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Can you smell the (virtual) roses? The influence of olfactory cues in virtual reality on immersion and positive brand responses☆,☆☆

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Abstract

Virtual reality (VR) has grown in popularity and technological ability, offering wider potential for retailers to immerse consumers in branded experiences. On the industry side, experts argue that integration of olfactory cues is the next big development for VR as such cues have the potential to improve immersion – the feeling of being 'plugged into' the experience – and possibly elicit positive brand responses. Despite its promise, integration of olfactory cues also has its challenges, such as financial costs and conflicting evidence of their effects in traditional retail contexts. Unfortunately, research has yet to explore the integration of olfactory cues in VR and offer insight to retailers and scholars. To address this deficit, this research builds upon the concept of immersion and integrates flow theory to explore the interplay and additive nature of olfactory stimuli and VR. We employ four studies using a variety of both ambient (i.e., actual scents) and imagined (i.e., prompted through description) olfactory cues in field (i.e., Facebook A/B testing), online, and laboratory settings. Our findings show through both measured mediation and moderation that in retail-centric VR environments, the presence (vs. absence) of olfactory cues heightens immersion. In turn, immersion elicits flow, which improves brand responses. Our research contributes to the sensory marketing and VR literatures and offers recommendations to retailers seeking to build or expand their VR strategies.

Keywords: Virtual reality; Sensory marketing; Olfactory; Immersion; Flow.

Introduction

Virtual reality (VR) is a computing technology that transports users into a virtual environment where they navigate and interact (Berg and Vance, 2016; Guttentag, 2010). Importantly, VR is predicted to transform shopping experiences (XR Today, 2022), making its integration critically important for retailers in offline and online settings. VR has already been employed by retailers in many creative ways. For example, in partnership with MasterCard, Swarovski uses virtual headsets (i.e., head-mounted displays [HMDs]) to expand their selling space in retail locations via a virtual atelier. Other retailers have incorporated VR in their physical stores to showcase strategic aspects of their operations, such as Nike's supply chain and Toms' charity work (Marr, 2021), or to educate consumers, such as Lowe's training for DIY projects. In the online space, Chinese retailer Alibaba developed a VR-based platform called Buy+ to provide consumers the ability to shop for products using the Alipay payment platform. Other retailers create VR experiences to enhance their brand positioning (e.g., Top Shop's VR waterslide through London) or to drive interest toward the retail location (e.g., Anne Frank Museum visit through Meta Quest). These examples illustrate the multitude of ways retailers can and do incorporate VR in online and offline settings.

For consumers, the interest in using this technology stems from its immersive nature. *Immersion* reflects feeling

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physically and mentally 'plugged into' an experience (e.g., concert, massage, video game; Carù and Cova, 2007; Harrison, Haruvy, and Rutström, 2011; Kim, Oh, and Shin, 2010; Pine and Gilmore, 1999). Consumer demand for immersive technologies has led to the exponential growth of VR and augmented reality markets, which were originally estimated to reach $1.6 billion by 2025 but totaled $18.8 billion in 2020, and are expected to grow another $16.1 billion in the next few years (Jovanovic, 2022; ReportLinker, 2022; Statista, 2020). Further, VR benefits not only consumers but also retailers. While nearly a third of current online purchases result in returns, shopping within VR can reduce return rates by 23% (Castellani, 2019). In fact, a mere one percent increase in retailers' use of AR and VR technology holds potential to generate additional sales opportunities worth $66 billion (XR Today, 2021).

VR developers say that the next step in VR is integration of the senses because sensory integration has the potential to enrich the immersive capability of VR (Carù and Cova, 2007; Gromer et al., 2018). In particular, olfactory technology for VR is on the rise because scent is the 'realest sense' (Stewart, 2022), olfaction and vision together produce a 'superadditive effect' (Elder and Krishna, 2021; Lwin, Morrin, and Krishna, 2010), and olfactory cues tend to improve memory recall and integrity (Krishna, Lwin, and Morrin, 2010; Morrin and Ratneshwar, 2000, 2003), in line with similar findings for VR and memory (Braun, 1999; Braun-Latour and Zaltman, 2006; Johnson and Adamo-Villani, 2010). To that end, OVR Technology created a scent mask compatible with VR headsets. This mask simulates hundreds of smells and makes virtual environments more realistic, such that when in a virtual forest, consumers actually smell trees and lush vegetation (OVR Technology, 2022). According to its CEO, "[*i*]t's critical that scent be [part of] metaverse development... or we're completely limiting the potential" (Ryan, 2022). What is not known, however, is how consumers respond to the addition of olfactory cues into VR, particularly in retail contexts.

When examining how and why olfactory cues might influence brand responses in VR, the answer is likely more complex than prior retail research suggests. Psychological mechanisms such as scent pleasantness (Spangenberg et al., 2005) and ease of processing (Hermans et al., 2005; Li et al., 2008), while appropriate for explaining brand responses in offline and basic online channels, may not be suitable for VR. VR elicits unique psychological processes (e.g., immersion, flow; Pizzi, Vannucci, and Aiello, 2019) that differ from other channels in multiple ways (e.g., higher cognitive demand; Cowan et al., 2021). For instance, scent pleasantness might not be as important as long as a scent feels real and enhances immersion, which is critical for VR (see Banos et al., 2004).

Given the ripe potential for olfaction in VR, the differences in VR vs. other environments, and the lack of prior investigation of scent in VR, the current research investigates the additive effects of olfactory cues in VR experiences and the novel underlying mechanisms of these effects. We present the following research questions. First, do olfactory cues in the VR environment improve brand responses (e.g., purchase intentions, online engagement)? Second, what psychological process underlies this relationship? Third, how might high vs. low VR immersivity moderate the effect of olfactory cues on positive brand responses?

In exploring these questions, the current investigation offers four contributions to theory and practice. First, this research integrates literature from sensory marketing, immersion, and flow theory to show that adding olfactory sensory stimuli, whether ambient (i.e., actual scents) or imagined (i.e., prompted through description), leads to more favorable brand responses. Second, we document a novel process explaining these effects: compared to conventional retail channels, where the effects of sensory cues are underscored by other mechanisms (e.g., processing fluency, Hermans et al., 2005; sensory imagery, Lwin et al., 2010; non-conscious processing, Krishna, 2011), we propose and demonstrate an immersion account. Using both measured mediation and moderation, we find that in VR, the presence (vs. absence) of olfactory stimuli increases immersion, which in turn fosters a flow state that improves brand responses (e.g., purchase intentions, online engagement). Third, this research offers a new perspective regarding why and how system immersivity influences the role of olfactory cues in brand responses. Specifically, olfactory cues lead to more positive brand responses in VR systems with high (vs. low) immersivity. Finally, this research offers guidance to retailers on using olfactory cues in VR to facilitate positive brand responses.

Conceptual framework

The role of immersion in VR

Immersion is central to a user's experience in VR (Cowan and Ketron, 2019a). Despite considerable debate over the definition and operationalization of immersion, very few studies investigate how immersion influences consumer responses (purchase intentions, attitudes, etc.; see Hudson et al., 2019). Slater and Wilbur (1997) conceptualize immersion as a feature of VR equipment, which can differ (number of simulated senses, display size, stereoscopic view, etc.). We adopt this conceptualization as *system immersivity*, "delivering an inclusive, extensive… illusion of reality to the senses of a human participant" (Slater and Wilbur 1997, p. 604). Current operationalizations of system immersivity range from 'fully immersive' (e.g., VR headsets, or HMDs) to 'semi-' or 'non-immersive' (e.g., 360-degree VR presented on a computer screen; Kostyk and Sheng, 2022; McLean and Barhorst, 2021). However, this conceptualization relegates immersion to an experience created by technology, precluding its existence in non-technology-mediated environments (e.g., concerts, museums, theaters).

To address this lack of consistency in the literature and to provide construct clarity for this and future work, we draw on, integrate, and advance Pine and Gilmore's (1999) and Carù and Cova's (2003a, 2003b) definitions of immersion. Pine and Gilmore (1999) suggest that individuals' connections to the environment range from weak (i.e., absorption) to strong (i.e., immersion), resulting from physical and mental connections to the context of the experience. Building on this, Carù and Cova (2006, p. 5; 2007) contend that immersion results from a process of accessing and plunging into an experience in which individuals 'let themselves go,' whereby individuals feel that an environment is more proximal. From this perspective, immersion represents a more subjective experience. In addition to these key facets of immersion, Shin (2018) adds that immersion is temporary. Integrating these conceptualizations, we define immersion as an embodied, subjective process in which users engage to temporarily access an environment mentally and physically, such that the environment seems more physically and psychologically proximal (i.e., users feel 'plugged into' the environment).

Given this refined definition, we highlight two important characteristics of immersion. First, research suggests that the degree of immersion can vary on a continuum and that it can be experienced immediately (akin to a 'deep dive') or gradually by progressively and repeatedly 'dipping one's toes into the pool' (Carù and Cova, 2003a, 2007). Second, immersion is not tied to a specific emotional valence (Hudson et al., 2019), so heightened immersion does not necessarily lead to more favorable outcomes on its own. Thus, we would not expect immersion itself to contribute to more positive brand responses; rather, we propose heightened or deep immersion as instrumental to activating a state of flow, which in turn elicits positive brand responses. We discuss flow and brand responses next.

Triggering flow via immersion to improve brand responses

Csikszentmihalyi (1975) developed *flow* theory to describe how individuals engage in work to achieve peak efficiency and defined flow as a "holistic sensation that people feel when they act with total involvement" (p. 36). Flow produces cognitive states in which individuals feel highly involved (i.e., nothing else matters) and time passes quickly (Chen, Wigand, and Nilan, 1999). Accordingly, features of flow include focus, concentration, and (importantly) pleasure, a positively-valenced consequence (Nakamura and Csikszentmihalyi, 2002).

Flow states require a balance of sufficient challenge (e.g., conducting research, running long distances, interacting within a virtual environment) and necessary skills to address the challenge (e.g., research skills, athletic experience, the ability to navigate within VR). While there are learning curves to all of the above examples and flow can emerge during the learning process, all of these flow states require action (i.e., flow cannot occur passively). Critically, consumers can experience flow while in retail contexts. This arises due to challenges such as information search in the retail environment (Mathwick and Rigdon, 2004), as well as engaging and entertaining experiences which induce quick passage of time (Kim and Han, 2014; Lavoie and Main, 2022; Lavoie and Zheng, 2023). In VR, the consumer experience is engaging and entertaining, but also challenging. Consumers need to navigate the virtual environment and use multiple senses to process information, making them susceptible to entering the state of flow.

Prior research supports flow as triggered from various technological affordances in VR, such as feelings related to being 'transported elsewhere' (Domina, Lee, and MacGillivray, 2012; Faiola et al., 2013) and entertainment value (Kim et al., 2010; Willems, Brengman, and Van Kerrebroeck, 2019). Likewise, literature on immersion suggests that flow states can be prompted from extremely high or otherwise optimal immersive states (Brown and Cairns, 2004; Carù and Cova, 2003b; Csikszentmihalyi, 2000; Jennett et al., 2008). Thus, we argue that VR offers significant potential for generating flow because the technology boosts immersion. While some researchers theoretically propose immersion as an antecedent of flow within VR (e.g., Cowan and Ketron, 2019b), empirical evidence is currently lacking. We suggest tactics that can induce a deep sense of immersion have the potential to elicit a flow state.

Importantly, immersion and flow are different constructs. First, immersion can result from passive experiences (e.g., a massage), while flow requires active participation in a task that poses some amount of challenge (e.g., running a marathon; Nakamura and Csikszentmihalyi, 2002). Second, one can feel immersed without experiencing flow (e.g., when watching a theatrical performance), yet flow would be triggered only at peak immersion levels when sufficient challenge is present (e.g., at the deepest immersion level when playing a video game; Jennett et al., 2008). Third, flow coincides with positive emotions, whereas immersion is not tied to a specific emotional valence (Hudson et al., 2019). The positive emotions resulting from flow lead to more positive responses such as attitudes, purchase intentions, satisfaction, and loyalty (Hudson et al., 2019; Mathwick and Rigdon, 2004; Ozkara, Ozmen, and Kim, 2017). Given that the presence of flow is routinely linked with such enhanced brand responses, we hypothesize that it is flow specifically that enhances brand responses via immersion in VR (as opposed to immersion enhancing brand responses on its own). To that end, we next discuss how olfactory cues can enhance immersion and, as a result, flow.

Enhancing immersion and flow through olfactory cues

Generally, stimulation of the five senses can help individuals experience immersion (Carù and Cova, 2007; Cowan and Ketron, 2019b; Gromer et al., 2018; Kim et al., 2010; Schmitt, 1999). Olfaction has generated the least attention of all the senses within sensory marketing (see Morrin and Ratneshwar, 2000, 2003; Morrin, 2010). However, research provides some insight into how olfactory cues might interact with consumer processing of visual sensory information and the powerful impact this sense has been shown to have (e.g., Biswas, Labrecque, and Lehmann, 2021; Biswas and Szocs, 2019; Elder and Krishna, 2021; Krishna, 2011). Neuroscientific evidence suggests that the same areas of the brain that process vision also process olfactory elements

(Rolls et al., 2010). However, individuals tend to process visual (vs. olfactory) cues faster (Herz, 2007; Herz and Engen, 1996), and processing visual cues dominates olfactory cues (Biswas et al., 2021; Gottfried and Dolan, 2003). Moreover, consumers have difficulty processing olfactory cues in the absence of confirmatory cues, such as vision (Morrin, 2010). For instance, scent tests often result in misidentification, where people express high familiarity with the scent though unable to identify it (Stevenson, Case, and Mahmut, 2007). As a result, individuals appear better able to imagine a scent given visual or verbal imagery compared with the scent alone (Krishna, Morrin, and Sayin, 2014; Stevenson et al., 2007). This is true whether scent cues are physically present or merely evoked from visual imagery (Krishna et al., 2014). In other words, both real and imagined scents engage similar processing styles and lead to the same downstream consequences. In fact, combining visual and olfactory cues, rather than stand-alone visual elements, enables imagining objects more easily (Elder and Krishna, 2010; Krishna et al., 2014).

Taking this prior literature on olfaction together with our above argument on immersion and flow in VR, olfactory cues in VR environments should lead to more positive brand responses due to increased immersion and, therefore, flow (Cowan and Ketron, 2019a, 2019b; Guttentag, 2010; Harrison et al., 2011). Formally:

H1: VR environments with olfactory cues present (vs. absent) will lead to more positive brand responses.

H2: Immersion and flow will sequentially mediate the relationship between olfactory cues in VR and positive brand responses.

Combining system immersivity and subjective immersion in VR

Thus far, we have outlined how olfactory cues have the potential to increase the degree of immersion experienced in VR environments and therefore elicit a state of flow. We have also stated that VR systems feature varying levels of system immersivity depending on their technical characteristics such as field of view, display size, and more (Cummings and Bailenson, 2015). For example, 360-degree VR is common in tourism, hospitality, charitable giving, and other fields (Feng, 2018; Kandaurova and Lee, 2018; Kristofferson, Daniels, and Morales, 2022; Lo and Cheng, 2020; The National Gallery, 2023). It is often presented on a computer or mobile screen, rendering it a less immersive form of VR than, for example, VR HMDs or projection-based VR rooms (Kostyk and Sheng, 2022; McLean and Barhorst, 2021).

Given that a sufficient level of immersion should be reached to foster a flow state, we predict that system immersivity should moderate the effect of olfactory cues on positive brand responses. As discussed, incorporating additional senses into an experience can enhance immersion (Carù and Cova, 2007; Schmitt, 1999). Further, experiences leading to deeper immersion are more likely to elicit states of flow (Brown and Cairns, 2004; Jennett et al., 2008). The addition of olfactory stimuli with visual stimuli could make the experience more deeply immersive as the user would feel more 'submerged' into the virtual environment, which would thereby position the user to more likely experience flow.

We argue that this effect should be enhanced with high (e.g., HMD) vs. low system immersivity (e.g., 360 VR on a computer screen). That is, when VR system immersivity is low, adding an olfactory cue may enhance immersion but not to a sufficiently deep level for flow to result. Conversely, when VR system immersivity is high, we propose olfactory cues will have a positive effect on immersion and subsequently flow. While one may argue that under high system immersivity, olfactory cues might not further increase immersion (or flow), our reasoning is informed by prior work on 'superadditive effect'. Specifically, consistent with our theorizing regarding immersion, multiple sensory cues (e.g., visual and olfactory) can increase immersion (Carù and Cova, 2007; Schmitt, 1999) alongside the aforementioned 'superadditive effect' of vision and olfaction (Elder and Krishna, 2021; Lwin et al., 2010). As such, we argue that the presence (vs. absence) of an olfactory cue in a highly immersive VR environment should result in a sufficient level of immersion to activate flow. Consequently, we contend that only sufficiently deep immersive experiences (i.e., high immersivity systems plus an olfactory cue) will affect brand responses. Formally, we hypothesize:

H3: VR system immersivity will moderate the effect of olfactory cues on brand responses, such that the presence (vs. absence) of olfactory cues will lead to more positive brand responses in VR systems offering high (vs. low) immersivity.

We present our conceptual framework graphically in Fig. 1.

Overview of studies

We present four experiments to test our hypotheses. Study 1 tests our conceptual model and offers evidence that olfactory scents in VR increase purchase intentions (H1). Moreover, we test and show support for our proposed serial mediation process via measured mediation (H2). Study 2 provides further process support via moderation through the interruption of the immersion process. Study 3 builds on these results by using a custom online consumer panel developed for this VR research to compare the effects of olfactory cues in VR systems with low vs. high immersivity (H3). In study 4, we partnered with an organization and conducted a field study to examine H1 with a real social media campaign in which we tested whether the presence (vs. absence) of olfactory cues in the organization's VR advertising stimuli improved positive brand responses.

Across our studies, we utilize real, retailer-centric VR content (e.g., FMCG, consumer-facing retail, hospitality services) to maximize external validity for the retail context. Addition-

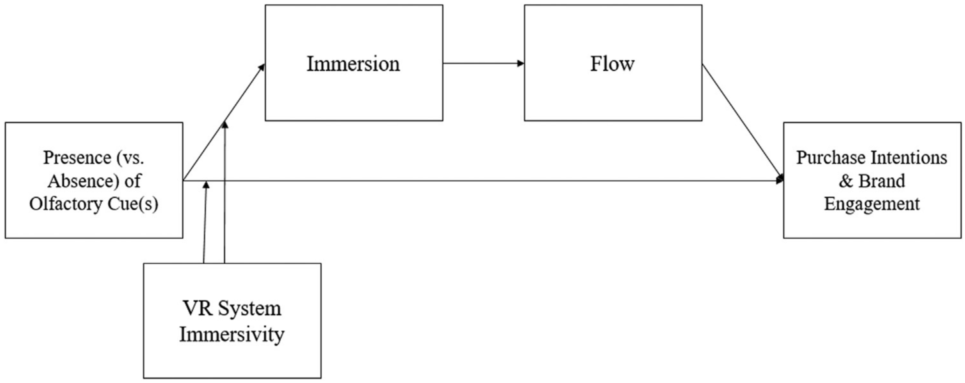

Fig. 1. Conceptual model.

ally, we partnered with an organization to create multiple virtual experiences that served as that organization's actual promotional materials. This partnership allowed us to both test our hypotheses in a controlled manner and maximize external validity of the investigation and theoretical propositions. We also utilized real (ambient scents; studies 1 and 2) and imagined (scents stimulated through description; studies 3 and 4) olfactory cues to investigate the multiple ways in which retailers can incorporate olfactory stimuli in VR. Finally, we pre-registered our designs and materials for studies 1 and 2 and materials can be found here: study 1: https://aspredicted.org/LST_1NM; study 2: https://aspredicted.org/SNQ_QVJ.

Study 1: the impact of olfactory cues on purchase intentions

The goal of study 1 was threefold. First, we sought to investigate the effect of olfactory cues on purchase intentions in VR. Second, we aimed to provide evidence for our proposed process through measured mediation. Finally, we tested potential alternative explanations of proximity, vividness, novelty, imagery, and presence.[1]

Participants and procedure

One-hundred ninety-five undergraduate students from a large North American university (46.7% women, $M_{\text{age}} = 19.36$, $SD_{\text{age}} = 1.04$) were assigned to one of two conditions (Olfactory Cue: Absent vs. Present) in a between-participants design. Participants were run individually in private pull-out rooms (i.e., individual rooms closed off from the main lab space in which participants can engage in experimental tasks without outside distractions or influences) by trained experimenters.

All participants viewed a VR marketing campaign by the chocolate brand Villakuyaya. This brand was chosen due to its low presence in the local market to mitigate any influence of prior brand knowledge. In line with pre-registered exclusion criteria, prior to data analysis, nineteen participants were removed for experiencing technical issues with the headset, three for experiencing feelings of dizziness or nausea, seven for correctly identifying the purpose of the study, and seven for failing to follow the instructions. This left 159 usable responses (46.5% women, $M_{\text{age}} = 19.12$, $SD_{\text{age}} = 1.01$).

Using the highly immersive Oculus Go HMD (virtual goggles and accompanying hand controllers; see Web Appendix A), participants 'walked' through the cocoa plantation and learned about the Villakuyaya chocolate production process. In the olfactory cue present condition, participants viewed the VR content in the presence of an ambient chocolate scent, achieved through burning a chocolate-scented candle (hidden from participants). In the olfactory cue absent (control) condition, no ambient scent was present in the room, and participants viewed the identical virtual content. Consistent with prior work (Herrmann et al. 2013), the scent conditions were blocked and the experimental room thoroughly ventilated between conditions to ensure effective scent manipulation. This procedure was successfully pilot tested ten days prior to study execution to ensure the chocolate scent was noticeable and identifiable in the room. After completing the virtual experience, participants returned to their individual computer terminals to respond to the questionnaire.

Participants indicated their intentions to purchase Villakuyaya chocolate by responding to three items ("How willing/likely/inclined are you to buy Villakuyaya's chocolate?"; 1 = not at all to 7 = very; $\alpha = 0.88$). Prior brand familiarity was measured via a yes/no question (none of the participants in the final dataset were familiar with the brand).

Following our extensive review of prior literature and in line with our construct definition in the Conceptual Framework section, we created four new items to assess immersion in the VR experience ("I lost interest in the real world around me," "The experience limited the intrusion of distractions," "The experience allowed me to escape the real world," and "I felt 'at one' with the experience;" 1 = strongly disagree, 7 = strongly agree; $\alpha = 0.77$). We created these new items because there is not an established, comprehensive measure of immersion in prior literature. In fact, immersion has been operationalized through other indicators, such as number of

[1] We refer to presence, conceptualized as 'telepresence', as feeling transported from the real environment to the virtual one (Spielmann & Mantonakis, 2018)

sensory modalities and visibility of the virtual environment (Smith and Mulligan, 2021), or represented by other scales, such as escapism or presence (Lee et al., 2020; Simon and Greitemeyer, 2019). While a scale to measure immersion has been previously used (Yim, Chu, and Sauer, 2017), that scale does not possess adequate face validity for our conceptualization of immersion. Further, we pre-registered and tested two different scales to assess flow (two-item scale: "Seemed that time passed differently than normal" and "Extremely rewarding experience;" adapted from Huang, 2006; and a three-item scale: "I underwent a state of 'flow' while watching the VR video," "I felt completely absorbed in what I was doing," and "I experienced 'flow' when watching the VR video;" Novak, Hoffman, and Yung, 2000). Two scales were used deliberately given that a unified measure of flow has yet to be established (Choi, Kim and Kim, 2007; Hoffman and Novak, 2009). Given the novelty of these measurement instruments, and factoring in the potential conceptual similarities between immersion and flow, we chose to pre-register our focal purchase intentions test as confirmatory and all mediation tests as exploratory.

Collected data were subjected to exploratory factor analysis (EFA; see Web Appendix B).[2] Only two immersion scale items loaded on the immersion factor and thus were retained ("I lost interest in the real world around me" and "The experience limited the intrusion of distractions;" $r = 0.51$, $p < .001$), while the other two items loaded on the flow factor. All flow measurement items loaded on the flow factor. Confirmatory factor analysis and discriminant validity analysis further indicated that, as measured on either of the flow scales, flow is distinct from immersion (full results are provided in Web Appendix C). Combined with the previously outlined conceptual differences, this evidence supports that immersion and flow are distinct constructs. Importantly, analysis revealed that the three-item flow measurement scale exhibited higher reliability ($\alpha = 0.95$) than the two-item measurement scale ($r = 0.46$); as such, the three-item flow measure was retained. However, we note that our findings remain unchanged across both flow scales (full results are provided in Web Appendix D).

Finally, we used seven-point scales to measure the following alternative explanations: *proximity* (two items: "Villakuyaya feels…[*close/far away from me, like here/far from here*];" Ruzeviciute, Kamleitner, and Biswas, 2020; $r = 0.80$, $p < .001$), *vividness* (five items: "How would you describe the VR video?" clear/vague, detailed/not detailed, strong/weak, sharp/fuzzy, and vivid/dull; Ruzeviciute et al., 2020; $\alpha = 0.85$), *imagery* (three items: "I fantasized about Villakuyaya chocolate," "I imagined what it would be like to try Villakuyaya chocolate," and "I imagined how Villakuyaya chocolate would taste;" Ruzeviciute et al., 2020; $\alpha = 0.89$), *presence* (five items: "While looking at the VR video, I felt I was in Ecuador," "While I was observing the VR video, my mind was in Ecuador on the tour, not in my room," "While I was looking at the VR video, my body was in this room, but my mind was in Ecuador, touring Villakuyaya," "When the VR video was finished, I felt like I came back to the real world after a journey," and "The VR video created a new world for me, which left when the video was finished;" Spielmann and Mantonakis, 2018; $\alpha = 0.93$), and *novelty* (four items: "To what extent would you use the following descriptors to describe the 360 VR video?" new, unique, different, and usual; 1 = not at all to 7 = very much; Yim, Cicchirillo, and Drumwright, 2012; $\alpha = 0.85$). Finally, demographic measures were taken.

Results and discussion

To test our primary hypothesis, we conducted an ANOVA using olfactory cue (0 = absent, 1 = present) as the independent variable and purchase intentions as the dependent variable. As predicted, participant purchase intentions were significantly higher after partaking in a VR experience when an olfactory cue was present (vs. absent; $M_{\text{Present}} = 5.13$, $SD_{\text{Present}} = 1.21$ vs. $M_{\text{Absent}} = 4.62$, $SD_{\text{Absent}} = 1.26$; $F(1, 157) = 6.600$; $p = .011$; $\eta^2 = 0.040$).

To test our prediction that olfactory cues increase purchase intentions due to increased immersion and subsequent flow (H2), we performed a serial mediation analysis (PROCESS Model 6, Hayes, 2017; 95% CI and 10,000 bootstrapped samples), such that immersion was the first mediator and flow was the second mediator between olfactory cues and purchase intentions. The results showed that olfactory cue presence increased immersion ($b = 0.65$, $t = 2.77$, $p = .006$), immersion increased flow ($b = 0.33$, $t = 4.54$, $p < .001$), and flow increased purchase intentions for Villakuyaya ($b = 0.33$, $t = 4.79$, $p < .001$). Central to our framework, the overall serial indirect effect was significant ($b = 0.07$, SE = 0.04; CI_{95}: 0.016, 0.163). Neither immersion ($b = 0.01$, SE = 0.04; CI_{95}: −0.075, 0.100) nor flow ($b = −0.03$, SE = 0.07; CI_{95}: −0.111, 0.183) were mediators alone. As noted, analysis using the two-item flow measure also supported our serial mediation account (see Web Appendix D).

Finally, we examined potential alternative explanations in two ways. First, we examined the proposed alternative explanations individually using ANOVAs. We summarize the results here and provide full statistical analysis in Web Appendix D. Only imagery and novelty were impacted by the presence of an olfactory cue (proximity, vividness, presence p's > 0.10). Moreover, higher novelty was observed in the olfactory cue absent (vs. present) condition, ruling it out as an alternative process. Second, we ran the proposed serial mediation model using imagery and novelty as covariates. In support of our framework, the indirect effect remained significant ($b = 0.05$, SE = 0.03; CI_{95}: 0.006, 0.112). Indeed, only imagery was a significant covariate ($b = 0.27$, $t = 4.85$, $p < .001$). Third, we ran a parallel mediation model with imagery as an additional mediator that allowed us to compare the alternative paths. As shown in Web Appendix D, while mediation via imagery was present, the comparison contrast with our focal serial process did not yield differences. Thus,

[2] We provide full statistical details in Web Appendix B and include only the key results here for brevity and manuscript readability.

we acknowledge that imagery may play a role and note that the role of olfactory cues on brand responses is likely multiply determined. However, given theoretical support for our proposed immersion (and subsequent flow) account, we contend this process plays a crucial role in driving positive brand responses by olfactory cues in VR.

Overall, study 1 provides support for H1 and H2, such that the inclusion of olfactory sensory cues in a VR experience increases purchase intentions. Importantly, we found that the presence of olfactory cues increased immersion, which then increased flow, and in turn increased purchase intentions. In addition to providing empirical evidence for our proposed account, we rule out potential alternative explanations, acknowledging that it is possible our effects are multiply determined (e.g., imagery may be a parallel account). In study 2, we provide additional support for our proposed process through moderation by inhibiting the immersion process.

Study 2: inhibiting immersion

The goal of study 2 was to provide process support by moderation (Spencer, Zanna and Fong, 2005). If immersion is the critical process through which olfactory cues in VR increase purchase intentions, then inhibiting immersion should mitigate the positive influence of olfactory cues on purchase intentions toward the given brand. Put another way, inhibiting immersion through interruption should sever the link between olfactory cue presence and purchase intentions because the role of olfactory cues in immersing participants would be diminished. We posit that interruption breaks immersion in VR as the latter is defined as a subjective process by which VR environment seems more physically and psychologically proximal. By extension, if consumers are 'pulled back' into their real, non-virtual environment, that environment will appear more physically and psychologically proximal, and VR immersion will be inhibited.

Participants and procedure

Four hundred undergraduates from a large North American university (31.8% women; $M_{\text{age}} = 19.06$, $SD_{\text{age}} = 1.25$) were assigned to one of four conditions in a 2 (Olfactory Cue: Absent vs. Present) x 2 (Interruption: Absent vs. Present) between-participants design. In line with pre-registration, 44 participants were removed for the following reasons: experiencing headset issues, failing to follow instructions, correctly guessing the purpose of the study, or prior familiarity with the brand. We note that one additional participant was excluded because they informed the experimenter that their responses were influenced by having one of the authors as their professor. This situation was not anticipated and therefore was not included as a pre-registered exclusion criterion. This resulted in a final usable sample of 356 participants (30.5% women; $M_{\text{age}} = 19.05$, $SD_{\text{age}} = 1.25$). Participants were run one at a time in a separate pull-out room by trained experimenters. Olfactory cue presence conditions were blocked (with the room ventilated prior to switching), and interruption conditions were blocked by morning/afternoon with the order rotated each day.

The procedure was similar to that used in study 1. In the olfactory cue present condition, a chocolate-scented candle was allowed to burn in the room out of view of participants, while in the olfactory cue absent condition, no ambient scent was present in the room. However, in the interruption present condition, a trained research assistant performed a series of interruptions at timed intervals to inhibit participant immersion in the VR experience from taking place (full script in Web Appendix E). For example, the research assistant's phone purportedly rang loudly, prompting her to leave the room. Shortly after her (announced) return, she knocked a full case of pens on the floor.[3] We assessed purchase intentions using the same three items as in study 1 ($\alpha = 0.87$). While the focal test of a process by moderation account (by manipulating the mediator) is the effect on the dependent measure (Spencer et al. 2005), for completeness we note that we also measured the same scale items as in study 1 and *processing fluency* (four items: "Please indicate the extent to which the VR video was:" difficult to process/easy to process, takes a long time to process/takes a short time to process, difficult to understand/easy to understand, and unclear/clear; Kostyk et al., 2021; $\alpha = 0.87$), before demographics (analyses provided in Web Appendix F). We note purchase intentions was pre-registered as confirmatory and other measures as exploratory.

Results and discussion

To confirm the manipulation of immersion, two ANOVAs were run with the immersion interruption condition (0 = absent, 1 = present) and the olfactory cue (0 = absent, 1 = present) factors as the independent variables and immersion and flow as dependent variables. Participant immersion was significantly higher with the interruption absent ($M = 4.85$, $SD = 1.30$) vs. present ($M = 4.43$, $SD = 1.39$; F (1, 354) = 8.53; $p = .004$; $\eta^2 = 0.024$). The results also suggest that flow was significantly higher when interruption was absent ($M = 5.03$, $SD = 1.32$) vs. present ($M = 4.67$, $SD = 1.45$; F (1, 354) = 5.96; $p = .015$; $\eta^2 = 0.015$; see Web Appendix F for a manipulation check with an alternative two-item flow measure).

In the focal analysis, we expected to replicate the positive effects of olfactory cues on purchase intentions observed in study 1 when the immersion interruption was absent (i.e., control) but not when immersion was inhibited. The results supported our predictions. Following a significant two-way interaction analysis of olfactory cue and interruption (F (1, 352) = 4.944; $p = .027$; $\eta^2 = 0.014$), planned contrasts revealed that in the interruption absent condition, the presence of the chocolate olfactory cue led to significantly higher purchase intentions ($M_{Present} = 4.86$, $SD = 1.08$) than when the olfactory cue was absent

[3] We note that our immersion-interruption manipulation likely also interrupted flow. We thank an anonymous reviewer for raising this point.

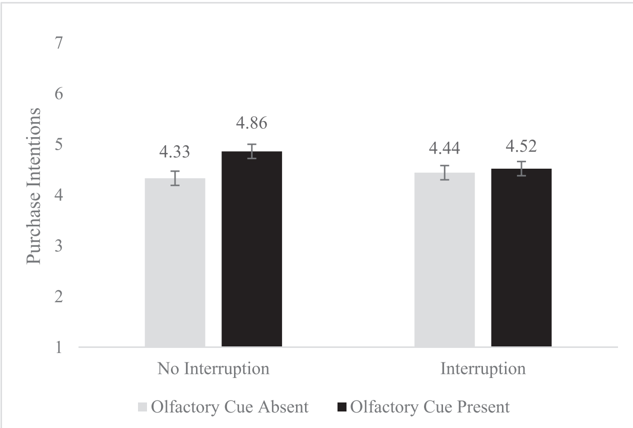

Fig. 2. Interaction of Immersion Interruption and Olfactory Cue Absent vs. Present on Purchase Intentions (Study 2).

(M_{Absent} = 4.33, SD = 1.13; F (1, 352) = 8.745; p = .004; η^2 = 0.052, see Fig. 2). However, when the immersion process was inhibited through interruption, we observed no differences in purchase intentions across olfactory cue conditions ($M_{Present}$ = 4.44, SD = 1.37, vs. M_{Absent} = 4.52, SD = 1.41; F (1, 352) = 0.179; p = .673; η^2 = 0.001). Analyzed differently, within the olfactory cue present conditions, purchase intentions were significantly higher in the interruption absent vs. interruption present conditions ($M_{Interruption\ Absent}$ = 4.86, SD = 1.08 vs. $M_{Interruption\ Present}$ = 4.44, SD = 1.37, F (1, 352) = 5.171; p = .024; η^2 = 0.028), while no differences emerged between conditions when olfactory cues were absent ($M_{Interruption\ Absent}$ = 4.33, SD = 1.13 vs. $M_{Interruption\ Present}$ = 4.52, SD = 1.41, F (1, 352) = 0.88; p = .349; η^2 = 0.005). This result provides support for the crucial role immersion plays in olfactory cues increasing purchase intentions in VR. Finally, we note that no main effect of interruption condition emerged ($M_{Interruption\ Absent}$ = 4.63, SD = 1.13 vs. $M_{Interruption\ Present}$ = 4.48, SD = 1.39; F (1, 352) = 0.682; p = .410 η^2 = 0.002), but the olfactory cue was directional ($M_{Olfactory\ Cue\ Present}$ = 4.65, SD = 1.25 vs. $M_{Olfactory\ Cue\ Absent}$ = 4.45, SD = 1.30; F (1, 352) = 2.577; p = .109; η^2 = 0.007).

The results of study 2 provided additional evidence for our proposed process via moderation (H2; Spencer et al., 2005). When immersion was allowed to flourish (control/no interruption condition), we replicated the positive effect of olfactory cues on purchase intentions observed in study 1. However, when the VR experience was interrupted and immersion inhibited, the presence (vs. absence) of an olfactory cue had no influence on purchase intentions. This is because interrupting immersion suppresses the role that olfactory cues play in boosting immersion and flow, which therefore attenuates the influence of olfactory cues on purchase intentions.

We further ran ANOVAs with immersion interruption (0 = absent, 1 = present) and olfactory cue (0 = absent, 1 = present) factors as the independent variables and the alternative explanations as the dependent variables (see Web Appendix E). Only proximity and imagery were significantly greater with olfactory cues present (vs. absent). We additionally ran PROCESS Model 4 with the immersion interruption condition as a covariate to further assess proximity and imagery as alternative explanations for the effect of olfactory cues on purchase intentions. Only the imagery account was supported, consistent with the results of study 1.

While the results consistently demonstrate the role of scent, we note that we used a pleasant scent across both studies (i.e., chocolate). As immersion is not tied to a specific emotional valence (Hudson et al., 2019), we did not expect scent pleasantness to impact responses to VR environments. To ensure scent pleasantness did not play a role, we conducted an additional field experiment using Facebook A/B test functionality (also known as a split test). In split tests, Facebook randomly presents users one of the two versions of the message. Facebook considers the social media engagement of the posts, including reach, interaction, likes, costs, and similar metrics, and dynamically adjusts the exposure of each ad. The Facebook algorithm then statistically analyzes the user interactions to identify the message performing in a superior manner given the goal (e.g., likes, follows). A non-significant result (e.g., no winner) between VR ads with pleasant vs. unpleasant olfactory cues would support our assertion that scent pleasantness is unimportant in VR environments. This is exactly what we found. We provide full details of this study in Web Appendix G and report results in line with Kearns et al. (2021) and Szocs, Williamson, and Mills (2022).

Having demonstrated the effectiveness of olfactory cues in VR and support for our proposed process, we next integrate VR system immersivity to understand how VR may provide a novel medium for integrating sensory inputs across devices.

Study 3: the impact of olfactory cues across VR immersivity levels

The goal of study 3 was to explore the moderating role of VR immersivity level on the downstream effects of olfactory sensory inputs in VR (H3). Our framework suggests that when the initial level of system immersivity is high via HMDs (vs. low via devices that do not dominate the field of view), the presence (vs. absence) of an olfactory cue will increase purchase intentions because user immersion level will be sufficiently raised to elicit a state of flow. We do not expect this difference to be as pronounced when the level of system immersivity is low.

In study 3, we operationalized olfactory cue presence via description. This study was conducted during the COVID-19 pandemic; as such, in-person experimentation was impossible, and we adapted our investigation to use online samples. In this unprecedented situation, we undertook a thorough, time-intensive process to construct a custom VR panel using Prolific Academic. We present a summary of the panel creation process below and a full description with panel statistics in Web Appendix H.

Demonstrating our predicted positive brand response effects using olfactory cue description (vs. ambient scent) represents an important implication for retailers. Specifically, showing that the use of olfactory cues in VR via description can still elicit positive downstream responses even in situations in which retailers cannot infuse real smells into an experience provides retailers with additional flexibility to integrate olfactory sensory information into virtual environments.

Participants and procedure

We recruited participants for the study using a two-step process. In the first step, we screened participants for inclusion in the panel. First, following Ma et al. (2018), we ran a pre-screening survey on Prolific to identify participants who owned at least one VR HMD. Included in the screening instrument were questions regarding specific details of participants' HMDs (e.g., brand, model, mobile vs. stand-alone), length of ownership, and any challenges they had with using the device (e.g., VR sickness, technological malfunctions). Next, participants were required to share a picture of their device(s) alongside a piece of paper with their Prolific ID. The rationale behind this step was to both ensure data quality (i.e., that they actually owned the HMD they claimed) and inform researchers' choice of the VR content (i.e., virtual content for mobile VR devices or stand-alone VR). In total, 461 participants qualified for the next stages as owners of VR systems with high immersivity.

In the second stage of recruitment, we directly invited qualified panelists to participate in the high immersivity VR condition of the study (containing separate but comparable instructions to that of the low immersivity condition; see Web Appendix A). As differences in VR devices can change responses toward brands (e.g., Martínez-Navarro et al., 2019), we controlled for this through specific device recruitment, and only participants owning wearable mobile HMDs were invited to participate. Participants in the low immersivity condition were regular Prolific panelists (excluding VR panelists to avoid repeat exposure to the experiment) who viewed the VR experience in 360° on a desktop or laptop computer screen (following McLean and Barhorst, 2021).

A total of 161 participants participated in the study in exchange for monetary compensation. The study utilized a 2 (VR System Immersivity: Low (no HMD) vs. High (HMD)) x 2 (Olfactory Cues: Absent vs. Present) between-participants design. Eighteen participants indicated that they experienced technical issues in viewing the video and were removed from the analysis, yielding a final sample of 143 usable responses (18.6% of the VR panel; 40% women; M_{age} = 27.18 years, SD_{age} = 8.08 years).

All respondents were presented with a sample of a VR tour for a Scottish museum. For this study, we collaborated with the museum and developed the virtual tours using Google's Poly Tours platform. The tours included five different 360-degree VR scenes with audio narrations and textual information that explained the scenes participants were viewing. This digital tour was akin to physically touring the site with a physical or audio tour guide. We created two versions of the tour to explicitly test our olfactory cues hypothesis. The visual stimuli were identical across the two tours; however, we manipulated the presence of olfactory cues through the audio narrations and corresponding text in three of the five scenes. In the olfactory cue present condition, the tour's audio guide and within-scenes text explicitly featured olfactory sensory imagery. For example, in one scene in which a settler is cooking inside the Celtic Roundhouse, participants heard the following: *"You enter the dark, **smoky** roundhouse where someone tends the fire. He is preparing to boil some water for the evening. The roundhouse feels quite warm **and smells of campfire**."* In the olfactory cues absent condition, these olfactory cues (**in bold**) were omitted from audio narrations and text.

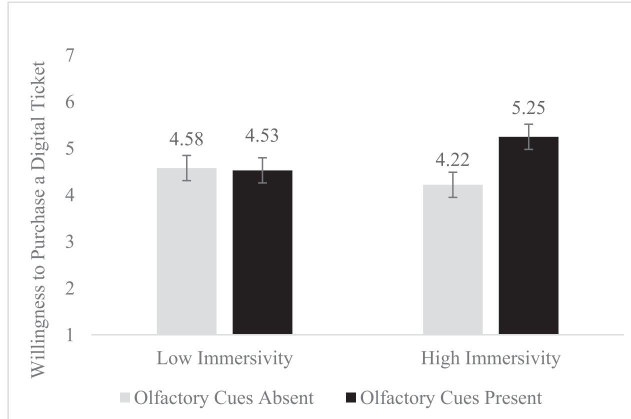

Fig. 3. Interaction of Immersivity and Olfactory Cues Absent vs. Present on Willingness to Purchase a Digital Ticket (Study 3).

After respondents completed the experience (a sample of the full virtual tour), we assessed purchase intentions via willingness to purchase a digital ticket for the museum's digital content. Specifically, participants were presented with a promotional ad for the museum's digital ticket (see Web Appendix I). Participants indicated their intentions to purchase the ticket via the same scale used in prior studies (α = 0.94). Participants also indicated whether they had known of the museum before with a yes/no question. Finally, participants responded to demographic and exploratory questions.

Results and discussion

An ANOVA with VR system immersivity (0 = low, 1 = high) and olfactory cues (0 = absent, 1 = present) as the independent variables and willingness to purchase the digital ticket as the dependent variable yielded the two-way interaction predicted by H3 (F (1, 139) = 3.882; p = .051; η^2 = 0.027). Replicating the results of our previous studies, planned contrasts within the high immersivity VR condition showed that present olfactory cues (M = 5.25, SD = 1.16) increased willingness to purchase the digital ticket compared to the olfactory cue absent condition (M = 4.22, SD = 1.89; F (1, 139) = 5.300; p = .023; η^2 = 0.037, see Fig. 3). However, this positive difference was reduced and non-significant within the low immersivity VR condition (M_{Absent} = 4.58, SD_{Absent} = 1.54 vs. $M_{Present}$ = 4.53, $SD_{Present}$ = 1.53; F (1,

139) = 0.026; p = .872). In addition, within the olfactory cue present condition, participants viewing the virtual tour in high immersivity VR displayed a higher willingness to purchase the digital ticket than those who viewed the tour in low immersivity VR (M_{High}= 5.25, SD_{High} = 1.16 vs. M_{Low} = 4.53, SD_{Low} = 1.53; F (1, 139) = 3.425; p = .066; η^2 = 0.024). No difference emerged within the olfactory cue absent condition (M_{Low} = 4.58, SD_{Low} = 1.54 vs. M_{High} = 4.22, SD_{High} = 1.89; F = 1, 139) = 0.872; p = .352). Lastly, we note that while there was no main effect of VR system immersivity on purchase intentions (M_{Low} = 4.56, SD_{Low} = 1.53 vs. M_{High} = 4.74, SD_{High} = 1.63; F (1, 139) = 0.425; p = .516), a main effect from the olfactory cues emerged (M_{Present} = 4.77, SD_{Present} = 1.45 vs. M_{Absent} = 4.46, SD_{Absent} = 1.66; F (1, 139) = 3.177; p = .077; η^2 = 0.022), consistent with the prior studies.

Further, because the descriptions of the tour differed slightly in their length and descriptive detail, we ran a post-test on Prolific with 100 UK panelists (73.0% women; M_{age} = 39.68, SD_{age} = 12.95) to determine whether sensory cue complexity ("The social media post was complex;" 1 = strongly disagree to 5 = strongly agree), imagery ("To what extent could you imagine visiting the museum while reading the post?"; 1 = none at all to 5 = a great deal), and information richness ("How much information about the museum was provided in the post?"; 1 = none at all to 5 = a great deal) differed significantly between conditions. ANOVAs with the olfactory cue condition as the independent variable and each of the three items as dependent variables indicated non-significant differences across complexity (p = .78),[4] imagery (p = .87),[5] and information richness (p = .30).[6]

The results from study 3 support our prediction that VR systems with high immersivity can enhance consumer responses with olfactory cues compared to both the same VR content without olfactory cues and VR systems with low immersivity (H3). This result is consistent with our immersion account as the process driving the positive effects of olfactory cues on purchase intentions.

Study 4: the impact of olfactory cues on brand responses in the field

The goal of study 4 was to provide real-world evidence via a field experiment of the benefits that olfactory cues in VR can have on positive brand responses, operationalized in this study via online engagement (i.e., social media page 'likes,' H1). To achieve this goal, we partnered with the same museum in Scotland from study 3 to produce and conduct a social media (Facebook) VR campaign with an objective of increasing their number of followers (i.e., page 'likes'). We set the target audience for the campaign as local residents 24 years old and above who were interested in "Adventure," "History," and "Museum." The campaign ran on Facebook from April 1, 2021 to May 3, 2021.

A/B test design

We created two versions of a 360-degree VR Facebook ad to test our hypotheses (Olfactory Cues: Present vs. Absent). The ads featured a 360-degree VR scene featuring museum's replica of a Celtic roundhouse with a lit fire and figure of a Celtic villager. Importantly, 360-degree VR Facebook scenes allow users to interact and manipulate the view (Facebook, 2016). A flat projection of the 360-degree VR scene is presented in Web Appendix I. The manipulations were as follows:

Ad #1 (Olfactory Cues Present): *"Smell the fireplace smoke at the hearth of this Celtic Roundhouse? Follow [museum] to experience the fascinating history of the earliest Christian community in Scotland. #smell[museum] #[museum] #destination[museum] #ScotlandStartsHere #visit[location] #supportlocal #ScotlandLovesLocal #museumfromhome #virtualtour"*

Ad #2 (Control/Olfactory Cues Absent): *"Here is a sneak peek of the [museum's] virtual tour. Follow [museum] to experience the fascinating history of the earliest Christian community in Scotland. #see[museum] #[museum] #destination[museum] #ScotlandStartsHere #visit[location] #supportlocal #ScotlandLovesLocal #museumfromhome #virtualtour"*

To test our predictions, Ad #1 was compared with Ad #2 on Facebook via A/B testing functionality by randomizing the distribution over the 32-day period (the test ran for 30 days and was concluded by the industry partner staff on the next working day after a weekend). Details of the A/B methodology are provided in the follow-up field study to study 2. We predicted that the ad with olfactory cues present (#1) would elicit higher online engagement than the olfactory cues absent ad (#2, control ad).

Results and discussion

Our prediction regarding the influence of olfactory cues on online engagement (H1) was supported. Results showed that the VR ad that included olfactory cues performed better than the control ad in achieving the set marketing goals (i.e., number of page likes). Specifically, it reached an audience of 8012 (vs. 5576) Facebook users from the target audience and generated 71 (vs. 30) page likes at the cost of £1.41 (vs. £1.67) per result (Kearns et al., 2021).[7] Thus, this field study

[4] Complexity: Olfactory Cues Absent (M = 2.30, SD = .97) vs. Olfactory Cues Present (M = 2.24, SD = 1.15).

[5] Imagery: Olfactory Cues Absent (M = 3.00, SD = 1.21) vs. Olfactory Cues Present (M = 2.96, SD = 1.18).

[6] Richness: Olfactory Cues Absent (M = 2.06, SD = .89) vs. Olfactory Cues Present (M = 1.88, SD = .82).

[7] The ad that included olfactory cues generated a larger proportion of page likes (71/7941 = 0.9%) than the ad without olfactory cues (30/5546 = 0.5%; OR=1.65, p = .021; Szocs et al., 2022; Field, 2018). Please note that the

provides real-world evidence that pairing olfactory cues with VR content leads to favorable brand responses (in this case, online engagement via page likes), in support of H1.

While this study offers impactful and measurable insights in an actual marketplace setting through collaboration with a real organization, as with any field experiment, there are limitations. Specifically, given the presence of extraneous factors that affect an A/B test on social media, we cannot unequivocally say the presence of olfactory sensory cues is responsible for the difference. As such, we conducted a post-test to rule out some alternative explanations. We tested the two ads used in study 4 using a Prolific sample of UK Facebook users ($N = 102$; 74 women; $M_{age} = 39.76$, $SD_{age} = 13.29$). After the participants were presented with one of the two randomly allocated descriptions, they responded to the same items from the study 3 post-test measuring sensory cue complexity, imagery, and information richness. ANOVAs with the olfactory cue condition as the independent variable and each of the three items as dependent variables indicated non-significant differences across complexity ($p = .51$),[8] imagery ($p = .16$),[9] and information richness ($p = .91$).[10] Thus, these alternative explanations do not appear to influence the effects observed in the A/B test.

General discussion

The results of this research support the incorporation of olfactory cues in VR retailing experiences to positively influence consumer responses. Specifically, we demonstrate that olfactory cues in VR enhance brand responses (e.g., purchase intentions and online engagement) and document a unique psychological process for these effects: immersion. Using both measured mediation (study 1) and process by moderation (study 2) approaches, we find that olfactory cues in VR increase immersion. This heightened immersion fosters a state of flow, which in turn results in higher purchase intentions. System immersivity moderates these effects, such that olfactory cues elicit stronger brand responses in high immersivity compared to low immersivity (study 3), indicating that retailers need to 'build' a sufficient level of immersion into a VR experience to trigger more favorable consumer outcomes associated with flow.

In support of research suggesting that imagined scents can be just as powerful as scents physically provided in the environment (e.g., Krishna et al., 2014), our research includes evidence that both olfactory imagery (studies 3 and 4) and ambient scents introduced in VR experiences (studies 1 and 2) produce consistent effects – an important finding for retailers as this increases the available options to harness these positive outcomes. Further, through the use of Facebook A/B (field) testing, partnership with industry, and creation of a custom VR online panel specific to VR research and the alignment of the panel results with our field and lab settings, this work fosters external validity such that our results generalize to mass audiences online. We provide several theoretical and managerial contributions.

Theoretical contributions

This research offers four key implications for scholarship. First, this research integrates literature from sensory marketing and flow to demonstrate how sensory inputs – specifically olfactory cues – affect VR experiences and downstream brand responses. These results offer some evidence consistent with research in physical stores (e.g., Biswas et al., 2021), yet they diverge from other sensory research in digital channels (e.g., Herrmann et al., 2013). This is explainable by the motivations and goals triggered by shopping online vs. in-store. In stores, consumers have a greater desire for pleasure and browsing, whereas online consumers often shop with a greater utilitarian focus (Hult et al., 2019; Jones, Mothersbaugh, and Beatty, 2000). Thus, the results suggest that VR, though technically a digital channel, fosters consumer processing styles typically reserved for in-store shopping (e.g., it feels real). As such, this research offers greater generalizability regarding how other sensory inputs might affect consumer responses in retail-related VR experiences.

Second, we document immersion and flow as a novel serial mechanism through which olfactory cues impact consumer responses in VR. More importantly, we broaden the concept from merely visual immersion to sensory immersion, clarifying prior literature on immersion as it relates to VR, expanding understanding of the connection between immersion and flow (i.e., Brown and Cairns, 2004; Carù and Cova, 2007; Cowan and Ketron, 2019a; Jennett et al., 2008), and empirically establishing immersion as an important construct in VR marketing. Moreover, our research integrates multiple theoretical perspectives to demonstrate the role of senses and immersion. Prior research argues that congruent olfactory cues lead to realism and immersion via sensory layering (e.g., Schmitt, 1999). At the same time, other literature proposes that realism and immersion can help foster flow states (e.g., Cowan and Ketron, 2019a). As such, our research combines the streams of research on immersion and flow to provide novel insights into the effects of VR on brand responses.

Third, by integrating theoretical perspectives from both sensory marketing and VR, we document how system immersivity moderates the role of olfactory stimuli in VR. Specifically, we find that for high immersivity VR, olfactory stimuli via description lead to more positive brand responses. These findings suggest that the sensory stimuli necessary to increase immersion and activate flow within VR differ depending on VR system immersivity (Brown and Cairns, 2004; Jennett et al., 2008; Hudson et al., 2019).

Finally, this research offers a methodological contribution by procuring and maintaining an online Prolific VR panel.

Facebook algorithm dynamically adjusts each ad's reach based on the other ad's performance.

[8] Complexity: Olfactory Cues Absent (M = 2.63, SD = 1.14) vs. Olfactory Cues Present (M = 2.78, SD = 1.09).

[9] Imagery: Olfactory Cues Absent (M = 2.13, SD = .82) vs. Olfactory Cues Present (M = 2.38, SD = .92).

[10] Richness: Olfactory Cues Absent (M = 2.15, SD = .72) vs. Olfactory Cues Present (M = 2.14, SD = .54).

This custom panel is available for use by VR researchers and enables online studies with a geographically dispersed, heterogeneous population of VR users in situations in which researchers either prefer to use this method or are confined to online data collection. As such, this panel helps researchers interested in studying VR while facing space and/or financial constraints.

Substantive contributions to retailers

Prior research has shown that VR (vs. other digital environments) typically improves brand attitudes (Pleyers and Poncin, 2020) and increases purchase intentions (Peukert et al., 2019), willingness to pay (Wen and Leung, 2021), willingness to donate to charity (Kristofferson, et al., 2022), and willingness to volunteer (Kandaurova and Lee, 2019). In this vein, the current work offers retailers and brands insights into the benefits of incorporating olfactory cues when developing VR experiences for consumers. Specifically, addressing the calls to provide more strategic guidance for VR marketing (Kostyk and Sheng, 2022), we show that olfactory cues in VR, whether physically present or imagined, can elicit superior brand support responses of purchase intentions and online engagement. Therefore, when developing these experiences online for consumption at home (i.e., online shopping) or immersive digital retail experiences, our results suggest retailers should include imagined olfactory stimuli. For example, retailers could include verbal prompts (either written or spoken) regarding olfactory stimuli in the environment, such as the smell of foliage, food, and other objects, that would enhance the consumer's ability to imagine those olfactory elements alongside the given narrative. While the results of study 3 suggest that such cues may be especially effective with high immersivity systems, study 4 indicates that a 'teaser' of olfactory descriptors can help to boost consumer responses even with low immersivity social media posts. Moreover, by using imagined scents, a retailer would not need to invest in the more expensive VR equipment and can even test how multiple cues affect brand responses.

When including these experiences in pop-up shops, permanent stores, or other physical locations, retailers could strategically use diffusers, candles, bottled sprays, scent masks, or other means to introduce ambient scent. Retailers could use a variety of scents to accompany VR experiences, such as floral, grassy, or dusty scents for outdoor experiences (i.e., hiking) or culinary scents for food/beverage products. While our investigation utilized a chocolate-scented candle, the specific olfactory mechanism should depend on room size, density, budget, and operational constraints. Additionally, our research suggests that the scent need not be pleasant in the VR environment. As such, unlike traditional retail environments, VR experiences can include 'dusty,' 'smoky,' or other non-pleasant scents, which can work effectively in immersing consumers.

As VR continues to evolve, multisensory integration will continue to advance in its capabilities, and even at-home VR experiences could more easily include real olfactory stimuli. For example, the development of a 'Virtual Cocoon' will allow stimulation of all five senses at once (Engineering and Physical Sciences Research Council, 2009), and advancements such as OVR's VR headset attachment simulate hundreds of scents via aroma cartridges (OVR Technology, 2022). With such advances, retailers will be able to create even more tailored olfactory experiences, which could highlight relevant environmental features for a given product or test layering of different scents for a more unique experience. In order to heighten brand responses and help consumers achieve a flow state, the VR content accompanying these scents should be highly immersive, such as using HMDs (e.g., Meta Quest) or other highly-immersive VR systems (e.g., CAVEs; games).

However, retailers should consider sensory integration in VR carefully. As the technology is still in its early stages, trying to do too much in terms of sensory inputs could be costly and might risk interrupting immersion as the environment may overload consumers if the environments have too many inputs or if the experience is 'too real' (Stewart, 2022). Additionally, retailers should plan experiences that will yield the greatest returns by focusing on consumers who are most likely to respond well to VR (i.e., their readiness to adopt and use the technology is sufficient) and tying the experience to brand-relevant outcomes (e.g., purchasing or awareness; Kostyk and Sheng, 2022).

Finally, as study 2 shows, interruptions in VR experiences can be detrimental to immersion, flow, and downstream consumer responses. Thus, when retailers design and develop VR experiences, they should ensure that interruptions are minimized. For example, in many branded games, pop-up ads or messages are common. However, these kinds of messages would likely backfire in VR, so retailers are advised to wait until experiences are complete before ads or other communications are introduced. Additionally, the negative influence of interruption underscores the importance of a VR experience that is free of glitches and lags – such technical issues also threaten immersion, so the retailer should invest properly in the development of the experience.

Limitations and future research

While the results support differences in the way consumers engage with and process inputs in low vs. high immersivity VR, more research is needed to investigate the intricacies present in these system differences. In our studies, we applied our framework to understand and hypothesize relationships between olfactory cues and brand responses through immersion and flow with complementary scents. We contend that complementarity also plays a role in VR as some initial research suggests that incongruent ambient noises dampen flow (Calogiuri et al., 2018). Thus, future research should consider the impact from non-complementary olfactory cues on immersion.

As a key contribution of this research, we also reconceptualize and test immersion as the process mechanism, demonstrating sensory cues as one means to increase immersion.

However, we theorize other means of enhancing immersion and suggest that future research test those mechanisms (e.g., enhancing the realism of movement in the virtual environment, or providing rich environmental narratives could also increase immersion alongside sensory cues, or multiple olfactory cues). Additionally, our use of interruption as a moderator in study 2 may have affected processes beyond immersion as interruptions can inhibit the overall cognitive processing, so future research may seek to disentangle possible influences of other cognitive processes related to olfactory cues and immersion in VR.

Further, immersion and flow, while conceptually distinct, share a strong link that may make them inseparable. As such, we acknowledge this as a potential limitation and direction for future research to further tease apart these two constructs. During studies 1 and 2, the measurement of these variables and the measurement of the dependent variable were not randomized, so the order of the questions could have affected the results. While we would not expect the results to change, we caveat this as a limitation of the current study and advocate future research to further disentangle the concepts of flow and immersion. Additionally, given that both immersion and flow are crucial within the expanding metaverse, future research should continue to improve on existing measures of those constructs through scale development and validation.

Across the first two studies, we ruled out multiple alternative explanations, including novelty, proximity, presence, processing fluency, and vividness. However, we note that we observed differences between the olfactory cue present (vs. absent) condition on imagery and novelty for study 1 and imagery for study 2, suggesting that olfactory cues, and perhaps sensory cues in general, can impact novelty and imagery. However, the presence (vs. absence) of the olfactory cue reduced novelty. As we do not have a theoretical explanation for this effect, future research should explore how sensory cues affect novelty and subsequent brand responses. While imagery seemed to compete as an underlying mechanism in studies 1 and 2, running a parallel model with imagery as another mediator to compare the alternative paths did not yield statistically significant differences with the theorized process of imagery and flow. Rather, it seems that the two processes co-occur. Future research could explore the role of imagery within cognitive involvement of the VR environments and the combined effect from sensory cues.

Finally, we acknowledge that the sample size in study 3 was somewhat limited given the COVID-19 pandemic and the necessity of an online panel during lab facility shutdowns. While we believe the well-powered pre-registered lab studies and the totality of the study package provide overall support for our predictions and reveal multiple important insights for multisensory VR, additional studies with larger samples could be conducted.

Conclusion

We believe the findings of this research will foster further interest and inquiry into multisensory integration in VR. While we highlight olfaction in VR as an important and viable mechanism for boosting positive brands responses (i.e., purchase intentions and online engagement) through immersion and flow, other sensory domains offer additional opportunities for both scholarship and retailing practice that will continue to grow as VR technology matures. In sum, we hope that retailers will find new and exciting ways to incorporate olfaction and other sensory inputs into VR experiences and overall strategies as the line continues to blur between the physical and digital retailing worlds.

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