Touching Products Virtually: Facilitating Consumer Mental Imagery with Gesture Control and Visual Presentation

Yang (Alison) Liu
National University of Singapore
15 Computing Drive, Singapore 117418
yangliu@comp.nus.edu.sg

Zhenhui (Jack) Jiang
The University of Hong Kong
Pokfullam Road, Hong Kong SAR
and
National University of Singapore
15 Computing Drive, Singapore 117418
jiangz@hku.hk

Hock Chuan Chan
National University of Singapore
15 Computing Drive, Singapore 117418
chanhc@comp.nus.edu.sg

Touching Products Virtually: Facilitating Consumer Mental Imagery with Gesture Control and Visual Presentation

YANG (ALISON) LIU, ZHENHUI (JACK) JIANG, HOCK CHUAN CHAN

YANG (ALISON) LIU (liuyang@u.nus.edu) is a Research Fellow in the Department of Information Systems & Analytics at National University of Singapore. Her research interests include online consumer behavior, human computer interaction, algorithmic decision making, and digital innovation. Her work has appeared and received best paper award in top Information Systems conferences, such as ICIS.

ZHENHUI (JACK) JIANG (jiangz@hku.hk; corresponding author) is a professor of Innovation and Information Management at Faculty of Business and Economics, the University of Hong Kong. He is also a professor of Information Systems and Analytics at School of Computing, National University of Singapore. His research interests include social media, visual analytics, e-commerce, information privacy, and human-computer interaction. His work has been published in top Information Systems journals, such as MISQ, ISR, JMIS, and JAIS, and top Computer Science conferences, such as CHI. He currently serves as an SE of JAIS and AE of ISR and has served on the editorial board of MISQ and IEEE TEM.

HOCK CHUAN CHAN (chanhc300@gmail.com) is an Associate Professor in the Department of Information Systems and Analytics at National University of Singapore. He works on information systems, human computer interaction and healthcare IT. His work has been published in top Information Systems journals, such as MISQ and ISR. He has served as an associate editor for MIS Quarterly and was on the editorial board of Journal of Databased Management and AIS Transactions on Human-Computer Interaction.

Abstract

Gesture-based interaction has greatly changed the way in which we interact with online products by allowing users to control digital systems with hand movements. This study investigates how gesture-based interaction modes, namely, mid-air gesture and touchscreen gesture, compared with mouse-based interaction, affect consumers' virtual product experiences (VPE) by eliciting mental imagery (i.e., haptic imagery and spatial imagery). Furthermore, we explore how visual product presentation can be designed to facilitate different types of interaction modes. Through a lab experiment, we find that touchscreen gesture outperforms mid-air gesture and mouse-based interaction in terms of eliciting haptic imagery, and this effect is mitigated when 3D presentation is used. We also find that mid-air gesture outperforms touchscreen gesture and mouse-based interaction in terms of eliciting spatial imagery when 3D presentation is used. Both haptic imagery and spatial imagery can further reduce consumers' product uncertainty. Our results extend prior work on interactivity design of VPE and further contribute to the emerging literature on gesture-based interaction.

Keywords: virtual product experience, gesture-based interaction, grounded cognition, mental imagery, product presentation

Introduction

Online retail sales have steadily increased over the past decade. A recent report from eMarketer predicted that by 2020, the e-commerce industry will surpass $4 trillion and will account for 14.6% of all consumer retail spending [30]. Although people are becoming increasingly accustomed to online shopping, the lack of physical experiences with products still creates barriers for consumers in making informed decisions, resulting in uncertainty, dissatisfaction and product returns [33, 39]. Hence, it is important to explore innovative ways to create a realistic and immersive online shopping experience. Indeed, researchers and practitioners have endeavored to improve consumers' virtual product experience (VPE), which is defined as the process by which consumers interact with and learn about products in a virtual environment [18, 42, 98]. For example, many retailers allow consumers to browse and interact with products by touching, swiping, and dragging on touchscreens. Furthermore, innovative retailers, such as Marks & Spencer and Topshop, have recently deployed virtual reality applications and virtual mirrors in their physical stores, and customers can interact with products virtually by waving their hands in the air [90].

The above examples show new possibilities for the design of VPE using gesture-based interaction technologies. In recent years, the development of touchscreen devices (e.g., smartphones, tablets and touchscreen laptops) and mid-air gesture controllers (e.g., Microsoft Kinect, Wii and Leap Motion) has revolutionized the way in which we interact with products virtually. While touchscreen gesture allows consumers to tap, drag, and stretch products with hand movements on touchscreens, mid-air gesture enables consumers to reach, point, and manipulate products using a hand in the air [87]. Compared with conventional mouse-based interaction, the two types of gesture-based interaction is believed to provide a more natural and intuitive interaction experience [28], leading to sensorial and imaginative immersion

[76]. Indeed, practitioners have endeavored to design hardware devices and software applications to support different types of gesture-based interaction. For example, laptop and smartphone manufacturers, such as Microsoft and Apple, are contemplating incorporating mid-air gesture input into their new products [34, 75]. E-commerce giants, such as Amazon, are providing tools and platforms for developers to create innovative digital experiences suitable for gesture-based input devices [64]. It is thus important for marketers and retailers to understand the opportunities to enhance consumers' VPE through the use of sensory-enriched gesture-based interaction modes [25, 40, 76]. Therefore, the primary objective of this study is to provide a rigorous examination of the effects of interaction modes (mid-air gesture vs. touchscreen gesture vs. mouse-based interaction) in the VPE context.

Prior research has identified two independent and distinct facets essential to the design of VPE: the way in which users interact with products and the representational quality of how product information is conveyed to users visually [44, 89]. Hence, in addition to considering simulating users' interactions with products, VPE research has focused on increasing the vividness of the visual presentation [21, 38, 44, 86, 104]. In this study, we examine two prevalent visual presentation formats, 2D vs. 3D. In 2D format, products are presented using multiple static images. In 3D format, products are presented in a continuous and smooth rotation format. The two presentation formats are expected to exert different sensorial impacts on users, leading to different product perceptions. Furthermore, when people synthesize information gained from different sensory channels (e.g., visual and bodily), multiple sensory cues may facilitate or inhibit each other in influencing consumer perception [3, 95, 97]. Accordingly, this study not only explores the effects of interaction mode and visual presentation individually but also examines how their interplay determines consumers' VPE. Our findings will assist online retailers and marketers in understanding how to properly display products for consumers using different interaction modes.

In particular, we are interested in the impacts of interaction mode and visual presentation on consumer's mental imagery. Past research has suggested that consumers make judgments and purchase decisions based on multiple sensory inputs, i.e., vision, touch, audition, smell, and taste [50, 54]. A lack of actual sensory input often results in product uncertainty, which is defined as a buyer's difficulty in evaluating product characteristics and predicting how a product performs [27, 46]. Under such circumstances, people rely on mental imagery elicited by external stimuli to judge product performance [29, 53, 103]. *Mental imagery*, also called mental simulation, is a cognitive process in which a sensory experience is represented in working memory [65]. The process resembles actual perceptual experience but occurs in the absence of real sensory input. Although the prior VPE literature has revealed the importance of mental imagery in driving online purchase intentions [88, 114], these studies considered mental imagery as a general simulation of product exploration and did not consider its multisensory nature. Recent studies have shown that mental imagery consists of different aspects, e.g., olfactory imagery, haptic imagery, spatial imagery, and gustatory imagery, which are triggered by different mechanisms [52, 95]. This complexity calls for a more fine-grained conceptualization of mental imagery in VPE research.

In this study, we focus on two types of mental imagery, i.e., haptic imagery and spatial imagery, both of which are important for product evaluation but difficult to elicit with mere visual stimuli [47]. According to grounded cognition theory, an individual's bodily feelings and actions, e.g., gestures, can help them retrieve past experiences stored in memory, activate mental representations associated with these feelings and thus facilitate mental imagery [7]. In daily life, we employ different gestures to explore product haptic attributes (e.g., texture and material) and spatial attributes (e.g., size and structure). Hence, different types of gesture control (i.e., touchscreen gesture and mid-air gesture) may consist of distinct sensorimotor information and facilitate haptic imagery and spatial imagery to different extents.

In summary, this study aims to investigate the ability of different *interaction modes* (i.e., mid-air gesture vs. touchscreen gesture vs. mouse-based interaction) and visual presentation formats (i.e., 2D vs. 3D) to elicit consumer mental imagery (i.e., haptic imagery and spatial imagery) and further affect the online consumer experience (i.e., reducing product uncertainty). Furthermore, to investigate how our minds integrate information from different sensory modalities (i.e., bodily and visual), we will also study the interplay between the interaction mode and visual presentation and thereby provide a holistic understanding of VPE design. The remainder of the paper is organized as follows. First, we present a review of theories and related studies, as well as their application to our research context. Then, we propose our research model and describe a lab experiment designed to test the research model. Finally, we discuss the results, contributions, and future research directions.

Theoretical Foundation and Related Work

In this section, we first review the literature on VPE, followed by that on mental imagery, which plays a critical role in product evaluation when actual sensory experience is lacking. Finally, we describe grounded cognition theory, which explains why our bodily feelings and actions, e.g., the gestures that we use to interact with products virtually, can facilitate mental imagery.

Virtual Product Experience

Online shopping constrains the extent to which consumers can feel and experience products, raises barriers to product perception, and creates “distance” between consumers and products [104]. To overcome these barriers, certain designs of IT artifacts have been proposed to enable VPE, i.e., an online experience that simulates consumers’ ability to feel, touch, and test products [18, 42, 98]. By creating a satisfactory substitute for a direct experience with a product, VPE design aims to facilitate the mental activities involved in product evaluation, such as product understanding and consumer learning and judgment [43, 111, 113]. To achieve these goals, much attention has been paid to improving the interactivity of VPE design. Interactivity refers to the experience that occurs when a consumer interacts with a virtual representation of a product on a website and can be defined as “the degree to which consumers perceive that a product presentation is two-way, controllable, and responsive to input” [18, 44]. Studies have shown that VPE designs with higher levels of interactivity generally perform better in terms of improving product learning and evaluation [88, 89, 96].

Indeed, researchers have proposed and evaluated various VPE designs with varying levels of interactivity, such as visual and functional control [42, 44, 88], virtual mirror application [104], and restricted interaction [113]. However, most of these studies have been conducted in the mouse-based context, where only limited input approaches (i.e., clicking, hovering and dragging) can be supported. In recent years, the use of hand movements as input enabled by gesture-based interaction technologies has greatly changed the way consumers interact with products. Gesture-based interaction technology allows users to control and manipulate products directly with their hands and removes the need for any intermediary devices (e.g., a mouse or a stylus). Several advantages of gesture-based interaction have been identified, including naturalness and expressiveness, learnability, freedom, and the ability to leverage existing dexterous skills in different contexts [74, 84, 85].

Two types of gesture-based interaction deserve particular attention, i.e., touchscreen gesture and mid-air gesture, both of which are increasingly adopted in the VPE context. While the former requires users to touch the screen or surface of a device physically, the latter allows freeform gestures in the air [87]. Although both touchscreen gesture and mid-air gesture enable users to interact with products using hands directly, they differ in several aspects. For instance, mid-air gesture controllers (e.g., Leap Motion and Microsoft Kinect) can capture hand postures and motions in a three-dimensional space, while touchscreens only allow users to move their hands on a flat surface [117]. In addition, touchscreens allow consumers to touch a tangible interface, which is not possible using mid-air gestures [105].

Prior research has investigated how consumers evaluate products and make decisions on different devices, i.e., touch-based tablets and mouse-based PCs. For example, compared with a mouse-based PC, a touch-based tablet led to greater engagement and enjoyment [22] and enhanced consumers' perceived ownership and endowment of the focal product [14]. Furthermore, touchscreens were observed to lead to more impulsive and diversity-seeking purchase behavior [4, 112]. However, the results of the interaction mode in these studies may be confounded by other factors, such as screen size and portability (e.g., iPad compared to a laptop) [14]. In addition to touchscreen gesture, mid-air gesture has shown great potential in the VPE context. Many retailers have explored ways to engage customers with the digital experience enabled by mid-air gesture-based devices. For example, to promote their homeware, Marks & Spencer allows its customers to drag and drop items with mid-air gestures to create a digital living space displayed in virtual reality (VR) [26]. Timberland and Topshop have implemented virtual fitting applications in which consumers can see themselves try on different shoes and clothes displayed on a screen by waving their hands in the air [90]. However, despite the increasing use of gesture-based interactions by practitioners, there have been no systematic examinations of the differences between the three interaction modes, i.e., mid-air gesture, touchscreen gesture, and mouse-based interaction.

In summary, prior research has highlighted that the effects of VPE may be influenced by the way in which users interact with products and that such interaction experience can be enormously enriched by gesture-based interaction technologies. In this study, we incorporate different types of gesture control into the VPE framework and thus provide a holistic understanding of the interactivity design of VPE.

Consumer Mental Imagery

Prior research has documented the importance of sensory input in consumer judgments and purchase decisions [50, 54]. However, due to the technological limitations of the digital interface, it is often difficult for buyers to acquire sufficient sensory input to fully evaluate products. In this case, people rely on mental imagery in their judgments and evaluations [19, 49]. Mental imagery is defined as a cognitive process in which sensory information is represented in working memory [65]. It entails sensory representations of ideas, feelings, and objects or experiences with objects, which allow people to more accurately anticipate the actual consequences of imagined scenarios. Indeed, many studies have demonstrated that vivid mental imagery can enhance purchase and consumption intentions. For example, advertisements using imagery-eliciting messages result in more favorable attitudes toward the advertised product [2]. Similarly, appetitive stimuli can activate simulations of consuming and enjoying a particular food and thus enhance purchase intention [73]. Although the role of mental imagery has been well-recognized in advertising and marketing research, it remains to be explored whether consumer mental imagery can potentially reduce product uncertainty, which is one of the most serious obstacles in online shopping [39, 46].

Despite a large number of studies on mental imagery as a general consumption experience, recent studies have started to investigate different dimensions of mental imagery, e.g., gustatory imagery [94], olfactory imagery [53], haptic imagery [78], and spatial imagery [16]. These studies have suggested that different types of mental imagery are triggered by various stimuli and through different mechanisms [49]. When people shop online, it is often difficult, if not impossible, for online shoppers to examine two types of product attributes, i.e., haptic attributes (e.g., texture, hardness, smoothness) and spatial attributes (e.g., shape, structure, orientation, motion), although they are important to product evaluation [48, 58]. Accordingly, we focus on both types of mental imagery in our study, i.e., haptic imagery and spatial imagery, both of which can be facilitated by gesture control and visual presentation.

Specifically, haptic imagery is mental representations of a touch experience when the actual touch sense is not accessible [17, 78]. Vivid haptic imagery can facilitate product evaluation as a surrogate for actual touch [78]. Initial evidence has shown that the involvement of the hand even without actual haptic experience, e.g., seeing other people touch a product or touching a product displayed on a tablet, can induce more thoughts on haptic attributes in product evaluation [15, 80]. Spatial imagery is mental representations of spatial properties, such as spatial relations among components, locations of objects in space, movements of objects and other parts, and other complex spatial transformations [13, 16, 31]. Spatial imagery is also important for online consumers, who need to picture the physical shape, outline, and structure of the product, as well as how the product can fit into the environment, in their minds. Allowing people to gesticulate has been found to improve user performance in several spatial cognition tasks, such as geometric understanding, location navigation, and spatial memory [45, 101, 115]. Overall, previous studies have yielded considerable evidence that gesture-based interaction can facilitate haptic and spatial thinking. However, it remains to be explored how different types of gesture-based interaction perform regarding the elicitation of haptic imagery and spatial imagery.

In summary, the findings from existing research suggest that, when actual sensory information is not fully accessible, mental imagery plays an important role in consumer judgment and behavior. Complementing the literature investigating mental imagery as a general consumption experience in the VPE context [88, 89], this study further explores two types of mental imagery: haptic imagery and spatial imagery. While previous studies have demonstrated that specific verbal and visual information can elicit mental imagery [63, 71], recent advancements in grounded cognition show that bodily feelings and actions can often serve as triggers of mental imagery. In the following, we will describe the theory of grounded cognition, which explains why mental imagery can be stimulated by our own bodily feelings and actions.

Grounded Cognition

While traditional psychological theories have viewed cognition as the computation of amodal symbols in a modular system, the theory of grounded cognition holds that an individual's cognition is grounded by the environment, situations, as well as one's bodily feelings and actions [7, 10]. In other words, our cognitive activities can be influenced by sensorimotor processes and situated in specific contexts and situations. In particular, the idea that our bodily feelings and actions modulate our cognition has received much empirical support from psychology and consumer behavior research. For instance, it has been found that the action of taking (active requiring) a product, compared to receiving (passive requiring), creates an illusion of choice and enhances the attractiveness of the product [35]; physically touching a product (vs. not touching it) can increase emotional attachment and greater purchase intention [80].

The reason for these emerging findings on grounded cognition is that our brain captures states (e.g., perceptual, motor, and introspective) across different modalities and integrates them with a multimodal representation stored in memory [5, 55-57]. Later, when knowledge is needed to represent a scenario, multimodal representations captured in past experiences are activated to help people simulate an actual experience in their minds. For example, when one eats a piece of cake, the brain registers the various sensory experiences involved in this consumption (e.g., how the cake appears visually, what it smells like, and what it tastes like). When an individual is later exposed to an incomplete sensory exposure, e.g., the smell of a cake factory, he or she can mentally simulate earlier experiences associated with the cake, resulting in the activation of many sensory regions in the brain that were active during actual consumption. Thus, when exposed to the smell of cake, people might recall the sweet taste and picture various cakes in their minds. Several neuroimaging studies have corroborated this proposition [94, 116].

According to grounded cognition theory, similar to verbal and visual information, our bodily actions can activate consumers' associated experiences stored in their memories, and the activated mental representations can supplement the missing sensory experience that consumers need to evaluate products. When people interact with products physically, they use various gestures to explore different attributes and properties. When induced to perform these gestures, people might remember the associated product interaction experience and thus generate mental imagery. In daily life, hardness, texture, and temperature (i.e., haptic attributes) can be examined with hand movements on the product surface, while the examination of volume, shape, structure, and function (i.e., spatial attributes) requires gesturing in three-dimensional space [48, 58]. Because the hand is one of the principal sources of input to explore objects' haptic [79] and spatial information [107], we believe that hand movements, as a specific type of bodily actions, can influence consumers' *haptic imagery* and *spatial imagery*.

Grounded cognition theory has significant implications for mental imagery and VPE research. First, this theory suggests that users' bodily actions used to interact with products can affect their mental imagery because they can activate related knowledge and experiences stored in memory. Furthermore, grounded cognition theory suggests that people can synthesize inputs from different sensory modalities in an ongoing and dynamic fashion [7, 8, 10]. It is noteworthy that when the mental representations triggered by one channel are inconsistent with the actual sensory input from another channel or the mental representations activated by another channel, people have difficulty in synthesizing the information to construct coherent mental imagery [51, 81]. For example, viewing a visually graspable product induces a mental representation of the required action, i.e., reaching out with one's dominant hand to hold the object. In this case, restriction of the dominant hand (e.g., because it is currently holding another object) will hamper the ease of mentally representing this action and further result in negative attitudes [91]. In the VPE context, such sensory incongruence experience is more likely to occur because both visual and gestural inputs are created artificially. Therefore, it is important to study the interplay between visual presentation and interaction mode in creating a realistic and coherent VPE.

Hypothesis Development

This study investigates how the interaction mode and visual product presentation affect consumers' VPE from a mental imagery perspective. Three interaction modes were compared, namely, mid-air gesture, touchscreen gesture and mouse-based interaction. For visual presentation, we focus on two popular presentation formats: 2D (i.e., presenting several static images of a product) and 3D (i.e., presenting the product with 360-degree rotation), both of which allow users to view products from different angles and perspectives. In the next section, we first present the effects of visual presentation format and interaction mode on consumers' haptic imagery and spatial imagery, respectively. Then, we reveal the downstream effects of haptic and spatial imagery on product uncertainty. The research model is depicted in Figure 1.

[insert Figure 1 about here]

The Effects of Visual Presentation and Interaction Mode on Haptic Imagery

Prior research has found that visual stimuli can trigger thoughts on haptic exploration when actual haptic input is not accessible. For example, orienting a product toward an individual's dominant hand could elicit mental simulation of touching and holding the product, subsequently leading to more favorable attitudes toward the product [23, 29]. In the VPE context, visual cues that simulate stroking of the cloth in response to mouse dragging elicited more realistic touch sensations and improved the diagnosticity of haptic attributes in product evaluation [72]. These findings imply that visual information can allow for the mental simulation of touch without any actual haptic input.

3D presentation allows consumers to use their input devices (e.g., mouse, touchscreen, mid-air gesture controller) to modify the viewing angle of the product and receive real-time visual feedback. Products rotate smoothly and continuously in response to their input. As such, 3D presentation not only provides product cues but also offers some product experience cues that consumers typically would perceive when the product is under their control in proximity. Indeed, the prior literature suggests that 3D presentation, compared with 2D presentation, elicits higher perceived control [21] and that such experience in the actual world often requires touching, holding and manipulating [79]. Thus, when consumers have stronger control over the product stimulated by responsive visual feedback, they might infer that they are close to the product and can touch and manipulate the product as in the physical environment. In other words, 3D presentation allows the consumer to inspect the product in such a way that it, at least to some extent, resembles product inspection in unmediated settings. Accordingly, 3D presentation will lead to vivid haptic imagery. By contrast, with 2D presentation, consumer actions result in discrete image switching. Such interaction experiences can cause people to feel that they are simply interacting with product images, instead of touching and manipulating an actual product. The visual feedback of image switching is not able to provide them with an experience that mimics the inspection of a product in the real world. Thus, it would be more difficult for consumers to transform 2D presentation into vivid haptic imagery. Therefore, we propose the following.

H1: Compared with 2D presentation, 3D presentation leads to more vivid haptic imagery.

Although visual information can facilitate haptic imagery, the hand is still regarded as the most important sensory source of haptic information [48, 79]. According to the theory of grounded cognition, when making judgments, consumers not only rely on available sensory information but also recall their prior experience associated with the sensory input [6, 7]. Because in daily life, people often use their hands to explore a product's haptic attributes (e.g., texture, hardness and smoothness), the gestures users apply to interact with products virtually can activate their prior experience and thus facilitate haptic imagery. As the three interaction modes support different hand movements and gestures, they are expected to facilitate haptic imagery to different extents.

When using touchscreen gestures, consumers can sense the motions of their hands, which are often employed when they are interacting with an actual product. The gesture of reaching out to touch the screen is similar to the gesture of reaching out to touch the product [92]. By stimulating the kinesthetic feelings involved in touch, touchscreen gestures thus can facilitate the retrieval of past haptic exploration experience and provide consumers with natural and vivid simulations of touch. In addition, on touchscreens, consumers can directly touch the product images, which simulates physical contact with a product despite the contact actually being mediated via the touchscreen. Indeed, prior research has suggested that both kinesthetic feelings experienced from body movements and tactile feelings experienced from physical contact with a product contribute to the formation of haptic perception [58, 60]. As both the kinesthetic experience and tactile experience are well-simulated in interaction with products via touchscreen, we can expect that touchscreen gestures can elicit vivid haptic imagery.

Unlike touchscreen which allows consumers to use their hands and fingertips directly, people move and click the mouse to interact with products when using a mouse. The naturalness of the product experience is greatly constrained by the intermediary device, i.e., the mouse [18]. Therefore, it will be difficult for consumers to mentally transform the mouse movements into a vivid touch experience. In addition, the prior literature suggests that occupying one's dominant hand can inhibit haptic simulation [91]. Hence, people may have difficulty in portraying themselves touching the product when holding the mouse. When people interact with products using mid-air gestures, consumers move their hands and fingers in the air. Although mid-air gestures also provide the kinesthetic experience often involved in haptic exploration, it is difficult for users to achieve simulated physical contact with the product by moving their hands in the air. The prior literature suggests that touch is considered a near or "proximal" sense because it needs to be achieved by bodily contact [54]. When the hands are not in close proximity to a product or images of a product, users will be less likely to feel that they can touch and inspect the product [60]. The absence of simulated contact with the product thus may inhibit consumers using mid-air gestures from forming vivid haptic imagery. Therefore, we hypothesize the following.

H2: Touchscreen gesture leads to higher haptic imagery than (a) mouse-based interaction and (b) mid-air gesture.

As grounded cognition theory suggests, when an experience occurs, the brain captures states across the modalities and integrates them with a multimodal representation stored in memory [6, 9, 10]. While sensory input from multiple channels can trigger different mental representations, our minds can synthesize the information. In real life, when we touch and move our hands on a product, we see the product react to our gestures by stroking, turning, rotating, etc. Therefore, although we theorize that touchscreen gesture will perform best in terms of enhancing haptic imagery, such effects may be moderated by the visual presentation format.

As discussed earlier, compared to 2D presentation, 3D presentation responds to user input in a more responsive way by rotating and spinning, which can evoke a higher sense of control. Given that consumers associate direct product experiences with high levels of control [60, 72], they might perceive products in which they have greater control to be more tangible. In addition, when we touch and manipulate a product in the physical world, the product rotates and transforms smoothly, instead of shifting images. The responsive visual feedback enabled by 3D presentation, which provides concrete information similar to one's established mental model of a touch experience, will complement the information needed to construct vivid haptic imagery [62, 88]. Under such circumstances, even when mental representations of touch activated by bodily actions are low (i.e., when people use mouse-based interaction or mid-air gesture), consumers can still picture a haptic exploration experience in their mind, facilitated by effective visual feedback. Therefore, the differences among the three interaction modes in terms of eliciting haptic imagery will become less prominent when 3D presentation is provided.

With 2D presentation, user input, e.g., swiping on the touchscreen, waving in the air, and dragging the mouse, will result in discrete image switching. The mere visual feedback of image switching cannot offer sufficient support to stimulate haptic imagery. Touchscreen users can have tangible contact with product images via the touchscreen and interact with products using natural touch gestures. In this case, even when the visual stimuli are not substantial, users can still picture a touch experience in their mind vividly. However, mid-air gesture and mouse users in this case have to pay additional effort to retrieve information associated with touch from prior experience to transform the discrete image switching into a holistic touch experience. Accordingly, the advantage of touchscreen gesture over mid-air gesture and mouse-based interaction will prevail with 2D presentation. Therefore, we propose the following.

H3: The superior effect of touchscreen gesture over (a) mouse-based interaction and (b) mid-air gesture on eliciting haptic imagery is stronger when 2D is used than when 3D is used.

The Effects of Visual Presentation and Interaction Mode on Spatial Imagery

Although spatial representations can be triggered by various cues, there is a general consensus on the crucial role of visual information, which can depict spatial relationships more directly [77]. It is well-documented that pictorial representations are more effective than textual representations when people are involved in spatial cognition tasks, such as solving geometric problems, finding a place, and learning complex mechanical functions [1]. Therefore, we believe that the visual presentation of a product is important for the creation of spatial imagery.

When 3D presentation is used, products are rotated smoothly and presented from different perspectives. 3D provides more concrete spatial information and vivid spatial transformation [61]. As the theory of grounded cognition suggests, people make inferences about the missing elements based on their past experience and memory. When information is rich, they do not need to mentally supply much information based on prior experience. Accordingly, it will be easier for them to form mental representations of spatial properties, e.g., shape, structure, and motions. Accordingly, individuals can easily portray products in a multi-dimensional way in their minds as if they are in the actual environment. By contrast, when browsing a product in 2D presentation, which depicts the product from different perspectives with different images, consumers need to mentally transform the discrete 2D images into spatial concepts and properties. They have to spend extra effort recalling past experience to build mental representations of various spatial aspects, e.g., product components, their relationship with the environment, and spatial transformation. Therefore, it will be difficult for them to construct vivid spatial imagery. Hence, we propose the following.

H4: Compared with 2D presentation, 3D presentation leads to more vivid spatial imagery.

In addition to visual information, previous findings also imply that gestures can facilitate spatial information processing [107]. Because the exploration of spatial characteristics often involves motor processes, such as contour following, part motion, and enclosure [60], hand movements and spatial representations might be interwoven in one’s memory. According to the theory of grounded cognition, our brain automatically complements information based on our stored knowledge and experience. The close connection between hand movements and spatial cognition in people's daily lives indicates that interaction modes supporting different hand movements may differ in their ability to facilitate spatial imagery. Indeed, many prior studies have observed positive effects of mid-air gestures on spatial memory performance (i.e., memory of locations) [41, 101].

When exploring spatial attributes, such as object shapes and structures, consumers will rotate or manipulate parts of the object via hand movements in three-dimensional space. Using mid-air gestures to interact with products, people can move their hands freely, and these hand movements resemble the gestures employed to explore spatial properties in the real world. Thus, mid-air gestures can activate spatial representations and thereby facilitate spatial imagery. In addition, to fully represent the spatial details of a product mentally, people often need to rotate and transform the product to understand the spatial relationships among components and between the product and the environment. Evidence has shown that mental rotation relies on processes analogous to those involved in physical rotation [108]. Thus, rotating and moving one's hand in the air might facilitate the spatial transformation process in the mind.

By contrast, when interacting with products using a mouse and touchscreen gesture, people make hand movements on a flat surface, either on a desk or on a touchscreen. The prior literature suggests that mental and physical rotations interfere with one another and that judgments about mental rotations are influenced by concurrent physical rotation [109]. Thus, mouse-based interaction and touchscreen gesture, which do not support physical rotation and transformation, may inhibit one's ability to perceive spatial information. Therefore, it is conceivable that allowing users to move and rotate their hands in the air, as supported by mid-air gesture-based interaction, will elicit more vivid spatial imagery compared with moving their hand on a flat surface via a mouse or a touchscreen. Hence, we propose the following.

H5: Mid-air gesture leads to higher spatial imagery than (a) mouse-based interaction and (b) touchscreen gesture.

As the theory of grounded cognition suggests, the human brain uses multiple sources of sensory information to form coherent and robust perceptions of objects. To obtain a complete spatial representation of a product, people often use their hand to rotate and manipulate the product to view the product from different angles. Thus, both visual and gestural channels are involved in spatial information processing [37, 77]. Therefore, although we expect mid-air gesture to be more effective in eliciting spatial imagery than touchscreen gesture and mouse-based interaction, this effect might also differ depending on specific visual presentation formats.

3D presentation can visually present rotations and spatial transformations about a product in response to user input. In this case, consumers using mid-air gestures can see the product rotate and transform, following their natural gestures as if the product was in the physical environment. In actual spatial exploration, people move their hands back and forth and see products rotate and transform. Thus, 3D presentation and mid-air gestures create a simulated spatial exploration experience resembling the actual experience. As such, when mid-air gestures are used, consumers can create vivid spatial imagery. By contrast, touchscreen gesture and mouse-based interaction are less likely to facilitate spatial representations because the hand movements are on a flat surface and thus are limited in their ability to embody spatial information. In this case, even when people receive vivid spatial information from the visual channel enabled by 3D presentation, they may not be able to synthesize the information well because of the incongruence between the visual information and bodily actions. Therefore, mid-air gesture will lead to higher spatial imagery than touchscreen gesture and mouse-based interaction when 3D presentation is employed.

Although 2D presentation can also display a product from different angles by using multiple images, it cannot depict smooth and vivid spatial transformations. Although we hypothesize that mid-air gesture can facilitate mental representations of spatial properties, such effects might be mitigated by the incongruent 2D visual feedback. When people perform certain actions, they make inferences about what is likely to happen in the current situation via the process of "pattern completion" [7]. When exploring the spatial attributes of products, people usually move their hand following the outline and structure of the product and expect the product to react to their gestures by rotation, transformation, decomposition, etc. Such reactions occur in a 3D space and are difficult to execute in a 2D environment. Therefore, 2D presentation can result in a strong sense of incongruence between the expectations triggered by mid-air gestures and the actual visual input. Such incongruence might inhibit people from constructing spatial imagery by synthesizing information from gestural and visual channels. Thus, 2D presentation could weaken the positive effects of mid-air gesture on eliciting spatial imagery. According, we hypothesize the following.

H6: The superior effect of mid-air gesture over (a) mouse-based interaction and (b) touchscreen gesture on eliciting spatial imagery is stronger when 3D presentation is used than when 2D presentation is used.

The Effects of Mental Imagery

The intangible nature of online shopping means that consumers are deprived of complete sensory experience, resulting in product uncertainty. Unlike consumers in physical markets, buyers in online markets can experience products via the virtual interface only by reading descriptions and customer reviews and by virtually interacting with the product through images or videos. To understand new products, consumers can use the prior knowledge and experience already encoded in their memories as a source of information [68, 99]. Previous neuropsychological work has also indicated that mental simulation is associated with increased activation of brain areas involved in processing real sensory information [94]. Thus, mental imagery could compensate for actual sensory input, helping people to anticipate the performance of the product. In particular, vivid haptic imagery could make people feel that they are close to the product and thus create a sense of non-mediation. When a product is perceived as more physically present with a consumer, instead of only being present on the screen, consumers may have a stronger sense of ownership, eliminating concerns about negative performance [93]. For spatial imagery, when people can clearly visualize the spatial details of the product in mind, such as spatial relationships among the components, shape, and outline of the product, they will feel more knowledgeable about the product and thus become more confident in product evaluation. Therefore, we believe that when people can portray haptic exploration processes and spatial properties vividly in the mind, they will feel less uncertain about the product. Hence, we expect the following.

H7: Increased haptic imagery reduces product uncertainty.

H8: Increased spatial imagery reduces product uncertainty.

Methods

Experiment Design

To test the hypotheses, a 3 (interaction mode: touchscreen gesture vs. mid-air gesture vs. mouse-based interaction) by 2 (visual presentation: 2D vs. 3D) between-subjects lab experiment was conducted. The participants were randomly assigned to the six conditions and were asked to complete a product evaluation task. A lounge chair was selected as the focal product because both haptic attributes (e.g., softness and texture) and spatial attributes (e.g., design, shape, size, structure, fit to environment) are important when judging the product. The interaction mode was manipulated with different types of input devices. The participants were required to complete the task on a laptop using a mouse, the touchscreen of the laptop, or a mid-air gesture controller (i.e., Leap Motion[1]).

Two websites were developed to display the product with either 3D presentation or 2D presentation. In the 3D conditions, the product was presented in a continuous and smooth rotation format. Mouse users could drag the mouse to rotate the chair; touchscreen users could place a finger on the chair and drag it by moving left and right; and Leap Motion users could wave their hand left and right in the air to rotate the chair. In the 2D conditions, five images presenting the chair from different angles were displayed on the website. Mouse users could click on the product, touchscreen users could flick a finger left and right on the product, and Leap Motion users could move their hands left and right in the air to switch the images. We also provided a short description of the chair beside the product to explain the material, size, components and other features. The experimental website is presented in Figure 2.

Experimental Procedure

A recruitment advertisement was posted on the online forum of a major university in Asia three weeks before the experiment. In the advertisement, we described the general purpose of the study and provided a registration link. Specifically, university students were invited to participate in an online shopping task and answer some questions about their shopping experience. During the registration, participants were asked to select a time slot and provide some demographic information, such as age, gender, prior online shopping experience, need for touch, and spatial imagery capability. Upon arrival, they were randomly assigned to one of the six experimental conditions. The participants first underwent a training session in which we provided instructions on how to interact with the product using the specific

[1] Leap Motion is a device that facilitates user interaction with the computer via mid-air gestures. It can create a virtual “touch” surface in the 3D space and recognize users’ gestures around the virtual surface. An illustration of Leap Motion usage is presented in Figure 2. More information about the device can be accessed via www.leapmotion.com.

interaction mode. Subsequently, they were asked to imagine that they had just moved to a new apartment and needed to acquire some furniture. They were then asked to evaluate a lounge chair for potential purchase. The participants performed the product evaluation task on the same laptop using a mouse, the touchscreen of the laptop or Leap Motion. To ensure that the participants used the specific interaction mode as instructed and would not interfere with each other, we assigned only one participant to each session. After completing the product evaluation task, the respondents were asked to answer a post-experimental questionnaire that captured major constructs, i.e., haptic imagery, spatial imagery, and product uncertainty. A list of the specific measurement items is presented in Online Appendix C. At the end of the experiment, each participant received approximately US$5 as a reward. On average, each session took approximately 15 minutes.

Data Analysis and Results

Subjects' Background Information

One hundred eighty-three participants were recruited from 6 academic faculties/schools and 22 departments, representing very diverse backgrounds. They were randomly assigned to the six conditions, resulting in approximately 30 participants in each condition (as shown in Table 2). This ensured a sufficient statistical power of 0.8 for a medium effect size [24, 32]. Among them, 60% were female. The age of the subjects ranged from 18 to 32 (M = 22). There were no significant differences in the measured demographic variables across the six conditions.

Instrument Validity

The measurement model was first assessed by examining the reliability and validity of key constructs. Cronbach's alpha of the measures of haptic imagery, spatial imagery and product uncertainty was 0.84, 0.72, and 0.80, respectively, indicating adequate reliability of the measurement scales [20, 69]. The correlations between these variables were reported in Table 3. We further evaluated the model's convergent validity and discriminant validity with exploratory factor analysis. The results showed that measurement items loaded heavily on their intended factor and lightly on other factors, indicating adequate convergent and discriminant validity (see Table 4 for factor loadings) [102].

[insert Table 3 and Table 4 about here]

Results for Haptic Imagery and Spatial Imagery

Multivariate analysis of variance (MANOVA) was conducted to detect the joint effects of interaction mode and visual presentation on haptic imagery and spatial imagery. The results yielded overall significant effects of visual presentation format ($F(2, 176) = 6.87$, Wilks' lambda = 0.928, $p < 0.005$), interaction mode ($F(2, 176) = 2.81$, Wilks' lambda = 0.939, $p < 0.05$) and the interaction between visual presentation and interaction mode ($F(4, 352) = 3.16$, Wilks' lambda = 0.932, $p < 0.05$) on the dependent variables (i.e., haptic imagery and spatial imagery). Whereas MANOVA was useful in validating the importance of the independent variables on the dependent variables, its results did not verify their respective effects on each of the dependent variables. Therefore, to test the effects of the independent variables on each of the dependent variables separately, separate analyses of variance (ANOVAs) were conducted.

ANOVA with haptic imagery as the dependent variable revealed a significant effect of visual presentation ($F(1, 177) = 10.90$, $p < 0.005$, $\eta^2_p = 0.06$) and a significant effect of interaction mode ($F(2, 177) = 4.86$, $p < 0.01$, $\eta^2_p = 0.05$) on haptic imagery (as shown in Table 5 and Table 6). In general, 3D ($M = 4.34$) led to stronger haptic imagery than 2D ($M = 3.80$). Hence, H1 was supported. Planned contrast tests revealed that touchscreen gesture ($M = 4.43$) led to higher haptic imagery than mid-air gesture ($M = 3.84$, $p < 0.05$) and mouse-based interaction ($M = 3.93$, $p < 0.05$). Hence, H2a and H2b were supported.

[insert Table 5 and Table 6 about here]

In addition, because the interaction effect between visual presentation format and interaction mode on haptic imagery ($F(2,177) = 2.55$, $p = 0.08$, $\eta^2_p = 0.03$) was significant (albeit marginally), we further proceeded to conduct a simple main effect analysis. The results suggested that visual presentation moderated the effect of interaction mode on haptic imagery. Pairwise comparison tests further revealed the following: (1) with 2D presentation, touchscreen gesture elicited stronger haptic imagery ($M = 4.42$) than mid-air gesture ($M = 3.42$, $p < 0.005$) and mouse-based interaction ($M = 3.55$, $p < 0.01$); (2) with 3D presentation, the different interaction modes did not differ in eliciting haptic imagery ($M_{mouse} = 4.32$ vs. $M_{touchscreen} = 4.44$ vs. $M_{mid\text{-}air} = 4.27$, $p > 0.1$). Therefore, H3a and H3b were supported. A plot of the interaction effect can be found in Figure 2.

[insert Figure 2 about here]

The ANOVA results with spatial imagery as the dependent variable are presented in Table 7 and Table 8. The results showed that there was a significant main effect of presentation format on consumers' spatial imagery ($F(1, 177) = 7.46$, $p < 0.01$, $\eta^2_p = 0.04$). Specifically, 3D presentation ($M = 5.16$) elicited stronger spatial imagery than 2D presentation ($M = 4.74$, $p < 0.01$, $\eta^2_p = 0.04$). Hence, H4 was supported. However, no main effect of interaction mode was observed ($F(2, 177) = 0.11$, $p > 0.1$). There was no difference among different interaction modes in terms of eliciting spatial imagery ($M_{mouse} = 4.90$ vs. $M_{touchscreen} = 4.95$ vs. $M_{mid\text{-}air} = 5.00$). Thus, H5a and H5b were not supported.

[insert Table 7 and Table 8 about here]

As expected, we observed a significant interaction effect between visual presentation and interaction mode on spatial imagery ($F(2,177) = 4.45$, $p < 0.05$, $\eta^2_p = 0.05$). A simple main effect analysis was conducted to further examine the significant interaction effect between visual presentation and interaction mode on spatial imagery. Specifically, pairwise comparisons revealed the following: (1) with 2D presentation, mid-air gesture (M = 4.46) did not elicit stronger spatial imagery than touchscreen gesture (M = 4.91, $p > 0.1$) and mouse-based interaction (M = 4.84, $p > 0.1$); and (2) with 3D presentation, mid-air gesture (M = 5.54) led to stronger spatial imagery than touchscreen gesture (M = 4.99, $p < 0.05$) and mouse-based interaction (M = 4.97, $p < 0.05$). Hence, H6a and H6b were supported. A plot of this interaction effect is presented in Figure 3.

[insert Figure 3 about here]

Results for Product Uncertainty

Product uncertainty was regressed on haptic imagery and spatial imagery. Together they explained 12.2% of the variance in product uncertainty. The results indicated that haptic imagery (β = -0.18, t = -2.24, $p < 0.05$) and spatial imagery (β = -0.26, t = -3.33, $p < 0.005$) can serve as sources of information to reduce users' product uncertainty (R^2 = 12.2%). Because measures of the three constructs were obtained from the same subjects at the same point in time, common method biases may contribute to the observed relationships. To assess the potential common method bias, Harman's one-factor test [83] was conducted on the three constructs in our theoretical model: haptic imagery, spatial imagery, and product uncertainty. The results showed that no single factor emerged from the exploratory factor analysis, and the most covariance explained by one factor was 36.37%, indicating that common method bias was not a likely contaminant of our results. In addition, we used the single-common-method-factor approach to control for method effects, which is recommended as one possible remedy for common method bias in experimental research [82]. Therefore, we included a common method latent variable, i.e., an unmeasured latent variable containing all measures employed as indicators. The inclusion of this additional latent variable resulted in an increase of less than 1% in the R^2 for explaining product uncertainty. Based on these assessments, we can conclude that common method bias is not a threat to our results.

Discussion of Results

Consistent with most of our predictions, the findings show that visual presentation and interaction mode affect users' haptic imagery and spatial imagery and further influence their perceived product uncertainty. The results suggest that, when people do not have the opportunity to interact with the real product, mental imagery provides supplementary information beyond the descriptive content provided by the website and thus reduces consumers' uncertainty. While the prior literature highlights the importance of factual information (e.g., product descriptions, product reviews, product specifications) in reducing product uncertainty [27, 39, 46], our study shows that consumers' mental imagery triggered by their own bodily actions can also act as a source of information in their judgment and decision-making and thus alleviate product uncertainty.

In terms of haptic imagery, consistent with our predictions, 3D presentation leads to stronger haptic imagery. The 360-degree spinning of the product makes it easier for consumers to simulate a haptic experience in their mind. More importantly, the interaction mode also contributes to consumers' haptic imagery. Specifically, touchscreen gesture creates stronger haptic imagery than mid-air gesture and mouse-based interaction. As we discussed earlier, kinesthetic experience (gained from hand movements) and tactile experience (gained from contact with a tangible object) are two critical contributors in the formation of haptic imagery [58-60]. Using touchscreen gesture, consumers can directly touch product images, although the contact is mediated by the touchscreen. Thus, they can achieve a substantial tactile experience. In addition, consumers can interact with products using natural touch gestures and obtain the kinesthetic feelings that are often associated with an actual touch experience. Accordingly, touchscreen gesture performs best in terms of eliciting haptic imagery. In addition, we found that the visual presentation format can moderate the effects of interaction mode on haptic imagery. Specifically, there are significant differences among touchscreen gesture, mid-air gesture and mouse in 2D conditions; however, when 3D presentation is used, the three interaction modes perform similarly. It appears that by providing more interactive and responsive visual feedback, the 3D presentation provides additional information needed for the construction of haptic imagery and that such information is well-assimilated by mid-air gesture and mouse users to construct haptic imagery. Therefore, the superiority of touchscreen gesture in terms of eliciting haptic imagery becomes less prominent when 3D presentation is used.

In terms of spatial imagery, 3D presentation elicits more vivid spatial imagery, as expected. Although we did not find a main effect of mid-air gesture on spatial imagery, we found that mid-air gesture outperformed the other two interaction modes when 3D presentation is used. It appears that the lack of a main effect of mid-air gesture is caused by its poor performance when used together with 2D presentation. Indeed, prior research shows that when multiple sensory cues (e.g., visual and bodily) are synthesized to create mental imagery, the overall effect is greatly contingent upon the congruence of different sensory cues [50, 51]. Mid-air gesture enables users to perform hand movements in a three-dimensional space, resembling the gestures employed to explore the spatial properties of products in the real world. Thus, mid-air gestures can activate spatial representations, and thus users will expect products to reveal spatial information vividly in response to their hand movements. Because 3D presentation can effectively depict spatial transformations, the superiority of mid-air gesture over touchscreen gesture and mouse-based interactions will prevail. By contrast, 2D presentation may result in a sense of incongruence between the expectations triggered by mid-air gestures and the 2D visual cues, which suppresses the ability of mid-air gesture in facilitating spatial imagery. Therefore, the superiority of mid-air gesture in eliciting spatial imagery can only be observed when 3D presentation is used.

Table 9 presents a summary of the hypothesis testing.

[insert Table 9 about here]

Implications of the Findings

This study investigates the effects of three interaction modes and two visual presentation formats on consumers' VPE. It enriches the literature on VPE by introducing the interaction mode, i.e., the way in which people interact with the system (e.g., via mid-air gesture, touchscreen gesture, and mouse-based interaction) into the traditional VPE framework. We suggest that mouse movements, touchscreen gestures and mid-air gestures can deliver different sensory information, and this sensory experience has the potential to influence our mental activities in product evaluation. In addition, our results reveal that visual presentation and interaction mode jointly affect the consumer experience jointly. Specifically, touchscreen gesture leads to higher haptic imagery and thus is more suitable for haptic exploration tasks; such effects become weaker when 3D presentation is adopted. Mid-air gesture leads to higher spatial imagery when accompanied by appropriate visual presentation, i.e., 3D presentation, and thus is more suitable for spatial exploration tasks. Overall, our study calls for the incorporation of bodily actions and feelings experienced from interaction with devices into VPE research and reveals the importance of the interplay between visual presentation and interaction mode in creating VPE.

Our study also provides insights on consumer mental imagery research. First, our study demonstrates the role of mental imagery in reducing product uncertainty. Online consumers often experience product uncertainty caused by the inability of digital interfaces to provide sufficient sensory experience to evaluate a product, e.g., touch, smell, and taste [27, 110]. Our research reveals that when actual information is not available, mental imagery can act as a source of information and reduce their perceived uncertainty in product evaluation. Second, our work broadens our understanding of the triggers of mental imagery. Prior research on this topic has examined primarily how the visual representations of an object influence mental imagery (e.g., product orientation toward the right or left side or the concreteness of pictures) [2, 100]. Recently, studies have begun to examine how other sensory channels (e.g., touch and smell) can trigger mental imagery [14, 50]. This study extends this stream of the literature by elucidating the role of the bodily feelings gained from interacting with a digital interface as triggers of mental imagery. Third, while the prior literature has tended to consider mental imagery as a general consumption experience, we further conceptualize two types of mental imagery related to hand movements and their corresponding visual feedback, i.e., haptic imagery and spatial imagery. Our results suggest that different dimensions of mental imagery are facilitated by different types of gesture control and visual presentation.

By showing how our mental activities (i.e., mental imagery) are grounded in multiple sensory modalities (i.e., visual and bodily), our study shows that grounded cognition is a valid theoretical lens for studying the design and evaluation of immersive systems and multisensory user interfaces. Specifically, we find that by involving the human body as input, mid-air gesture and touchscreen gesture can facilitate users' mental imagery. Previous research has revealed that vivid mental imagery can enhance sensorial and imaginative immersion [106]. Therefore, our study suggests that gesture-based interaction can be leveraged to create immersive experience. Moreover, by revealing the interplay between visual presentation and interaction mode, our study suggests that the congruence between information conveyed by different sensory modalities plays an important role in constructing a realistic and coherent virtual experience. As a wider range of immersive sensorial dimensions can be provided by advanced interaction technologies, e.g., 3D surround sound, gestures, vibrations, and VR/AR display, understanding the effects of sensory-enriched interface design and the interaction among multiple sensory modalities will create a new research field with considerable potential. For example, a recent study showed that manipulating visual proprioceptive cues can alter movement-evoked pain: pain occurred at a lesser degree of head rotation when visual feedback overstated the true physical rotation and at a greater degree of rotation when the visual feedback understated the true physical rotation [36]. Our study encourages future studies in the growing and evolving field of multisensory human-computer interaction, which involves senses beyond vision [67, 70].

The advancement of interaction technology also brings new approaches to studying grounded cognition. By illustrating the interaction between different sensory modalities involved in VPE (i.e., visual and bodily), our study demonstrates the potential of virtual environments to study multisensory information processing and grounded cognition effects. Such interaction effects have seldom been investigated in grounded cognition research because multisensory experience is difficult to manipulate in the real world [54]; in the digital environment, researchers can manipulate sensory cues from one modality without interfering sensory cues from another modality.

The present study also has implications for retailers, marketers and designers. First, our study highlights the ability of different interaction modes in shaping consumers' VPE. According to our results, touchscreen gesture performs best in terms of eliciting haptic imagery. Hence, touchscreen gestures could be helpful in experiencing products with haptic attributes that are important, e.g., apparel products. Retailers selling these products can encourage their customers to experience products using touchscreen devices when they shop online by adding a message suggesting "the product is best experienced on a touchscreen" on their website. They can also consider setting up virtual try-on applications and information kiosks accompanied by touchscreen gestures in their physical stores. We also find that mid-air gesture, especially when paired with 3D presentation, creates higher spatial imagery. Therefore, mid-air gesture could be beneficial in promoting products with spatial attributes that are essential, e.g., furniture or complex functional products. Vendors selling these products should consider providing digital channels accompanied by mid-air gesture technology. Second, our study suggests that, when designing for multisensory interactions, e.g., VPE enabled by gesture control and visual presentation, it is important to maintain the congruence of the information delivered by different sensory modalities. Sensory incongruence can result in difficulties or bias in product evaluation. By revealing the interplay between interaction mode and visual presentation, our study provides implications regarding how to properly display products to consumers using different interaction modes. For instance, when designing for VPE on devices supporting mid-air gestures, it is better to adopt 3D presentation to leverage the ability of mid-air gestures in facilitating spatial imagery. In general, with the maturation of advanced interaction technologies, e.g., virtual reality, augmented reality, and gesture control technologies, which allow for a richer sensory experience, practitioners must consider the interaction among different sensory channels. Finally, we emphasize that, in a VPE context in which sensory experience is crucial but lacking, retailers' ability to evoke mental imagery is vital. We encourage practitioners to leverage the ability of advanced interaction technologies to elicit mental imagery pertinent to their products, e.g., gustatory imagery for food products and haptic imagery for apparel products.

Overall, this study integrates research on VPE, grounded cognition and mental imagery into the gesture-based interaction context. It extends the traditional stream of research, which has focused on the visual modalities of VPE, to a more complicated context. In this context, researchers and practitioners must think beyond visual design and consider other sensorimotor experience that users might undergo when exposed to advanced interaction technologies. In particular, the findings are expected to improve our understanding of how consumer cognition is shaped by different interaction modes and visual presentations and how online retailers can make informed choices regarding different technologies to foster better product experience.

Limitations and Future Research Directions

This research is not without its limitations, which in turn provide opportunities for future research. First, we only investigated simple mid-air and touchscreen gestures and two popular visual presentation formats in VPE design in our study. We focused on the fundamental differences between mid-air gestures and touchscreen gestures but did not consider the specific gestures supported by each interaction mode. The prior literature indicates that different gestures, e.g., moving the hand up and moving the hand down, might be associated with and trigger different mental representations [11]. Thus, more effort is necessary to investigate the impacts of different gestures. Similarly, with advancements in output technology, more complex visual presentation formats can be afforded [66]. Future research can explore how to leverage the power of different interaction modes with immersive output technology, such as head-mounted virtual reality and augmented reality.

Second, only one product, i.e., a chair, was used as the focal product in our experiment. Therefore, while we find that gesture-based interaction can facilitate mental representations (i.e., haptic imagery and spatial imagery) and thus reduce product uncertainty, caution is needed in generalizing and applying our findings to other product types or contexts. Indeed, creating a realistic interaction experience for different kinds of products might require different gesture designs and visual presentation designs. Thus, future studies can design and evaluate gesture-based interactions for other types of products, such as apparel or complex functional products. It could also be promising to study how gesture-based interaction technologies can be used to create a realistic virtual store experience in which people can browse and interact with different products as if they were in a physical store.

Third, our study focused on the impacts of gestural control and visual presentation on consumer mental imagery and produce uncertainty; beyond this point, it is also important to understand how these factors affect consumer judgment and choice. Prior research has revealed that people may mistakenly consider sensory experiences that are not directly related to the focal product they are evaluating. For example, when people carry a heavy bag (compared with a light bag), they tend to perceive a mountain in front of them to be steeper [12] because they incidentally incorporate the sensorial fatigue triggered by carrying a heavy bag in their judgment. Touchscreens are hard, smooth and glasslike in nature, and the tactile properties of touchscreens may be different from those of the products under examination. It would be interesting to investigate whether such dissonance could lead to a bias in judgment when one is exploring products with different haptic attributes, e.g., soft cashmere sweaters. In addition, allowing users to interact with the digital environment using gestures might also affect consumer choice. For example, Shen, Zhang and Krishna [92] found that consumers were more likely to choose an affect-laden alternative over the cognitively superior option on touchscreens. Future studies could explore whether VPE design with mid-air gestures can shift product preference and consumer choice.

Conclusion

Gesture-based interaction is increasingly used in immersive systems. This study represents one of the first attempts to investigate how gesture control can be leveraged to enhance users' virtual product experience. Specifically, this study complements extant studies by introducing interaction mode into the VPE design framework and empirically comparing three types of interaction mode (i.e., mid-air gesture vs. touchscreen gesture and mouse-based interaction) on eliciting consumer mental imagery. Furthermore, our research highlights the synergistic effects between gesture control and visual presentation and demonstrates grounded cognition as an effective theoretical lens in guiding multisensory user interface design. The findings of this study serve as a basis for future theoretical development on VPE design and provide valuable practical implications for marketers, retailers, and designers.

Acknowledgement

The authors thank the Ministry of Education of Singapore (Academic Research Fund Tier 1 and Tier 2) and the University of Hong Kong (Seed Fund) for their financial support.

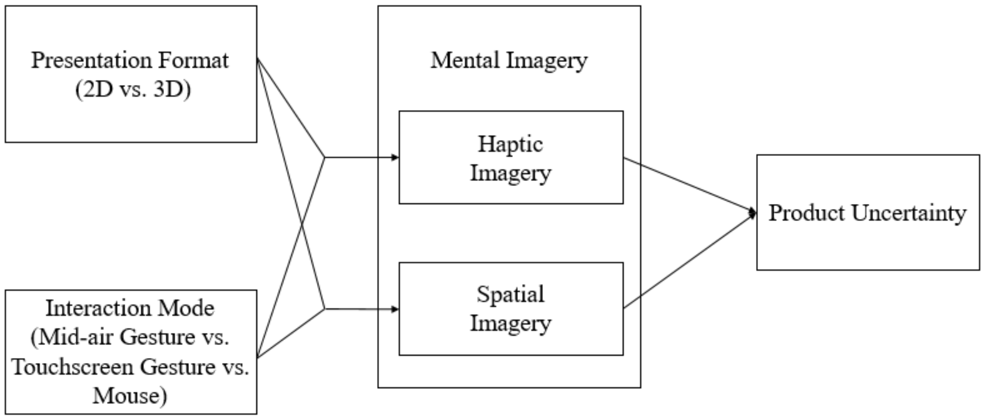

Figure 1. Research Model

Figure 2. An Illustration of Leap Motion Usage and Experimental Website

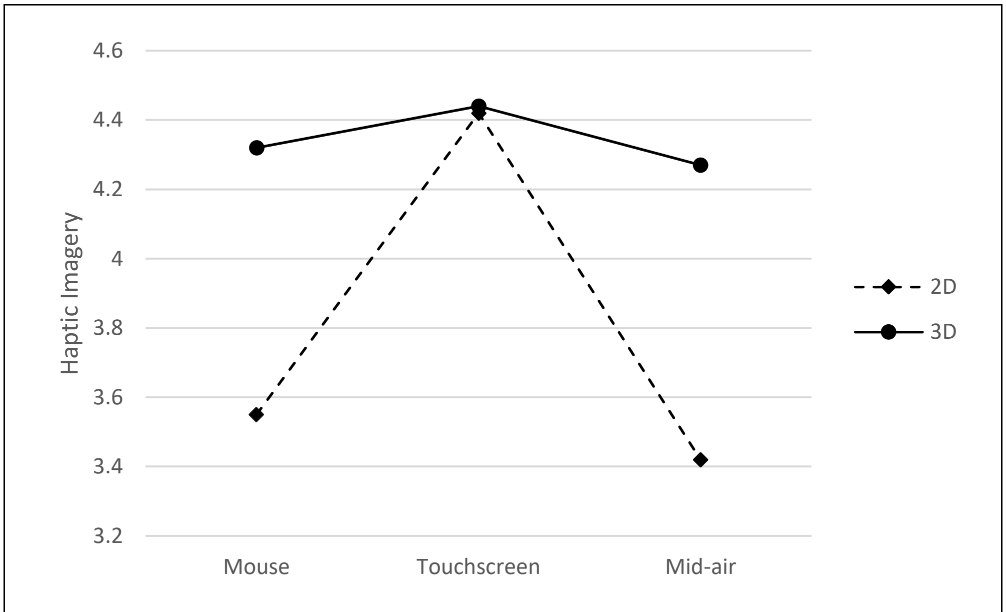

Figure 3. Plot of Interaction Effect on Haptic Imagery

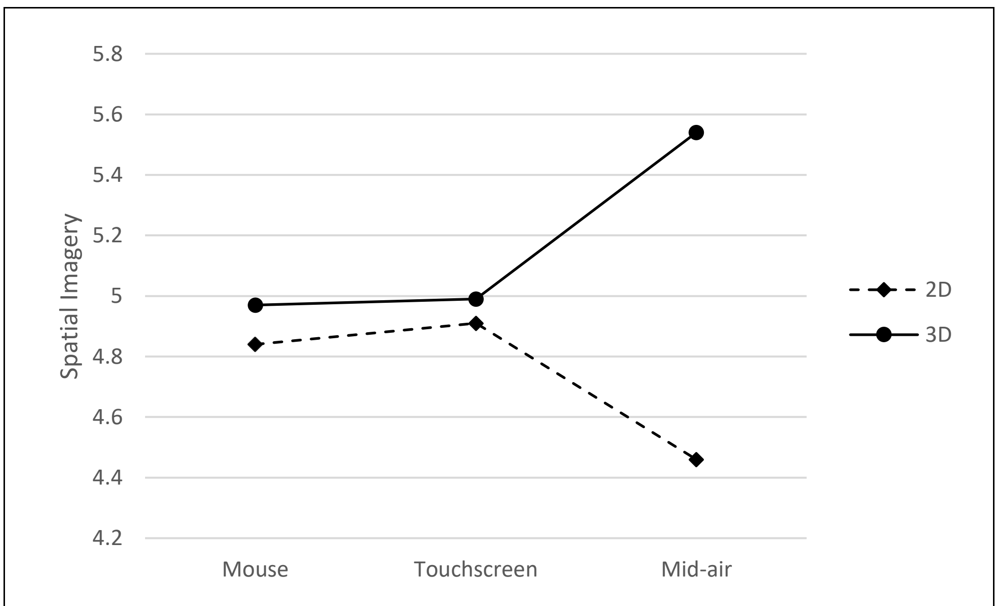

Figure 4. Plot of Interaction Effect on Spatial Imagery

Table 1. Measurement Items (Using a Seven-Point Likert Scale)		
Construct	Measures	Adapted From
Haptic Imagery	I felt that I could imagine moving my fingers on the chair during the interaction. I felt as if the chair was in my hands during the interaction. I felt that I could examine the texture of the chair during the interaction.	[78]
Spatial Imagery	I felt that I could easily imagine how the chair fits in the environment during the interaction. I felt that I was examining the chair in a 3D space during the interaction. I felt that I could explore the shape and spatial structure of the chair during the interaction.	[13]
Product Uncertainty	I felt uncertain about how the chair would look in real life. I felt certain that I fully understood everything that I need to know about the chair. (reverse) I felt that purchasing this chair would involve a high degree of uncertainty. I was concerned that the chair would be different from how I expected.	[27]

Table 2. Group Sizes			
	Mouse	Touchscreen	Mid-air
2D	31	30	31
3D	31	30	30

Table 3. Correlations Between Variables			
	Haptic Imagery	Spatial Imagery	Product Uncertainty
Haptic Imagery	1		
Spatial Imagery	0.369	1	
Product Uncertainty	-0.260	-0.312	1

Table 4. Rotated Factor Loadings			
	Haptic Imagery	Spatial Imagery	Product Uncertainty
haptic1	0.821	0.235	-0.028
haptic2	0.887	0.045	-0.151
haptic3	0.839	0.187	-0.148
spa1	0.111	0.794	-0.172
spa2	0.208	0.773	-0.098
spa3	0.108	0.764	-0.107
uncer1	-0.040	-0.084	0.766
uncer2	-0.179	-0.166	0.658
uncer3	-0.044	-0.195	0.842
uncer4	-0.106	-0.021	0.822
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			

Table 5. Main and Interaction Effects on Haptic Imagery				
Source	df	Mean Square	F	Sig.
Mode	2	6.10	4.86	0.009
Visual	1	13.67	10.90	0.001
Mode*Visual	2	3.20	2.55	0.081

Table 6. Means and Standard Deviations of Haptic Imagery				
	Mouse	Touchscreen	Mid-air	Overall
2D	3.55 (1.28)	4.42 (1.15)	3.42 (1.08)	3.80 (1.25)
3D	4.32 (1.07)	4.44 (1.18)	4.27 (0.89)	4.34 (1.05)
Overall	3.93 (1.24)	4.43 (1.16)	3.84 (1.07)	4.07 (1.18)

Table 7. Main and Interaction Effects on Spatial Imagery				
Source	df	Mean Square	F	Sig.
Mode	2	0.13	0.11	0.892
Visual	1	8.34	7.46	0.007
Mode*Visual	2	4.98	4.45	0.013

Table 8. Means and Standard Deviations of Spatial Imagery				
	Mouse	Touchscreen	Mid-air	Overall
2D	4.84 (1.12)	4.91 (1.13)	4.46 (1.20)	4.74 (1.16)
3D	4.97 (0.93)	4.99 (1.12)	5.54 (0.85)	5.16 (0.98)
Overall	4.90 (1.03)	4.95 (1.12)	5.00 (1.14)	4.95 (1.09)

Table 9. Summary of Hypothesis Testing	
Hypotheses	Supported or Not Supported
H1: Compared with 2D presentation, 3D presentation leads to more vivid haptic imagery.	Supported
H2: Touchscreen gesture leads to higher haptic imagery than (a) mouse-based interaction and (b) mid-air gesture.	Both H2a and H2b are supported
H3: The superior effect of touchscreen gesture over (a) mouse-based interaction and (b) mid-air gesture on eliciting haptic imagery is stronger when 2D presentation is used than when 3D presentation is used.	Both H3a and H3b are supported
H4: Compared with 2D presentation, 3D presentation leads to more vivid spatial imagery.	Supported
H5: Mid-air gesture leads to higher spatial imagery than (a) mouse-based interaction and (b) touchscreen gesture.	Neither H5a nor H5b is supported
H6: The superior effect of mid-air gesture over (a) mouse-based interaction and (b) touchscreen gesture on eliciting spatial imagery is stronger when 3D presentation is used than when 2D presentation is used.	Both H6a and H6b are supported
H7: Increased haptic imagery reduces product uncertainty.	Supported
H8: Increased spatial imagery reduces product uncertainty.	Supported

References

1. Alibali, M.W. Gesture in spatial cognition: Expressing, communicating, and thinking about spatial information. *Spatial Cognition and Computation*, 5, 4 (2005), 307-331.

2. Babin, L.A., and Burns, A.C. Effects of print ad pictures and copy containing instructions to imagine on mental imagery that mediates attitudes. *Journal of Advertising*, 26, 3 (1997), 33-44.

3. Balaji, M., Raghavan, S., and Jha, S. Role of tactile and visual inputs in product evaluation: a multisensory perspective. *Asia Pacific Journal of Marketing and Logistics*, 23, 4 (2011), 513-530.

4. Bang, Y., Lee, D.-J., Han, K., Hwang, M., and Ahn, J.-H. Channel capabilities, product characteristics, and the impacts of mobile channel introduction. *Journal of Management Information Systems*, 30, 2 (2013), 101-126.

5. Bargh, J.A. What have we been priming all these years? On the development, mechanisms, and ecology of nonconscious social behavior. *European Journal of Social Psychology*, 36, 2 (2006), 147-168.

6. Barsalou, L.W. Perceptions of perceptual symbols. *Behavioral and Brain Sciences*, 22, 04 (1999), 637-660.

7. Barsalou, L.W. Grounded cognition. *Annual Review of Psychology*, 59 (2008), 617-645.

8. Barsalou, L.W. Grounded cognition: Past, present, and future. *Topics in Cognitive Science*, 2, 4 (2010), 716-724.

9. Barsalou, L.W., Niedenthal, P.M., Barbey, A.K., and Ruppert, J.A. Social embodiment. *Psychology of Learning and Motivation*, 43 (2003), 43-92.

10. Barsalou, L.W., Simmons, W.K., Barbey, A.K., and Wilson, C.D. Grounding conceptual knowledge in modality-specific systems. *Trends in Cognitive Sciences*, 7, 2 (2003), 84-91.

11. Beilock, S.L., and Goldin-Meadow, S. Gesture changes thought by grounding it in action. *Psychological Science*, 21, 11 (2010), 1605-1610.

12. Bhalla, M., and Proffitt, D.R. Visual–motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance*, 25, 4 (1999), 1076.

13. Blajenkova, O., Kozhevnikov, M., and Motes, M.A. Object-spatial imagery: a new self-report imagery questionnaire. *Applied Cognitive Psychology*, 20, 2 (2006), 239-263.

14. Brasel, S.A., and Gips, J. Tablets, touchscreens, and touchpads: How varying touch interfaces trigger psychological ownership and endowment. *Journal of Consumer Psychology*, 24, 2 (2014), 226-233.

15. Brasel, S.A., and Gips, J. Interface Psychology: Touchscreens Change Attribute Importance, Decision Criteria, and Behavior in Online Choice. *Cyberpsychology, Behavior, and Social Networking*, 18, 9 (2015), 534-538.

16. Campos, A. Spatial imagery: A new measure of the visualization factor. *Imagination, Cognition and Personality*, 29, 1 (2009), 31-39.

17. Campos, A., Lopez, A., and Perez, M.J. Vividness of visual and haptic imagery of movement. *Perceptual and Motor Skills*, 87, 1 (1998), 271-274.

18. Cano, M.B., Perry, P., Ashman, R., and Waite, K. The influence of image interactivity upon user engagement when using mobile touch screens. *Computers in Human Behavior*, 77 (2017), 406-412.

19. Castaño, R., Sujan, M., Kacker, M., and Sujan, H. Managing consumer uncertainty in the adoption of new products: Temporal distance and mental simulation. *Journal of Marketing Research*, 45, 3 (2008), 320-336.

20. Chin, W.W. The partial least squares approach for structural equation modeling. In, Marcoulides, G., (ed.), *Modern Methods for Business Research*, Mahwah, NJ: Lawrence Erlbaum Associates, 1998, pp. 295-333.

21. Choi, Y.K., and Taylor, C.R. How do 3-dimensional images promote products on the Internet? *Journal of Business Research*, 67, 10 (2014), 2164-2170.

22. Chung, S. Do touch screen users feel more engaged? the impact of touch interfaces on online shopping. *ACR Asia-Pacific Advances* (2015).

23. Cian, L., Krishna, A., and Elder, R.S. This logo moves me: dynamic imagery from static images. *Journal of Marketing Research*, 51, 2 (2014), 184-197.

24. Cohen, J. Statistical power analysis for the behavioral sciences. 2nd. Hillsdale, NJ: erlbaum, 1988.

25. Cummings, J.J., and Bailenson, J.N. How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychology*, 19, 2 (2016), 272-309.

26. Deighton, K. M&S enters the world of VR with Loft Homeware tour. 2015. https://www.campaignlive.co.uk/article/m-s-enters-world-vr-loft-homeware-tour/1364085.

27. Dimoka, A., Hong, Y., and Pavlou, P.A. On product uncertainty in online markets: theory and evidence. *MIS Quarterly*, 36, 2 (2012), 395-426.

28. Dourish, P. *Where the action is: the foundations of embodied interaction*. Cambridge, Mass.: MIT Press, 2004.

29. Elder, R.S., and Krishna, A. The “visual depiction effect” in advertising: Facilitating embodied mental simulation through product orientation. *Journal of Consumer research*, 38, 6 (2012), 988-1003.

30. eMarketer. Retail Ecommerce Sales Worldwide, 2016-2021. 2018. https://www.emarketer.com/Chart/Retail-Ecommerce-Sales-Worldwide-2016-2021-trillions-change-of-total-retail-sales/215138.

31. Farah, M.J., Hammond, K.M., Levine, D.N., and Calvanio, R. Visual and spatial mental imagery: Dissociable systems of representation. *Cognitive Psychology*, 20, 4 (1988), 439-462.

32. Faul, F., Erdfelder, E., Lang, A.-G., and Buchner, A. G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39, 2 (2007), 175-191.

33. Gu, Z.J., and Tayi, G.K. Consumer Pseudo-Showrooming and Omni-Channel Placement Strategies. *MIS Quarterly*, 41, 2 (2017), 583-606.

34. Gurman, M. Apple Working on Touchless Control and Curved iPhone Screen. 2018. https://www.bloomberg.com/news/articles/2018-04-04/apple-is-said-to-work-on-touchless-control-curved-iphone-screen.

35. Hadi, R., and Block, L. I take therefore I choose? The impact of active vs. passive acquisition on food consumption. *Appetite*, 80 (2014), 168-173.

36. Harvie, D.S., Broecker, M., Smith, R.T., Meulders, A., Madden, V.J., and Moseley, G.L. Bogus Visual Feedback Alters Onset of Movement-Evoked Pain in People With Neck Pain. *Psychological Science*, 26, 4 (2015), 385-392.

37. Hegarty, M., and Kozhevnikov, M. Types of visual–spatial representations and mathematical problem solving. *Journal of Educational Psychology*, 91, 4 (1999), 684.

38. Hess, T.J., Fuller, M.A., and Mathew, J. Involvement and decision-making performance with a decision aid: The influence of social multimedia, gender, and playfulness. *Journal of Management Information Systems*, 22, 3 (2005), 15-54.

39. Hong, Y., and Pavlou, P.A. Product Fit Uncertainty in Online Markets: Nature, Effects, and Antecedents. *Information Systems Research*, 25, 2 (2014), 328-344.

40. Hu, G., Bin Hannan, N., Tearo, K., Bastos, A., and Reilly, D. Doing while thinking: Physical and cognitive engagement and immersion in mixed reality games. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*: ACM, 2016, pp. 947-958.

41. Jetter, H.-C., Leifert, S., Gerken, J., Schubert, S., and Reiterer, H. Does (multi-) touch aid users' spatial memory and navigation in'panning'and in'zooming & panning'UIs? , *Proceedings of the International Working Conference on Advanced Visual Interfaces*: ACM, 2012, pp. 83-90.

42. Jiang, Z., and Benbasat, I. Virtual product experience: Effects of visual and functional control of products on perceived diagnosticity and flow in electronic shopping. *Journal of Management Information Systems*, 21, 3 (2004), 111-147.

43. Jiang, Z., and Benbasat, I. The effects of presentation formats and task complexity on online consumers' product understanding. *MIS Quarterly* (2007), 475-500.

44. Jiang, Z., and Benbasat, I. Investigating the influence of the functional mechanisms of online product presentations. *Information Systems Research*, 18, 4 (2007), 454-470.

45. Kim, J.-S., Gračanin, D., Yang, T., and Quek, F. Action-transferred navigation technique design approach supporting human spatial learning. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 22, 6 (2015), 30.

46. Kim, Y., and Krishnan, R. On product-level uncertainty and online purchase behavior: An empirical analysis. *Management Science*, 61, 10 (2015), 2449-2467.

47. Klatzky, R.L., and Lederman, S.J. Haptic object perception: spatial dimensionality and relation to vision. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 366, 1581 (2011), 3097-3105.

48. Klatzky, R.L., and Peck, J. Please touch: Object properties that invite touch. *IEEE Transactions on Haptics*, 5, 2 (2012), 139-147.

49. Kosslyn, S.M., Thompson, W.L., and Ganis, G. *The case for mental imagery*. Oxford University Press, 2006.

50. Krishna, A. An integrative review of sensory marketing: Engaging the senses to affect perception, judgment and behavior. *Journal of Consumer Psychology*, 22, 3 (2012), 332-351.

51. Krishna, A., Elder, R.S., and Caldara, C. Feminine to smell but masculine to touch? Multisensory congruence and its effect on the aesthetic experience. *Journal of Consumer Psychology*, 20, 4 (2010), 410-418.

52. Krishna, A., Lee, S.W., Li, X., and Schwarz, N. Embodied Cognition, Sensory Marketing, and the Conceptualization of Consumers' Judgment and Decision Processes: Introduction to the Issue. *Journal of the Association for Consumer Research*, 2, 4 (2017), 377-381.

53. Krishna, A., Morrin, M., and Sayin, E. Smellizing cookies and salivating: a focus on olfactory imagery. *Journal of Consumer research*, 41, 1 (2014), 18-34.

54. Krishna, A., and Schwarz, N. Sensory marketing, embodiment, and grounded cognition: A review and introduction. *Journal of Consumer Psychology*, 24, 3 (2013), 159-168.

55. Lakoff, G., and Johnson, M. *Philosophy in the flesh: The embodied mind and its challenge to western thought*. Basic books, 1999.

56. Lakoff, G., and Johnson, M. *Metaphors we live by*. Chicago: University of Chicago Press, 2008.

57. Landau, M.J., Meier, B.P., and Keefer, L.A. A metaphor-enriched social cognition. *Psychological Bulletin*, 136, 6 (2010), 1045.

58. Lederman, S.J., and Klatzky, R.L. Hand movements: A window into haptic object recognition. *Cognitive Psychology*, 19, 3 (1987), 342-368.

59. Lederman, S.J., and Klatzky, R.L. Extracting object properties through haptic exploration. *Acta Psychologica*, 84, 1 (1993), 29-40.

60. Lederman, S.J., and Klatzky, R.L. Haptic perception: A tutorial. *Attention, Perception, & Psychophysics*, 71, 7 (2009), 1439-1459.

61. Lee, Y., and Chen, A.N. Usability design and psychological ownership of a virtual world. *Journal of Management Information Systems*, 28, 3 (2011), 269-308.

62. Li, H., Daugherty, T., and Biocca, F. Impact of 3-D advertising on product knowledge, brand attitude, and purchase intention: The mediating role of presence. *Journal of Advertising*, 31, 3 (2002), 43-57.

63. Lien, N.-H., and Chen, Y.-L. Narrative ads: The effect of argument strength and story format. *Journal of Business Research*, 66, 4 (2013), 516-522.

64. Lunden, I. Amazon Sumerian, a platform for building AR, VR and 3D apps, is now open to all. 2018. https://techcrunch.com/2018/05/15/amazon-sumerian-a-platform-for-building-ar-vr-and-3d-apps-is-now-open-to-all/.

65. MacInnis, D.J., and Price, L.L. The role of imagery in information processing: Review and extensions. *Journal of Consumer research*, 13, 4 (1987), 473-491.

66. Meißner, M., Pfeiffer, J., Pfeiffer, T., and Oppewal, H. Combining virtual reality and mobile eye tracking to provide a naturalistic experimental environment for shopper research. *Journal of Business Research* (2017).

67. Minas, R.K., and Dennis, A.R. Visual Background Music: Creativity Support Systems with Priming. *Journal of Management Information Systems*, 36, 1 (2019), 230-258.

68. Moreau, C.P., Markman, A.B., and Lehmann, D.R. “What is it?” Categorization flexibility and consumers' responses to really new products. *Journal of Consumer research*, 27, 4 (2001), 489-498.

69. Nunnally, J.C. *Psychometric Theory*. New York: McGraw-Hill, 1978.

70. Obrist, M., Velasco, C., Vi, C., Ranasinghe, N., Israr, A., Cheok, A., Spence, C., and Gopalakrishnakone, P. Sensing the future of HCI: touch, taste, and smell user interfaces. *Interactions*, 23, 5 (2016), 40-49.

71. Ostinelli, M., and Bockenholt, U. On Believing Our Imagination: The Role of Mental Imagery in Belief Generation and Resilience. *ACR North American Advances* (2009).

72. Overmars, S., and Poels, K. Online product experiences: The effect of simulating stroking gestures on product understanding and the critical role of user control. *Computers in Human Behavior*, 51 (2015), 272-284.

73. Papies, E.K., Best, M., Gelibter, E., and Barsalou, L.W. The role of simulations in consumer experiences and behavior: Insights from the grounded cognition theory of desire. *Journal of the Association for Consumer Research*, 2, 4 (2017), 402-418.

74. Park, W., and Han, S.H. An analytical approach to creating multitouch gesture vocabularies in mobile devices: A case study for mobile web browsing gestures. *International Journal of Human-Computer Interaction*, 30, 2 (2014), 126-141.

75. Parrish, K. Microsoft patent paves way for a touch- and smudge-free tablet future. 2018. https://www.digitaltrends.com/computing/new-microsoft-patent-eliminates-smudges-with-touchless-input/.

76. Pasch, M., Bianchi-Berthouze, N., Van Dijk, B., and Nijholt, A. Immersion in movement-based interaction. *International Conference on Intelligent Technologies for Interactive Entertainment*: Springer, 2009, pp. 169-180.

77. Pasqualotto, A., and Proulx, M.J. The role of visual experience for the neural basis of spatial cognition. *Neuroscience & Biobehavioral Reviews*, 36, 4 (2012), 1179-1187.

78. Peck, J., Barger, V.A., and Webb, A. In search of a surrogate for touch: The effect of haptic imagery on perceived ownership. *Journal of Consumer Psychology*, 23, 2 (2013), 189–196.

79. Peck, J., and Childers, T.L. To have and to hold: The influence of haptic information on product judgments. *Journal of Marketing*, 67, 2 (2003), 35-48.

80. Peck, J., and Shu, S.B. The effect of mere touch on perceived ownership. *Journal of Consumer research*, 36, 3 (2009), 434-447.

81. Petrova, P.K., and Cialdini, R.B. Fluency of consumption imagery and the backfire effects of imagery appeals. *Journal of Consumer research*, 32, 3 (2005), 442-452.

82. Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y., and Podsakoff, N.P. Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88, 5 (2003), 879.

83. Podsakoff, P.M., and Organ, D.W. Self-reports in organizational research: Problems and prospects. *Journal of Management*, 12, 4 (1986), 531-544.

84. Radhakrishnan, S., Lin, Y., Zeid, I., and Kamarthi, S. Finger-based multitouch interface for performing 3D CAD operations. *International Journal of Human-Computer Studies*, 71, 3 (2013), 261-275.

85. Rempel, D., Camilleri, M.J., and Lee, D.L. The design of hand gestures for human–computer interaction: Lessons from sign language interpreters. *International Journal of Human-Computer Studies*, 72, 10 (2014), 728-735.

86. Roggeveen, A.L., Grewal, D., Townsend, C., and Krishnan, R. The impact of dynamic presentation format on consumer preferences for hedonic products and services. *Journal of Marketing*, 79, 6 (2015), 34-49.

87. Saffer, D. *Designing gestural interfaces: Touchscreens and interactive devices*. Sebastopol, Calif.: O'Reilly Media, 2008.

88. Schlosser, A.E. Experiencing products in the virtual world: the role of goal and imagery in influencing attitudes versus purchase intentions. *Journal of Consumer research*, 30, 2 (2003), 184-198.

89. Schlosser, A.E. Learning through virtual product experience: The role of imagery on true versus false memories. *Journal of Consumer research*, 33, 3 (2006), 377-383.

90. Sheehan, A. How These Retailers Use Augmented Reality to Enhance the Customer Experience. 2018. https://www.shopify.com.sg/retail/how-these-retailers-are-using-augmented-reality-to-enhance-the-customer-experience.

91. Shen, H., and Sengupta, J. If you can't grab it, it won't grab you: The effect of restricting the dominant hand on target evaluations. *Journal of Experimental Social Psychology*, 48, 2 (2012), 525-529.

92. Shen, H., Zhang, M., and Krishna, A. Computer Interfaces and the "Direct-Touch" Effect: Can iPads Increase the Choice of Hedonic Food. *Journal of Marketing Research*, 53, 5 (2016), 745-758.

93. Shu, S.B., and Peck, J. Psychological ownership and affective reaction: Emotional attachment process variables and the endowment effect. *Journal of Consumer Psychology*, 21, 4 (2011), 439-452.

94. Simmons, W.K., Martin, A., and Barsalou, L.W. Pictures of appetizing foods activate gustatory cortices for taste and reward. *Cerebral Cortex*, 15, 10 (2005), 1602-1608.

95. Spence, C., and Gallace, A. Multisensory design: Reaching out to touch the consumer. *Psychology & Marketing*, 28, 3 (2011), 267-308.

96. Steinmann, S., Kilian, T., and Brylla, D. Experiencing Products Virtually: The Role of Vividness and Interactivity in Influencing Mental Imagery and User Reactions. *35th International Conference on Information Systems*, Auckland, New Zealand, 2014.

97. Streicher, M.C., and Estes, Z. Multisensory interaction in product choice: grasping a product affects choice of other seen products. *Journal of Consumer Psychology*, 26, 4 (2016), 558-565.

98. Suh, K.-S., and Lee, Y.E. The effects of virtual reality on consumer learning: an empirical investigation. *MIS Quarterly*, 29, 4 (2005), 673-697.

99. Sujan, M., and Dekleva, C. Product categorization and inference making: Some implications for comparative advertising. *Journal of Consumer research*, 14, 3 (1987), 372-378.

100. Symes, E., Ellis, R., and Tucker, M. Visual object affordances: Object orientation. *Acta Psychologica*, 124, 2 (2007), 238-255.

101. Tan, D.S., Pausch, R., Stefanucci, J.K., and Proffitt, D.R. Kinesthetic cues aid spatial memory. *CHI'02 Extended Abstracts on Human Factors in Computing Systems*: ACM, 2002, pp. 806-807.

102. Thompson, B. *Exploratory and confirmatory factor analysis: Understanding concepts and applications*. American Psychological Association, 2004.

103. Tucker, M., and Ellis, R. On the relations between seen objects and components of potential actions. *Journal of Experimental Psychology: Human Perception and Performance*, 24, 3 (1998), 830-846.

104. Verhagen, T., Vonkeman, C., Feldberg, F., and Verhagen, P. Present it like it is here: Creating local presence to improve online product experiences. *Computers in Human Behavior*, 39 (2014), 270-280.

105. Wachs, J.P., Kölsch, M., Stern, H., and Edan, Y. Vision-based hand-gesture applications. *Communications of the ACM*, 54, 2 (2011), 60-71.

106. Weibel, D., Wissmath, B., and Mast, F.W. Influence of mental imagery on spatial presence and enjoyment assessed in different types of media. *Cyberpsychology, Behavior, and Social Networking*, 14, 10 (2011), 607-612.

107. Wesp, R., Hesse, J., Keutmann, D., and Wheaton, K. Gestures maintain spatial imagery. *The American Journal of Psychology*, 114, 4 (2001), 591.

108. Wexler, M., Kosslyn, S.M., and Berthoz, A. Motor processes in mental rotation. *Cognition*, 68, 1 (1998), 77-94.

109. Wohlschläger, A., and Wohlschläger, A. Mental and manual rotation. *Journal of Experimental Psychology: Human Perception and Performance*, 24, 2 (1998), 397.

110. Xu, D.J., Benbasat, I., and Cenfetelli, R.T. A Two-Stage Model of Generating Product Advice: Proposing and Testing the Complementarity Principle. *Journal of Management Information Systems*, 34, 3 (2017), 826-862.

111. Xu, J., Benbasat, I., and Cenfetelli, R.T. The nature and consequences of trade-off transparency in the context of recommendation agents. *MIS Quarterly*, 38, 2 (2014), 379-406.

112. Xu, K., Chan, J., Ghose, A., and Han, S.P. Battle of the channels: The impact of tablets on digital commerce. *Management Science*, 63, 5 (2016), 1469-1492.

113. Yi, C., Jiang, Z.., and Izak, B. Enticing and Engaging Consumers via Online Product Presentations: The Effects of Restricted Interaction Design. *Journal of Management Information Systems*, 31, 4 (2015), 213-242.

114. Yoo, J., and Kim, M. The effects of online product presentation on consumer responses: A mental imagery perspective. *Journal of Business Research*, 67, 11 (2014), 2464-2472.

115. Zagermann, J., Pfeil, U., Fink, D., von Bauer, P., and Reiterer, H. Memory in Motion: The Influence of Gesture-and Touch-Based Input Modalities on Spatial Memory. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*: ACM, 2017, pp. 1899-1910.

116. Zatorre, R.J., and Halpern, A.R. Mental concerts: musical imagery and auditory cortex. *Neuron*, 47, 1 (2005), 9-12.

117. Zhu, K., Ma, X., Chen, H., and Liang, M. Tripartite Effects: Exploring Users' Mental Model of Mobile Gestures under the Influence of Operation, Handheld Posture, and Interaction Space. *International Journal of Human–Computer Interaction*, 33, 6 (2017), 443-459.