
I would use the AR tool again for my shopping purposes. (3)	0.782	17.497
Spatial Presence (α = 0.901; CR = 0.754; AVE = 0.625)		
I had the impression that I was actively engaging with the [product] as if it was in the real world. (1)	0.879[a]	---
It was as though the true location of the [product] had shifted into the real-world environment. (2)	0.836	25.293
I felt like the [product] meshed with the real-world surroundings. (3)	0.865	26.86
It seemed as if the [product] actually took part in the action in the real world. (4)	0.867	24.575
Decision Comfort (α = 0.865; CR = 0.761; AVE = 0.643)		
I am comfortable with the decision I made. (1)	0.785[a]	---
I feel good about my decision. (2)	0.853	21.01
I am experiencing positive emotions about decision. (3)	0.801	19.721
Customer Engagement (α = 0.816; CR = 0.715; AVE = 0.576)		
I feel good when I use AR for shopping online. (1)	0.788[a]	---
Using AR stimulates my interest to learn more about it. (2)	0.786	19.997
I feel very positive when I shop online using AR. (3)	0.718	18.411
I spend a lot of time using AR shopping tool compared to a usual online shopping. (4)	0.821	19.941
Having AR shopping experience makes me happy. (5)	0.852	22.54
Technology Innovativeness (α = 0.875; CR = 0.821; AVE = 0.617)		
I enjoy the challenge of figuring out new technologies. (1)	0.786[a]	---
I have fewer problems than other people in making technology work for me. (2)	0.790	19.514
I am among the first in my circle of friends to acquire a new technology. (3)	0.765	18.747
I keep up with the latest technological developments. (4)	0.814	20.212
Visual Pleasantness (α = 0.878; CR = 0.784; AVE = 0.591)		
Unpleasant physical appearance: Pleasant physical appearance (1)	0.783[a]	---
Disliked the physical appearance very much: Liked the physical appearance very much (2)	0.797	19.665
The physical appearance left me with a really bad feeling: The physical appearance left me with a really good feeling (3)	0.833	20.735
Product Involvement (α = 0.912; CR = 0.756; AVE = 0.623)		
This product tells other people something about me. (1)	0.775[a]	---

his product helps me express my personality. (2)	0.808	20.431
I am interested in this product. (3)	0.821	20.854
I think this product is exciting. (4)	0.838	21.395
I feel this product is relevant to me. (5)	0.852	21.877
Product Experience (α = 0.92; CR = 0.802; AVE = 0.675)		
I have used this product during the last year. (1)	0.865[a]	---
I have shopped for this product. (2)	0.831	24.962
I have obtained information from friends about this product. (3)	0.827	24.742
I have searched information on Internet about this product. (4)	0.856	26.282
I have read customer reports and comments about this product. (5)	0.859	26.463

Notes: [a] Initial loading was fixed to 1 to set the scale of the construct.
CR = construct reliability; AVE = average variance extracted

Lastly, to evaluate discriminant validity, we checked if the AVE's are higher than the variance that they have in common with each other. Fornell and Larcker (1981) suggested that AVE values should be greater than squared correlations between the one construct and the other constructs. Using this process, we found that the AVE values are considerably larger than the squered correlations of each two constructs. This is evidence for discriminant validity, and thereby separability of the constructs (See Table the results of Fornell and Larcker Criterion).

Table 5: Descriptive Statistics and Discriminant Validity

	Mean	SD	1	2	3	4	5	6	7	8
1. Behavioural Intentions	6.705	1.38	**0.739**							
2. Spatial Presence	6.628	1.59	0.612	**0.79**						
3. Customer Engagement	7.032	1.16	0.551	0.629	**0.758**					
4. Decision Comfort	6.946	1.21	0.515	0.546	0.559	**0.801**				
5. Product Involvement	6.297	1.32	0.644	0.745	0.614	0.462	**0.789**			
6. Visual Pleasantness	7.292	1.49	0.563	0.652	0.468	0.476	0.633	**0.768**		
7. Technology Innovativeness	6.817	1.38	0.558	0.663	0.584	0.656	0.663	0.575	**0.785**	
8. Product Experience	3.549	1.13	0.358	0.524	0.349	0.133	0.568	0.512	0.395	**0.821**

Numbers along the diagonal (in bold) are square roots of AVEs
Numbers off the diagonal are correlations

5.3.2 Hypotheses Testing

5.3.2.1 Direct effects

First, to investigate H1, we conducted one-way ANOVA with AR audio-enhancement as a factor and behavioural intentions as dependent variable. The mute condition was coded as 0 and the study groups which had sound in the AR environment were coded as 1. We found no significant main effect of enhancing AR with audio on behavioural intentions ($F (926) = .243$, $p= .622$). For the conditions where the AR environment has sound, participants' behavioural intentions was slightly lower than the mute condition ($M_{withsound} = 6.69$, $SD_{withsound} = 1.41$ vs. $M_{mute} = 6.73$, $SD_{mute} = 1.32$; $t (924) = -.493$, $p= .622$). To further investigate the main reason for such results, in the second phase, we first compared mute study groups with the conditions where there was a pleasant sound. To do so, we coded mute condition as 0 and study groups with pleasant sound as 1. The results showed a significant main effect of enhancing AR with audio on customers' behavioural intentions ($F (626) = 5.271$, $p= .022$). Planned contrast results reveal that participants in the pleasant sound condition had higher intentions to purchase the product, recommend the experience to their family and friends, and use AR tool again for their purchase ($M_{withsoundp} = 7.63$, $SD_{withsoundp} = 1.21$) compared to participants in the mute condition ($M_{mute} = 6.73$, $SD_{mute} = 1.32$; $t (626) = 2.596$, $p < .05$). Furthermore, we compared mute condition with the less pleasant study groups. To do so, mute condition was coded as 0 and the less pleasant group as 1. One-way ANOVA analysis shows significant negative effect of enhancing AR environment with less pleasant sound on behavioural intentions ($F (592) = 9.324$, $p= .002$). The less pleasant sound group showed significantly lower behavioural intentions ($M_{withsoundup} = 5.75$, $SD_{withsound} = 1.55$) in comparison to the mute study group ($M_{mute} = 6.73$, $SD_{mute} = 1.32$; $t (626) = -3.054$, $p < .01$). It can be inferred from the results that the less pleasant sound has such negative influence on the positive effect of pleasant sound, which can lead to an insignificant result when comparing mute and with-sound conditions. Therefore, H1 was only partially supported given the fact that participants had higher behavioural intentions when the AR environment has enhanced with a pleasant sound (compared to enhancing with a less pleasant sound).

We also tested for the direct effect of sound pleasantness on behavioural intentions. To do so, we compared the behavioural intentions in pleasant and less pleasant study groups using one-way ANOVA and we coded pleasant as 1 and less pleasant as -1. Results indicate a significant effect of sound pleasantness on behavioural intentions ($F (628) = 28.903, p> .001$), in that pleasant sound has higher behavioural intentions compared to less pleasant sound ($M_{pleasant} = 7.25$, $SD_{pleasant} = 1.21$ vs. $M_{lesspleasant} = 6.37$, $SD_{lesspleasant} = 1.55$; $t (628) = -5.376$, $p < .001$). Hence, sound pleasantness positively influences behavioural intentions in customers who interact with audio-enhanced AR which shows support for H4a. Customers are more willing to purchase the product, recommend the experience to their family and friends, and use AR tool again for their purchase, if they hear a pleasant sound (vs. less pleasant sound).

5.3.2.2 Mediation Analysis

Mediation Analysis (with-sound vs. mute condition). To investigate hypotheses 1-3 in a comprehensive model, we first coded all with-sound conditions as 1 and mute condition as 0, and ran PROCESS macro (Hayes 2017, Model 80). Model 80 regressed behavioural intentions on AR audio-enhancement, with customer engagement and decision comfort as sequential mediators. We found a significant negative effect of AR audio-enhancement on customer engagement ($\beta = -.249$, $p = .0476$) while the effect on decision comfort was not significant ($\beta = .026$, $p > .1$). We propose that the negative effect of AR audio-enhancement on customer engagement may be the result of the less pleasant sound in this analysis. As we have put both pleasant and less pleasant sound groups in one category, we think that the less pleasant sound has such negative effect that makes this relationship significantly negative. Moreover, Customer engagement significantly predicted decision comfort ($\beta = .244$, $p < .01$) and also, decision comfort had positively predicted behavioural intentions ($\beta = .176$, $p < .01$). Moreover, customer engagement has a significant effect on behavioural intentions ($\beta = .150$, $p < .01$).

On the other hand, no significant effect of AR audio-enhancement on spatial presence was observed ($\beta = -.021$, $p = .75$) showing no support for H3a ($\beta = 0.0005$, LLCI = -0.0048 ULCI = 0.0028). As previously discussed in the section regarding direct effects, there was also no direct effect of AR audio-enhancement on behavioural intentions ($\beta = .043$, $p > .1$). We estimated the indirect effects of AR audio-enhancement using bootstrapping procedure with 5,000 samples and found a positive indirect effect of AR audio-enhancement through customer engagement and decision comfort on behavioural intentions ($\beta = 0.0521$, LLCI = 0.0014 ULCI = 0.1083) and also just through customer engagement (AR audio-enhancement -> Customer Engagement -> Behavioural Intentions) ($\beta = 0.0343$, LLCI = 0.0129 ULCI = 0.0653) in support of H3b showing sequential mediating effect.

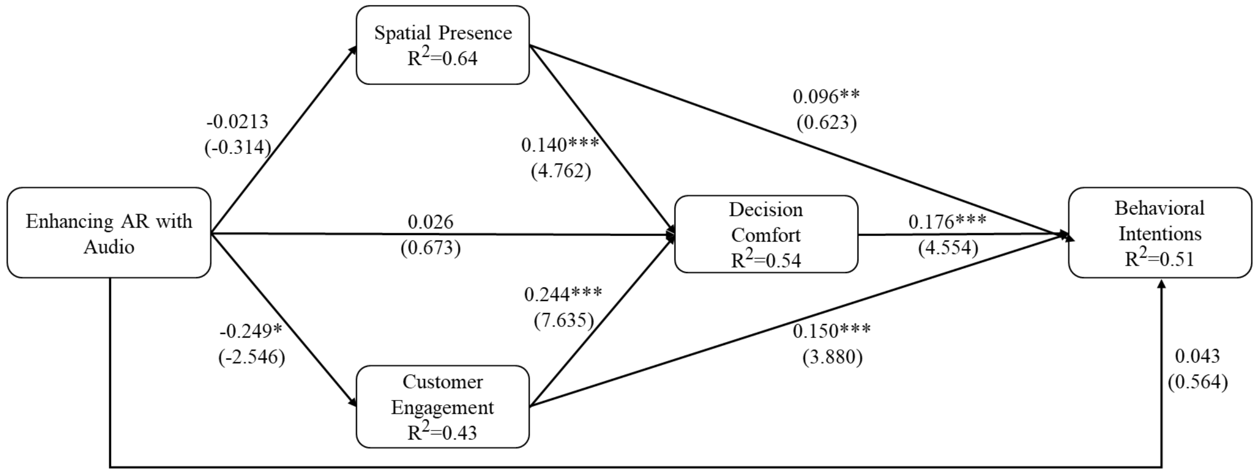

Figure 5: Enhancing AR with audio

Note: + $p < 0.1$ * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. The figures in parentheses are t values

This model compares mute and with-sound study groups

Mediation Analysis (pleasant vs. mute condition). Next, we ran model 80 using the pleasant sound versus mute condition. To do that, study groups with pleasant sound were coded as 1 and mute condition was coded as 0. Our results reveal that AR audio-enhancement had a significant positive effect on customer engagement ($\beta = .38$, $p < .01$). This result confirms our explanation about the negative effect of AR audio-enhancement on customer engagement which was found in the previous section. In addition, there was no direct effect of AR audio-enhancement on decision comfort ($\beta = .0098$, $p > .1$) and spatial presence ($\beta = .004$, $p > .1$). We estimated the indirect effects on behavioural intentions by means of a bias-corrected bootstrapping procedure with 5,000 samples. This resulted in a significant positive indirect effect of enhancing AR with pleasant sound through customer engagement and decision comfort on behavioural intentions ($\beta = 0.0269$, LLCI = 0.0104 ULCI = 0.0514). There is also a significant effect through the indirect path of customer engagement ($\beta = 0.0409$, LLCI = 0.0011 ULCI = 0.0852). The explained variance of the mediator customer engagement and decision comfort was $R^2 = .42$ and R2 = .58 respectively, and the value for the dependent variable behavioural intentions was $R^2 = .57$ (Figure 6).

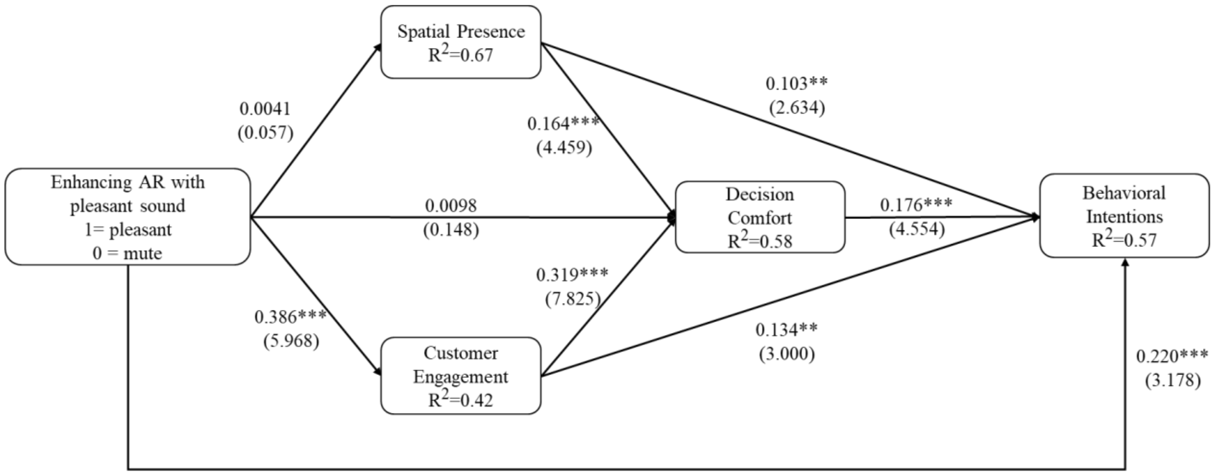

Figure 6: Enhancing AR with pleasant sound

Note: + p < 0.1 * p < 0.05; ** p < 0.01; *** p < 0.001. The figures in parentheses are t values

This model compares mute and pleasant sound study groups

Mediation Analysis (less pleasant vs. mute condition). We also compared mute and less pleasant sound groups using model 80. To do so, we coded mute condition as 0 and less pleasant condition as 1 and found significant negative effect of AR audio-enhancement on customer engagement (β = -.189, p = .023) and behavioural intentions (β = -.192, p = .044), as we predicted. This model also shows a significant effect of AR audio-enhancement on decision comfort (β = .145, p = .025). To explain this positive effect, we think that less pleasant sound brings decision comfort for customers, as they can easily decide they do not want to buy the observed product or recommend this unpleasant experience to their family and friends. Therefore, they are provided with a piece of information which helps their decision making. Moreover, this model demonstrated the indirect effect of AR audio-enhancement on behavioural intentions through customer engagement and decision comfort (β = 0.0367, LLCI = 0.0154 ULCI = 0.0489).

As mentioned earlier, the path between AR audio-enhancement and decision comfort was only significant when comparing less pleasant sound and mute conditions. Hence, we conclude that enhancing AR with audio only has direct effect on decision comfort when it is enhanced with a less pleasant sound, and this is because customers are offered with information about the product which shows that this product does not have a pleasant sound. This information makes it easy for them to decide upon their purchase.

5.3.2.2.1 Analyzing Products Independently (Acoustic Guitar & Portable Speaker)

We tested our hypotheses for each product independently (i.e., acoustic guitar and portable speaker). The following models show how model 80 works for each product independently, when the AR environment is enhanced with either pleasant or less pleasant sound:

Acoustic Guitar:

Mediation Analysis (pleasant vs. mute condition). The following model (Figure 7) uses the data for acoustic guitar and investigates enhancing AR environment with peasant sound. To do so, the study groups with pleasant sound was coded as 1 and the study group with no sound was coded as 0. An additional independent sample t-test (t (335) = 3.643, $p < .01$) and one-way ANOVA (F (335) = 31.846, $p < .01$) revealed a significant difference between the means of customer engagement for pleasant group versus mute condition ($M_{pleasant} = 7.44$, $SD_{pleasant} = 0.89$ vs. $M_{mute} = 6.78$, $SD_{mute} = 1.26$). There is also a significant t-test (t (335) = 4.830, $p < .001$) and one-way ANOVA results (F (335) = 23.326, $p < .01$) between means of behavioural intentions for pleasant sound group versus mute condition ($M_{pleasant} = 7.13$, $SD_{pleasant} = 1.16$ vs. $M_{mute} = 6.34$, $SD_{mute} = 1.82$). Moreover, there is no significant t-test (t (335) = .466, $p > .1$) and one-way ANOVA results (F (335) = .007, $p > .1$) between means of spatial presence for pleasant sound group versus mute condition ($M_{pleasant} = 6.74$, $SD_{pleasant} = 1.69$ vs. $M_{mute} = 6.73$, $SD_{mute} = 1.50$). We estimated the indirect effects of AR audio-enhancement using bootstrapping procedure with 5,000 samples and found a positive indirect effect of AR audio-enhancement through customer engagement and decision comfort on behavioural intentions (β = 0.0111, LLCI = 0.0054 ULCI = 0.0296) and also just through customer engagement (AR audio-enhancement -> Customer Engagement -> Behavioural Intentions) (β = 0.0500, LLCI = 0.0062 ULCI = 0.1113).

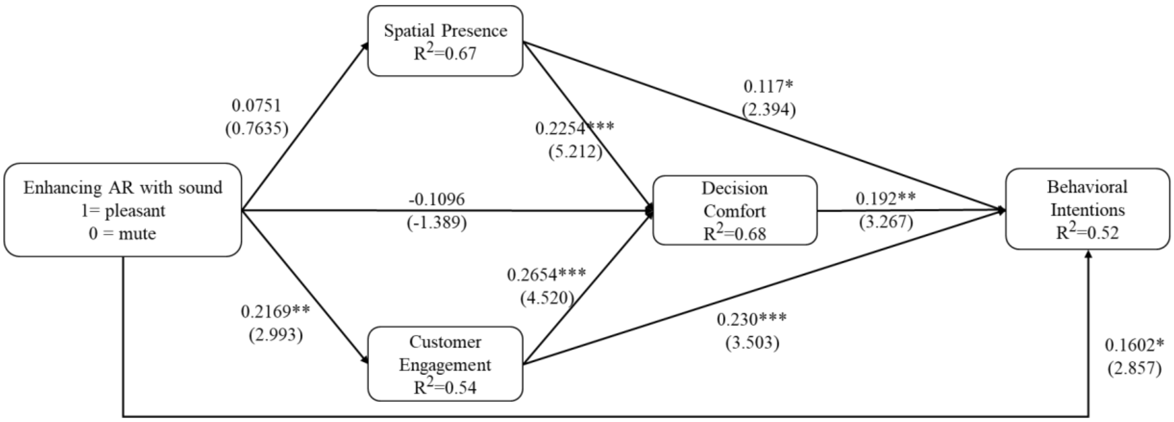

Figure 7: Enhancing with pleasant sound (Acoustic Guitar)

Note: + p < 0.1 * p < 0.05; ** p < 0.01; *** p < 0.001. The figures in parentheses are t values

Mediation Analysis (less pleasant vs. mute condition). The following model (Figure 8) is also run for data regarding acoustic guitar, in that it compares less pleasant sound with mute condition. To run this model, less pleasant sound study group was coded as 1 and mute as 0. An additional independent sample t-test (t (342) = -4.803, $p < .001$) and one-way ANOVA (F (342) = 23.066, $p < .01$) revealed a significant difference between the means of customer engagement for less pleasant group versus mute condition ($M_{lesspleasant}$ = 6.07, $SD_{lesspleasant}$ = 1.63 vs. M_{mute} = 6.78, SD_{mute} = 1.26). There is also a significant t-test (t (342) = 5.275, $p < .001$) and one-way ANOVA (F (343) = 19.244, $p < .01$) between means of behavioural intentions for pleasant sound group versus mute condition ($M_{lesspleasant}$ = 5.56, $SD_{lesspleasant}$ = 1.46 vs. M_{mute} = 6.34, SD_{mute} = 1.82). Moreover, there is no significant t-test (t (342) = -1.035, $p > .1$) and one-way ANOVA results (F (342) = 1.071, $p > .1$) between means of spatial presence for pleasant sound group versus mute condition ($M_{lesspleasant}$ = 6.57, $SD_{lesspleasant}$ = 1.60 vs. M_{mute} = 6.73, SD_{mute} = 1.50). We estimated the indirect effects of AR audio-enhancement using bootstrapping procedure with 5,000 samples and found a positive indirect effect of AR audio-enhancement through customer engagement and decision comfort on behavioural intentions (β = 0.0143, LLCI = 0.0104 ULCI = 0.0346).

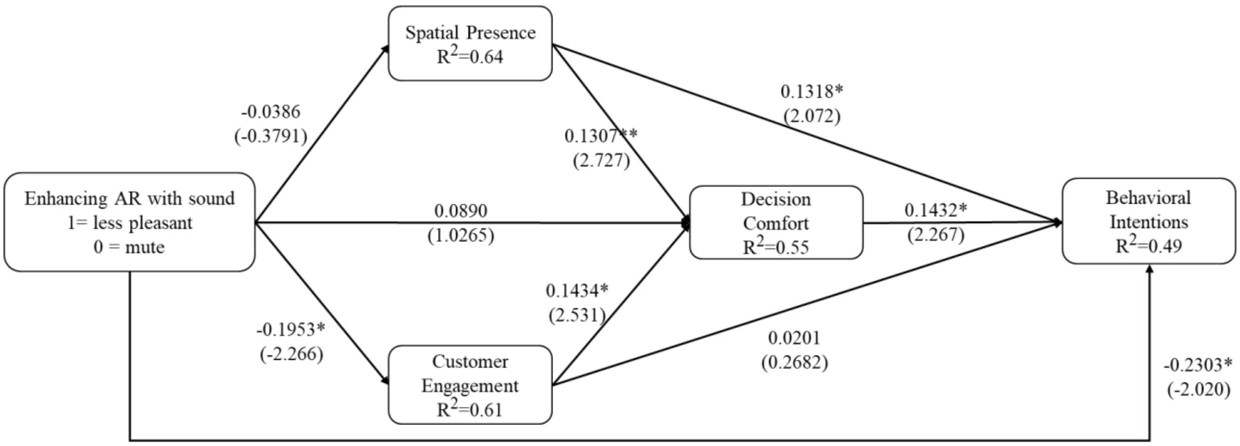

Figure 8: Enhancing with less pleasant sound (Acoustic Guitar)

Note: + p < 0.1 * p < 0.05; ** p < 0.01; *** p < 0.001. The figures in parentheses are t values

Portable Speaker:

Mediation Analysis (pleasant vs. mute condition). The following model (Figure 9) is for data regarding portable speaker, in that it compares pleasant sound with mute condition. To run this model, pleasant sound study group was coded as 1 and mute as 0. An additional independent sample t-test (t (275) = 3.777, $p < .001$) and one-way ANOVA (F (275) = 38.861, $p < .001$) revealed a significant difference between the means of customer engagement for pleasant group versus mute condition ($M_{pleasant}$ = 7.39, $SD_{pleasant}$ = 0.96 vs. M_{mute} = 6.46, SD_{mute} = 1.49). There is also a significant t-test results (t (275) = 5.275, $p < .001$) and one-way ANOVA (F (275) = 26.524, $p < .001$) between means of behavioural intentions for pleasant sound group versus mute condition ($M_{pleasant}$ = 7.25, $SD_{pleasant}$ = 1.26 vs. M_{mute} = 6.67, SD_{mute} = 1.25). Moreover, there is no significant t-test (t (275) = .600, $p > .1$) and one-way ANOVA results (F (275) = .360, $p > .1$) between means of spatial presence for pleasant sound group versus mute condition ($M_{pleasant}$ = 6.82, $SD_{pleasant}$ =

1.59 vs. M_{mute} = 6.73, SD_{mute} = 1.38). We estimated the indirect effects of AR audio-enhancement using the bootstrapping procedure with 5,000 samples and found a positive indirect effect of AR audio-enhancement through customer engagement and decision comfort on behavioural intentions (β = 0.0592, LLCI = 0.0145 ULCI = 0.1302) and also just through customer engagement (AR audio-enhancement -> Customer Engagement -> Behavioural Intentions) (β = 0.0629, LLCI = 0.0030 ULCI = 0.1412).

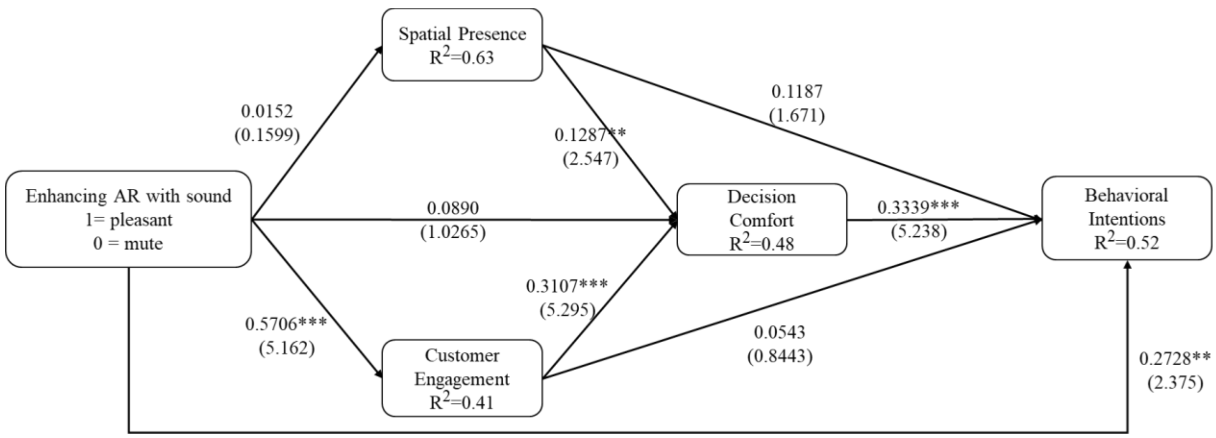

Figure 9: Enhancing with pleasant sound (Portable Speaker)

Note: + p < 0.1 * p < 0.05; ** p < 0.01; *** p < 0.001. The figures in parentheses are t values

Mediation Analysis (less pleasant vs. mute condition). The following model (Figure 10) is also run for data regarding portable speaker, in that it compares less pleasant sound with mute condition. To run this model, less pleasant sound study group was coded as 1 and mute as 0. An additional independent sample t-test (t (247) = -3.564, p < .001) and one-way ANOVA (F (247) = 11.572, p < .001) revealed a significant difference between the means of customer engagement for less pleasant group versus mute condition ($M_{lesspleasant}$ = 5.74, $SD_{lesspleasant}$ = 1.32 vs. M_{mute} = 6.46, SD_{mute} = 1.49). There is also a significant t-test results (t (247) = -4.275, p < .01) and one-way ANOVA (F (247) = 9.434, p < .01) between means of behavioural intentions for pleasant sound group versus mute condition ($M_{lesspleasant}$ = 5.92, $SD_{lesspleasant}$ = 1.16 vs. M_{mute} = 6.67, SD_{mute} = 1.25). Moreover, there is no significant t-test (t (247) = -2.262, p > .05) and one-way ANOVA results (F (247) = 5.071, p > .05) between means of spatial presence for pleasant sound group versus mute condition ($M_{lesspleasant}$ = 6.27, $SD_{lesspleasant}$ = 1.78 vs. M_{mute} = 6.73, SD_{mute} = 1.38). The bootstrapping procedure using 5,000 samples also showed a positive indirect effect of AR audio-enhancement through customer engagement and decision comfort on behavioural intentions (β = 0.0018, LLCI = 0.0033 ULCI = 0.0103).

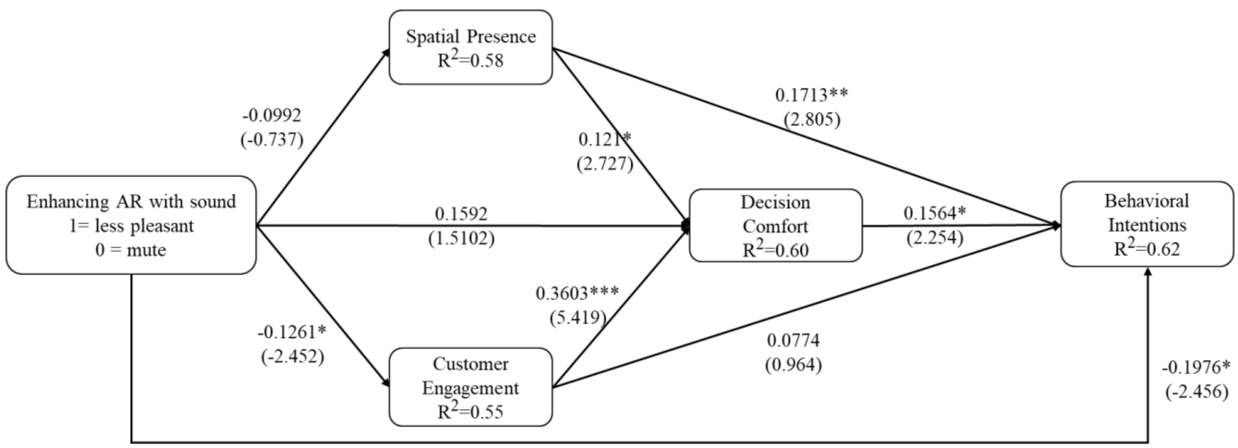

Figure 10: Enhancing with less pleasant sound (Portable Speaker)

Note: + p < 0.1 * p < 0.05; ** p < 0.01; *** p < 0.001. The figures in parentheses are t values

As it can be seen from the above analysis, some models show a significant direct path between customer engagement and behavioural intentions, whereas some models do not show this effect. Therefore, we do not rely on the indirect effect of AR audio-enhancement on behavioural intentions through customer engagement (AR audio-enhancement -> Customer Engagement -> Behavioural Intentions). Additionally, no significant effect of enhancing AR with sound was shown on spatial presence, showing no partial mediating effect through spatial presence and decision comfort (H3a). Therefore, we conclude that AR audio-enhancement is partially mediated only through the sequential mediating effect of customer engagement and decision comfort (in support of H3b).

To investigate hypotheses 4, we used Hayes Model 6 and we coded study groups with pleasant sound as 1 and study groups with less pleasant sound as -1. Results demonstrated a significant influence of sound pleasantness on customer engagement ($\beta = .241$, $p < .01$) and customer engagement on decision comfort ($\beta = .26$, $p < .01$). Moreover, sound pleasantness, customer engagement and decision comfort showed significant effect on behavioural intentions. These results show support for H4a and H4b:

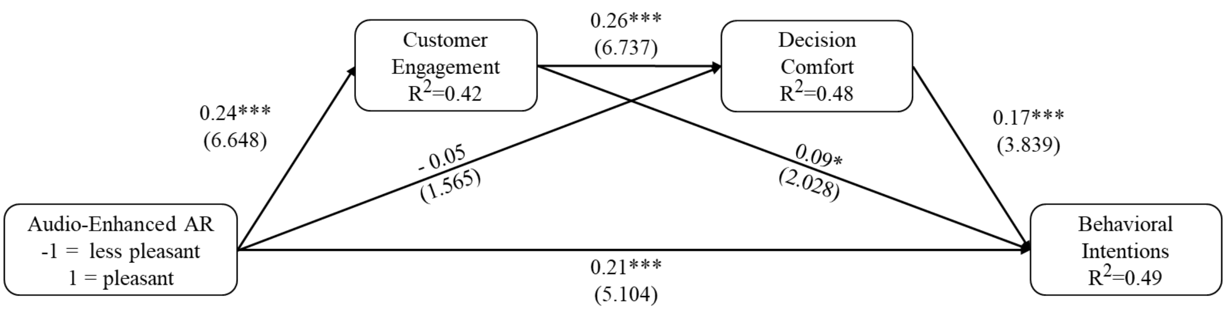

Figure 11: Audio-enhanced AR, comparing pleasant and less pleasant sounds

Note: + p < 0.1 * p < 0.05; ** p < 0.01; *** p < 0.001. The figures in parentheses are t values

5.3.2.3 Moderation analysis

It was initially hypothesized that sound controllability has a moderating effect on the effect of sound pleasantness on customer engagement (H5). To test the moderation effect of sound controllability, we used Hayes Model 83. Model 83 test for the mediating effects of customer engagement and decision comfort as well as the moderating effect of sound controllability on the relationship between sound pleasantness and customer engagement.

To analyze the data regarding sound controllability, a dummy variable was created and users who had control over the sound during their AR experience were coded as 1 and the users who did not have control were coded as 0. Findings show support of H5, in that sound controllability significantly moderates the relationship between sound pleasantness and customer engagement (β = .18, p = .0104). The conditional effects showed that sound pleasantness had a more significant, positive effect on customer engagement in the presence of sound controllability (β = .33, t (628) = 6.45, p < .01, LLCI = .2333, ULCI = .4374) compared the absence of it (β = .15, t (628) = 2.89, p < .05, LLCI = .0517, ULCI = .2489).

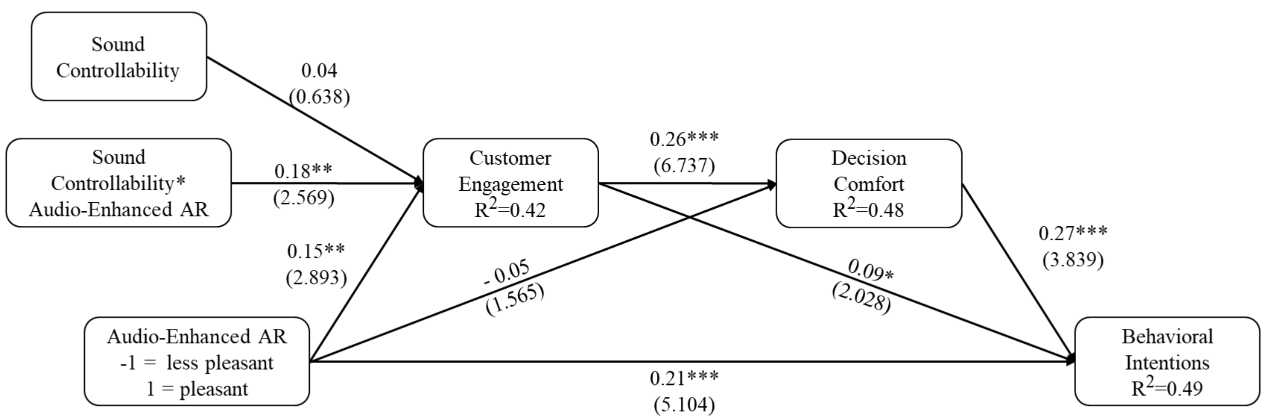

Figure 12: Moderation effect of Sound Controllability for both products (Acoustic Guitar & Portable Speaker)

Note: + p < 0.1 * p < 0.05; ** p < 0.01; *** p < 0.001. The figures in parentheses are t values

The corresponding plot show that in existence of sound controllability, the relationship between sound pleasantness and customer engagement in more intense and strengthened (Figure 13). This moderating effect also works for each product independently.

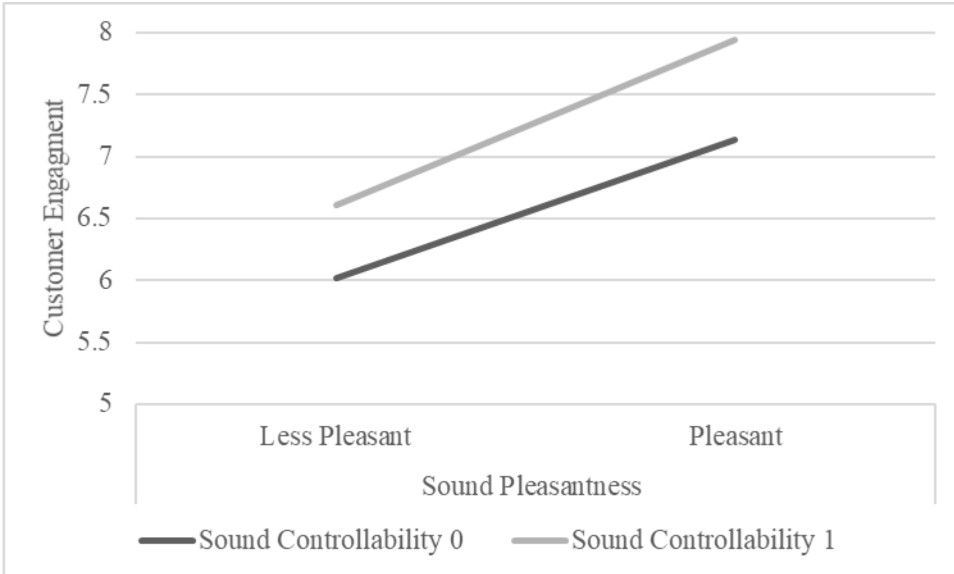

Figure 13: Effects of sound controllability on the relation between sound pleasantness and customer engagement

5.4 Summary

This chapter provided relevant data analysis for the proposed theoretical model and hypotheses along with the findings of the study, and also discussed the statistical methods used for data analysis. Overall, eight hypotheses were tested, six of which were supported by the data. First, Hypothesis 1 was partially supported by the data. It was initially hypothesized that enhancing AR with any sound can increase behavioural intentions in customers who interact with the AR environment, as the sound can play the role of a piece of information which helps customers for product trial and also, the sound increases the realness of the product trial, making it closer to a real shopping situation. However, data shows that sound pleasantness plays an important role in this relationship, such that people who hear pleasant sound have higher behavioural intentions and those who hear less pleasant sound will have lower behavioural intentions.

Additionally, data did not demonstrate significant effect of two indirect mediating paths (AR audio-enhancement -> decision comfort -> behavioural intentions) and (AR audio-enhancement -> spatial presence -> decision comfort -> behavioural intentions) showing no support for H2 and H3a. Thus, it can be concluded that enhancing AR with audio has only one indirect mediating effect, which is through customer engagement and decision comfort, in support of H3b.

As predicted, sound pleasantness has significant direct and indirect effect on behavioural intentions showing support for H4a and H4b. Sound controllability also had a significant moderating effect on the relationship between sound pleasantness and customer engagement. Therefore, hypothesis H5 was also supported.

Table 6: Tested Hypotheses and Results

Hypothesis	Results
H1: Customers searching for products through audio-enhanced AR will have higher behavioural intensions compared to the silent mode.	Partially Supported
H2: Decision comfort mediates the relationship between AR audio-enhancement and behavioural intentions.	Not Supported
H3a: The relation between AR audio-enhancement and behavioural intentions is sequentially mediated by spatial presence and decision comfort.	Not Supported
H3b: The relation between AR audio-enhancement and behavioural intentions is sequentially mediated by customer engagement and decision comfort.	Supported
H4a: Pleasantness of the sound in an audio-enhanced AR environment has a direct effect on behavioural intentions of the customers.	Supported
H4b: The effect of sound pleasantness on behavioural intentions is sequentially mediated by customer engagement and decision comfort.	Supported
H5: Direct effect of sound pleasantness on customer engagement is strengthened by sound controllability.	Supported

6. Discussion

This research explored the effectiveness of sound and its different components (i.e., sound pleasantness and sound controllability) in an AR shopping environment. It mainly investigated the mechanisms through which adding sound to an AR shopping environment can enhance customers' behavioural intentions during their shopping experience. Customer engagement and decision comfort were presented as two of the important underlying factors in this process, showing how sound sequentially affects customers' engagement with the AR environment, which influences their comfort in decision making, leading to higher behavioural intentions. Sound has both affective and informative effects on the shopping experience, influencing customers' affections, as well as providing them with information about the product. Customer engagement and decision comfort are both influenced by these aspects of the sound. We also introduced the moderating effect of sound controllability, which can enhance the shopping experience as well as behavioural intentions of the customers. Findings of this study advance marketing, online shopping, and augmented reality literature.

Previous chapters have presented a comprehensive literature review on augmented reality and its influence on the online shopping experience, as well as a complete review on sound and its effect as a marketing factor in influencing the shopping experience and arousing customers' affections. The following discussion contains a review of the study's objectives, a summary of key findings, and a detailed discussion regarding the meaning of these results. This chapter concludes by providing overall implications for theory and practice along with limitations and future research directions.

6.1 Review of Study Purpose

This study aimed to develop academic knowledge on audio-enhanced augmented reality and its purpose for online shopping apps. Almost all research regarding AR technology in marketing literature focuses on vision as the dominant sense and has investigated it from many aspects. However, according to many researchers, other sensory modalities may also affect the AR experience, which is worth investigating (e.g., Lavoye and Tarkainen, 2021). Auditory sensory modality is the second most important sense in human beings, which can significantly affect augmented reality experiences, but has been overlooked by the academic literature. In this research, we try to bring insights into how audio and auditory sensory can change the AR shopping experience by resembling the actual product trial; by influencing customers' affections and also increasing their knowledge about the product.

This study tried to understand how adding product sounds to an AR shopping app can influence customers' purchasing process and therefore their behavioural intentions. Drawing upon the active inference theory adopted from Heller et al. (2019b), we proposed that sound provides additional sensory control and feedback in an AR shopping experience, leading to a decreased mental intangibility in customers. When shopping online through an AR shopping app, customers try to gain sensory control and receive sensory feedback by projecting the AR hologram of the product in their own physical environment and observing it from different angles and resizing it. Adding sound to an AR environment increases the sensory control over the product (i.e., having the option to hear the product's sound and control its sound), and the customer gains additional sensory feedback from the product (i.e., understanding the product's sound).

In this study, we also tried to investigate the underlying mechanism of the relationship between AR audio-enhancement and behavioural intentions (i.e., customer engagement and decision comfort), as well as looking into two important sound components in an AR shopping app setting (i.e., sound pleasantness and sound controllability). We proposed that adding sound to an AR hologram leads to higher brain engagement in users, as the experience is enhanced with a sensory modality and brain functions through a combination of senses we receive from the outside world. Additionally, sound increases user decision comfort through both affective and informative aspects, as sound can increase our knowledge about the product and also influence our mood during the shopping session. Sound controllability was also proposed to have positive moderating effect on the shopping experience, as the customer's control over the product will be improved and sound control also increases touching experience in the AR environment.

6.2 Summary of Main Findings and Discussion

This study used the Zappar website, and Zappar augmented reality app to conduct the research. We also designed the AR shopping environment using ZapWorks Studio Software, developed by Zappar. Participants were recruited through Amazon MTurk and were asked to download the Zappar app on their smartphones. They were led to the AR environment using a link in the survey, which directly opened the AR app and presented them with the shopping environment. Participants were presented with a shopping scenario and were asked to observe the product in the AR environment to make a purchasing decision. Then, they were directed to the main survey, where they answered several questions regarding their overall experience and their behavioural intentions. The data from 926 usable responses were analyzed. The hypotheses were tested using SPSS.

Findings show that enhancing AR apps with sound can significantly influence behavioural intentions in customers who are shopping online. However, this effect remarkably depends on the level of sound pleasantness, in that enhancing AR with a pleasant sound increases customers' engagement with the AR app and their comfort in decision-making, leading to their intention to buy the product or recommend the shopping experience to family and friends. On the other hand, enhancing the AR app with a less pleasant sound decreases users' engagement with the app and their intention to use the app or buy the product.

The indirect path of sequential mediating effect through customer engagement and decision comfort was also approved, showing that adding sound to an AR environment, influences customers' engagement with the app and their decision comfort, leading to different levels of behavioural intentions in them. Data also showed that the level of pleasantness in sound can have positive or negative effects on behavioural intentions, both through the direct path, and the indirect path of (sound pleasantness -> customer engagement -> decision comfort -> behavioural intentions).

Data, however, did not show any effect of adding sound to AR hologram on spatial presence, nor any effect of sound pleasantness on spatial presence. Although the literature regarding augmented reality lacks appropriate research regarding the influence of sound on AR, literature in other domains such as computer science and virtual reality has investigated the influence of adding sound to a virtual environment and has proved that the integration of sound with virtual environments leads to higher levels of presence (e.g., Poeschl et al., 2013). Nevertheless, the current study shows no proof for such an effect, suggesting that enhancing AR with sound may act differently in this matter, and sound does not have a significant effect on the level of presence in AR environments.

Data also did not show any significant effect of AR audio-enhancement on behavioural intentions through the indirect path of decision comfort. The influence of adding sound to AR on decision comfort was only significant on some occasions where AR was enhanced with a less pleasant sound. Moreover, sound pleasantness had an insignificant but negative effect on decision comfort. According to this result, we conclude that enhancing AR with sound does not have any direct effect on decision comfort when the sound is pleasant. Yet, this effect can be significant when we have a less pleasant sound, and we predict that this is due to both affective and informative aspects of less pleasant sound, in that customers feel negative emotions about the product and shopping experience and gain knowledge about the sound of the product. This makes the decision-making process easier, in a way that they can decide they do not want to buy such a product or recommend this experience to others.

Sound controllability demonstrated a moderating effect in our second model on the effect of sound pleasantness on customer engagement and behavioural intentions, such that when having control over the sound, users were more engaged with the AR app and had higher behavioural intentions in the end. This suggests the importance of sound controllability in AR apps and in the process of online shopping. As previously discussed, sound controllability improves the sensory control in the AR experience and results in higher levels of touching experience in this environment. It also adds to the AR app's functionality, such that customers do not need to control sound using their phone's buttons.

6.3 Theoretical Implications

The present study contributes to the online shopping and augmented reality literature in many ways. First, the reported findings contribute to the existing literature regarding augmented reality and its usage in online shopping setting. Augmented reality has been widely studied in different categories (i.e., entertainment, education, shopping experience) and one of the most famous ones is its usage in e-commerce and the way it can ease product evaluation process, as it can visualize products in the customer's environment and assist product customization without the need for attending physical store (Tan et al., 2021). Most previous studies on AR usage in e-commerce have focused on vision as the dominant sense used to gain sensory information during product evaluation. This study showed the importance of the auditory sense in the AR context and how it can influence customers' AR experience as well as their behavioural intentions during shopping. The goal of enhancing AR with other senses, such as auditory and touch (multisensory AR) is to resemble an actual product evaluation situation which can help customers in a better way. The current research pointed out a simple yet inevitable aspect of a multisensory AR experience (audio), which needs further consideration. It tries to put further insight into the sensory experience of AR tools and address the importance of multisensory experience in e-commerce.

Second, this research proposed and tested the underlying mechanism of the relationship between AR audio-enhancement and behavioural intentions. It demonstrated how sounds can enhance customers' AR experience of online product evaluation through sequentially improving customers' engagement with the AR app and strengthening the sense of comfort in decision-making by enriching affective and informative aspects of the online shopping procedure, leading to different levels of behavioural intentions in the customers. This study also explored the effect of adding sound to an AR experience on the spatial presence and found that spatial presence is not affected when enhancing AR with audio. This can be an important contribution to the augmented reality literature, where spatial presence plays an important role. Although previous literature on augmented reality did not investigate how sound might influence spatial presence in an AR environment, literature on virtual reality and computer science has shown that sound can enhance the sense of spatial presence for users. As AR is different in the level of digital content the users are engaged with compared to other realities and computer games, we can conclude that the effect of sound on this environment is also different from others.

Third, this study investigated two important sound components (i.e., sound pleasantness and sound controllability) in the AR context and showed how these factors can influence the AR shopping experience for customers. Sound can induce a pleasant (versus annoying) moment for the customer, which can considerably influence affective and cognitive aspects of decision comfort, leading to different intentions in decision-making. This study points out the importance of sound pleasantness and its effect on the process of product evaluation and decision making, in that pleasant sounds induce a better feeling toward the product, and less pleasant sounds provide an uncomfortable experience. The current research also calls attention to the ability to control the sound in an AR experience. Many AR apps today do not take advantage of sound controllability in their environment. They are primarily not associated with a sound, and if they do, there is no control over the sound in their environment. In this research, I highlight that such add-on controllability can enhance customers' experience in an AR shopping app leading to more customer engagement during product evaluation.

6.4 Managerial Implications

We will soon live in a world where we can see digital holograms in our physical environment through eyeglasses and lenses. In this era, augmented reality technology can play an important role. This study can be helpful for managers, marketers, and advertisers who are eager to understand more about such technology and help us for a better transition to the digitally enhanced world.

First, this study has managerial implications for companies who offer online shopping apps with AR features. We propose that enhancing AR with the sound of products significantly influences customers' value perception of the product (Heller et al., 2019b). This research highlights the value of sound as an essential factor during product evaluation and how it can influence the shopping process through its informative and affective aspects. Previous research has demonstrated the mental intangibility barrier for customers in the online shopping context and how AR can resolve this problem (Hilken et al. 2017, Heller et al. 2019b). Along with the literature, our research emphasizes auditory sensory and how its absence can cause mental intangibility in product evaluations where sound plays an important role. Our findings clearly indicate that adding sound to an AR shopping experience increases sensory inputs received by the customers who are evaluating the product, which causes more brain engagement and consequently more customer engagement with the AR app. More importantly, we highlight that brain engagement also results in higher decision comfort, as customers have a more productive product evaluation process, meaning that sound does not directly result in decision comfort; it is through its effect on customer engagement that brings comfort for the users.

Second, along with the importance of sound, we highlighted the value of sound pleasantness, which needs considerable attention when equipping an AR environment with sound. App developers and marketers offering AR features in their shopping apps and are willing to equip their AR feature with audio need to consider the level of sound pleasantness in that environment. Although enhancing AR with sound can add an informative aspect to the shopping experience, an unpleasant or a less pleasant sound influences the affective aspect of the shopping experience, which then results in negative behavioural intentions in customers. This is not limited to products and AR shopping apps and can also include any type of AR experience and any type of sound, such as environmental sounds.

Third, as guidance to those responsible for designing AR shopping apps and app developers, we show the moderating influence of sound controllability on customer engagement. This research has investigated sound controllability in the context of e-commerce and highlights that controlling sound can add sensory control over product, leading to higher engagement with the AR app. According to the active inference theory, "sensory control over product focuses on minimizing a discrepancy between sensory feedback and mental representation at each point in time" (Heller et al. 2019b). Sound controllability can be considered a sensory control which helps customers in shaping a mental representation of the product and reduce their mental intangibility. Hence, our study emphasizes the importance of having control over the sound in an AR shopping environment, where sound is included.

6.5 Limitations and Future Research Directions

Although the findings of this research have important implications for academic researchers and practitioners, several limitations of the current study lead to opportunities for future research. First, this research was done remotely by recruiting participants from Amazon MTurk. Although most marketing-related studies are conducted using such a platform, in most AR-related studies, an in-person study was conducted along with it. The primary reason for using remote participants was limitations in accessing research facilities in the university during the COVID-19 pandemic and also the expense of conducting in-person experiments. The second reason was that we wanted the experiment to be the same as an actual shopping situation, in that customers use an AR shopping app to evaluate a product in their own comfortable space. However, even though the data from the MTurk panel was cleaned using multiple attention checks, it is still possible that MTurk respondents answered randomly to the questions of the survey. Therefore, we would recommend repeating this study both in an in-person setting and also in a remote setting using a different participant recruitment platform to compare the results with this study.

Second, this study used two products, both of which have sound as their core product. From a marketing perspective, a core product means a product's benefit or a need that a product resolves, which is the primary reason an individual buys that product. In his book, Kotler (1967) introduces three levels of a product and identifies the core product as the first level, followed by the actual product and the augmented product. He explains that the core product is not about the product itself but the utility it provides for the customer by using it. Hence, if the core product of a device is its sound, this means that the sound is the primary benefit of the product. However, enhancing AR with sound in the shopping context is not limited to products that have sound as their core product. Product sounds incorporate a large category of products, some of which have sounds that result from operating motors inside the device (i.e., operational sounds), or they may be intentionally added to a device and has informatory purposes (e.g., ringing sound of a clock). Therefore, to add to the generalizability of the results, we recommend that future research include other types of products with different product sounds.

This study was focused on enhancing AR with sound in a shopping context, as we believe sound can play an important role in the product evaluation process and shopping experience. However, enhancing AR with sound is not limited to products and shopping contexts. AR experiences are made in different ways using different types of holograms, such as Google’s AR experience, which shows animals in their natural sizes with augmented reality. Therefore, future studies can also consider enhancing AR with sound in other contexts and domains. Moreover, it is also important that future studies also consider sound as an environmental factor and investigate enhancing AR with environmental sounds. Although we did not find any significant effect on AR audio-enhancement on spatial presence, future studies that investigate environment sounds may find this relationship significant.

Third, this study investigated the effect of sound controllability in the context of e-commerce and argued that controlling sound can increase the sensory control over the AR hologram, leading to higher customer engagement and result in lower mental intangibility in customers (Heller et al., 2019b). However, the effect of sound controllability is not limited to the shopping context and can be implied to other types of AR experiences. However, we cannot generalize the effect of sound controllability in other AR experiences by relying on active inference theory (Heller et al., 2019b). This theory is focused on the value of gaining control over the product during product evaluation, and based on this theory, we have hypothesized the effect of sound controllability in the shopping context. Therefore, we suggest that future studies search for the effect of sound controllability in other contexts and explore how it can influence AR users' experiences.

Fourth, the AR environment which was designed for this study lacked some features that may not induce the experience of an AR shopping app. This was due to lack of professional skills in designing an AR environment. We believe the design of AR environment can better help in inducing the experience of online shopping. Therefore, we suggest that future studies repeat this study using an actual AR shopping app or design an AR environment this includes several components of a real shopping app.

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