Touching the Untouchable

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Touching the Untouchable: Exploring Multi-Sensory Augmented Reality in the Context of Online Retailing

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Abstract

Mental intangibility during product evaluation remains one of the greatest drawbacks for online purchasing. However, emerging multi-sensory Augmented Reality (m-AR) applications offer a potential solution for this online retailing problem. Drawing on active inference theory, this article proposes a conceptual framework to assess how sensory control and feedback modalities affect consumer value judgements by reducing mental intangibility. We show how touch control, compared to voice control, positively affects consumers' willingness-to-pay. The underlying mechanism is a sequential process of reduced mental intangibility and increased feeling of decision comfort. In addition, we highlight a positive moderating effect of congruent auditory feedback on decision comfort. We also demonstrate a novel consumer boundary condition. Consumers high in assessment orientation experience a stronger reduction in mental intangibility. The results are consistently replicated across three experiments implying theoretical and managerial contributions for m-AR in the context of online retailing.

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Introduction

Mental intangibility, or a consumer's inability to imagine the experience of using a product or service, remains a pertinent challenge to online retailers. Unlike traditional brick-and-mortar outlets where consumers can touch a product, online purchasing is generally not a sensory experience. This makes it more difficult for consumers to picture moving an IKEA lamp around in their study and evaluate its suitability and experience in use (Hultén et al. 2009). These sensory deficiencies decrease the perceived value of online offerings and frequently result in product returns and dissatisfaction with the purchase experience. When consumers decide to order a lamp online, it frequently appears

different when it is delivered and/or it is not how a consumer pictured it based on the limited sensory interaction offered in online environments (Ketron 2018).

This is corroborated by prior research that uncovered the effect of mental intangibility on evaluation of offerings (Laroche et al. 2004; McDougall 1987) and perceived risk (Laroche et al. 2005; Laroche et al. 2012). At the same time, a set of emerging technologies, collectively referred to as Augmented Reality (AR), offers the potential to overcome the undesirable impact of intangibility (Azuma 1997). From a sensory marketing perspective, all consumer experiences are based on sensory input of some sort (Krishna, Cian, and Sokolova 2016; Krishna 2013; Krishna 2012). Yet, emerging digital technology like AR has been mostly studied from a visual aspect, but the different control modalities of consumers' interactions with AR have so far been overlooked, despite the recent calls for further research (Petit, Velasco, and Spence 2019). Compared to other technologies (e.g., Virtual Reality (VR)), within retailing AR is more readily incorporated into consumers' day-to-day activities as it easily integrates with existing in-use devices, especially

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smartphones. Indeed, technology companies, such as Apple and Microsoft, steer developments towards AR as technology designed to enhance buying experiences by adding additional sensory dimensions, thereby redefining customer-retailer conversations (Leswing 2016; van Esch et al. 2016; Heller et al. 2016). From the latter's perspective, multi-sensory Augmented Reality (m-AR) blends the perception of a consumer's physical environment with digitally enhanced interactive visual, auditory and tactile sensory information. For instance, Mr. Spex, a German eyewear retailer, offers its online consumers an AR-based virtual try-on to facilitate selecting a pair of glasses (Hilken et al. 2017). Seeing how a virtual pair of glasses looks on her face, a consumer intuitively controls the point of view of the image with head movements. These movements generate sensory feedback that informs mental representation of experiential product use. Most mobile phone AR applications nowadays allow for control via swiping and pinching fingers using touch screens, while voice-based control for holograms and other interactive content is on the rise (Stambor 2017; Cowan et al. 2017). Cutting-edge technologies like Microsoft's HoloLens expand the range of sensory controls to include hand gestures, voice commands and gaze control (Kalantari and Rauschnabel 2018; Taylor 2016; Carrozzi et al. 2019). Based on the premise that multi-sensory interaction affects mental representation of experiential product use (Merel 2019), there is a pressing need for retailers to develop an in-depth understanding of m-AR and explore its role in alleviating the challenges of mental intangibility.

To address this need, we draw on emerging theorization on active inference (Friston 2012). This body of scholarship suggests that to express an evaluative judgment, such as the willingness-to-pay (WTP) for a product or service, consumers rely on sensory control and feedback inferred from their behaviour when interacting with an object. Our research reported here is based on the conjecture that m-AR's enhanced repertoire of sensory control (as opposed to non-enhanced virtual retail environments) offers an advantage in reducing mental intangibility when it comes to product evaluation. In order to explore this conjecture, there is a theoretical need to develop a specific understanding of control feedback modalities enabled through m-AR. We need further insights on the precise connection between m-AR sensory controls over a hologram (such as touch or voice) and the importance of sensory feedback when consumers gather information on a physically absent product. A further gap in the body of knowledge is that it is unclear whether one sensory control modality outperforms another, or whether m-AR control modalities affect consumer mental intangibility at all. Finally, we lack in-depth knowledge on how active inference contributes to consumer's feelings of decision comfort or, of particular relevance to a retailer, willingness-to-pay for a product.

It has been reported that some customers benefit more from active inference than others (Kardes, Posavac, and Cronley 2004). However, we possess limited knowledge with respect to the underlying causes that lead to observed heterogeneity. As consumers use active inference to reach a certain goal, such as carefully evaluating a product, people with a strong desire to compare different options should be strongly affected by

sensory control offerings of m-AR. Therefore, we explore regulatory mode that describes motivation towards assessment as an aspect of consumer self-regulation (Avnet and Higgins 2003). Customers with a strong assessment orientation are motivated to make the right decision. These individuals typically engage in greater information searches and more extensive comparisons (Mathmann et al. 2017). Since comparisons involve active inference, regulatory mode is relevant in the context of m-AR. However, the relation of active inference and regulatory mode theory has not been developed conceptually or examined empirically in the literature.

In order to address these gaps in our understanding, this article sets out to contribute to the retailing literature in three distinct ways. First, we theorize that m-AR behaviour is an active inference process, allowing us to focus on multi-sensory control and feedback loops that explain consumer value judgements, such as willingness-to-pay. To do so, we investigated specific sensory control modalities of touch and voice control, as well as multi-sensory feedback during m-AR shopping to show that consumers paid more because they felt more comfortable given congruent auditory feedback when interacting with a hologram. Second, we uncovered the role of mental intangibility and decision comfort as sequential mediators of the effect of sensory control modalities in WTP. Third, we investigated the role of consumers' assessment orientations in relation to m-AR's distinct sensory control modalities to account for observed heterogeneity in value judgements.

Conceptual Background & Hypotheses Development

Active Inference

Emerging thinking emphasises the important role that behaviour plays in information processing. Developing the notion of 'active inference', Friston (2018) argues that perception is an active process. That is, the mental representations (internal perceptions of a product) that serve to guide our evaluations, choices and, hence, goals are constantly updated through consumer's actions. Consumers will naturally handle, move and try products before purchase to generate sensory feedback that guides internal perceptions. For example, while evaluating a desk lamp in a physical store, a consumer will walk around, pick-up, turn upside-down, place in a different spot, walk away, come back, and switch on and off the lamp in an attempt to generate sensory feedback to update mental representation of the product. The theory posits that sensory control focuses on minimising a discrepancy between sensory feedback and mental representation at each point in time. The consumer does so by controlling both the feedback and the mental representation (Friston 2018). Thinking a chair will fit to a desk, a consumer controls feedback by moving the chair towards the desk only to realise the chair is too big. The discrepancy generated in this action changes the mental representation allowing the consumer to update a value judgement and ultimately re-consider purchasing the chair. Within the active inference framework, perception can be conceived of as a set of 'control and feedback loops' designed to initiate purposeful behaviour. The behaviour fol-

lows mental representations and through actions, updates those representations (Kessler and Thomson 2010), which reflect new evaluations and goals. For example, when inspecting a desk lamp, a consumer may flip a switch expecting a specific outcome. Based on sensory feedback of the brightness being as expected, then the mental representation is reinforced and the goal maintained. If brightness deviates (too bright or too dim) the mental representation is redefined, which modifies the perceived value of the product and affects future behaviour intentions.

Active Inference within a Retailing Context

From a sensory marketing perspective, the active inference concept readily translates to retailing. While ‘offline’ retailing supports consumers in their endeavours by providing opportunities for sensory control, online retailers lack the integrated multi-sensory control over products. Previous research noted the absence of sensory control modalities beyond visuals in the online environments (Childers et al. 2002; Eroglu, Machleit, and Davis 2001; Gallace et al. 2012). The absence of a physical product at the point of purchase naturally inhibits control and feedback loops and prevents a consumer from updating the mental representation of the product (Laroche et al. 2005). This can exacerbate mental intangibility (Laroche et al. 2005). The problem for online retailers is that consumers can only act on the product once delivered - meaning they initiate the process of updating the mental representation *after* the purchase. For consumers, this increases the chances of being disappointed and for retailers this can increase the volume of returns and negative feedback (Song and Kim 2012).

We argue that AR technology provides the necessary conditions to address these problems. While previous research revealed that AR outperformed traditional media due to its interactive and embedding features (Hilken et al. 2017; Javornik 2016), few researchers investigated the sensory aspects of AR. For example, wearable m-AR smart glasses embody rich digital information allowing consumers to manipulate and control holograms using various sensory modalities. Using hand gestures, consumers can ‘click’ on digital buttons and select products, move, or resize as they navigate through augmented environments with their hands. We propose that this replicates the range of controls that consumers can use for an active inference process. Furthermore, previous research shows that m-AR is perceived best when products are embedded and embodied in a consumer’s environment in a meaningful way (Hilken et al. 2018). By situating holograms in the physical environment, m-AR blends digital control and physical feedback across the same sensory modalities allowing the brain to integrate digital holograms into its representation of the environment. For example, placing a hologram of an IKEA chair next to a physical table creates a mental representation of the room that includes the hologram as an integral part. In this way, m-AR enables consumers to exercise the necessary control and feedback loops that reduce mental intangibility.

Fig. 1. Conceptual framework.

Augmenting Control and Feedback Loops in Active Inference

We further argue that m-AR extends the range of sensory controls and expands the boundaries of control and feedback loops as originally conceptualized in active inference. AR holograms offer functions beyond those of physical objects. Consumers can manipulate holograms and use sensory modalities not available in physical products. For example, m-AR smart glasses enable a consumer to not only move an IKEA chair across a room, but additionally change its colour or size. Furthermore, voice commands can be used to move a holographic chair. Although, these expanded options exceed those of the physical, we argue that the mechanism of active inference is maintained in m-AR. That is, the brain follows the same process of initiating actions and updating its mental representation through the feedback. As such, it creates a unified perception based on an unusual combination of sensory interactions. Accordingly, this offers novel opportunities to reduce mental intangibility and enhance consumer experiences. Understanding these expanded multi-sensory options will continue to gain in importance as modern m-AR glasses begin to digitise feedback processes across an increasing range of multi-sensory dimensions (Taylor 2016).

By describing active inference, we investigate the impact that sensory modalities have on a retailer’s success in an m-AR context. Our premise is that different forms of sensory control and feedback vary in the extent to which these affect mental product representations and impact consumer evaluation. In the context of retailing, we operationalize evaluation of a product as WTP. Interpreting active inference theory, we assume that controlling m-AR across multiple sensory modalities reduces mental intangibility by allowing the consumer an expanded range of actions that help verify his or her mental representation. As a mental representation develops, the discrepancy between the product’s performance and how the consumer anticipates it is minimised. Because discrepancy is a negatively valenced experience, we conjecture that mental intangibility likely suppresses decision comfort and ultimately WTP in m-AR retail settings. We present our conceptual model in Fig. 1.

In line with previous research we posit that the experience of holographic, interactive, three-dimensional visuals (as opposed to two-dimensional pictures, e.g., on online retailer websites) offer greater opportunity for active inference through both touch and voice control than traditional online retailers (Bonetti, Warnaby, and Quinn 2018; Hilken et al. 2017; de Ruyter, Keeling, and Ngo 2018).

A current trend in retailing is upgrading the retail frontline towards voice-based search assistants such as Amazon's Alexa or Google Assistant (Stambor 2017). Consumers can use voice commands for product interaction and evaluation, and according to recent forecasts, within the next five years fifty percent of all Internet product searches will be conducted using voice commands to navigate websites and interact with retailer's offerings (Billault 2018). Already today voice-commands are used by consumers in various interactions on their phones, in cars, or smart homes to control lights or thermostats (Aldrich 2003; Portet et al. 2013), yet for holographic product interaction, there has been no research on whether voice commands actually benefit the consumers' decision-making processes and in turn value perceptions.

Opposed to voice commands, currently consumers use their smartphones or computers to interact with holographic offerings. These involve controlling a hologram using swiping and pinching movements with fingers, pressing buttons with fingers or a computer mouse, yet hand-movements that resemble touch are not in use (Krishna 2011). Across prior studies (Hilken et al. 2017; Hilken et al. 2018; Poushneh and Vasquez-Parraga 2017; Hilken et al. 2019), consumers either viewed holograms through a mobile device (phone or tablet) or interacted with a hologram using the touchscreen of the device that resulted in higher value judgements compared to traditional media. From studies conducted outside of m-AR, we know touch can trigger impulse buying, reduce uncertainties and decrease perceived evaluation difficulties (Peck and Childers 2006; Peck and Wiggins 2006; Laroche et al. 2005). Previous research on touch showed that physically touching a product, or even imagining touching a product, could increase value perception of this product if it was inspected visually previously (Suzuki and Gyoba 2008). We argue that AR smart glasses offer an embodied way to touch the intangible holograms. These AR smart glasses allow a consumer to view a holographic product and act as if they are touching its physical counterpart using similar kinaesthetic movements without experiencing haptic feedback. Indeed, in order to touch a given product or its holographic representation, a consumer has to reach actively towards the product, control hand gestures and investigate the product. Therefore, the perception of controlling a (holographic) product, deciding when, where and how to investigate its features by establishing a direct connection with it using hand gestures, might explain how touch control can lead to higher value perceptions (Petit, Velasco, and Spence 2019; Spence and Gallace 2011).

Thus, m-AR allows consumers to simulate the touching experience in a physical and interactive context, as consumers move their hands to initiate control over the hologram and test the product features. Compared to other sensory control modalities such as voice commands, controlling holograms with hand gestures closely resembles the kinaesthetic aspects of touch and affects consumer perceived value and the WTP for a product (Gallace and Spence 2014; Ho et al. 2013; Gallace et al. 2012). Therefore:

H1. Holographic touch control (vs. voice control) increases WTP.

When the physical product to be evaluated is absent or product interaction is limited, consumers may struggle to form a tangible mental representation of the product. In other words, consumers are not able to formulate or update their mental representations adequately because they are isolated from the requisite sensory feedback. Consequently, buying a lamp online may feel 'intangible' as the consumer experiences uncertainty because they cannot directly act to generate feedback to test their mental representations of the product. Within the context of online retailing, the concept of 'mental intangibility' has been developed to encapsulate these difficulties in product and risk evaluations for consumers (Laroche et al. 2005; Laroche et al. 2012). Mental intangibility refers to the multi-sensory nature of product use. A product may be physically tangible but without direct experience, the sensory nature is hard to grasp mentally (Mazaheri et al. 2014). Due to mental intangibility, consumers often fail to have a clear, defined mental representation of the product they are going to purchase (Laroche et al. 2004). Importantly, a body of scholarship suggests that mental intangibility increases the perceived complexity of the buying process, resulting in feelings of discomfort and a higher chance of postponing the purchase (Breivik and Troye 2015; Nepomuceno, Laroche, and Richard 2014; Laroche et al. 2005; Eggert 2006).

Mental intangibility in a retailing context reflects the fact that a consumer is not able to ensure a clear and vivid correspondence between sensory experience of a real product and a mental simulation of such experience. Laroche et al. (2012) define mental intangibility as deficiency in multi-sensory representation of a product. As a consequence, consumers find that mentally intangible products require a higher processing effort (McDougall 1987), are harder to evaluate (Laroche et al. 2005), and that purchasing comes with higher perceived risk (Wilson et al. 2012). One of the major differences between online and offline retailing environments contributing to mental intangibility is undoubtedly the lack of truly multi-sensory experiences, given that online retailing primarily focuses on visual features (Petit, Velasco, and Spence 2019). Consequently, an important aspect of consumer decision making when buying a product, namely the ability to touch a product to obtain information, is missing (Krishna 2011). Importantly, touch as a sensory control is executed to obtain haptic information and kinaesthetic properties (Peck 2011). The active inference of embodied sensorimotor actions that resemble touch in m-AR retailing become a critical sense to reduce consumers' mental intangibility of a product. Consumers see touch as a discovery sense, and the sensory-motor experiences of virtually touching an object often illicit the feeling that the object is more tangible than an object that is only seen (Taylor, Lederman, and Gibson 1973; Heller 1982). Therefore, controlling a hologram with hand gestures should induce the feeling of tangibility, despite the absence of actual haptic sensations. We thus posit that controlling a hologram with touch control (vs. voice control) will reduce mental intangibility of a product.

Extant literature signals that an effect of mental intangibility is increased perceived risk and evaluation difficulties in retail environments (Nepomuceno, Laroche, and Richard 2014; Mazaheri et al. 2014; Laroche et al. 2005). Touch control inher-

ent to m-AR increases a consumer's assurance of its sensory properties. Consequently, feeling of decision comfort is an evaluation of the degree of mental intangibility. That is, tangibility is evaluated with a feeling of comfort, and intangibility with discomfort in a decision. We further argue that the correspondence between the consumer's mental representation and sensory perception of the product is increased through trial and error of the product features using touch control (Friston 2012). A resulting feeling of comfort provides an evaluation that mental intangibility is low, and this becomes a signal to behaviour (Bechara and Damasio 2005). When consumers perceive product representations as tangible, they feel more at ease, or more comfortable, when deciding on whether to purchase the product. The consumer's affective sense of feeling at ease when making a choice, termed decision comfort, has been highlighted as an important aspect of retailing experiences in general (Parker, Lehmann, and Xie 2016) and in AR experiences in particular (Heller et al. 2019; Hilken et al. 2017). In our context, decision comfort is a necessary part of the affective behaviour control process that translates mental representations to behaviour intentions. We argue that behavioural intentions sequentially flow from decision comfort. Therefore:

H2. The relationship between holographic touch control and WTP is sequentially mediated such that touch control reduces mental intangibility which leads to higher decision comfort, which in turn leads to higher WTP.

Consumers have different motivations to engage with active inference and vary in the accuracy required from their mental representations and perceptions (Friston 2009). Regulatory mode theory suggests that consumers adopt one of two independent orientations when pursuing a goal such as searching for product information, namely an assessment or locomotion orientation (Kruglanski et al. 2000). While locomotion orientation is mainly concerned with moving on during the decision-making process, the assessment-oriented consumer will extend the decision process in order to progress to the right decision. Literature suggests that consumers with locomotion orientation do not value comparison or in-depth evaluation of products when making a decision and thus locomotion should not affect the relation between sensory control and mental intangibility. In addition, locomotion orientation is often referred to as 'just do it', indicating that consumers with a locomotion orientation complete activities such as product evaluation at a very high pace and a high level of decisiveness (Kruglanski et al. 2013). Both these attributes of the locomotion orientation indicate that locomotors should not be affected by the sensory control that m-AR offers. Consumers that have a high assessment orientation choose to carefully learn as much as possible about a product and handling it to receive sensory input (Kruglanski et al. 2013). Assessors are occupied with making comparisons between options aimed at finding the 'right' option and usually a desire for perfection accompanied with anxiety for possible errors (Kruglanski et al.

2013; Kruglanski et al. 2000).¹ A modality of the product interaction that is different from what a consumer is used to can disrupt task focus or flow of a product interaction and raise negative concerns (Avnet and Higgins 2003). In the case of m-AR and using augmented sensory control to assess a product's features, controlling a hologram with hand gestures resembles a control modality that is closer to an actual, familiar kinaesthetic touch experience than voice control. Thus, the fit-to-task modality of augmented touch control should result in lower anticipated regret, self-evaluative thoughts and negative concerns for consumers high in assessment, whilst not negatively affecting consumers with a low assessment orientation. Hence, we hypothesize:

H3. The effect of holographic touch control on mental intangibility is stronger for participants that are high in assessment orientation.

Active inference relies primarily on visual feedback to for various forms of sensory control in m-AR. However, m-AR retailing is not limited to visual feedback. Consumers may be exposed to additional forms of sensory feedback, such as auditory feedback, allowing for truly multi-sensory feedback that combines feedback from different senses. When it comes to auditory feedback, sounds elicited when consumers touch or use many everyday objects typically convey potentially useful information regarding the product itself (Spence and Zampini 2006). Auditory feedback, when present in isolation, has been shown to be informationally rich enough for consumers to assess attributes such as size, shape or surface material of a product (Giordano and McAdams 2006; Grassi 2005). A growing body of literature supports the notion that adding auditory feedback during product interaction has a strong effect on the perception and evaluation of these products (Petit, Velasco, and Spence 2019; Petit et al. 2015; Hagtvedt and Brasel 2016). For example, when consumers had to evaluate an electronic mixer, the absence of sound resulted in negative evaluations as the mixer was not perceived as powerful, strong and functional (Cox 1967). In comparison to solely visual feedback, the simultaneous presence of multi-sensory cues (i.e., visual and auditory feedback) provides additional guidance during the product inspection and assists in m-AR product evaluation. However, since touch control is primarily responsible for the reduction in mental intangibility, we propose that the addition of complementary and synchronized auditory feedback creates redundancy of feedback in another sensory modality.

Because visual feedback is the dominant form of sensory feedback in m-AR, it is likely that adding auditory feedback may not necessarily affect mental intangibility. As intangibility is driven by the lack of physical haptics in an offering (Carter and Gilovich 2012; Laroche, Bergeron, and Goutaland 2001), it should not be strongly affected by the presence or absence of acoustic feedback. Nevertheless, the redundancy of feedback can act as confirmation to the dominant visual feedback mode,

¹ Based on research by Kruglanski et al. (2009) we expect a prevalence of predominant locomotors in our samples.

which should improve a consumer's confidence in that information. This would likely be reflected in increased decision comfort. Hence, the simultaneous presence of visual and auditory feedback, resulting in multi-sensory feedback, can present an alternative route to decision comfort independent of the product's mental intangibility. Thus, auditory feedback as an enabler for multi-sensory feedback offers an additional explanation on how consumer decision comfort might be increased further when using touch control to interact with holographic offerings. As touch control is hypothesized to impact mental intangibility directly and auditory feedback presumably only plays a significant role for consumer's assurance of comfort, we hypothesize:

H4. The effect of touch control on decision comfort will be moderated by multi-sensory feedback, such that decision comfort will be higher if multi-sensory feedback is present.

Empirical Studies

We designed four experiments to sequentially test the aforementioned hypotheses by extending the number of variables per study as illustrated in Fig. 1. In Study 1, we tested whether augmented touch control (vs. voice control) led to higher decision comfort and the underlying mediating mechanism of mental intangibility. Furthermore, we explored the moderating role of assessment on the relationship of touch control and mental intangibility. In Study 2, to establish serial mediation throughout our model, we tested the proposition that augmented touch control (vs. voice control) led to higher WTP (H1) which was sequentially mediated by mental intangibility and decision comfort (H2). Additionally, we showed that the effect of touch control was stronger for assessors (H3). In Study 3, we replicated Study 2 and introduced a different product as well as another WTP measure. In Study 4, we explored the serial-mediation process established in Study 3 and introduced auditory feedback as an additional moderating variable.

Equipment

Augmented reality smart glasses offer seamless control feedback mechanisms that allow consumers to simulate truly multi-sensory experiences in retailing environments. At the time of the data collection for this study, the Microsoft HoloLens was one of the first m-AR smart glasses available that allowed users to embed AR holograms into physical environments and manipulate these via different sensory control mechanism (Taylor 2016). The HoloLens had not been released to retailing environments and multi-sensory software on the device was limited. Thus, we used an application on the device, Microsoft's Holostudio to allow for multi-sensory interaction with holograms. Holostudio allows users to initiate sensory control over AR holograms such as repositioning, resizing and 360-° rotation. The HoloLens technology allows for spatial mapping of the environment, which results in holograms realistically sitting on surfaces such as a floor or a table, instead of floating through the room. For the studies, participants had augmented sensory

control (touch vs. voice) over a wooden chair (Study 1 & 2) and a desk lamp (Study 3 & 4). The choice of the stimulus material was in line with (Heller et al. 2019) who identified the chosen stimulus as products that required context to be evaluated. Participants wearing the HoloLens could resize the AR holograms, use full 360-° spherical rotation, adjust the product's position or move it anywhere in the room. In addition to the visual feedback that was treated as a constant in all studies, the HoloLens allowed for congruent auditory feedback using the integrated stereo speakers (Study 4).

Study 1

Participants and Design

To investigate our conceptual model that included a serial-mediation process, we designed Study 1 to establish the link between the independent variable touch control (vs. voice control) and mental intangibility and decision comfort. We employed a between-subject experiment with two sensory control modalities: Touch control vs. voice control. In Study 2, we introduced the dependent variable WTP and tested whether the relationships found in Study 1 held. A total of 139 undergraduate and students (71% female, average age = 21.36) completed the experiment at a dedicated laboratory. Participants were compensated with gift vouchers.

Measures

Across all studies, we used mental intangibility and decision comfort as covariates to test for mediating effects. We measured mental intangibility prior to decision comfort. We measured mental intangibility using a seven-point Likert scale ("strongly disagree" = 1 to "strongly agree" = 7) with five items such as "I need more information about this item to make myself a clear idea of what it is" or "This is not the sort of item that is easy to picture" by Laroche, Bergeron, and Goutaland (2001). We used the construct developed by Parker, Lehmann, and Xie (2016), a six item construct on a seven-point Likert scale (1 = "strongly disagree" to 7 = "strongly agree") to measure decision comfort (e.g. "I was satisfied with my experience of deciding which option to choose"). Last, we measured assessment using a twelve item instrument on a six-point scale by Avnet and Higgins (2003). All scale items are presented in Appendix A.

Materials and Procedure

Participants were informed they would interact with AR holograms using wearable AR technology and later complete a questionnaire. Participants were randomly distributed to either one of the control groups and received training tutorials in the form of pre-recorded videos to learn how to fit the HoloLens on their head as well as how to use the sensory control mechanisms (either touch or voice). Participants could control the HoloLens with hand gestures (touch control condition), by pointing their fingers on the hologram and tapping their index finger on their thumb, which would result in the hologram following their hand

movements until the fingers were released again. The other form of control that one group of participants had available was a selection of previously defined voice-commands (voice control condition). For example, participants could see the holographic product in front of them and say “Bigger” or “Move this” to initiate resizing or position adjustment of the hologram. Participants could watch the tutorials as often as they wanted and only after they indicated understanding of how to use the HoloLens would they be allowed to move on in the study. At the end of the tutorials, participants read the following instructions: “Imagine you need a new chair to study late at night as you have heard that it helps reducing back pain. You found a good chair online and the online retailer offers you to have a look at the chair in Augmented Reality. The chair looks like in the picture below. The retailer is testing this new technology and you are selected to be one of the first users to try it.” Afterwards, each participant was fitted with a HoloLens headset by a research assistant and asked to confirm that they could see the holograms in front of them as well as indicating if they felt confident controlling the holograms. The participants then received a list with several tasks that resembled the control actions a consumer usually would undertake to assess the product at hand. Participants were told to move the hologram from one point of the floor to another, resize and rotate the hologram and move it next to a physical table in the laboratory to gain perspective in order to resize it to a real-sized chair. A research assistant monitored each participant’s interaction with the holograms on a dedicated computer in the laboratory to ensure participants followed the instructions and to help participants if technical problems occurred.

Manipulation Check

To assess our augmented sensory control modality manipulations, participants rated two three item measures (Touch control: e.g., “I could select the hologram using my hands/fingers” or “I could move the hologram around using my hands” vs. Voice control: “I was able to control the hologram with my voice” or “I could move the hologram using my voice”) on seven-point Likert scales (“strongly disagree” = 1 to “strongly agree” = 7). Principal components analysis and reliability checks revealed that both manipulation check measures were reliable one-component constructs (Touch control: $\alpha = .93$, Voice control: $\alpha = .79$). As suspected, participants in the touch condition perceived significantly higher touch control than participants in the voice condition (Touch control_{Touch} = 6.45, Touch control_{Voice} = 3.91, $t(137) = -16.73$, $p < .001$). Similarly, participants in the voice condition perceived substantially higher voice control than participants in the touch condition (Voice control_{Voice} = 5.85, Voice control_{Touch} = 2.63, $t(137) = 15.45$, $p < .001$). In addition to the manipulation checks for the different control conditions, we also measured whether all participants could perceive the visual aspects of the hologram using a seven-point three-item Likert scale (“I was able to see the hologram”, “The hologram was visible to me from all angles”, and “I did not see anything” (reverse scored)). The construct (Visual feedback: $\alpha = .79$) did not differ between the two sensory control modalities (Visual feedback_{Touch} = 5.23, Visual feedback_{Voice} = 6.35,

Fig. 2. Study 1 – Effects of AR control with low or high assessment on mental intangibility.

$t(137) = -0.52$, $p > .1$). The results of the manipulation checks indicated that the manipulation worked as intended and that the modality of control did not impact the visual perception of the holograms. We report all manipulation check constructs, the full list of items, and the Cronbach’s alphas for each Study in Appendix B.

Results

To investigate the underlying mediating mechanisms prior to evaluation of our full mediation model, we first solely elicited our mediating variables and the moderator without our main dependent variable. We used the PROCESS macro (Hayes 2017, Model 7). Model 7 regresses decision comfort on sensory control modality (touch vs. voice) with mental intangibility mediators and assessment as a first-stage moderator. We found a significant negative effect of touch control on mental intangibility ($\beta = 1.99$, $p < .05$) while the effect on decision comfort was not significant ($\beta = .18$, $p > .1$). However, mental intangibility negatively predicted decision comfort ($\beta = -.28$, $p < .01$). In addition, we found a significant interaction effect of sensory touch control and assessment on mental intangibility ($\beta = -.75$, $p < .01$). The explained variance of mental intangibility was $R^2 = .23$, whereas the value for the dependent variable decision comfort was $R^2 = .19$. A floodlight analysis revealed a Johnson–Neyman significance region value of 3.27, which corresponded to a region 80.58% of the sample and below. The negative moderation effect is highlighted in Fig. 2 and visualises that high assessors benefit from a stronger reduction in mental intangibility when using touch control, whereas there is no significant difference for voice control.

We estimated the indirect effects on decision comfort using a bias-corrected bootstrapping procedure with 5,000 samples. These results found a significant positive indirect effect of touch control through mental intangibility on decision comfort for participants in the high assessment group ($\beta = .38$, LLCI = .17, ULCI = .62) but not for the low assessment participants ($\beta = .10$, LLCI = -.05, ULCI = .27). The index of moderated mediation for the indirect effect of touch control through mental intangibility on decision comfort was significant, resulting in moderated-mediation ($\beta = .20$, LLCI = .05, ULCI = .38).

Study 2

Participants and Design

To investigate our hypotheses 1–3, namely the effect of touch vs. voice control on WTP, its underlying sequential mediating mechanism, and the role of assessment orientation as a moderator, we replicated Study 1 and included the dependent variable WTP. A total of 108 undergraduate students from a subject pool (60% female, average age = 23.04) completed the experiment at a dedicated laboratory. Participants were compensated with gift vouchers.

Measures

We used the same measures as well as order of measures as in Study 1 and added the dependent variable WTP. WTP was measured with the questions “How much would you be willing to pay for the chair?” followed by a sliding scale from \$0 to 250 AUD.

Materials and Procedure

The design of the materials and experimental process were the same as in Study 1.

Manipulation Check

To assess our augmented sensory control modality manipulations, participants rated two three item measures (Touch control: e.g., “I could select the hologram using my hands/fingers” or “I could move the hologram around using my hands” vs. Voice control: “I was able to control the hologram with my voice” or “I could move the hologram using my voice”) on seven-point Likert scales (“strongly disagree” = 1 to “strongly agree” = 7). Principal components analysis and reliability checks found that both manipulation check measures were reliable one-component constructs (Touch control: $\alpha = .89$, Voice control: $\alpha = .97$). As suspected, participants in the touch condition perceived significantly higher touch control than participants in the voice condition (Touch control_{Touch} = 6.10, Touch control_{Voice} = 3.79, $t(106) = -8.75$, $p < .001$). Similarly, participants in the voice condition perceived substantially higher voice control than participants in the touch condition (Voice control_{Voice} = 6.61, Voice control_{Touch} = 3.35, $t(106) = 14.29$, $p < .001$). In addition to the manipulation checks for the different control conditions, we also measured whether all participants could perceive the visual aspects of the hologram using a seven-point three-item Likert scale (“I was able to see the hologram”, “The hologram was visible to me from all angles”, and “I did not see anything” (reverse scored)). The construct (Visual feedback: $\alpha = .67$) did not differ between the two sensory control modalities (Visual feedback_{Touch} = 5.98, Visual feedback_{Voice} = 6.19, $t(106) = 1.502$, $p > .1$). The results of the manipulation checks determined that the manipulation worked as intended and that

Fig. 3. Study 2 – Effects of AR control with low or high assessment on mental intangibility.

sensory control modality did not impact the visual perception of the holograms.

Results

First, to investigate H1, we conducted a GLM with sensory control modality as a factor and WTP as a dependent variable. We find a significant main effect of touch control on WTP ($\beta = 9.34$, $t(106) = 3.04$, $p < .01$) supporting H1. For the touch control conditions, participant WTP (measured in \$AUD) was significantly higher than for the voice control condition ($M_{\text{Touch}} = 31.16$, $SD_{\text{Touch}} (19.22)$ vs. $M_{\text{Voice}} = 18.95$, $SD_{\text{Voice}} = 11.76$). To investigate our hypotheses 1–3 in a comprehensive model, we used the PROCESS macro (Hayes 2017, Model 83). Model 83 regressed WTP on sensory control modality (touch vs. voice) with mental intangibility and decision comfort as sequential mediators and assessment as a first-stage moderator. We found a significant negative effect of touch control on mental intangibility ($\beta = 3.26$, $p < .05$) while the effect on decision comfort was not significant ($\beta = .26$, $p > .1$). However, mental intangibility negatively predicted decision comfort ($\beta = -.55$, $p < .01$). Importantly, supporting H2, WTP was positively affected by decision comfort ($\beta = 3.89$, $p < .01$) and touch control ($\beta = 7.55$, $p < .05$), which resulted in partial sequential mediation. In addition, we found a significant interaction effect of sensory touch control and assessment on mental intangibility ($\beta = -.87$, $p < .01$). The explained variance of mental intangibility was $R^2 = .29$ and for decision comfort $R^2 = .47$, whereas the value for the dependent variable WTP was $R^2 = .23$. A floodlight analysis revealed a Johnson–Neyman significance region value of 4.32, which corresponded to a region 82.41% of the sample and below. The negative moderation effect is highlighted in Fig. 3 and supports H2 indicating that high assessors benefit from a stronger reduction in mental intangibility when using touch control, whereas there is no significant difference for voice control.

We estimated the indirect effects on WTP using a bias-corrected bootstrapping procedure with 5,000 samples that found a significant positive indirect effect of touch control through mental intangibility and decision comfort on WTP for participants in the high assessment group ($\beta = 4.81$, $LLCI = 1.71$, $ULCI = 9.90$) but not for the low assessment participants ($\beta = 1.29$, $LLCI = -.83$, $ULCI = 4.18$). The index of moder-

ated mediation for the indirect effect of touch control through mental intangibility and decision comfort on WTP was significant, resulting in moderated sequential-mediation ($\beta = 2.90$, LLCI = .52, ULCI = 7.04).

Discussion

We provide evidence for hypotheses 1–3. Supporting H1, we demonstrated that touch control led to higher WTP when interacting with a hologram. Supporting H2, consumer decision comfort, partially through reduction of mental intangibility during the consumer's evaluation process, was significantly higher when holograms of products were controlled using touch control that influenced WTP. Specifically, touch control led to significantly higher decision comfort as compared to voice control. Supporting H3, we identified the relationship between sensory control modalities and assessment orientation as a moderator and revealed that high assessors experienced a stronger reduction in mental intangibility.

Study 3

To replicate the findings from Study 2, we repeated the experiment using a similar design with two distinct differences. First, we changed the product from a chair to a desk lamp to investigate whether a product in the same category (home/office furniture & supplies) would produce similar results. In addition, we extended Study 3 by introducing another WTP measure to strengthen the managerial relevance of the results (H1/H2).

Participants and Design

We employed the same between-subject experiment with two sensory control groups as in Study 2. A total of 106 undergraduate students (68% female, average age = 21.58) completed the experiment at a dedicated laboratory. Participants were compensated with gift vouchers.

Measures

The measures from Study 2 were used as well as a different (incentivised) WTP measure. To measure the perceived value of the lamp, we followed an established managerially relevant WTP procedure (Avnet and Higgins 2003; Mathmann et al. 2017) that asked participants how much they would be willing to spend for this lamp, were they to actually buy the lamp (Appendix B). This measure created an incentivised design, where participants spent a portion of their participation money to actually buy the product.

Materials and Procedure

The design of the materials and experimental process were the same as in Study 2 except for the lamp as a new product. After the tutorial and before moving to the HoloLens tasks, participants read the following scenario: "Imagine you need a new desk lamp to study late at night as you have heard that it helps your eyes

when reading. You found a good lamp online and the online retailer offers you to have a look at the lamp in Augmented Reality. The lamp looks like in the picture below. The retailer is testing this new technology and you are selected to be one of the first users to try it." The subsequent task to evaluate the product was similar as in Study 2.

Manipulation Check

We employed the same manipulation checks as in Study 2 with similar and expected results. Participants in the touch condition perceived significantly higher touch control than participants in the voice condition ($\text{Touch control}_{\text{Touch}} = 6.51$, $\text{Touch control}_{\text{Voice}} = 4.79$, $t(104) = -3.79$, $p < .01$). Similarly, participants in the voice condition perceived substantially higher voice control than participants in the touch condition ($\text{Voice control}_{\text{Voice}} = 5.98$, $\text{Voice control}_{\text{Touch}} = 3.54$, $t(104) = 8.33$, $p < .01$). As in Study 2, we ensured that all participants could see the visual aspects of the holograms and that the conditions did not affect the visual perception of the hologram, which was not the case in this study ($\text{Visual feedback}_{\text{Touch}} = 4.63$, $\text{Visual feedback}_{\text{Voice}} = 5.03$, $t(104) = 1.503$, $p > .1$).

Results

We again used Model 83 to calculate the sequential-mediation analysis including the interaction effect of sensory control and assessment on mental intangibility in one comprehensive statistical model (Hayes 2017). Similar to Study 2, we found a negative effect of touch control on mental intangibility ($\beta = 2.79$, $p < .01$) as well as positive direct effect of touch control on WTP ($\beta = 15.01$, $p < .01$). Mental intangibility emerged again as the sole negative predictor of decision comfort ($\beta = -.32$, $p < .01$) and did not directly influence WTP ($\beta = .68$, $p > .1$). Most importantly, decision comfort positively predicted WTP ($\beta = 12.74$, $p < .01$), again supporting H2 and partially explained the increase in WTP via touch control by the sequential mediating variables mental intangibility and decision comfort. In addition, the negative interaction effect of touch control and assessment on mental intangibility, as in Study 2, was significant ($\beta = -.98$, $p < .01$). The explained variance of the mediator mental intangibility and decision comfort was $R^2 = .19$ and $R^2 = .23$ respectively, whereas the value for the dependent variable WTP was $R^2 = .20$. A floodlight analysis revealed a Johnson–Neyman significance region value of 3.26, which corresponded to a region 68.88% of the sample and below.

We estimated the indirect effects on WTP by means of a bias-corrected bootstrapping procedure with 5,000 samples. This resulted in a significant positive indirect effect of touch control through mental intangibility and decision comfort on WTP for participants in the high assessment group ($\beta = 5.07$, LLCI = 1.65 ULCI = 10.44) but not for the low assessment participants ($\beta = .33$, LLCI = -2.16, ULCI = 2.50). The index of moderated mediation for the indirect effect of touch control through mental intangibility and decision comfort on WTP

was significant, resulting in moderated sequential-mediation ($\beta = 3.97$, LLCI = .95, ULCI = 9.23).

Discussion

The results of Study 3 replicated our findings and revealed that sensory touch control significantly increased WTP for a product inspected in m-AR. This effect was partially explained by a reduction of mental intangibility for the product which in turn increased decision comfort. Additionally, the replication of the results from Study 2 with a different product increased the validity of our model. Last, we highlighted that it is important for retailers to consider the sensory control modalities for product previews in AR as it can significantly impact revenue streams.

Study 4

We designed Study 4 to introduce sensory feedback (H4) and to investigate further the effects of sensory retailing experiences. The previous two studies showed the effects of different sensory control modalities on consumer decision comfort and spending behaviour isolated from all sensory feedback except visual. For both previous and this upcoming study, visual feedback (seeing the holograms) was treated as a constant, as it was not possible to experience AR without seeing a hologram. In this study, we introduced auditory feedback.

Participants and Design

A total of 136 undergraduate students (68% female, average age = 21.49) participated in the experiment. We employed a 2 (Sensory Control: Touch control vs. Voice control) $\times$ 2 (Sensory Feedback: Sound on vs. Sound off) between-subjects experimental design. We removed six participants from the sample due to technical difficulties (i.e., they could not see and/or control the hologram).

Materials and Procedure

The design of this study matched Study 3 with the exception of randomly assigning participants to the condition of sensory feedback. In the sensory feedback condition in which participants did not receive any auditory feedback (similar to Study 1, 2 and 3), the volume of the HoloLens was set to 0%. In the other condition, the volume of the HoloLens was set to 100% which resulted in auditory feedback for both sensory control conditions. Participants could hear a “clicking” sound like a mouse click when selecting a hologram or releasing it at any position in the room. In addition, when using their hands (or voice control) to move, resize or rotate the hologram, auditory feedback (next to the constant visual feedback) indicated to the participant that the control was activated.

Manipulation Check

We employed the same manipulation checks as in previous experiments and added another measure to check

the success of the sensory feedback manipulation. Participants in the touch condition perceived significantly higher touch control than participants in the voice condition (Touch control_{Touch} = 6.50, Touch control_{Voice} = 4.49, $t(128) = 4.40$, $p < .01$). Similarly, participants in the voice condition perceived substantially higher voice control than participants in the touch condition (Voice control_{Voice} = 5.85, Voice control_{Touch} = 3.67, $t(128) = 8.06$, $p < .01$). As in the previous two experiments, we ensured that all participants could see the visual aspects of the holograms and that the conditions did not affect the visual perception of the hologram, which was not the case in this study (Visual feedback_{Touch} = 4.65, Visual feedback_{Voice} = 4.95, $t(128) = 1.253$, $p > .1$). The auditory feedback manipulation was tested using a reliable ($\alpha = .96$) self-developed one-component manipulation check with three items (e.g. “I could hear sounds from the HoloLens”). Participants in the “Sensory feedback: Sound on” condition perceived significantly higher auditory control feedback than participants in the “Sensory feedback: Sound off” condition, which resulted in a successful and strong manipulation (AuditoryFeedback_{On} = 6.18, AuditoryFeedback_{Off} = 1.67, $t(128) = 37.67$, $p < .01$). A 2x2 ANOVA using the two conditions as fixed factors led to insignificant interaction effects for all conditions.

Results

To test the complete conceptual framework including H4, we again used PROCESS v3.0 (we customized Model 83 to allow for an additional moderator) to calculate our conceptual model (Fig. 1). As in previous studies, we found a negative effect of touch control on mental intangibility ($\beta = 4.67$, $p < .01$). Mental intangibility still negatively predicted decision comfort ($\beta = -.28$, $p < .01$), while it did not influence WTP directly ($\beta = 1.35$, $p > .1$). Again, decision comfort was the only predictor for WTP ($\beta = 9.17$, $p = .0687$) while all other variables and interactions remained insignificant. The negative interaction effect of touch control and assessment on mental intangibility replicated in this study ($\beta = -1.33$, $p < .01$). The explained variance of the mediator mental intangibility and decision comfort was $R^2 = .56$ and $R^2 = .47$ respectively, whereas the value for the dependent variable WTP was $R^2 = .41$. A floodlight analysis revealed a Johnson–Neyman significance region value of 3.66, which corresponded to a region 82.31% of the sample and below.

Most important, to support H4, we found a significant positive interaction effect of touch control and auditory feedback on decision comfort ($\beta = .58$, $p < .05$). The conditional effects showed that auditory feedback (“Sound on”) had a significant, positive effect on decision comfort in the touch control condition ($\beta = .86$, $t(124) = 4.32$, $p < .01$, LLCI = .46, ULCI = .1.25). No auditory feedback (“Sound off”) had no significant effect on decision comfort ($\beta = .27$, $t(124) = 1.35$, $p > 0.1$, LLCI = $-.13$, ULCI = .67). We illustrate the interaction effect in Fig. 4.

We estimated the indirect effects on WTP using a bias-corrected bootstrapping procedure with 5,000 samples to estimate the indirect effect of touch control through mental intangibility and decision comfort on WTP. We found a positive significant indirect effect for participants in the high

Fig. 4. Study 4 – Effects of auditory feedback with voice or touch control on decision comfort.

assessment group when sensory feedback was absent ($\beta = 5.23$, LLCI = .33, ULCI = 12.14) and present ($\beta = 6.40$, LLCI = 1.26, ULCI = 14.24). However, we did not find a significant indirect effect for the low assessment participants when sensory feedback was present ($\beta = 1.19$, LLCI = $-.34$, ULCI = 3.58) and absent ($\beta = .30$, LLCI = -1.58 , ULCI = 1.95).

Discussion

Study 4 replicated the results of the three previous studies and found supporting data for H4. While auditory feedback, if present, positively affects decision comfort for touch control, it does not affect decision comfort negatively for the voice control condition. It is also important to note that auditory feedback does not directly affect mental intangibility. We interpret this effect as follows: Consumers use various methods of sensory control in product interactions to reduce uncertainties such as mental intangibility of a product. Augmented touch control, as previously established, reduces mental intangibilities that translate into decision comfort. Acoustic feedback, in addition to visual feedback (treated as a constant across all studies), acts as a complementary cue that eases decision-making independently of the tangibility of the product. The synchronised occurrence of sensory feedback provides a complementary pathway to decision comfort. Thus, auditory feedback solely moderates consumer's feeling of decision comfort.

General Discussion

In modern online retailing environments, retailers are constantly striving to overcome the lack of sensory inputs and emerging digital technology can attract consumers by creating multi-sensory experiences (Petit, Velasco, and Spence 2019). While AR was investigated previously in retailing primarily from a visual perspective (Hilken et al. 2018, 2017), these results support the notion that AR can enable truly multi-sensory online retail environments by combining various sensory control and feedback modalities into a consumer's retail experience. Thus, retailers need to approach m-AR as a multi-sensory technology and carefully assess different modalities of control and feedback mechanisms, as well as a combination of these, when aiming to optimize their online retail environments with the help of AR technology.

Theoretical Implications

We investigated the role of m-AR technology in the context of online retailing by focusing on the problem of mental intangibility. Mental intangibility, or the inability by the consumer to mentally represent distant experiences with a product, is a significant barrier to online shopping, costing the retail industry in product returns and negative feedback (Song and Kim 2012). Drawing on active inference theory (Friston 2012, 2018), we argue that the lack of multi-sensory control and feedback within the online context exacerbates mental intangibility. Uncertainty inherent in the potential discrepancy between a mental representation of a product bought online and the sensory experience when it is delivered reduces comfort of online decision-making and restricts consumer's WTP. We posit that m-AR that blends the perception of a consumer's physical environment with digitally enhanced interactive visual, auditory and tactile sensory information directly addresses this problem via the active inference process because it expands multi-sensory control and resulting feedback within the online context. We conducted multiple experiments using the Microsoft's HoloLens m-AR technology to provide empirical evidence that within the online retailing context consumer behaviour could be made to approximate an active inference process and improve consumers' value judgements.

First, our theorising positions consumers' interactions with m-AR holograms as active inference. The technology allows consumers to apply sensory control and generate sensory feedback by controlling holograms in a physical environment and supports the natural process of testing and updating of mental representation. With regard to control, we show that choice of sensory control modality matters. Kinaesthetic touch control of holographic products can significantly increase WTP in comparison to another sensory control modality, namely voice commands. We argue that this is because the m-AR touch control effectively simulates the natural kinaesthetic aspects of touch that consumers use as an integral part of mental representation testing. With regard to feedback, we demonstrated that the presence of congruent auditory feedback positively moderated the effect of touch control on decision comfort. This work contributes to the body of multi-sensory marketing literature by highlighting that for AR, different sensory control modalities paired with different sensory feedback have a strong effect on consumers' experience and behaviour. Additionally, we show that AR whilst being a visual technology per-se, can be multi-sensory in terms of control and feedback mechanisms during the consumer experience. We demonstrated the effect of both control modality on consumer product evaluations and also congruent sensory feedback on consumer decision comfort in a m-AR online retailing (Spence and Zampini 2006). Our findings offer the first insights for managers and academics about the importance of sensory control and feedback mechanisms for m-AR environments to alter consumers' feelings of comfort and value judgements.

Second, we revealed how the process of multi-sensory control reduces mental intangibility and sequentially improves decision comfort in m-AR retail environments. The sequential link

between mental intangibility and decision comfort emerges as an important mediating mechanism across all our studies. This result contributes to literature on mental intangibility (Laroche et al. 2004; Laroche et al. 2005) as well as decision comfort (Spake et al. 2003; Parker, Lehmann, and Xie 2016) and offers a way to connect these two literature streams in the context of online retailing and as a result of multi-sensory experiences. Our findings consistently show the positive effect on WTP, highlighting the importance of low mental intangibility and the resulting increases in decision comfort for online retailer's revenue streams in m-AR.

Third, we investigated a relevant consumer boundary condition based on regulatory mode theory. We theorised that active inference via m-AR in online retail settings was relevant for high assessment-oriented consumers (i.e., those concerned with making comparisons to arrive at the right decision). We compared the interaction between sensory control modalities and consumers' high versus low assessment orientations. Our results affirmed the hypothesis that consumers with a high assessment orientation experienced less mental intangibility in m-AR with touch control as compared with voice control. This was in line with our predictions that touch control offered a realistic fit-to-task modality, which offered a stronger reduction in intangibility than voice control for consumers with a high assessment orientation. As consumers with a high assessment orientation are more self-evaluative and often experience negative concerns when interacting with an unusual control modality such as voice control, they respond better to touch control (Pierro et al. 2012). These results are, to the best of our knowledge, the first findings that contribute to the topic of how consumers' underlying assessment orientations can explain a preference for a specific sensory control modality in m-AR retailing environments.

Implications for Retailers

We propose that touch control, versus voice control, significantly increases consumer value perception for a product presented in an m-AR online retailing context. This highlights the potential caveats of the current upgrading of online retailing environments towards voice-based search assistants such as Amazon's Alexa or Google Assistant (Stambor 2017). As such it is important to determine the specific ways in which voice control offerings (for example, cognitive tasks such as making search tasks more accessible) versus touch control can be beneficial for consumers. In the context of m-AR product interactions, we showed that sensory control that closely resembles kinaesthetic aspects of actual product interactions significantly outperformed voice control for consumer value perception of a product, expressed in the WTP. Consideration should be given to the design of task-appropriate controls.

First, the kinaesthetic nature of touch control, which resembles aspects of interactions with a physical product, outperform voice control in terms of consumer value perceptions. This is crucial for managers to understand when developing AR applications at the retailing frontline to optimize outcomes towards retailing-relevant variables. Since these technologies are in development stage (i.e., at the time of our studies) our results

can help managers decide which sensory controls to invest in in order to maximise customers' value perceptions. Arguably, it is also important for a manager to know which sensory control is not a good investment, or, rather, not to assume that all sensory controls have utility in all decision contexts.

Second, we show that sensory touch control leads to reduced perceived mental intangibility that subsequently increases decision comfort. Previous research has shown that mental intangibility is a considerable problem for consumers, especially in online retailing, and that customers' decision comfort is a managerially relevant outcome for retailers, as it subsequently can affect utilitarian and hedonic experiences (Hilken et al. 2017) as well as WOM (Heller et al. 2019). Our findings clearly indicate that integrating m-AR in online retail environments offers a substantial advantage beyond hedonic experiences and affective responses (Hilken et al. 2017; Javornik 2016) by reducing mental intangibility that has been a problem for online retail environments for decades (Breivik and Troye 2015; Laroche et al. 2005; Laroche, Bergeron, and Goutaland 2001). As a result, consumers feel more comfortable in their decision making, which has been shown to impact consumer choice as well as positive WOM towards the retailer (Heller et al. 2019), whilst our results highlight the positive impact on consumers' WTP in m-AR online retail environments. More importantly, we show that an increased feeling of comfort is necessary to result in higher WTP for consumers, and that a reduction of intangibility alone does not have a direct effect on WTP. Similarly, m-AR does not affect decision comfort directly; it affects mental intangibility.

Third, as guidance to those responsible for designing m-AR interfaces within a retail context, not all consumers respond equally to m-AR online retail environments. We highlighted that understanding consumer fit was important, by noting that touch control had the strongest effect for consumers with a high assessment orientation, while consumers with low assessment orientations did not respond negatively to touch control. There are several studies (Mathmann et al. 2017; Kruglanski et al. 2013; Avnet and Higgins 2006; Avnet and Higgins 2003) that indicate the consumer characteristics of an assessment orientation. These studies suggest that when retailers develop segmentation strategies, managers can identify high assessors in various practical ways. Doing so in m-AR is relevant as these consumers benefit most from reduced intangibility inducements by touch control. Additionally, studies indicated that customers could be primed to be in an assessment orientation state with advertisements (Mathmann et al. 2017; Mannetti et al. 2009). Retailers are encouraged to segment m-AR control and feedback mechanisms as part of their sensory-enabled retailing offerings to maximize consumer decision-confidence and comfort (Grewal, Roggeveen, and Nordfält 2017; de Ruyter, Keeling, and Ngo 2018).

Limitations and Future Research

Across all four experiments, participants in our studies were students, digital natives and familiar with online shopping. While the samples in our studies represented an important target group for retailers seeking to augment their online retail

environment, future research must investigate how demographics, experience with online retailing and m-AR applications and focal tasks affect the impact on value judgements. For example, is it likely that digital natives may be more open to voice controls as a novel sensory control, whilst other generational groups may prefer touch control? Or is it the focal-task that is more important in determining receptivity to sensory control modalities? To further shine lights on the empirical results revealed in our studies, future research could explore research methods beyond laboratory experiments, such as analysing verbal protocols or focus groups.

Relatedly, to illustrate the active inference process in m-AR, our research focuses on two distinct sensory control modalities, touch control versus voice control. Previous research highlighted the overall importance of controlling holograms in retailing experience, thus concluding that different types of control modalities held important implications for retailers (Hilken et al. 2017). Yet, m-AR offers combinations of sensory modalities that go beyond usual sensory experience in physical settings. Future research should investigate other combinations of control modalities such as gaze control. In our studies we restricted modalities in the interest of experimental control; however, the effect of giving consumers multiple sensory control modalities to choose from when evaluating products was relevant. It would be interesting to investigate if and how choice of multiple control modalities impacts consumer-decision making in m-AR. One possibility is that the scope of AR flexibility in manipulating features might outperform, in terms of customer responses, physical versions of a product; especially given the physical limitations of store space to house all versions of a product. This aspect of AR could unfold additional opportunities for retailers to increase ROI of AR technology not just from augmenting the consumer experience but reducing the physical product offerings.

In line with current limited availability of sensory control modalities, we investigated the effect of visual feedback (treated as a constant across all studies) and auditory feedback in an m-AR retailing experience. Auditory feedback was measured as a dichotomous variable that indicated presence or absence of auditory feedback. Combining existing research on different types of auditory feedback (Biswas, Lund, and Szocs 2019) and other sensory feedback modalities, such as olfactory feedback, might add richness to our understanding of m-AR. Further investigations along different types and modalities of sensory feedback hold potential theoretical as well as managerial relevance (Heller et al. 2019). For example, it would be interesting to investigate the effects if consumers had access to different sensory controls and feedbacks, simultaneously. Furthermore, the content of sensory feedback, such as auditory responses, could vary from realistic utilitarian sounds to hedonic sounds that alter a consumer's experience. Future research should investigate when consumers prefer certain controls or feedbacks, and how the content of different sensory feedback conditions alters value judgements.

We highlight the consumer boundary condition of assessment orientation. While previous studies showed that assessment orientation could be primed by managers (Mathmann et al. 2017), future research should investigate whether these primes hold for

AR experiences. In addition, further consumer boundary conditions likely exist and these could include, but are not limited to, the need for touch (Peck 2011; Peck and Wiggins 2006; Peck and Childers 2003), awareness of scents (Smeets et al. 2008) or different processing styles (Wyer, Hung, and Jiang 2008). In addition, managers have a significant interest in understanding what product offerings benefit most from m-AR and in particular, which control and feedback modalities impose the strongest effects on consumers' value judgements (de Ruyter, Keeling, and Ngo 2018). Only if online retailing offers truly multi-sensory augmented experiences will consumers experience minimal mental intangibility and, in turn, feel comfortable in value judgements that benefit retailers for years to come. Executive summary

Mental intangibility, or a consumer's inability to imagine the experience of using a product or service, remains a pertinent challenge to online retailers. Unlike traditional brick-and-mortar outlets where consumers can touch a product, online purchasing is generally not a sensory experience. This is corroborated by prior research that uncovered the effect of mental intangibility on evaluation of offerings (Laroche et al. 2004; McDougall 1987) and perceived risk (Laroche et al. 2005, 2012). Recently, a set of emerging technologies, collectively referred to as Augmented Reality (AR), offers the potential to overcome the undesirable impact of intangibility (Azuma 1997). Compared to other technologies (e.g., Virtual Reality (VR)), within retailing AR is more readily incorporated into consumers' day-to-day activities as it easily integrates with existing in-use devices, especially smartphones. Multi-sensory Augmented Reality (m-AR) blends the perception of a consumer's physical environment with digitally enhanced interactive visual, auditory and tactile sensory information. Based on the premise that multi-sensory interaction affects mental representation of experiential product use (Merel 2019), there is a pressing need for retailers to develop an in-depth understanding of m-AR and explore its role in alleviating the challenges of mental intangibility.

We conducted multiple experiments using the Microsoft's HoloLens m-AR technology to provide empirical evidence that within the online retailing context consumer behaviour could be made to approximate an active inference process and improve consumers' value judgements. First, our theorising positions consumers' interactions with m-AR holograms as active inference. The technology allows consumers to apply sensory control and generate sensory feedback by controlling holograms in a physical environment and supports the natural process of testing and updating of mental representation. With regard to control, we show that choice of sensory control modality matters. Kinaesthetic touch control of holographic products can significantly increase WTP in comparison to another sensory control modality, namely voice commands. With regard to feedback, we demonstrated that the presence of congruent auditory feedback positively moderated the effect of touch control on decision comfort. This work contributes to the body of multi-sensory marketing literature.

Second, we revealed how the process of multi-sensory control reduces mental intangibility and sequentially improves decision comfort in m-AR retail environments. The sequential link

between mental intangibility and decision comfort emerges as an important mediating mechanism across all our studies. This result contributes to literature on mental intangibility (Laroche et al. 2004, 2005) as well as decision comfort (Spake et al. 2003; Parker, Lehmann, and Xie 2016) and offers a way to connect these two literature streams in the context of online retailing and as a result of multi-sensory experiences.

Third, we investigated a relevant consumer boundary condition based on regulatory mode theory. Our results affirmed the hypothesis that consumers with a high assessment orientation experienced less mental intangibility in m-AR with touch control as compared with voice control. This was in line with our predictions that touch control offered a realistic fit-to-task modality, which offered a stronger reduction in intangibility than voice control for consumers with a high assessment orientation.

Appendix A. Overview of constructs and measurements

Construct	Items
Mental intangibility (Laroche, Bergeron, and Goutaland 2001)	I need more information about this item to get a clear idea (image) of what it is. This is a difficult item to think about. This is not the sort of item that is easy to picture. I am comfortable with choosing this [product].
Decision comfort (Parker, Lehmann, and Xie 2016)	I feel good about choosing this [product]. I am experiencing negative emotions about choosing this [product]. ® Whether or not it is “the best choice,” I am okay with choosing this [product]. Although I don’t know if this [product] is the best, I feel perfectly comfortable with the choice I made. I never evaluate my social interactions with others after they occur. ® I spend a great deal of time taking inventory of my positive and negative characteristics. I like evaluating other people’s plans. I often compare myself with other people. I don’t spend much time thinking about ways others could improve themselves. ® I often critique work done by myself or others. I often feel that I am being evaluated by others. I am a critical person. I am very self-critical and self-conscious about what I am saying. I often think that other people’s choices and decisions are wrong. I rarely analyse the conversations I have had with others after they occur. ® When I meet a new person, I usually evaluate how well he or she is doing on various dimensions (e.g., looks, achievements, social status, clothes).
Assessment (Avnet & Higgins 2003)	

® = reverse scored.

Appendix B. Manipulation checks

Construct	Cronbach’s alpha	Item
Sensory control (touch)	Study 1 0.93	I could virtually touch the hologram
	Study 2 0.89	I could rotate the hologram using my hands/fingers
	Study 3 0.94	I could move the hologram around using my hands
	Study 4 0.93	
Sensory control (voice)	Study 1 0.79	I was able to control the hologram with my voice
	Study 2 0.97	I could rotate the hologram using voice-commands
	Study 3 0.92	I could move the hologram using my voice
	Study 4 0.91	
Sensory feedback (visual)	Study 1 0.79	I was able to see the hologram
	Study 2 0.67	The hologram was visible to me from all angles
	Study 3 0.72	I did not see anything ®
	Study 4 0.83	

® = reverse scored.

Appendix C. Willingness-to-pay measure

Imagine you would get the opportunity to buy the lamp. The price you pay is up to you; it can vary from \$1 to any amount you think the lamp is worth. If you would not like to buy the lamp for any price, please indicate zero.

However, imagine on the next page you would find the price of the lamp, which you would see later. If you offer a price that is more than or equal to the price on the next page, then you will get the lamp. If the price you offer is below the price on the next page, then you do not get the lamp and keep your money.

So how much would you be willing to pay for the lamp?

Notes: Measured on a slider, indicating prices from AUD \$0 to 250.

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Further reading

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