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SPATIAL MARKETING RESEARCH:

LEVERAGING 3D VIRTUAL AND INTERACTIVE SPACES TO STUDY MARKETING PHENOMENA

ABSTRACT

Research on spatial technologies is expanding rapidly but remains fragmented across diverse literature streams such as metaverse studies, virtual retail simulations, and virtual twins. As a result, their full value for marketing science remains unclear, limiting broader adoption. To overcome this limitation, the authors introduce *spatial marketing research* as a comprehensive approach for studying marketing phenomena within three-dimensional, virtual, and interactive spaces (3VIS). Drawing on an extensive literature review, they identify four distinct value streams through which 3VIS can advance marketing research: as a research object, application, method, and economical means. To help scholars realize this potential, the authors develop a methodological framework grounded in activity theory, which conceptualizes 3VIS through three core elements: 3D environments (e.g., virtual worlds), interacting entities (e.g., avatars), and access devices (e.g., headsets). This framework clarifies key trade-offs, such as open vs. closed virtual worlds, generic vs. customized entities, and 2D vs. 3D access. The authors further extend this framework into a step-by-step process model that helps researchers design 3VIS studies tailored to research projects' idiosyncratic validity demands, data needs, and resource constraints. Collectively, the paper contributes (1) a value creation typology and (2) a methodological framework to enable more impactful spatial marketing research.

Keywords: spatial marketing; metaverse; virtual worlds; virtual reality; mixed reality; marketing research; digital twins.

Spatial technologies like virtual reality (VR) and mixed reality (MR) are reshaping the business and marketing landscape, enabling new forms of collaboration, industrial applications, entertainment, and education (Bainbridge 2007; Gómez-Zará, Schiffer, and Wang 2023; Tao and Qi 2019). Leading tech companies promote their visions for these technologies under terms like spatial computing (Apple 2023), metaverse (Meta 2025), and omniverse (NVIDIA 2025). While trillion-dollar market projections have not yet been realized, spatial technology adoption is accelerating; in 2024, for example, metaverse-related revenue reached $105 billion USD, one quarter of which stemmed already from industrial applications (Elmasry et al. 2022; Grand View Research 2024). In addition, sales of VR and MR headsets grew by 10% in 2024, reaching almost ten million annual shipments (Ubrani, Llamas, and Reith 2025).

Reflecting the growing interest in spatial technologies, academic research in this area has clearly accelerated. Our review of leading journals in business, psychology, sociology, education, engineering, and the general sciences reveals that research output is expanding rapidly: we identified 2,355 relevant articles, 42% of which were published after June 2019. Marketing scholars are increasingly active in this space, studying topics such as virtual product evaluations (Harz, Hohenberg, and Homburg 2022), social interaction in the metaverse (Hennig-Thurau et al. 2023), haptic and auditory sensing (Luangrath et al. 2022; Ringler, Sirianni, and Christenson 2021), and spatial perception (Esteky 2022). Yet despite this momentum, the field remains highly fragmented. Our analysis empirically demonstrates this, identifying twelve distinct, siloed clusters that span domains ranging from video games and metaverse experiences to VR retail and virtual manufacturing.

While such disconnectedness is unsurprising given the novelty of spatial technologies, it complicates scholarly exchange and hinders the cumulative progress of the field. For marketing research, this fragmentation poses several persistent challenges. Chief among them is the lack of a shared understanding of the value these technologies can provide, even though all marketing studies using spatial technologies rely on the same fundamental research mechanics: whether the focus is the metaverse, virtual retail stores, or digital twins, all such studies must configure what we term *three-dimensional virtual and interactive spaces* (3VIS). In practice, this involves constructing such spaces and populating them with research subjects who can navigate and interact within them. As the empirical context for spatial marketing studies, 3VIS share three defining features (a) a depth dimension, distinguishing them from the flat interfaces of websites and apps; (b) virtuality, as they simulate physical environments through computer-generated representations (Cambridge Dictionary 2025); and (c) interactivity, enabling two-way exchanges between users and the environment (Quiring and Schwaiger 2008). In addition, prior work highlights that many marketing scholars using spatial technologies struggle to design their studies effectively (Bamberger, Reinartz, and Ulaga 2025; Kaplan and Haenlein 2024). The key reason behind these struggles is that 3VIS present a wide range of configuration options—from the type of virtual world to avatar design to whether (and which) VR headset should be used—each involving difficult trade-offs. Even after navigating these design challenges, researchers still face uncertainty over whether their chosen setup meets academic standards of rigor and relevance. In short, scholars currently lack clear design guidance and methodological standards.

To address these issues, this paper introduces *spatial marketing research*, which we define as all scholarly investigations of marketing topics conducted within 3VIS. In essence, spatial marketing research offers an integrative approach to studying marketing phenomena across diverse research streams that make use of 3VIS. This includes work on the metaverse, virtual shopping environments, consumer behavior in 3D contexts, virtual twins, and related areas. Building on this foundation, we seek to answer the following research questions:

RQ1: What types of value can 3VIS generate for marketing research?

RQ2: How to conduct high quality 3VIS studies for marketing research; in particular:

a) What are the core design elements, and what trade-offs do they involve?

b) What process steps should scholars follow to reach adequate designs?

In answering these questions, this investigation makes several contributions. First, we introduce a research typology delineating the types of value that spatial marketing research can generate. Blending existing conceptual work in other areas with the findings of our literature analysis, we identify four general value streams of spatial marketing research: (1) 3VIS as a research object, where scholarly value is created through the study of phenomena and relationships specific to virtuality; (2) 3VIS as an application, where value results from generating novel solutions for marketing challenges related to physical spaces by harvesting of 3VIS's unique features; (3) 3VIS as a method, which creates value by boosting the validity of studies about physical spaces, using 3VIS as a proxy for research methods applied in the 'real world'; and (4) 3VIS as an economical means, which—compared to traditional research designs used in 'real-world' settings—reduces the costs and efforts of research on physical spaces. We intend this research typology to spark the imagination of researchers interested in generating new marketing insights from working with 3VIS.

Second, we develop a methodological framework that provides guidance for effectively implementing spatial marketing research. While substantial guidance exist for empirical research in physical environments (Gneezy 2017; Hulland, Baumgartner, and Smith 2017; Rindfleisch et al. 2008) and some for two-dimensional digital spaces (Boegershausen et al. 2022; Lamberton and Stephen 2016; Yadav and Pavlou 2014), no existing resources yet address the unique challenges of 3VIS research, that is: to achieve the most appropriate configuration of 3VIS tailored to the idiosyncratic needs of a research project. Our methodological framework, which we triangulated from activity theory and design science research insights, an extensive literature analysis, and over ten years of the authors' experience in running 3VIS studies, contains both a design model and a process-step model. For the design model, we highlight three core elements essential to effective spatial marketing research: creating a virtual 3D environment, populating it with interacting entities, and enabling participant access through appropriate devices. We systematically outline the options researchers need to carefully choose from when configuring the 3VIS elements and provide actionable categorizations to simplify decision-making.

With the process model, we specify this framework in terms of three key decisions that researchers need to make subsequently: (1) determining whether a 3VIS study can create value for a particular project, (2) specifying the 3VIS requirements considering a project's idiosyncratic characteristics in terms of validity requirements, data needs, and resource constraints, and (3) translating these project-specific requirements into an adequate 3VIS configuration, avoiding both 3VIS under-specification and overpowering. We provide examples to demonstrate practical applications and offer targeted recommendations as well as a spatial data platform and a tutorial to aid marketing researchers in collecting and working with spatial data. Our methodological framework may help marketing scholars to better leverage the opportunities provided by 3VIS to generate lifelike (or even larger-than-life), controlled, data-rich environments (Bainbridge 2007; Gómez-Zará, Schiffer, and Wang 2023) in a rigorous and resource effective manner.

The remainder of this manuscript is structured as follows. We begin with empirically typologizing research from multiple disciplines related to 3VIS, which leads to the identification of four general value streams applicable to marketing scholars. We then derive our design framework of spatial marketing research to identify potential configurations and our step-by-step process model to guide marketing scholars in determining the adequate 3VIS configuration for their research. In concluding, we discuss the implications for future research and non-academic audiences.

RQ1: INTEGRATIVE TYPOLOGY OF SPATIAL MARKETING RESEARCH

To address our first research question—what types of value 3VIS can generate for marketing research—we empirically extract key topics from existing 3VIS studies in marketing and related disciplines and assess the current level of integration across this work. Integration is essential for generating value in scientific inquiry (MacInnis 2011). Identifying central 3VIS research topics both within and beyond marketing is therefore important for transferring extant knowledge into spatial marketing research. Building on this foundation, we develop a research typology that outlines the pathways through which spatial marketing research can create value, blending our empirical extraction with Fox, Arena, and Bailenson's (2009) historical typology of virtual environments, which we augment and adapt for the marketing context.

What Has Been Studied: Key Topics of Extant 3VIS Research

We began our review of extant 3VIS research by searching 289 scholarly journals in marketing and other business disciplines, information systems, economics, and selected general science outlets, based on the 70th edition of *Harzing's Journal Quality List* (Harzing 2023), which collates 11 different journal rankings (see Web Appendix A for the full list of journals included). Search terms covered key concepts related to 3VIS (i.e., VR, MR, AR, virtual worlds, metaverse, digital twins, video games, as well as variations of those terms) over the period 1969–2024. We combined an automated search of article titles and abstracts on EBSCOhost with a manual deep search of FT50 journals to minimize omissions. After removing erroneous matches (e.g., search terms appearing only in references) and duplicates, we identified 2,355 relevant articles.

The results reveal a clear upward trajectory of 3VIS research across disciplines, mirroring the rising economic and societal interest in spatial technologies (see Web Appendix B). Notably, more than half of the captured articles were published since 2019, coinciding with the launch of the first Meta Quest VR headset (originally Oculus Quest). Marketing and communication journals[1] account for 26.7% (629) of all 3VIS articles, including 50 publications in marketing's five FT50 journals (i.e., Journal of Consumer Research, Journal of Marketing, Journal of Marketing Research, Journal of the Academy of Marketing Science, and Marketing Science).

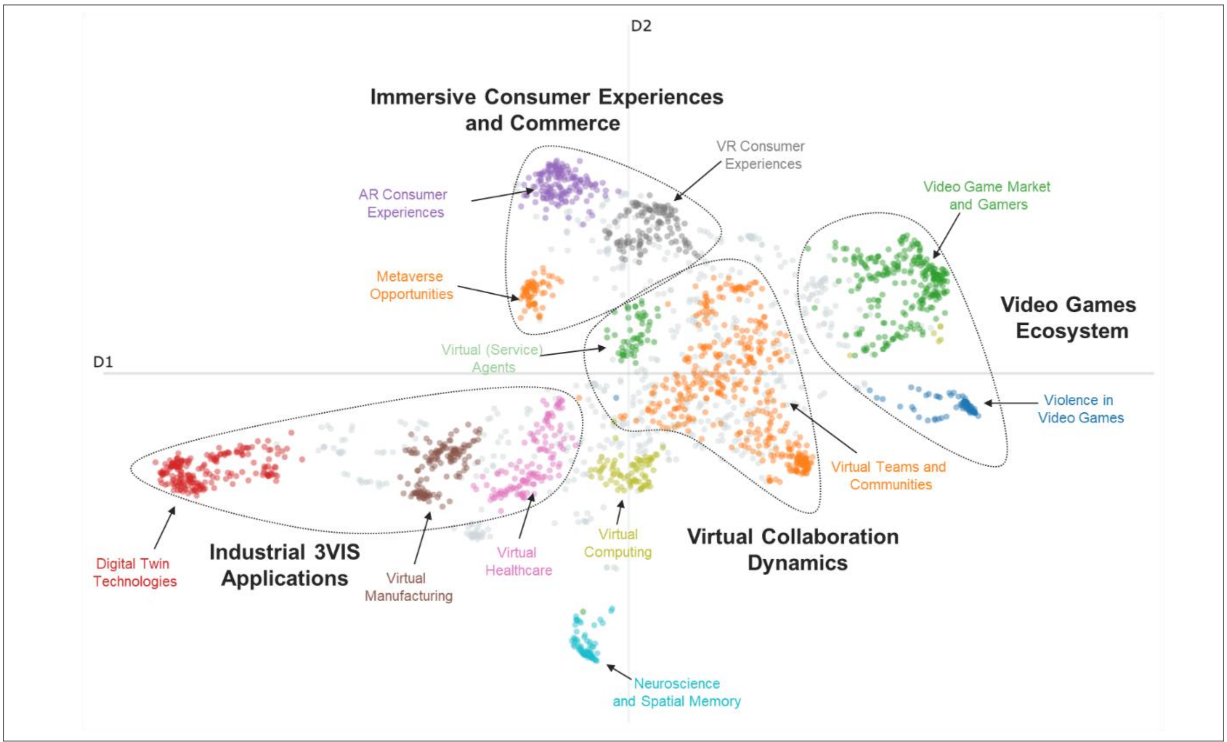
To extract key topics from this identified literature base, we applied a text-mining, NLP-based clustering approach. Specifically, we analyzed the titles and abstracts of the 2,355 compiled articles using the BERTopic framework (Grootendorst 2022), which leverages state-of-the-art LLM embeddings (see Web Appendix C for details). This analysis revealed 12 topic clusters of extant 3VIS research, which are displayed in Figure 1 within a two-dimensional map. Based on their positioning in this map, we condensed the clusters into four broader topical areas. The first key topic covers three clusters that broadly deal with industrial 3VIS applications; the second key topic combines two clusters that study virtual collaboration dynamics; the third key topic encompasses two clusters which focus on different facets of video games ecosystems; and the fourth key topic represents three clusters that analyze immersive consumer experiences and commerce. All four areas have at least some relevance to marketing research, as evidenced by contributions from marketing scholars. Together, these areas account for 1,622 publications, or roughly 70% of the identified articles. By contrast, the two remaining clusters (i.e., neuroscience studies on memory processes and technology-focused work on virtual/edge computing) are highly disciplinary and thus excluded from our review.

As Figure 1 illustrates, the 12 topic clusters show little overlap, with considerable distances between them, underscoring the high degree of fragmentation in extant 3VIS research. This fragmentation highlights the importance of spatial marketing research as an integrative

[1] Two coders independently assigned each journal to one of eight mutually exclusive areas: Marketing & Communication, Economics, Finance & Accounting, Information Systems & Computer Science, Policy, Sustainability & Society, Management & Organization, Operations, Supply Chain & Decision Sciences, Innovation & Entrepreneurship, or General Science. The coders sought agreement throughout the process and discussed edge cases until consensus was reached.

approach to harnessing insights from across clusters for marketing scholarship (for the epistemic value of integration, see Kindermann et al. 2024; MacInnis 2011).

Figure 1. 3VIS Topics Map



Key topic 1: industrial 3VIS applications. This topic area includes studies that address the transformation of industrial settings by spatial technologies. Prominent issues are digital twin technologies, virtual manufacturing, and virtual healthcare. Publications often build on context- and industry-specific literature and applications such as computer science, engineering, and medicine. Main contributions deal with how spatial technologies and real-time data integration can transform existing value creation processes (Albini et al. 2023, Zahedi et al. 2022) and how professionals can be trained with spatial technologies (Islam and Brunner 2019; Wolfartsberger et al. 2023). The topic represents 488 articles (=30.1% of all in key topics), with marketing hardly represented; only 8 (= 1.6%) of these articles have appeared in marketing and communication journals.

Key topic 2: virtual collaboration dynamics. Research within this topic area examines the role of technologies in shaping how individuals interact and collaborate in teams or as agents within virtual spaces. A regular theme is the role of virtual environments for team collaboration (Poppe et al. 2017), dynamics (Goh and Wasko 2012), and overall task effectiveness (Pridmore and Phillips-Wren 2011); while some studies deal with spatial environments (e.g., Aliman, Hennig-Thurau, and Henke 2024), several apply the term virtual to two-dimensional settings such as videochats. Another frequent issue is avatars, as virtual representations of users in computer-generated spaces (Miao et al. 2022). Scholars have examined the roles of avatar realism (Kim, Lee, and Chung 2023) and appearance (Lv et al. 2023), the potential of using avatars in service encounters (Verhagen et al. 2014), as well as their impact on user behaviors and perceptions (Bailenson and Yee 2005). This key topic contains 449 articles (=27.7%), with a decent representation of marketing and communication scholars which contribute 113 of these articles (= 25.2%).

Key topic 3: video games ecosystems. Research in this area covers various facets of the video game industry, a pioneering and financially substantive field of spatial technology, with now close to $200 billion in annual revenues (Buijsman et al. 2024). Exploring issues such as platform dynamics, their impact on users, and central user facets of gaming behavior, this research contributes to our understanding of 3VIS by offering insights into how consumers behave in commercial virtual worlds (Huang, Jasin, and Manchanda 2019), and the intricacies surrounding the effective design of those worlds and their business models (Li et al. 2023; Mai and Hu 2022). Although many of the worlds researched in this area are three-dimensional and interactive, they are usually accessed via lower-immersive devices such as PCs and consoles instead of high-immersive VR headsets. Gaming researchers have also studied potential adverse effects of virtual activities on consumers, mostly with a focus on violent content (Sheese and Graziano 2005). Research in this cluster demonstrates a rich understanding of 3VIS and their monetary opportunities, at least about hedonic/gaming content. This topic covers 328 articles (=20.2%), including 88 marketing and communication articles (= 26.8% of the topic).

Key topic 4: immersive consumer experiences and commerce. Research in this area explores how firms can generate value at the firm-customer interface with spatial technologies and the 'metaverse,' a heterogeneously defined concept with social interactions in virtual environments at its core (Barrera and Shah 2023). Focal contributions help understanding how spatial technologies impact managerially relevant consumer behavior (e.g., brand love, Rauschnabel et al. 2024; Huang 2019), how virtual environments can be designed effectively for consumers (e.g., through multisensory elements, Cowan et al. 2023), and how the metaverse and related technologies can be expected to impact the future of consumers (Hennig-Thurau, Herting, and Jütte 2024) and businesses (Harz, Hohenberg, and Homburg 2022; Wedel, Bigné, and Zhang 2022). The marketing studies—which dominate this topic—are fragmented in that they lack a common overarching structure when it comes to integrating existing finding, particularly those from other disciplines and key topics (e.g., engineering with virtual twins, media research on constructs like presence, as a consumer's sense of "being in a mediated space", Biocca 1997, p. 18). 357 articles (22.0%) are represented by this topic, with most of them (256, or 71.7%) having appeared in marketing and communication journals.

Value Streams of 3VIS Research

How can studies of 3VIS create value for marketing scholars, and how frequently is each value stream targeted in existing research? To address this question, we adapt and refine Fox, Arena, and Bailenson's (2009) historical conceptualization of virtual environments from media science. We distinguish four roles of 3VIS in research: as object, as application, as method, and as economical means.

Creating scholarly value by using 3VIS as object. This value creation stream focuses on insights into virtual spaces and the concept of "virtuality," with 3VIS constituting the research object. Research in this stream creates scholarly value by creating new knowledge about phenomena which are essential for 3VIS and often unique for them, as well as about the relationships among those phenomena and 3VIS users. Topics covered in this stream include avatars (Miao et al. 2022), social presence in virtual environments (Cummings and Bailenson 2015), or virtual consumption (Jung and Pawlowski 2014). By focusing on the distinctive nature of virtual spaces and their perception by or effects on consumers, this stream advances the understanding of user behavior and its economic impact in virtuality.

Creating value by using 3VIS as application. Unlike the first stream, the other three streams all use 3VIS to learn about the 'real world'. Specifically, this second stream builds on the idea of using 3VIS as application which substitutes or extends applications rooted in real-world environments to solve challenges. Researchers study the use of 3VIS as a tool or solution to improve existing approaches that are usually carried out in physical (or two-dimensional digital) environments. Topics covered in this stream are multifarious; they include the study of objects (Harz, Hohenberg, and Homburg 2022) or environments (Bhagwatwar, Massey, and Dennis 2018) that do not exist yet in the physical reality. This stream creates value by substantively expanding research ideas rooted in physical reality.

Creating value by using 3VIS as (superior) method. This and the fourth stream are methodological in nature. In this case, 3VIS serve as alternatives to established methods in physical settings (e.g., lab studies) or two-dimensional digital settings (e.g., vignette studies), with the goal of enhancing validity and thereby generating higher-quality findings. Scholars using 3VIS as a superior method leverage the unique properties of 3VIS to test theories in controlled yet ecologically valid environments, often by creating virtual replications of real-world contexts. Such studies allow researchers to examine effects under novel boundary conditions such as consumer characteristics' moderating role in retail settings (Sarantopoulos et al. 2019) or to combine granular behavioral tracking with A/B testing capabilities that mirror real-world consumer decision-making (Bainbridge 2007).

Creating value by using 3VIS as economical means. The fourth and final stream also considers 3VIS as a methodological alterative to existent empirical research designs but focuses on the economic side of science. By reducing the need for resource-intensive field experiments, this pathway aims to enable scalable and cost-effective research while maintaining rigorous methodological standards. For instance, virtual simulations allow researchers to test complex retail or factory layouts before implementing costly real-world changes (DeHoratius et al. 2025; Massara, Melara, and Liu 2014).

Blending 3VIS Key Topics and Value Streams

Through our exploratory quantitative analysis of the 3VIS literature, we identified four key topical areas: (1) industrial 3VIS applications, (2) virtual collaboration dynamics, (3) video game ecosystems, and (4) immersive consumer experiences and commerce. Adapting a historical conceptualization from media science, we then derived four value streams through which 3VIS studies can advance marketing science. In this section, we integrate these insights into an empirically grounded research typology that addresses our first research question. Table 1 summarizes this typology, blending the four value streams of 3VIS research with the four topical areas identified above and illustrating each cell with exemplary studies.

Based on this synthesis, we further quantify the extent to which prior research in general, and marketing scholarship in particular, has focused on each cell. To identify the respective share of studies among 3VIS research each value stream-topic cluster combination contributes and the prominence of marketing contributions to it, we used a large-language model (i.e., ChatGPT 5), providing it detailed information about the four value streams and asking it which of the streams an article based on abstract and title employed to create value; results could vary between all four streams and none of them (Web Appendix C also contains details about this).

Table 1. Research Typology: 3VIS Key Topics and Value Streams

Value Streams / **3VIS Key Topics**	Learning about *"Virtuality"*	Learning about *"Reality"*		
	(1) *3VIS as Object*: Studying phenomena and relationships (50.6%/ 79.6%)	(2) *3VIS as Application*: Findings solutions and tools (41.2%/ 28.4%)	(3) *3VIS as (Superior) Method*: Boosting research validity (6.2%/ 7.1%)	(4) *3VIS as Economical Means*: Reducing research costs (4.4%/ 1.5%)
Industrial 3VIS applications (30.1%)	e.g., Padmanaban et al. (2017) study how near-eye displays using computational optics enhance users' vision in virtual worlds. (13.3%/ 50.0%)	e.g., Wolfartsberger et al. (2023) benchmark traditional and virtual training methods to improve learning outcomes in assembly processes. (79.9%/ 37.5%)	e.g., Gisler et al. (2021) use a virtual training environment to understand, by analyzing behavioral data from VR headsets, what determines industrial training success. (5.5%/ .0%)	e.g., DeHoratius et al. (2025) conduct a real-effort task in a VR experiment to study execution failures in retail supply chains, leveraging VR to avoid the logistical costs of field experiments while retaining high external validity. (12.5%/ .0%)
Virtual collaborations dynamics (27.7%)	e.g., Miao et al. (2022) develop a taxonomy of avatars and suggest how avatars can be used in marketing. (68.8%/ 87.7%)	e.g., Moffet et al. (2021) expand communication theories to accommodate technological advances like VR to inform effective, efficient, and experiential communication design. (26.1%/ 17.7%)	e.g., Goode et al. (2014) examine gift giving behavior and outcomes related to status-seeking motivation in a virtual world, which are often hard to observe and isolate in real world contexts. (5.3%/ 2.7%)	e.g., Affinito et al. (2023) use a VR simulation to examine intergroup bias, leveraging VR to enable random assignment that would not be affordable in real-world settings. (.2%/ .1%)
Video games ecosystem (20.2%)	e.g., Borowiecki and Prieto-Rodriguez (2014) discuss features of video games and investigate video game usage. (46.6%/ 56.8%)	e.g., Edelblum and Giesler (2025) conduct a netnographic study of a VR startup for protests, showing how virtual environments can enable playful yet impactful forms of resistance. (4.9%/ 2.3%)	e.g., Bielen, Marneffe, and Mocan (2021) run a virtual reality criminal trial game to examine the role of racial bias in courtrooms. (5.5%/ 3.4%)	e.g., Van Berlo et al. (2021) conduct a VR experiment to examine how virtual product appeal and emotional responses shape brand responses. (.6%/ .0%)
Immersive consumer experiences and commerce (22.0%)	e.g., Hennig-Thurau et al. (2023) examine how social interactions in the metaverse generate value. (82.1%/ 86.3%)	e.g., Harz, Hohenberg, and Homburg (2022) derive pre-launch sales forecasts from virtual reality simulations of new, not yet existing durables. (40.6%/ 41.8%)	e.g., Sarantopoulos et al. (2019) test the moderating role of a consumer's shopping goals in a retail context with a virtual store simulation. (8.7%/ 10.6%)	e.g., Branca, Resciniti, and Loureiro (2023) study consumers' evaluation and choices of packaged products in a VR setting, finding it to be "efficient". (2.0%/ 2.3%)

Note: Numbers in the Key Topics column indicate the share of all assigned articles (N=1,622) that are assigned to the respective topic; these shares add up to 100%. The numbers in the cells show the share of each topic/value stream combination within the respective key topic across all scholarly disciplines (before the dash) and among marketing and communication articles (after the dash). Because several articles were allocated to more than one stream, the shares in the cells do not add up to 100%.

Notably, 80.7% of the articles were assigned to one or more of the value streams, substantiating our adapted typology. The majority (60.3%) was assigned to one of the four value streams, 19.3% contributed to two streams, 1% to three streams and 2 articles to all four streams.

Overall, extant research has made contributions to all four paths of value creation, though to different degrees. Most extant research studies 3VIS as object and application; however, almost 10% of articles also employ 3VIS to boost validity, and at least 4% to increase research efficiency. Marketing has demonstrated strong interest in 3VIS phenomena and relationships, but clearly less so for the methodological value potential of 3VIS; existing methodological uses often complement authors' use of 3VIS as a research object or application rather than being the focus of the research. Correspondingly, interest in value streams also varies between key topics. While industrial 3VIS studies predominantly create value through the '3VIS as application' stream and use 3VIS for its economic potential, research about immersive consumer experiences and commerce and virtual collaborations dynamics are both mainly interested in 3VIS itself (as 'object'). The same holds for video game studies, although a somewhat larger share in this area falls outside the identified value streams.

So far, we introduced the concept of spatial marketing research and developed a typology that shows how 3VIS studies can leverage this integrative approach to create value for marketing science. Building on this foundation, the next section addresses our second research question by deriving a methodological framework that links the identified value streams to actionable guidance for configuring 3VIS elements in marketing studies. Thus, while our approach formally falls into the methodological stream of 3VIS research which has so far received limited attention particularly from marketing scholars, our work also connects to all four value streams by enabling more powerful studies of 3VIS as objects, as applications to the physical world, as methodological enhancements, and as cost-efficient research tools.

RQ2A: DESIGN MODEL FOR SPATIAL MARKETING RESEARCH

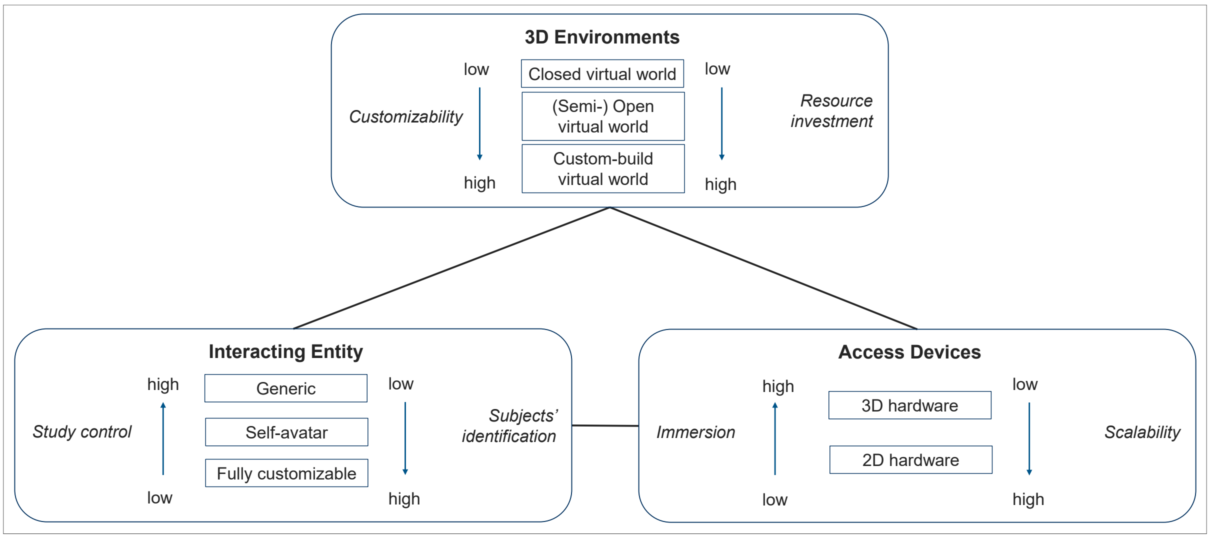
To address our second research question—how to create value by conducting high-quality 3VIS studies—we develop a methodological framework composed of two parts: a design model and a process model. In this section, we introduce the design model (RQ2a). We begin by outlining our theoretical lens, activity theory, which provides the foundation for identifying the 3VIS core elements, followed by an analysis of each element in detail.

Development of Design Model

To build a design model for spatial marketing research, we draw on activity theory (Engeström 1987). This theory views human action as shaped by tools and embedded in a broader social, material, and contextual system; it has been applied to human-computer interactions and guided information systems designs (e.g., Nardi 1996). At its core, activity theory holds that human activity is goal-directed and mediated by tools, unfolding through a dynamic relationship between a subject (the actor), an object (the focus or problem space), and the artifacts that shape and support the subject's engagement with the object (Kaptelinin and Nardi 2006).

In applying activity theory to spatial marketing research, we identify three core elements that structure and define such activity systems. First, the 3D environment functions as the object of activity. This may occur in two ways: either as the direct focus of investigation—when the virtual world itself is under study (the "3VIS-as-object" research stream); or as the contextual substrate that enables or frames other forms of inquiry, such as studies of social interaction or collaboration within 3VIS (the "3VIS-as-application/method/means" research streams). Second, an interacting entity, such as an avatar or other virtual representation of the researcher or participant, embodies the subject of the activity system; that is, the agent through whose perspective and goals the activity is carried out. Third, the access device (e.g., a VR headset) represents the mediating artifact that shapes how the subject perceives, engages with, and acts upon the object. It is a central enabler of mediated experience, conditioning both the possibilities and constraints of the activity. Figure 2 illustrates our design model and names the respective key trade-offs that spatial marketing scholars are facing regarding each of its core elements. We will elaborate on these key trade-offs in the subsections below.

Figure 2. Design Model for Spatial Marketing Research



Core Element 1: 3D Environment

Spatial marketing research requires a computer-generated 3D environment that provides participants with an immersive habitat for interaction (Gómez-Zará, Schiffer, and Wang 2023). Today, the range of 3D environments available to researchers is vast: from popular metaverse platforms such as Horizon Workrooms, VRChat, or Microsoft Mesh (Barrera and Shah 2023) to bespoke virtual models of diverse physical spaces, including retail stores (Burke 1996; Peukert et al. 2019) or manufacturing sites (Bamberger, Reinartz, and Ulaga 2025). This abundance leaves scholars with hundreds of potential options to consider, which differ in various ways such as aesthetics, functionalities, and governance.

Each design option carries distinct trade-offs in terms of accessibility, realism, and resource requirements. We systematically reviewed prior 3VIS research and synthesized the types of 3D environments employed (see Table WA-D1 in Web Appendix D for an overview). Our analysis indicates that the central trade-off that researchers need to resolve for choosing an adequate 3D environment lies between customization opportunities and the resources required of researchers and participants (i.e., costs, skills, and effort). On this basis, we differentiate three types of 3D environments: closed virtual worlds, semi-/open virtual worlds, and custom-built virtual worlds.

Closed virtual worlds are proprietary environments that cannot be altered by users (including marketing scholars), operate under the owner's terms and conditions, and are accessible for free or a predefined fee. Semi-/open virtual worlds allow users to customize existing code, scenes, and assets within predefined limits. Open virtual worlds provide software development kits (SDKs) that enable scholars to adapt environments to research needs, whereas semi-open worlds require project proposals to access their SDK for hosting scenes and assets on the platform. In contrast, custom-built virtual worlds are developed specifically for individual research projects and allow unlimited freedom in design and functionality. Such flexibility, however, comes at a cost: custom-built virtual worlds demand substantial technological expertise and resources, while closed and semi-/open worlds allow scholars to leverage the creators' infrastructure and investments. Custom-built worlds also add friction, particularly for studies involving social interactions, as enabling multiple participants to join the same environment remotely is technically demanding and may necessitate travel to dedicated labs.

To summarize, our analysis revealed that all 3D environments can essentially be allocated into one of three categories (i.e., closed, open/semi-open, and custom-built virtual worlds). Ultimately, researchers must balance how much flexibility their study requires with how much flexibility they can realistically afford. Framing the choice in terms of these categories simplifies the decision: rather than comparing hundreds of individual platforms, scholars can first select the most appropriate category and then fine-tune their choice among the available options within it.

Core Element 2: Interacting Entity

Interacting entities denote the self-representations of human subjects within a 3VIS, serving as vessels for subject embodiment (Bailenson, Blascovich, and Guadagno 2008). These entities facilitate personalized experiences and interactions within the virtual environment and with other entities, including both user-controlled and scripted characters. Prior research, including in marketing (Miao et al. 2022), has highlighted that providing adequate interacting entities poses a significant challenge for 3VIS researchers. This challenge arises from their critical role in transporting humans into 3VIS and shaping whether behaviors observed in 3VIS resemble or diverge from those in physical reality (Yee and Bailenson 2007). Indeed, interacting entity design can determine the success of a 3VIS activity: Siemens, for example, found that its VR industry training program only became effective after replacing generic avatars with individualized, human-like representations (Radhakrishnan, Chinello, and Koumaditis 2021).

The range of options available to researchers regarding interacting entities is vast, varying in terms of representation (e.g., hands vs. full body: Seinfeld and Müller 2020), customization (generic vs. personal: Radiah et al. 2023), anthropomorphism (more vs. less human-like: Cheymol et al. 2023), and realism (stylized vs. photorealistic: Latoschik et al. 2017). To structure this variety, we analyzed prior 3VIS research aiming to distill the central trade-off that researchers need to resolve for choosing an adequate interacting entity (Table WA-D2 in Web Appendix D). Findings reveal that for choosing adequate interacting entities the central tradeoff relates to choosing between a high level of control and offering a high level of identification potential with the entity, which can be addressed to varying degrees with generic entities, self-avatars, and fully customizable entities.

Generic entities include general abstract forms like gloved hands or robotic avatars, which provide a common, uniform appearance for all participants. These entities are straightforward to implement and afford researchers a high level of control (Luangrath et al. 2022). However, their use may result in lower subject identification, as reported for the Siemens case and by 3VIS scholars (Peng, Cowan, and Lo Ribeiro 2025). Self-avatars aim to capture or approximate the subject's actual or desired human appearance. For example, avatar creator *Ready Player Me* (https://readyplayer.me/) allow subjects to upload a personal photo to create a somewhat "realistic" avatar design. Such apps and many metaverse platforms also offer some customization options, from facial shape to makeup, providing subjects with the ability to fine-tune their self-avatars. Fully customizable entities offer nearly limitless customization options, both in breadth (i.e., which aspects of an avatar can be customized, such as face, height, weight, clothing) and depth (i.e., the range of customization options available for each aspect, such as the number of available T-shirts), allowing for the highest degree of subject identification but at the expense of researcher control. Advanced avatar editors in games like *Baldur's Gate 3* or platforms like *VRChat* enable subjects to adjust minute details or even adopt non-human forms by importing custom 3D models created in applications like Unity.

Researchers must balance how much control their study requires with how much identification with the interacting entity they need to motivate the required level of realistic behavior. This categorization reduces complexity by guiding scholars to choose the right interacting entity category first, and only then refine their choice within it.

Core Element 3: Access Device

Access devices denote the hardware through which human subjects are immersed into 3VIS. These devices provide the gateway that enables subjects to control their interacting entity and engage with the 3D environment. The available range is vast, spanning high-fidelity VR or MR headsets (e.g., Hubbard 2025; Luangrath et al. 2022), surround-projection chambers such as CAVE technology (Cruz-Neira et al. 1993; DeHoratius et al. 2025), and more ubiquitous devices such as computer screens, tablets, or smartphones (e.g., Fritz, Hadi, and Stephen 2023; Hoffmann et al. 2022). As with the other 3VIS elements, this abundance creates challenges in selecting the appropriate option. Our analysis of extant 3VIS research highlights a central trade-off in selecting access devices: immersion, the capacity of a device to transport users into a simulated environment, versus scalability, the ease of deploying studies to large and diverse samples (Oh, Bailenson, and Welsh 2018). Researchers are essentially confronted with the choice between 3D hardware, which enables spatial (3D) presentations, and 2D hardware, which restricts users to flat (2D) displays (Table WA-D3 in Web Appendix D).

3D hardware facilitates higher levels of immersion, which refers to the extent to which a technical device can generate spatial presence in the virtual environment (Bailenson et al. 2025) and, in multi-user settings, also social presence as the feeling of being there with other people (Biocca, Harms, and Burgoon 2003). High-immersion devices like VR headsets often elicit more realistic behaviors and intense experiences, which can strengthen effects in studies using 3VIS as an object, or enhance realism and ecological validity when 3VIS are used as an application, method, or economical means (van Zelderen et al. 2024).

However, this upside potential comes with costs: 3VIS studies using VR headsets consistently document higher levels of fatigue and cybersickness (Weech, Kenny, and Barnett-Cowan 2019). In addition, there is the need for expensive equipment and lab-based setups (Cipresso et al. 2018). While remote panel providers like *Prolific* (2025) introduced options to target participants owning 3D hardware, the lack of availability of 3D hardware among consumers limits the flexibility of empirical designs. In contrast, 2D hardware such as laptops, tablets, and smartphones, while containing a lower immersive potential that limits immersion and behavioral realism (Bowman and McMahan 2007), offers far greater scalability. Such devices are widely available, inexpensive, and technologically stable, enabling broad participant reach through online panels.

Essentially, researchers must balance how much immersion their study requires with how scalable it needs to be. Again, this categorization reduces complexity by guiding scholars to make the fundamental choice between 3D and 2D hardware first and then selecting the adequate specific devices within the category.

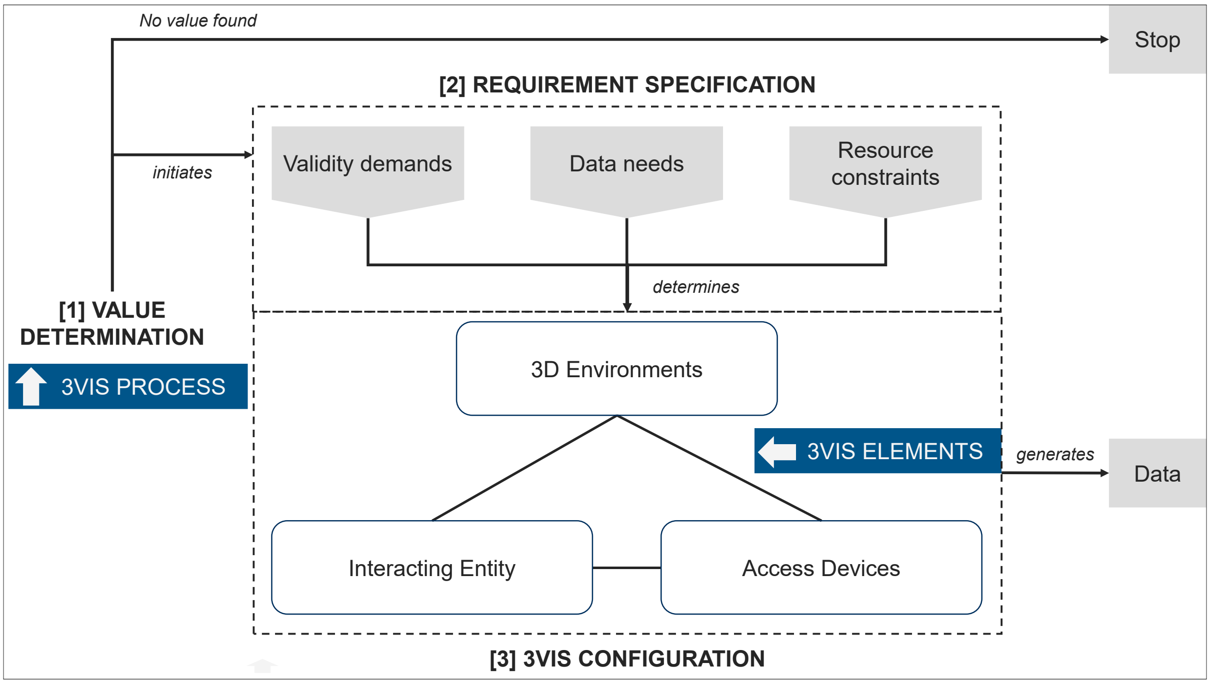
RQ2B: PROCESS MODEL OF SPATIAL MARKETING RESEARCH

To provide practical guidance for specific spatial marketing research projects, we extend our design framework by adding both a contextual and a procedural perspective. In this section, we present a process model that integrates these perspectives, offering marketing scholars a step-by-step approach (procedural) to configuring the elements of the design model in alignment with the specific requirements of their project (contextual).

Development of Process Model

The process model, shown in Figure 3, places the three 3VIS core elements at its center. It augments these elements with three essential steps that spatial marketing researchers must follow to conduct 3VIS studies. With this process model, we built on design science research (e.g., Hevner et al. 2004; Simon 1996). In line with design-science logic, our process model follows a problem–solution cycle: researchers first clarify the intended value contribution of using 3VIS (problem definition), then articulate the validity, data, and resource requirements their study must meet (requirements specification), and finally configure the 3VIS elements to align with these requirements (artifact design). This sequence ensures that 3VIS studies are not only technically feasible but also methodologically rigorous and problem relevant. We next detail each step and outline the associated decisions.

Figure 3. Process Model for Spatial Marketing Research



Step 1: Value Determination

Initially, scholars should evaluate whether a study can generate meaningful value for their project (Hevner et al. 2004). In the context of spatial marketing research, this evaluation concerns the value determination of a 3VIS study for a particular project and can be guided by four sequential questions, which we structured as a decision tree for marketing scholars.

Question 1: Is 3VIS the object of the research? The first question is whether a project seeks to investigate phenomena directly tied to 3VIS, its core elements, or the interactions that occur within such spaces. Examples include studies on digital goods in the metaverse (Yang 2024), avatar-related behaviors (Peng, Cowan, and Lo Ribeiro 2024), or foundational concepts of virtuality such as presence or cybersickness (Yim, Cicchirillo, and Drumwright 2012). If this is the case, the project treats 3VIS as its research object, and—unless designed as purely conceptual or ethnographic—the potential for value creation through empirical 3VIS studies is inherently substantial.

Question 2: Can 3VIS substantively expand the research? If a project does not treat 3VIS as its research object, it may still benefit from incorporating a 3VIS study. The second guiding question is whether 3VIS can meaningfully expand the scope of the research by enabling exploration of aspects that are unattainable in physical settings. In this role, 3VIS provides applications that advance the substantive research question. For instance, scholars have used 3VIS to investigate marketing channels that have not yet realized (Pfeiffer et al. 2020) or to improve forecasting for hypothetical products (Harz, Hohenberg, and Homburg 2022). In such applications, 3VIS extends the marketer's toolkit by transcending the limitations of physical reality and enabling richer exploration of novel approaches and scenarios.

Question 3: Can 3VIS improve the validity of the research? If both previous questions are denied, 3VIS may still add value for a project by serving as a methodological extension of traditional marketing research. The third guiding question is therefore whether 3VIS could offer a superior method that enhances the validity of the project. Loomis, Blascovich, and Beall (1999) have early theorized that 3VIS studies, if done well, can offer the potential to combine the external validity typically associated with field studies with the experimental control of laboratory studies, while also enabling the automatic tracking of high-frequency, objective spatial data (a point we elaborate on below, see "data needs" subsection). Organizational scholars van Zelderen et al. (2024) provide empirical evidence that immersive vignettes presented in 3VIS are superior to both text and video recording vignettes for measuring employee responses, because they increase respondents' "attention to critical study details" (p. 457), and we assume that such effects could also improve the ecological validity of vignette studies in marketing. More generally, marketing researchers should assess whether the internal or external validity of their existing empirical approach could be improved and whether incorporating a 3VIS study could mitigate this limitation. Some studies in marketing have already successfully applied 3VIS this route (though not for vignettes). For example, Esteky (2022) employed VR to manipulate social presence, thereby strengthening the internal validity of research conducted in physical settings. Luangrath et al. (2022) leveraged VR to examine additional dimensions of the nomological network of the vicarious touch effect within a controlled yet realistic environment, and Sarantopoulus et al. (2019) study a moderating role of shopping goal specificity in a retail context by combining the replication of a field design with high experimental control.

Question 4: Can 3VIS reduce the cost or effort of the research? Even if 3VIS does not provide value as an object, a substantive application, or a better method, scholars should still ask whether incorporating 3VIS can reduce the overall cost or effort of a research project (Wedel, Bigné, and Zhang 2020). While setup costs may be substantial, particularly for studies requiring custom-built virtual worlds, subsequent modifications to objects and scenes are often remarkably efficient (Cesanek et al. 2024; van Zelderen et al. 2024). Similarly, leveraging existing closed or open virtual worlds (e.g., Glue for team meetings or Synergy XR for training contexts) often proves highly cost-effective. Studies in marketing and related fields have already demonstrated these benefits. For instance, DeHoratius et al. (2025) used a VR experiment to investigate failures in retail supply chains, achieving field-like external validity at a fraction of the cost and effort of a field study, and Burke (1996) reports research studies on brand equity and product display by companies that use (early) 3VIS to reduce research costs. Cost savings also enable research designs that would otherwise be prohibitive. Constructing a physical museum to study visitor behavior or building a full-scale retail store is rarely feasible, but developing their virtual equivalents in 3VIS can be far more realistic. Although careful design is required to ensure valid transfer of insights to the physical world, 3VIS makes cost-efficient investigation of complex marketing phenomena possible.

If, after thorough consideration, researchers answer no to all four questions, their project likely does not align with either virtuality or physicality 3VIS research, and the potential value of a 3VIS study is limited. Typical examples include conceptual work, methodological innovations in other methods, or investigations of phenomena that are inherently two-dimensional, such as social media communication (e.g., Du, Xu, and Wilbur 2019; Kanuri, Chen, and Sridhar 2018). These “limited-value scenarios” offer little justification for employing 3VIS. That said, while such cases certainly exist, we argue that many marketing research projects will nevertheless find that a 3VIS study can add meaningful value as part of their broader empirical design.

Step 2: Requirement Specification

When added value through a 3VIS study can be expected, the next step is to specify the study’s specific requirements. We propose defining these requirements along three fundamental criteria: validity demands, data needs, and resource constraints. While these criteria are central to marketing research in general and in line with the principles of design science (e.g., Hevner et al. 2004), their trade-offs and implications manifest differently in the context of 3VIS. A clear specification of requirements allows scholars to configure 3VIS elements appropriately and to manage trade-offs between them more effectively.

Validity demands. To configure an adequate 3VIS for a specific project, researchers must first clarify their requirements regarding internal and external validity. 3VIS studies, in principle, offer the rare potential to combine the external validity of field research with the internal validity of laboratory experiments (Loomis, Blascovich, and Beall 1999; van Zelderen et al. 2024). However, realizing this potential is challenging and often costly (Cesanek et al. 2024; Hubbard and Aguinis 2023). To specify validity demands effectively, we recommend that scholars consider two aspects:

First, researchers should carefully assess the role of the 3VIS study within their overall empirical package. Prior work shows that 3VIS has been used as the sole empirical basis for an article (DeHoratius et al. 2025) as well as in combination with field, lab, and online studies (Esteky 2022; Luangrath et al. 2022; Sarantopoulos et al. 2019). When a 3VIS study serves as the primary data source, both internal and external validity demands are typically high. By contrast, when a 3VIS study complements a field experiment, the emphasis may shift. If the field experiment already provides strong external validity, the 3VIS study can focus on enhancing internal validity, for example by offering high levels of control and ruling out confounding factors or capturing fine-grained spatial data (see next subsection) to improve measurement and rule out alternative explanations. In such cases, a proxy 3D environment that resembles (but may not fully replicate) the field setting may suffice, saving time and resources.

Second, researchers should then carefully evaluate the type of 3VIS study they are conducting (i.e., virtuality versus physicality 3VIS research). Our analysis of prior work shows that especially external validity demands vary by study type. For instance, in a 3VIS-as-object study, such as research on in-game advertising in VR, external validity requires creating a 3VIS that convincingly resembles an actual VR game. By contrast, in a physicality-focused 3VIS study (e.g., using a virtual store to study shopper behavior), the benchmark for external validity is the physical environment itself. In such cases, a store must not only look like its real-world counterpart but also "feel" like it, eliciting comparable cognitive and emotional responses. In general, while virtuality-oriented studies must ensure equivalence to a type of virtual space, physicality-oriented studies must ensure equivalence to a physical setting, an important indicator to emphasize external validity.

We recommend that scholars specify validity demands by jointly assessing (1) the role of the 3VIS study within their empirical package and (2) the type of 3VIS study. The first consideration helps prioritize whether external validity (e.g., photorealistic environments, personalized avatars) or internal validity (e.g., spatial data extraction, experimental control) is more critical. The second clarifies what the 3VIS must be equivalent to—virtual or physical spaces—and thus sets the benchmark for how validity demands should be realized. Table WA-D4 in the Web Appendix provides examples of 3VIS studies on virtual as well as physical phenomena that enhanced validity through careful design.

Data needs. Determining the data needs of a 3VIS study requires particular attention to two aspects: the role of spatial data and the relevance of data privacy. These dimensions matter because 3D environments, interacting entities, and access devices—as 3VIS core elements—differ substantially in their ability to capture spatial data and to safeguard privacy. Thus, a clear understanding of whether and how a project depends on these data dimensions enables scholars to make informed and adequate configuration choices and to design studies that balance research ambition with technological and ethical constraints.

Spatial data refers to time-stamped, high-frequency recordings of participants' actions within 3VIS, including speech and spatial audio, gaze direction, controller and body movements, and interactions with objects (e.g., Steptoe and Steed 2012). We present a more detailed list of the types of spatial data in Web Appendix E. This data can be automatically tracked for certain 3VIS configurations.

Spatial data can enhance research by increasing transparency and generating novel insights. Regarding transparency, because every action can be—in certain 3VIS configurations—recorded and replayed as a full 3D simulation of the participant's experience, scholars can *objectively* verify what occurred during a specific session both outside the environment (e.g., whether a participant removed a headset) and inside the environment (e.g., whether and when a participant fixated on a stimulus). This allows researchers to provide process-level evidence in addition to traditional inputs (e.g., survey files) and outputs (e.g., datasets), aligning with journals' growing demands for transparency and reproducibility (see Web Appendix F for an example of a replay). Regarding novel insight generation, spatial data allows scholars to examine adjacent questions, especially about how navigation and interaction shape effects and outcomes. For instance, in a study of spatial openness and creativity (e.g., Brucks and Levav 2022), spatial data can reveal whether the effect depends on gaze patterns, actual movement, or the timing of such activity.

These benefits come at a cost though, as extracting spatial data requires a particular technical infrastructure, namely access to the application programming interface of open/semi-open environments or the implementation of spatial data extraction from a custom-built 3D environment (for details on how to extract spatial data from such environments, please see Web Appendix E). In addition, capturing spatial data may require specialized hardware for tracking gaze or controller inputs. Thus, it is usually only feasible in semi-open or custom-built environments, but not in closed virtual worlds (if the world owner does not provide special authorization). Moreover, the relevance of spatial data varies strongly between projects. While projects centered on navigation or interaction may find such data essential, studies focusing on perceptual or evaluative outcomes may benefit less from such detailed spatial tracking. In essence, spatial data offers transparency and potential for additional insights but requires sophisticated infrastructure and may not be necessary for all research questions.

The second key aspect for scholars to consider concerns data privacy demands. While privacy has numerous facets, in the context of 3VIS research it refers mostly to the kind of data that is generated and where it is stored (Martin and Murphy 2017). Privacy requirements directly shape which 3D environments, interacting entities, and access devices are appropriate for a project. When privacy demands are high, for example when face tracking of consumers is active, their personal environment is recorded, or if studies involve confidential innovation concepts, researchers must rely on custom-built virtual worlds. These environments enable the processing and storage of data on protected servers or on the access device, thereby maintaining the required confidentiality. When privacy is less critical, scholars can leverage the advantages of semi-open or open virtual worlds, which are usually more cost-effective and easier to implement, particularly for studies involving social interaction or multiple participants together in the same environment. Clarifying data privacy needs early in the design process is essential;

it not only protects participants and sponsors but also narrows the range of feasible 3VIS configurations, ensuring that researchers make informed and context-appropriate choices.

Resource constraints. With respect to resource constraints, scholars must evaluate time and budget as critical factors. Time constraints require assessing how quickly the 3VIS study must be executed to realize the study aims. Customizing or adapting 3D environments with tools such as Unity, or developing tailored interacting entities, can be time intensive. Building a 3D environment is comparable to designing a physical space: while the virtual construction itself can be executed much faster, extensive testing of functionalities (e.g., ensuring that objects have appropriate collision boundaries or that scripted interactions run smoothly) often requires substantial effort. Moreover, given the still-emerging nature of many 3VIS tools, usability challenges of the 3VIS can further increase the time burden. Regarding a project's budget, researchers must account for the full spectrum of expenses, which include the construction or adaptation of 3D environments and interacting entities, hosting fees (especially if spatial data extraction requires server capacity), and hardware costs such as purchasing or renting VR/MR headsets.

While custom-built environments or interacting-entity configurators can be expensive, the main cost driver is often the choice of access devices. Studies using 3D hardware typically require substantial investment, as high-fidelity headsets such as Apple's Vision Pro costs about $4,000 per unit and remain scarcely distributed in many populations, including consumers and many companies. To achieve representative samples, most studies still need central-location setups, which add costs for equipment, facilities, and participant travel reimbursements. Using student samples, if accessible, can reduce expenses, though at the potential cost of reduced generalizability and validity. Importantly, choosing 2D hardware for 3VIS studies (e.g., TV screens or monitors) or media such as cardboard devices (e.g., Esteky 2022) or virtual store screens (e.g., Burke 1996; Sarantopoulos et al. 2019) often lowers research costs and effort, but sacrifices psychological presence, as the “sine qua non” (Bailenson 2018, p. 19) of 3VIS, which often fundamentally changes results (e.g., Hennig-Thurau et al. 2023). Scholars must align budgets with research objectives, avoiding both overinvestment in elaborate 3VIS setups and underpowered designs that compromise study quality.

Step 3: 3VIS Configuration

Because each 3VIS core element involves inherent trade-offs, the configuration of these elements determines how effectively a study meets its goals for validity, data, and resources. In the following, we provide concrete recommendations for configuring 3VIS studies. We first address general requirements and specific considerations for each of the three core components: 3D environments, interacting entities, and access devices. We then turn to their interplay and show how configurations should be adapted to the intended value contribution of a research project.

How to design the 3D environment. A proper environment must first accommodate and fit the phenomena and behaviors to be studied. Concepts such as social presence require multi-user functionality, investigations of 3VIS shopping require store environments along with specific features such as check-out capabilities, and analyses of real-world aesthetics (e.g., car colors) rely on high-resolution (so-called “high-poly”) designs. 3D environments are usually specialized in certain domains and for certain tasks, and scholars will need to find the most fitting “world” for their study.

We consider it generally advisable to conduct “3VIS-as-object” studies within their ‘natural’ environments, i.e., closed or open/ semi-open virtual worlds. Those worlds and their respective audio-visual and interactive features are the result of extensive multi-year long research and development by the world provider and platform, something that scholars often cannot achieve in customized worlds. Studying user behavior in and responses to virtual worlds should not be compromised by world building limitations, which is why scholarly studies in this value stream often benefit from accepting the limitations of using such pre-existing environments. Similar arguments apply to many “3VIS-as-application” studies, which compare 3VIS tools with traditional tools outside 3VIS. By contrast, studies that employ 3VIS as a superior method often require custom-built worlds, particularly when scholars seek to support hypothesized relationships with spatial data, for which custom-built environments offer the most comprehensive options (Web Appendix E). Finally, studies that use 3VIS to reduce costs must navigate a trade-off between the higher validity potential of custom-built virtual worlds and their greater budget demands.

How to design the interacting entities. Scholars must make thoughtful decisions about interacting entities’ appearance, as they shape how 3VIS research subjects perceive themselves, interact with others, and experience the virtual setting. General design decisions here include the level of realism and human-likeness as central design features. While they determine the subject’s identification with the interacting entity, these features can also lead to feelings of eeriness and discomfort if subjects feel their representation falls into what is referred to as the “uncanny valley” (Mori, MacDorman, and Kageki 2012). They can also trigger social biases, which are often unintentional. Scholars should consider the available options for their study and then carefully weigh the pros and cons.

Further design features of interacting entities include first- versus third person perspective, interaction and sensory potential, personalization, and navigation. Third-person avatars might be preferred when research deals with spatial awareness (as the user has a wider view and is thus more aware of his appearance and actions), while first-person avatars are better suited when interactions are part of the study (which are more accurate for first-person avatars) and a sense of embodiment is desired (Gorisse et al. 2017). Interactive features such as grabbing objects and shaking hands of other avatars can increase the realism of a 3VIS scenario and boost social presence (Della Longa, Valori, and Farroni 2022), while scholars should be aware of the features' distraction potential in other study contexts. Avatar personalization can obviously increase subjects' identification with their virtual agent and help a study's realism (and thus external validity), but it also limits the scholars' control over the design, adding variability and the need for a scholar's trade-off.

Finally, avatar navigation can generally happen in three basic modes: by teleportation (i.e., moving an avatar from one location to another within the 3D environment by pointing and clicking on a destination), by virtual scrolling via analog controlling device, or by physical movements in roomscale applications alias "continuous body-based steering." As the latter mode replicates how we get around in physical environments, it offers higher external validity, while teleportation is most distinct from our usual way of movement. Particularly if participants are less experienced in 3VIS usage, researchers need to be aware that virtual scrolling tends to be most strongly associated with cybersickness and similar states (Hořejší et al. 2025).

Regarding value contributions, interacting entities have been a central focus of "3VIS-as-object" studies both within and beyond marketing (e.g., Holzwarth, Janiszewski, and Neumann 2006; Miao et al. 2022). Scholars view them as essential for shaping user behavior in 3VIS, making avatar features and user choices a fertile research area. For instance, when students in our virtual lectures choose between human-like and fantasy avatars, their responses vary substantially. Interacting entities also play an important role in "3VIS-as-application" studies: social psychologists use avatars to learn about social roles (e.g., male users are assigned female avatars) and as a new tool to reveal—and counter—social stereotypes. For "3VIS-as-method" studies, avatar realism can be considered a key design factor.

How to design access devices. Finally, regarding access devices, the capabilities of 3D and 2D hardware are of main interest, as they fundamentally affect data collection opportunities as well as the user experience. As argued above, 3D hardware is unique in its high immersion potential. This potential is closely tied to key constructs of 3VIS experiences, including higher levels of presence, but also higher cybersickness (e.g., Biswas, Mukherjee, and Bhattacharya 2024). At the same time, 3D hardware limits the scalability of research projects because of its limited availability and high costs. Moreover, as noted earlier, 3D hardware differs significantly in its capabilities. Some headsets, such as the Meta Quest Pro, support eye- and face-tracking, allowing researchers to collect data that are essential for studying user emotions in 3VIS alongside other spatial data. In addition, several devices offer so-called 'pass-through functionality' via external cameras, which enables studies in mixed reality.

For "3VIS-as-object" studies, we consider it essential for scholars to explicitly frame a study's contribution in the context of the used hardware. We noted several studies that—often implicitly—aim to generalize their 2D hardware-based findings to 3D hardware, something that we consider as not legitimate given the fundamental differences that exist in users' responses to the different kinds of access devices. We argue that immersive 3D hardware should be the standard for 3VIS researchers for such studies, as immersion is an essential part of the 3VIS phenomenon. Whenever scholars use 2D hardware or other hardware variations that lack the immersive potential of today's 3D hardware, this should be clearly mentioned along with the reasons for doing so as well as a discussion of resulting implications. One of those reasons for using less immersive hardware can be practical diffusion. With most metaverse users currently accessing virtual worlds, such as Roblox, still via 2D hardware, understanding advertising and branding effects in 3VIS can warrant the use of such hardware, as Kim and Lee (2024) do in the Zepeto app. Among the most intriguing issues when it comes to research the use of hardware for "3VIS-as-object" studies are the negative effects of high immersive devices, which contribute to their slower-than-expected adoption (e.g., Hennig-Thurau, Herting, and Jütte 2024).

When using "3VIS-as-application", the higher level of immersion for 3D hardware promises stronger contributions than 2D hardware for innovative solutions. For "3VIS-as-method" studies, the choice of 3D versus 2D hardware is more ambivalent, however. While the higher immersive potential of 3D hardware offers the potential to achieve higher levels of realism and thus external validity essential for generalizing results from the virtual to the physical environment, the side effects of high immersive device usage (e.g., cybersickness, exhaustion) can counteract such advantages. If reducing research costs is the main motivation for using 3VIS, scholars might be willing to tolerate limitations in performance alias external validity for the sake of the lower costs associated with less immersive devices.

How to account for the interplay between 3VIS elements. The paths between the three core 3VIS elements point out the structural dependence between them. Such interactions also need to be considered when configuring a 3VIS. Specifically, as using 3D (instead of 2D) hardware is not sufficient to fully realize the potential benefits associated with higher immersion for the scholar, its usage should be part of a 3VIS configuration that also avoids design factors that can mitigate the higher immersion-triggered benefits (e.g., causing exhaustion or cybersickness). Interacting entities whose navigation in the virtual environment mitigates negative side-effects of high immersive hardware such as cybersickness could be desirable. Particularly, as moving around in a virtual environment by teleportation causes substantially less motion-sickness than scrolling in the simulated world, it might be preferred over alternative modes of movement, at least when roomscale designs are not possible. Also, high user identification based on customized self-avatars might foster identification and help users to experience higher realism and presence.

Also, the design of the 3D environment and its interactive potential affect both the level of spatial presence perceived by the user as well as the net-benefits of immersion. Natural movement in roomscale environments has been shown to enhance presence perceptions, as have intuitive controls that match users' "real-world" expectations (e.g., opening a door in the virtual environment by turning the doorknob) (Hennig-Thurau et al. 2023). Further, spatial audio (i.e., the technique of simulating how sound is perceived in a 3D space) enhances presence by emulating physical experiences (e.g., Potter, Cvetkovic, and De Sena 2022; Verhulst et al. 2024).

Note that while some 3D environments are device independent (e.g., the training environments and avatars provided by Synergy XR can be accessed via Meta headsets, the Apple Vision Pro, as well as PCs and Macs), many others are device dependent, meaning that they work only with certain types of hardware. Moreover, high-resolution 3D environments sometimes can only be accessed with PC-powered VR headsets ("PC-VR"), because standalone VR devices lack the required processing power. For example, some virtual worlds within the VRChat app (e.g., "Amusement Park by Night") can only by accessed via PC-VR or a 2D device, but not with a standalone VR device.

In essence, scholars' design decisions regarding the core elements of 3VIS configurations must not be made in isolation but also consider the elements' interplay. The usefulness of immersive hardware depends on whether the other core elements are designed in ways that enable the benefits that the hardware's immersion advantage offers, and similar considerations apply for designing the interacting entity or 3D environment for a 3VIS study.

Avoiding common pitfalls and remedies. The complexity of 3VIS studies creates numerous opportunities for mistakes that can compromise desired research outcomes. In our own projects, we have experienced many flaws stem from inadequate configuration decisions, particularly those that hinder participants' ability to be transported into, navigate within, or interact effectively in 3VIS. Here we draw on these experiences to highlight pitfalls in 3VIS research and suggest practical remedies to help scholars avoid them.

Regarding transportation, a frequent challenge in moving participants from physical reality into 3VIS is 'erroneous avatar transfer.' For example, if a configured avatar is not saved correctly, participants may be randomly assigned an inappropriate representation (e.g., a female

African American participant entering the study as a male Caucasian avatar—or even as a comic-style monster). Such mismatches can compromise research integrity by biasing actions and perceptions, given the centrality of self-identity for behavior (Belk 1988). A simple yet effective remedy is to provide participants with a virtual mirror before entering the main study. This step allows them to confirm or adjust their avatar representation, while also giving researchers a post hoc check when reviewing replays of the session.

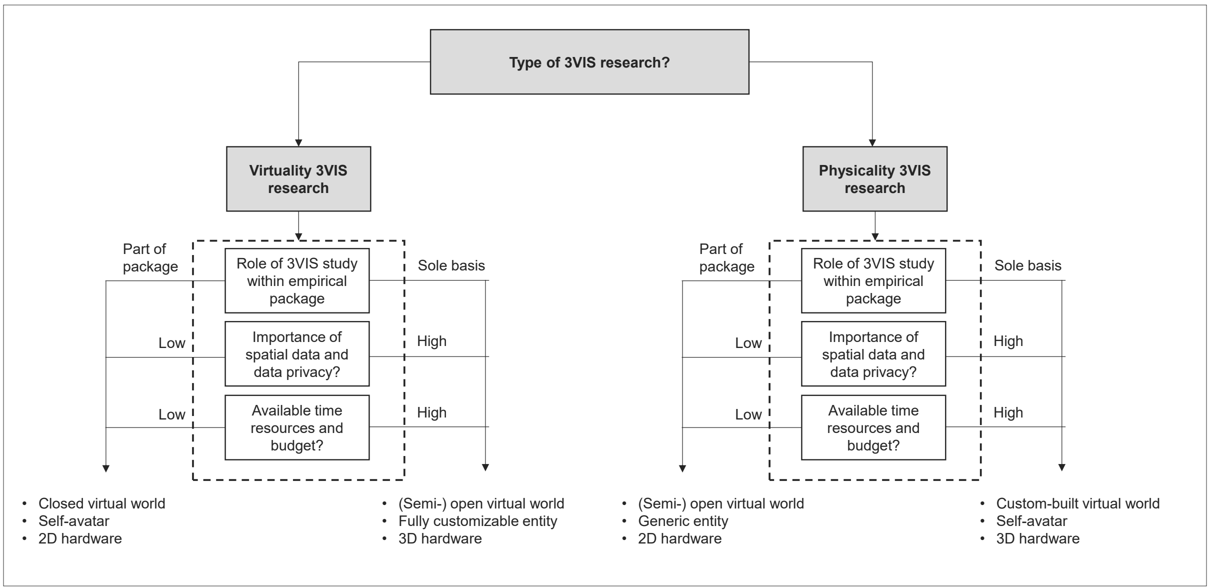
Regarding navigation, a standard pitfall arises from a 'device–simulation mismatch.' Misalignments between hardware input and its rendering in the 3VIS can result in participants being displayed at incorrect scales (e.g., appearing too tall or too short) which disrupts their ability to navigate (e.g., forcing tiptoeing, crouching, or awkward movements). Such mismatches remain common even with state-of-the-art 3D hardware and can undermine studies by distorting how participants move through the environment and by misaligning spatial tracking data (Jagadeeshan et al. 2015). A practical remedy is to check calibration during the participants' onboarding and correct discrepancies through the adjustment tools that most 3D environments provide. When direct researcher oversight during onboarding is not possible, standardized navigation protocols (e.g., all participants standing, disabling controller-based walking, restricting movement to teleportation) can further reduce errors caused by device–simulation mismatches.

Regarding interaction, researchers must ensure that participants are both comfortable and prepared when engaging with other people in a 3VIS study. Two common issues that can bias interaction behaviors are distractions (e.g., noises from the physical environment) and overexcitement, particularly among first-time 3VIS study participants who need time to acclimatize. Such effects can skew results by influencing interaction behavior and limiting validity. To address distraction, we recommend using a 'clean-and-protected' lab room. To avoid overexcitement, we recommend a short but targeted onboarding module (5–10 minutes) with simple navigation and interaction tasks before the main study begins. Such onboarding helps equalize VR skills and emotional responses, ensuring that outcomes reflect the focal relationships rather than disparities in user experience. Importantly, onboarding should not be confused with "novelty effects:" 3VIS studies should remain representative of the technology's current early lifecycle stage instead of speculating about future 3VIS designs and experiences, and researchers should acknowledge this contingency rather than attempt to negate it. To balance the trade-off, the onboarding, while critical, should be kept short and focused.

General 3VIS configuration guidelines. In our experience, every 3VIS study is different and there is no 3VIS configuration blueprint that can be applied across all 3VIS studies. Instead, experience has shown that adequately configuring a 3VIS for a particular study (i.e., avoiding over- and underpowering the 3VIS configuration) can only be achieved through a careful assessment of all design options and understanding the inherent trade-offs (the design model addressing RQ2a) and triangulating these options with the idiosyncratic project needs (the process model addressing RQ2b).

Despite these insights and the previous discussion of specific interdependencies between the 3VIS core elements, we conclude this section by synthesizing this approach into general guidelines that marketing scholars interested in 3VIS research may find useful (see Figure 4). These are of a general nature, and we acknowledge that specific project requirements can lead researchers to choose configurations that deviate from these guidelines, but our experience has shown that these guidelines should prove useful for the vast majority of 3VIS studies. In the figure, we use the key facets of each requirement criterion, namely whether 3VIS is the sole method used or part of a methods package (validity demands), how important spatial data and data privacy is for the study (data needs), and the amount of financial and time resources available (resource constraints) as guidance and derive corresponding design configurations for combinations of criteria, for 3VIS studies of both virtuality and of physicality (alias the "real world"). Moreover, in Web Appendix G, we exemplify these guidelines through two hypothetical 3VIS studies.

Figure 4. General Guidelines for 3VIS Configuration



DISCUSSION

This paper introduces spatial marketing research as a comprehensive approach that studies marketing phenomena within 3VIS, responding to the growing availability of new spatial technologies that enable the creation of 3VIS and the far-ranging opportunities that these technologies unleash. We integrate extant literature and identify 3VIS value streams for marketing scholars (RQ1), draw on activity theory to extract three 3VIS core elements and discuss their respective gestalt options (RQ2a), and develop a step-by-step process model of spatial marketing research that guides marketing scholars in adequately designing their 3VIS studies (RQ2b).

Academic Contributions and Future Research

First, we introduce spatial marketing research as a comprehensive approach to conducting marketing studies in 3VIS. This integrated perspective addresses the fragmentation that currently characterizes the 3VIS literature both in marketing and beyond it, as revealed in our quantitative literature analysis. Spatial marketing research provides a path forward for scholars to move beyond siloed approaches when employing 3VIS, fostering cross-learning and cumulative progress.

It also opens a wide range of opportunities for novel research across behavioral, strategic, and quantitative domains in marketing. From a consumer behavior perspective, scholars could explore how engaging in 3VIS reshapes consumers' self-concept, clarifying when and how the physical, extended, and virtual selves converge or diverge. Strategy research could examine the role of space in marketing mix decisions, for instance, how product and advertisement placements within virtual worlds, avatar-mediated endorsements, or spatial configurations (e.g., openness, crowding, social presence) influence customer journeys, brand experiences, and competitive differentiation. Quantitative research can leverage spatial data's unique granularity—such as gaze paths, motion trajectories, and interaction timing—to design stronger causal identification strategies, model fine-grained consumer journeys, and establish new validity benchmarks for 3VIS studies.

Second, we develop a research typology that delineates four pathways through which marketing scholars can derive value from 3VIS studies. The first stream positions 3VIS as a research object, focusing on phenomena unique to virtual environments. While this stream has been the most popular among marketing scholars, many research opportunities remain. Future work could further examine fresh digital phenomena such as avatars and metaverse in more detail. While consumer metaverse growth has not matched initial predictions, such environments remain novel and dynamic arenas that marketers and scholars should understand. Beyond consumer contexts, opportunities exist to explore industrial applications—such as the "industrial metaverse" or "omniverse"—where recent conceptual work highlights their growing relevance (Bamberger, Reinartz, and Ulaga 2025), but empirical evidence remains scarce.

The second stream uses 3VIS as an application to enhance decisions that affect the ‘real-world’. Here, 3VIS enables investigations that would be impossible in physical settings, such as market testing hypothetical objects or yet-to-be-developed solutions. The third and fourth streams leverage 3VIS as a method that can provide superior validity or as an economical means, respectively. Scholars can employ 3VIS to improve their research’s validity by combining realism with control, or to lower resource requirements compared with field or lab studies. In this way, 3VIS studies can complement existing empirical packages, ultimately producing more robust and cost-efficient research designs, as evidenced in an organizational context by van Zelderen et al. (2024) for 3VIS vignettes. It is our vision that 3VIS studies will become part of the ‘empirical package puzzle,’ just like field, lab, and online studies.

Third, we introduce a methodological framework which includes a design model as well as a process model. This framework guides marketing scholars to design rigorous spatial marketing research. The design model draws on activity theory to decompose 3VIS into their core elements, thereby structuring and simplifying the design decisions for researchers. The process model guides marketing researchers’ path through the design process, so that they can systematically address the complex trade-offs among 3VIS elements in their configurations. Future marketing research could build on these insights and explore the 3VIS design options and the interplay between the 3VIS elements in more depth. For example, while this investigation offers detailed guidance on the necessary process steps and elements requiring configuration in 3VIS studies, future research could focus on developing specific metrics to evaluate the 3VIS quality (e.g., equivalence, sharpness, and fluency scores) and the data derived from these studies (e.g., 3VIS validity and reliability scores, analogous to psychometric properties in survey research).

Implications for Academics as Editors and Reviewers

Beyond facilitating research studies, our investigation carries implications for other roles of marketing scholars, namely as editors and reviewers. We argue that for 3VIS research's quality and contributions to be adequately assessed by peers, some considerations should be implemented to counter potential biases. This is because reviewing a manuscript that includes—or even features—3VIS studies is often inherently challenging. Academic articles have been, and still are, limited to a 2D format of scholarly journals, which hampers the description (on behalf of the authors) and comprehension (on behalf of the review team) of a 3VIS empirical study. While researchers have developed transformational routines for such dimensional downscaling for phenomena in the 'real-world' (e.g., field or laboratory experiments), this is usually not (yet) the case for 3VIS studies, because of the lacking or limited experiences most marketing scholars have had with 3VIS and the widespread lack of access to state-of-the-art 3D hardware.

These disconnects can present substantive obstacles in the peer review process. A potential remedy could be that reviewers and editors immerse themselves more deeply in the 3VIS study. That is possible, as 3VIS offers several advantages over traditional research designs regarding transparency (see this paper's section on data demands for details). Instead of relying on descriptions or visuals, authors could provide anonymized links with access to the 3VIS study's design, allowing reviewers to directly relive – and thus better evaluate – the subjects' study experience. Similarly, from captured spatial data researchers can replay subjects' sessions, allowing reviewers to get a good sense of participants' experiences and challenges within the empirical 3VIS study (see Web Appendix F for examples).

To facilitate such experiences, marketing journals and their publishers could provide reviewers for such manuscripts with access to state-of-the-art 3VIS hardware, if requested by a reviewer. Journals and publishers could also assign administrative personnel the role of 3VIS contact person, who is responsible for handling 3VIS-related issues such as shipments and user support. Implementing such initiatives seems feasible, as hardware prices drop, companies around the world specialize in hardware rental and consulting models, and many business schools establish their own extended reality laboratories and staff.

Looking Beyond Research: Implications for Marketing Managers

Although this work primarily targets scholarly research and those who conduct it, it also offers some practical value for managers. Many decision makers have remained skeptical about the usefulness of spatial technologies, often based on limited knowledge of and experience with 3VIS. Our methodological framework addresses this concern and highlights an additional pathway to create value for marketing management, namely establishing in-house 'XR labs' as controlled environments for A/B testing and other forms of systematic knowledge generation. Such labs could be used to test shelf and point-of-sale arrangements, alter packaging colors and sizes, or evaluate new product concepts. Beyond product and placement decisions, XR labs can support innovation, user experience design, and event planning (e.g., comparing potential venues for an annual summit). In our experience, spatial technologies are particularly effective for exploring new objects (e.g., novel solutions, packaging, promotional materials), object positioning (e.g., retail layouts, shelf optimization), and spatial context (e.g., store design, event settings, virtual twin office).

Managers in other functions than marketing can also make use of such an XR lab, for example to apply spatial technologies to operational challenges related to objects and space, such as assessing execution failures in supply chains (DeHoratius et al. 2025). For all such applications, our methodological framework provides actionable guidance, extending beyond academic research to help firms design, implement, and evaluate high-quality spatial studies.

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WEB APPENDIX

SPATIAL MARKETING RESEARCH: LEVERAGING 3D VIRTUAL AND INTERACTIVE SPACES TO STUDY MARKETING PHENOMENA

Content

These materials have been supplied by the authors to aid in the understanding of their paper.

The AMA is sharing these materials at the request of the authors.

Web Appendix A – Journals Included in Literature Analysis

In our literature review, included a total of 289 scholarly journals in marketing as well as other business disciplines, information systems, economics, and some in general science, based on the 70th edition of Harzing's (2023) 'Journal Quality List', a collation of 11 different journal rankings. We included the following journals:

Economics, Finance & Accounting:

Accounting and Finance
Accounting Education: An International Journal
Accounting, Auditing & Accountability Journal
American Economic Review
Economics Letters
Energy Economics
European Journal of Law and Economics
Experimental Economics
Geneva Papers on Risk and Insurance: Issues and Practice
Industrial and Corporate Change (ICC)
International Journal of Industrial Organization
Issues in Accounting Education
Journal of Cultural Economics
Journal of Economic Behavior and Organization
Journal of Economic Psychology
Journal of Empirical Finance
Journal of Environmental Economics and Management
Journal of Industrial Economics
Journal of Law & Economics
Journal of Law, Economics, & Organization
Journal of Neuroscience, Psychology, and Economics
Journal of Risk and Insurance
Journal of Taxation
Kyklos
Managerial and Decision Economics
Managerial Auditing Journal
Qualitative Research in Accounting & Management
The Journal of Portfolio Management
The Quarterly Review of Economics and Finance

General Science:

American Psychologist
Cognitive Psychology
Journal of Experimental Psychology: General

Journal of Experimental Social Psychology
Journal of Personality and Social Psychology
Nature
Nature Human Behavior
Personality and Social Psychology Bulletin
Perspectives on Psych Science
Proceedings of the National Academy of Sciences (PNAS)
Psychological Science
Science
Scientific Advances

Information Systems & Computer Science:

ACM Computing Surveys
ACM Transactions on Computer-Human Interaction
ACM Transactions on Information Systems
Artificial Intelligence
Business Process Management Journal
Communications of the Association for Information Systems (CAIS)
Computer Supported Cooperative Work (CSCW)
Data & Knowledge Engineering
Decision Support Systems (DSS)
Electronic Commerce Research
Electronic Commerce Research and Applications (ECRA)
Electronic Markets (em)
European Journal of Information Systems (EJIS)
Human-Computer Interaction
IBM Journal of Research and Development
IEEE Computer
IEEE Software
IEEE Transactions on Pattern Analysis and Machine Intelligence
IEEE Transactions on Software Engineering
IEEE Transactions on Systems, Man, and Cybernetics: Systems
Information & Management
Information and Organization
Information Systems (IS)
Information Systems and e-Business Management
Information Systems Frontiers
Information Systems Journal (ISJ)
Information Systems Management
Information Systems Research (ISR)
Information Technology and Management
International Journal of Accounting Information Systems
International Journal of Electronic Business
International Journal of Electronic Commerce (IJEC)
International Journal of Information Management
International Journal of Information Technology & Decision Making

International Journal of Knowledge Management (IJKM)
International Journal of Mobile Communications
Journal of Decision Systems
Journal of Electronic Commerce in Organizations
Journal of Electronic Commerce Research
Journal of Enterprise Information Management
Journal of Information Systems
Journal of Information Technology
Journal of Knowledge Management
Journal of Management Information Systems
Journal of Organizational Computing and Electronic Commerce
Journal of the Association for Information Systems (JAIS)
Management Information Systems Quarterly (MISQ)
MIS Quarterly Executive
The Journal of Strategic Information Systems

Innovation & Entrepreneurship:

Creativity and Innovation Management
Entrepreneurship & Regional Development
Entrepreneurship: Theory and Practice (ET&P)
Industry & Innovation
International Entrepreneurship and Management Journal
International Journal of Entrepreneurship and Innovation Management
International Journal of Innovation and Technology Management
International Journal of Innovation Management
International Journal of Product Development
International Journal of Technology Management
Journal of Business Venturing (JBV)
Journal of Engineering and Technology Management
Journal of International Entrepreneurship
Journal of Product Innovation Management (JPIM)
Journal of Small Business and Entrepreneurship
Journal of Small Business Management (JSBM)
R&D Management
Research Policy (RP)
Research-Technology Management (RTM)
Small Business Economics
Technological Forecasting and Social Change
Technology Analysis & Strategic Management
Technovation

Management & Organization:

Academy of Management Journal (AMJ)
Academy of Management Learning & Education

Academy of Management Review (AMR)
Administrative Science Quarterly (ASQ)
Applied Psychology
Australian Journal of Management
British Journal of Management (BJM)
Business Horizons
Business Research (früher: BuR - Business Research)
Business Strategy Review
California Management Review
Cross Cultural Management: An International Journal
Employee Relations
European Journal of Work & Organizational Psychology
European Management Journal
Gender, Work & Organization
Group & Organization Management
Human Relations
Human Resource Management
Human Resource Management Review
Industrial and Labor Relations Review (ILR Review)
International Business Review
International Journal of Human Resource Management
International Journal of Management Reviews IJMR
Journal of Applied Behavioral Science
Journal of Applied Psychology
Journal of Business and Psychology
Journal of Business Economics (JBE)
Journal of Business Strategy
Journal of Change Management
Journal of International Business Studies (JIBS)
Journal of Management (JOM)
Journal of Management and Governance
Journal of Management Education
Journal of Management Studies (JMS)
Journal of Managerial Psychology
Journal of Organizational Behavior
Journal of Vocational Behavior
Journal of World Business
Leadership Quarterly
Long Range Planning
Management Decision
Management International Review
Management Learning
Management Revue Socio-Economic Studies
MIT Sloan Management Review
Negotiation Journal
Nonprofit and Voluntary Sector Quarterly
Nonprofit Management & Leadership

Organization
Organization Science
Organization Studies
Organizational Behavior and Human Decision Processes
Organizational Dynamics
Organizational Research Methods
Personnel Psychology
Scandinavian Journal of Management
Strategic Management Journal (SMJ)
Strategy & Leadership
Thunderbird International Business Review
Work, Employment and Society
Zeitschrift für Arbeits und Organisationspsychologie A&O
Zeitschrift für Personalforschung: German Journal of Research in Human Resource Management

Marketing & Communication:

Advances in Consumer Research
European Journal of Marketing
Industrial Marketing Management
International Journal of Advertising
International Journal of Nonprofit and Voluntary Sector Marketing
International Journal of Research in Marketing
International Journal of Retail & Distribution Management
International Journal on Media Management
International Marketing Review
International Review of Retail, Distribution and Consumer Research
Journal of Advertising
Journal of Advertising Research JAR
Journal of Brand Management
Journal of Business & Industrial Marketing
Journal of Business Research
Journal of Business-to-Business Marketing
Journal of Communication
Journal of Computer-Mediated Communication (JCMC)
Journal of Consumer Affairs
Journal of Consumer Behaviour
Journal of Consumer Marketing
Journal of Consumer Psychology
Journal of Consumer Research
Journal of Customer Behaviour
Journal of Global Marketing
Journal of Interactive Marketing
Journal of Marketing
Journal of Marketing Management
Journal of Marketing Research
Journal of Marketing Theory and Practice

Journal of Media Economics
Journal of Product & Brand Management
Journal of Relationship Marketing
Journal of Retailing
Journal of Retailing and Consumer Services
Journal of Service Management
Journal of Service Research - JSR
Journal of Services Marketing
Journal of Strategic Marketing
Journal of the Academy of Marketing Science
JPP&M Journal of Public Policy & Marketing
JPSSM - Journal of Personal Selling & Sales Management
Managing Service Quality
Marketing Letters
Marketing Science
Marketing Theory
Psychology & Marketing
Quantitative Marketing and Economics (QME)
Service Industries Journal

Operations, Supply Chain & Decision Sciences:

Annals of Operations Research
Asia-Pacific Journal of Operational Research
Benchmarking: An International Journal
Central European Journal of Operations Research
Computers and Industrial Engineering
Computers and Operations Research
Computers in Industry
Decision Sciences
European Journal of Operational Research (EJOR)
Flexible Services and Manufacturing Journal (FSM)
Group Decision and Negotiation
IEEE Transactions on Engineering Management
IIE Transactions
Interfaces
International Journal of Forecasting
International Journal of Logistics Management
International Journal of Operations & Production Management
International Journal of Physical Distribution & Logistics Management
International Journal of Production Economics
International Journal of Production Research
International Journal of Productivity and Performance Management
International Journal of Project Management
JORS. Journal of the Operational Research Society
Journal of Behavioral Decision Making
Journal of Operations Management

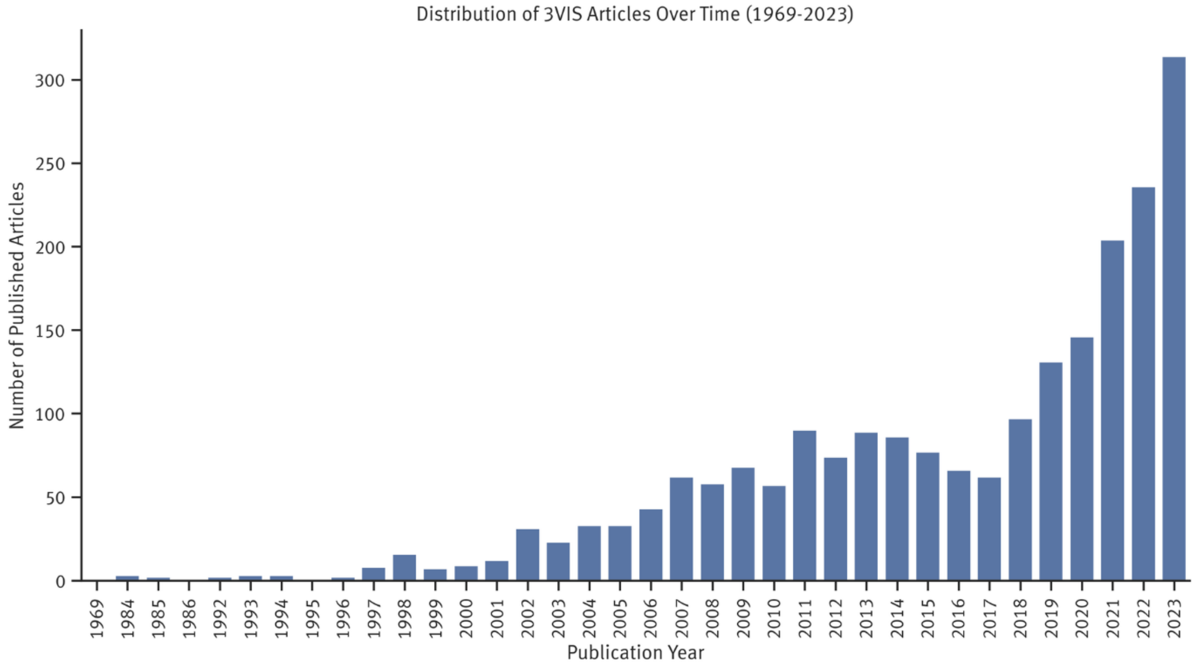
Journal of Revenue and Pricing Management
Management Science
Manufacturing & Service Operations Management (M&SOM)
Mathematical Methods of Operations Research
Mathematical Programming
Naval Research Logistics
Omega
Operations Research
Operations Research Letters
OR Spectrum
Production and Operations Management
Production Planning & Control
Project Management Journal
Supply Chain Management: An International Journal
System Dynamics Review
Transportation Research Part B: Methodological
Transportation Research Part E: Logistics and Transportation Review

Policy, Sustainability & Society:

American Journal of Sociology
BMC Health Services Research
British Journal of Healthcare Management
Business and Society Review
Business Strategy and the Environment
Energy Policy
International Journal of Technology Assessment in Health Care
Journal of Business Ethics
Journal of Cleaner Production
Journal of Environmental Management
Journal of Environmental Planning and Management
Journal of Healthcare Management
Organization & Environment
PharmacoEconomics
Public Administration Review
Public Management Review
Telecommunications Policy
Transportation Research Part A: Policy and Practice
Transportation Research Part D: Transport and Environment
Value in Health
Zeitschrift für Wirtschafts- und Unternehmensethik - Journal for Business, Economics & Ethics

Web Appendix B – Distribution of 3VIS Articles Over Time

The following figure shows the distribution of 3VIS articles (i.e., articles that appeared in one of the 289 scholarly journals listed in Web Appendix A) over time, from 1969 until 2023.



Web Appendix C – Technical Details for Literature Analysis

Details about NLP-based clustering

As a first step, we created embeddings, i.e., a high-dimensional numeric tensor representation that captures the meaning of text based on its context (not just the words used), for each paper's combined title and abstract. We use one of the best performing general text embedding models according to the MTEB leaderboard, gte-Qwen2-7B-instruct (Li et al. 2023;Hugging Face 2025; Muennighoff et al. 2023), the de-facto standard when it comes to ranking embedding performance on several key metrics. The resulting embeddings are highly dimensional (3,584 dimensions), posing challenges for traditional clustering approaches as the curse of dimensionality leads to almost equidistant points in complex spaces, rendering (dis-) similarity assessments fruitless (Assent 2012).

As a second step, we therefore reduced the dimensionality using UMAP (McInnes, Healy, and Melville 2020), projecting embeddings to nine dimensions (as with all hyperparameters, we extensively tested multiple configurations to ensure the robustness of our solution). UMAP draws on strong theoretical foundations in Riemannian geometry and algebraic topology to create a high-dimensional graph representation of data. Through this, it can preserve data structures well when projected to lower dimensions and offers comparatively better performance to approaches like t-SNE (see Coenen and Pearce 2019 for an illustration).

As a third step, to identify clusters from the reduced embeddings, we use HDBSCAN (Campello, Moulavi, and Sander 2013), a hierarchical variant of density-based clustering that overcomes limiting and unrealistic assumptions of traditional clustering methods, e.g., spherical and equally dense and sized clusters forming around a centroid as well as the absence of outliers and noise in the data in the case of k-means (see Berba 2020 for an illustration) and is generally considered to yield robust solutions. To select hyperparameters for cluster identification, we used the Density Based Cluster Validity score (Moulavi et al. 2014), which accounts for the density and connectedness of clusters. We then refined this selection through human expert judgments concerned with the stability and face validity of the solutions.

Value Stream Classifications of Articles

To classify articles into the four value streams of 3VIS, (1) as a research object, (2) as an application, (3) as a rigorous method, and (4) as an economical method, we adopted a few-shot learning strategy utilizing OpenAI's GPT-5 with the temperature parameter fixed at 1. This setting controls the stochasticity of token sampling, balancing diversity and determinism in the model's outputs. Few-shot learning relies on supplying detailed task and context descriptions to guide a large pretrained model in performing classification without traditional without gradient-based task training and without dev-set tuning, while still achieving performance comparable to supervised classifiers (Brown et al., 2020; Schick and Schütze 2022).

We engineered an effective task-specific prompt by providing precise category definitions aligned with the value stream descriptions in the main text. To enhance adherence, the model was instructed to articulate its reasoning and return structured JSON-formatted outputs. Each article could be assigned to none, one, or multiple categories.

Two domain experts (in 3VIS research and NLP methods) iteratively refined the prompt. In each iteration, the experts randomly selected 78 articles (plus one article with which they were intimately familiar) stratified across clusters and evaluated the model's output against established classification metrics (accuracy, precision, recall, and F1 score). The final prompt, reported below, achieved satisfactory performance even when being strict (i.e., treating edge cases as wrong classifications):

Table WA-C1: Classification Metrics

	Accuracy	Precision		Recall		F1-Score	
		0	1	0	1	0	1
3VIS as research object ($n_1 = 30$)	92%	100%	83%	100%	100%	93%	91%
3VIS as an application ($n_1 = 26$)	90%	96%	80%	89%	92%	92%	86%
3VIS as a rigorous method ($n_1 = 11$)	97%	99%	91%	99%	91%	99%	91%
3VIS as an economical method ($n_1 = 6$)	97%	99%	83%	99%	83%	99%	83%

Note: N = 79 articles stratified across 13 clusters (12 clusters + unassigned articles = noise). All articles coded by two domain experts and judged against predicted classes produced by few-shot prompt engineering using ChatGPT-5.

System prompt:

```
You are a diligent and detail-oriented research assistant, who underwent
rigorous academic training and is an expert in virtual technologies and
applications.
```

User prompt:

```
# Context
You are working on a research project that tries to understand the existent
interdisciplinary literature landscape involving three-dimensional,
virtual, and interactive spaces (3VIS).
In the course of this, your team has identified four distinct value
streams:

(1) First stream: 3VIS as a research object
This stream deals with the human experience of virtuality and thus focuses
on 3VIS as the research object.
The stream focuses on creating new knowledge about phenomena which are
essential and often unique in 3VIS, the relationships among those phenomena
and 3VIS users, as well as their economic impact.
Exemplary research topics focus on avatars, virtual consumption, revenue
models, specific applications (e.g., virtual retail), and facets of
consumer behavior (e.g., presence, flow, brand perceptions) among others.

(2) Second stream: 3VIS as an application
This stream leverages 3VIS to progress and understand physical world
applications (the real-world opposite to virtuality) and thus sees 3VIS as
an application.
The stream builds on the idea of using 3VIS as an application to (a)
understand or solve real-world challenges or (b) substitute/augment/extend
applications rooted in reality. Researchers use/study 3VIS as a tool to
improve existing approaches usually carried out in physical (or two-
dimensional digital) environments.
```

Exemplary research topics include virtual prototyping to predict sales, team meetings, and employee trainings among others.

(3) Third stream: 3VIS as a rigorous method
This stream is methodological in nature and uses 3VIS as a better replication of current methods used in real-world settings (e.g., physical methods like lab studies or 2D digital methods like digital vignettes). Scholars aim to leverage the unique properties of 3VIS to test theories in controlled yet ecologically valid settings, building on virtual replications of real-world settings.
Examples of research applications include the investigation of consumer behavior under controlled settings (e.g., the in-depth investigation of vicarious touch in immersive settings) or combine granular behavioral tracking with A/B testing capabilities that mirror real-world consumer decision-making (such as studies conducted in virtual worlds like World of Warcraft) among others.

(4) Fourth stream: 3VIS as an economical method
This stream is methodological in nature and considers 3VIS as methodological alternative to existent empirical research designs, which is more cost-effective. By reducing the need for resource-intensive field experiments, this pathway aims to enable scalable and cost-effective research while maintaining rigorous methodological standards.
Examples of research applications include the test of complex factory layouts or retail store configurations that are costly and resource intensive in the real world among others.
The streams are not mutually exclusive. One paper can belong to many streams.

Task
Your task is to (a) classify which of the value streams and (b) provide the reasoning behind your explanation to document our choices.

Input
Please classify the following paper based on its title (delimited by four plus signs ++++) and abstract (delimited by four minus signs ----)
Title: ++++{PLACEHOLDER FOR TITLE}++++
Abstract: ----{PLACEHOLDER FOR ABSTRACT}----

Desired Output
Please provide your output as JSON (do not include any text outside the JSON object), strictly following this format:

```
{{research_object: int [1 indicates that the paper belongs to the stream "3VIS as a research object", 0 otherwise],
  application: int [1 indicates that the paper belongs to the stream "3VIS as an application", 0 otherwise],
  method_rigorous: int [1 indicates that the paper belongs to the stream "3VIS as a rigorous method", 0 otherwise],
  method_economical: int [1 indicates that the paper belongs to the stream "3VIS as an economical method", 0 otherwise],
  reasoning: str [2–4 sentences explaining the classification, explicitly referencing phrases from the abstract/title that support the assignment]]
}}
```

Web Appendix D – Additional Information on Methodological Framework

Table WA-D1. 3D Environments and Central Tradeoff for Researchers

	Closed virtual worlds	**Open and semi-open virtual worlds**	**Custom-build virtual worlds**
Central tradeoff: customizability vs. resource investment	- No customization of objects and scenes possible - Minimal resources required (e.g., accepting the terms and conditions or a small usage fee)	- Customization of scenes and objects within boundaries of owner - Certain resources required (e.g., entering objects and scenes via the SDK)	- Full customization possibilities - High resource investment (e.g., complete software development, travel costs for participants)
Examples	Horizon Worlds, Horizon Workrooms, Bigscreen	Spatial, Remio, VRChat, Microsoft Mesh	A virtual model of a physical retail space
Prior research (selection)	Abramczuk et al (2023); Edelblum and Giesler (2025); Szita et al. (2024)	Saffo et al. (2020); Sykownik et al. (2021)	Luangrath et al. (2022); Bigne, Llinares, and Torrecilla Moreno (2016); Pfeiffer et al. (2020)

Table WA-D2. Overview of Interacting Entities and Central Tradeoff to Be Solved

	Generic Entity	Self-Avatar	Fully Customizable Entity
Central tradeoff: study control vs. subjects' identification with the interacting entity	- High control: all subjects are represented by the same entity (e.g., hands only or robotic avatar) - Limited identification: while subjects can become present in a virtual world, they may not easily identify with a generic entity	- Medium control: avatars differ across subjects, but in pre-defined constraints - Medium to high identification: subjects can achieve proximity to ideal or actual human self within given constraints	- Limited control: avatars can differ across subjects even more as in physical reality - High identification: representation through the actual or ideal self
Examples	Hands only in a single-player VR shopping simulation	*Ready Player Me* (based on photo upload)	Meta Avatars; *Baldur's Gate 3*
Prior research (selection)	Senyuz, Hasford, and Wang (2025); Skowronski, Busching and Krahé (2021)	Lin et al. (2021); Messinger et al. (2019); Yang et al. (2023)	Taylor et al. (2024); Seymour et al. (2021)

Table WA-D3. Overview of Access Devices and Central Tradeoffs to Be Solved

	3D Hardware	2D Hardware
Central tradeoff: immersion vs. scalability of the study and resources	- High immersion and tracking capabilities: subjects are transported to the 3VIS in 3D and all of their actions can be tracked - Limited scalability: for many studies, a central location lab will be required	- Limited immersion and tracking capabilities: subjects are transported to the 3VIS in 2D and some of their actions can be tracked (e.g., object tracking) - High scalability: studies can be run remotely on personal computers of subjects
Examples	Meta Quest 3, Apple Vision Pro	Tablets and smartphones (e.g., iPhone, iPad) 2D computers/laptops
Prior research (selection)	Luangrath et al. (2022); Meißner et al. (2020); Seymour et al. (2021)	Fritz, Hadi, and Stephen (2023); Hoffmann et al. (2022); Bhagwatwar, Massey, and Dennis (2018); Pizzi, Vannucci, and Aiello (2020)

Table WA-D4: Exemplary Marketing Studies That Use 3VIS for Research to Enhance Validity

3VIS Studies (selection)	**Research Aim**	**Role of 3VIS within Empirical Package**	**Type of 3VIS Study**	**Internal Validity Demands**	**External Validity Demands**
Branca, Resciniti, and Loureiro (2022)	Analyzing consumers' behavior toward packaged products	Part of a package	3VIS as economical means to reduce costs and effort and 3VIS as application	• Medium (perceptual data)	• Medium (proxy 3D environment)
DeHoratius et al. (2025)	Examining effects of execution failures in retail supply chains	Sole empirical basis	3VIS as economical means to reduce costs and effort	• High (usage of spatial data)	• High (real-effort task)
Harz, Hohenberg, and Homburg (2022)	Forecasting purchase behavior regarding new (hypothetical) products	Sole empirical basis	3VIS as application (as a prediction tool)	• High (usage of spatial data)	• High (photorealis-tic 3D environment)
Hennig-Thurau et al. (2023)	Examining social interaction in high-immersive settings	Sole empirical basis	3VIS as object (behavior in 3VIS) and 3VIS as application (3D meetings)	• Medium (perceptual data)	• High (leading metaverse platforms)
Sarantopoulos et al. (2019)	Studying the moderating role of shopping goal specificity in a retail context as part of a larger framework	Part of a package	3VIS as (superior) method to boost research validity	• Medium (passive observation)	• Medium (simulated 3D depiction)

Web Appendix E – Spatial Data Extraction Tutorial

Web Appendix E provides a practical tutorial for extracting spatial data from a 3VIS study. The goal is to help democratize 3VIS research, which often requires advanced technical expertise such as Unity programming. To lower these barriers, the tutorial offers detailed guidance along with curated resources, including links to platforms that support spatial data extraction, explanations of the underlying technical foundations, and Python code snippets. By doing so, it empowers non-technical scholars to leverage the opportunities of 3VIS more effectively and to rigorously collect the spatial data needed to test their hypotheses. The tutorial is structured as follows:

Table WA-E1: Spatial Data Extraction Tutorial Overview

#	Topic	Content
1	**Overview of Spatial Data**	A brief overview of spatial data, its characteristics as well as of applied and academic use cases.
2	**Resources**	A curated list of tools and learning materials required to begin 3VIS development that enables spatial data extraction.
3	**Extracting Spatial Data**	A detailed guide through a mockup experiment, covering: 1. *Scene setup*: Configuring a simple 3D environment in Unity for effective data capture. 2. *Sample experiment*: Hands-on demonstration of preparing an experimental application to extract spatial data.

Overview of Spatial Data

Spatial data must be accessed directly through the 3D environment, which is possible in open, semi-open, or custom-built virtual worlds (see manuscript section "3D Environments"). This tutorial focuses on custom-built virtual worlds, as they provide the broadest range of extractable spatial data (Cesanek et al. 2024; Hubbard and Aguinis 2023). Access is typically enabled through game engines such as Unity or Unreal Engine, yet these engines and their tools are designed for commercial software development (Wölfel et al. 2021) and mostly lack built-in tools for systematic academic data collection, posing significant challenges. To address this issue, we provide practical guidance on extracting, structuring, and analyzing spatial data from 3VIS environments. Our goal is to offer an accessible entry point for non-technical researchers. By outlining foundational steps for setting up a VR environment and extracting spatial data, this tutorial helps scholars focus on research objectives rather than technical hurdles.

Spatial data denotes the time-stamped, high-frequency recordings of participants' actions within a 3VIS study (see manuscript subsection "Data Needs"). Table WA-E2 provides a non-exhaustive overview of common spatial data categories, their definitions, and associated research opportunities and challenges. A defining characteristic of these data types is their intrinsic relationship to the virtual 3D environment. For instance, while audio can be recorded in the physical world (falling under "lassical Observational Methods"), it only becomes *spatial audio* within a 3D environment when its origin, direction, and attenuation are tracked relative to the interacting entities and the environment's geometry (Ruotolo et al. 2013). This relational context is fundamental to all forms of spatial data.

Table WA-E2: Spatial Data Categories

Type	Definition	Resources	Typical Challenges
Between Interacting Entities	Interaction between entities in 3VIS, such as gestures, body language and distance.	(McCall, 2016)	(1) Interpreting subtle social cues and non-verbal communication from avatar interactions. (2) Ensuring smooth and synchronized interactions between users across networks, especially with varying latency. (3) Transporting social signals and intentions through interacting entities.
Interacting Entities and Environment	Interaction of a single avatar with objects in the world, such as picking up objects or clicking buttons.	Harz, Hohenberg, and Homburg (2022)	(1) Ensuring the entity's interaction with the world feels realistic and engaging for the user. (2) Translating diverse real-world user actions into meaningful and

Type	Definition	Resources	Typical Challenges
			intuitive interactions in the 3D environment.
Spatial Audio	Audio can be created in 3D and originate from avatars or the virtual environment.	(Rutolo et al. 2013)	(1) Creating and capturing convincing 3D soundscapes that accurately reflect real-world acoustics. (2) Evaluating such data can be computationally intense.
Gaze	Where the user is looking within the 3D environment	(Kim 2024)	Understanding what gaze data shows is not trivial in terms of user attention, intention, or cognitive processes and subject to variables like the field of view.
Eye	In extension to gaze, pupils can be measured to get more precise information on what users are looking at.	(Bischof et al. 2024)	(1) Eye-tracking data can be noisy and affected by blinks, saccades, and technical limitations. (2) Linking eye metrics (pupil dilation, blink rate) reliably to specific cognitive or emotional states is complex.
Locomotion	Users move and navigate within 3D environment.	(Boletis und Cedergren 2019)	Room-scale 3D environment setups have physical boundaries, restricting natural walking locomotion.
Full Face and Body Capture	Comprehensive data captured about various body parts of users.	(Murray and Basu 1994; Rogers et al. 2022)	(1) Real-time processing of full face and body capture data can be computationally very intense. (2) Realistically animation and capturing are difficult.

Resources

While several game engines can be used to create 3D environments, this tutorial focuses on Unity. We chose Unity for its accessibility, market leadership, and the extensive library of community-developed tools that support research applications. That said, the principles outlined here are largely transferable to other platforms, such as Unreal Engine.

For researchers new to programming and 3D development, the learning curve can seem steep, but it becomes manageable when core skills are learned in a structured order. Beyond this tutorial, acquiring basic coding knowledge is essential, and we recommend beginning with the following fundamentals.

Core Programming Skills (C# Language)

At its core, interacting with Unity involves programming. Unity uses the C# programming language to define all custom logic, from how a participant moves, to how an object responds when touched, to the very scripts that will extract your spatial data. A basic understanding of programming concepts can be very helpful. For absolute beginners:

- Microsoft's official C# fundamentals: Start here to learn the absolute basics of the language, independent of Unity. Understanding variables, functions, and conditional logic is essential. Microsoft C# 101 Video Series.
- "Introduction to scripting" by Unity: Once you understand basic C# concepts, this official Unity tutorial will teach you how to apply them within the Unity environment. Unity Learn: Introduction to Scripting.

Understanding the Unity Editor

The Unity editor is your virtual laboratory, the software where you will build your 3D environment, place objects, and run your experiments. Before you can program within it, you must be comfortable navigating its interface. Key concepts to master:

- The editor interface: Learn what the scene view, game view, hierarchy, project window, and inspector are.
- Game objects and components: Understand that everything in your scene is a Game object (an avatar, a product, a light source) and its properties and behaviors are defined by components (e.g., a "rigid body" component makes an object obey physics). This is the foundational logic of all Unity development.
- "Getting Started" pathway by Unity: This official tutorial series is the best place to begin. It will guide you through the interface and core concepts in a structured way. Unity Learn: Get Started with Unity.

VR-Specific Development in Unity

Once you are comfortable with basic C# and the Unity editor, you can begin focusing on VR-specific functionality. This involves integrating your headset and controllers with the Unity engine so a user can see and interact with your virtual world.

- Core VR setup: Unity provides a toolkit to simplify this process, which handles tasks like tracking the headset's position, reading controller inputs, and enabling interactions like pointing and grabbing.
- Unity's XR Interaction Toolkit (XRI): This is the modern, official package for VR development in Unity. Learning how to set it up is a critical step. Official learning pathway.

Essential Development Practices

To ensure your research project is manageable and your data is secure, adopting professional development practices from the start is vital:

- Version control (Git): This is a system for tracking changes in your project files. It is essential for collaborative work, for backing up your project, and for reverting to a previous version if an error is introduced. All serious development work, academic or otherwise, relies on version control. Set up version control.

Hardware and Setup

Finally, ensure your physical hardware is correctly configured for development:

- System requirements: You will need a VR-ready computer and a supported VR headset (e.g., Meta Quest).
- Connecting your headset: For development, you will need to connect your headset to your computer. For standalone headsets like the Meta Quest, this is typically done via a USB-C cable or a dedicated wireless connection (Air Link). You will also need the relevant PC software (e.g., the Meta Quest Link App).

Extracting Spatial Data

Before starting, please make sure that you have installed Unity and connected a VR headset to your computer. The VR headset should be ready and tested for development purposes. Be sure to have the device in developer mode and full admin rights to debug and install custom apps. For this tutorial we are using editor version 2022.3.15, you should use the latest version available. If you have not done this, the following links should get you started:

- Meta Quest
- HTC Vive
- Pico

Further, if you have some experience with Unity and want to see the results of this tutorial, you can download the finished project and test it yourself:

https://github.com/AnonymousUserAc/SpatialDataExtractionTutorial

Setting Up Your Unity Scene

First, we need to create a new project. Choose to create a new Unity project using the **3D URP/3D (Built-In Render Pipeline)** template. You may need to download the template before using it.

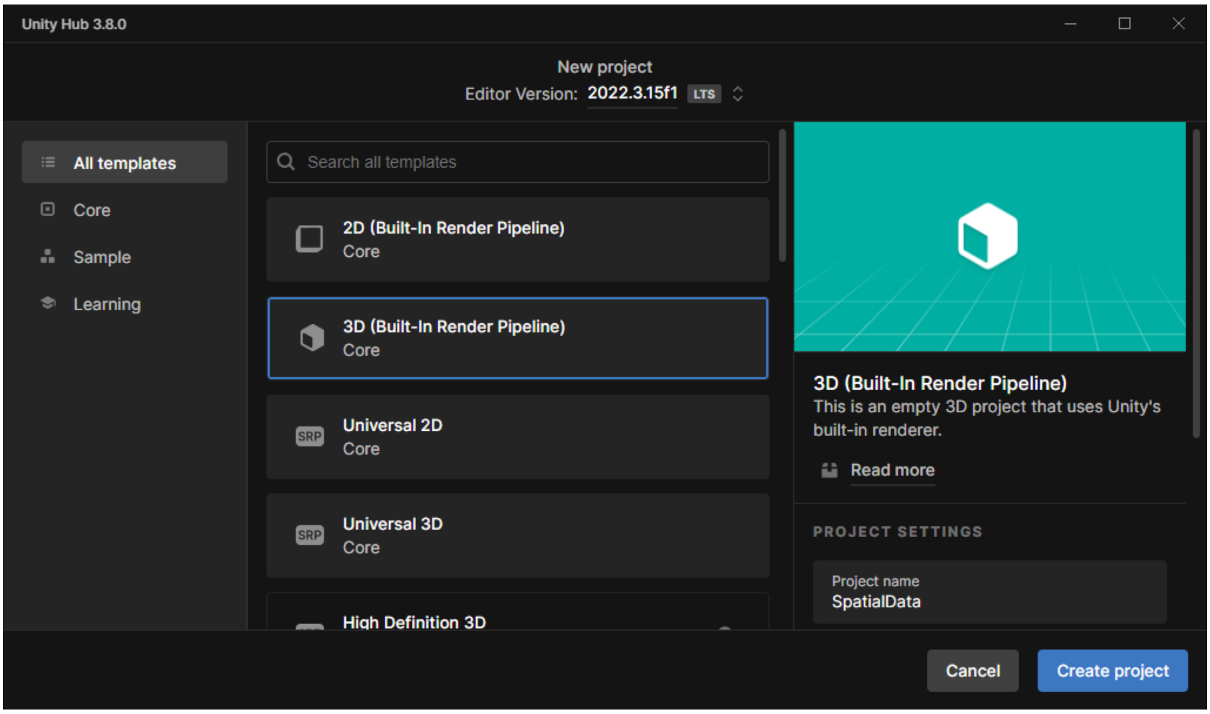


Figure WA-E1: New 3D URP Project

Next, install **XR Plugin Management**, once the installation is complete, select **OpenXR** as the plug-in provider for both PC and Android platforms. Add the interaction profile that corresponds to the device you are using. Then install the **XR Interaction Toolkit** from the package manager, you can find this in the Unity editor under **Window** > **Package Management** and proceed as seen in Figure WA-E2. After the installation is complete, find the samples section within the same window and import the **Starter Assets**.

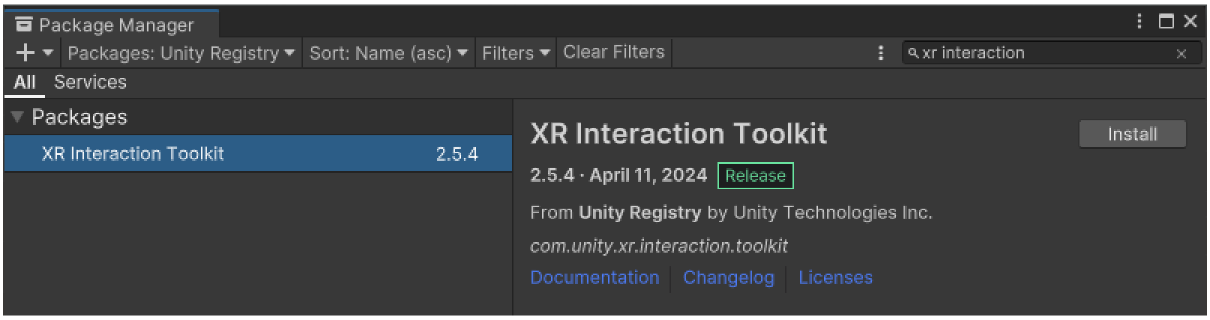


Figure WA-E2: Import XR Interaction Toolkit

For the first spatial data extraction project, add a plane to your scene and give it a material with the color black. Now, we need to set up the XR system. Right-click in the scene hierarchy again and go to XR > **XR Origin (VR)**. This action will create a new main camera along with left- and right-hand controllers. XR Origin (VR) is available after you have installed the **XR Interaction Toolkit** and importing the Starter Assets**.** You can now delete the existing **Main Camera** that was initially created in your scene. Select the **XR Origin** and change the tracking origin mode in the inspector to **Floor**. This adjustment ensures that the player's height is accurately considered when they wear the VR headset.

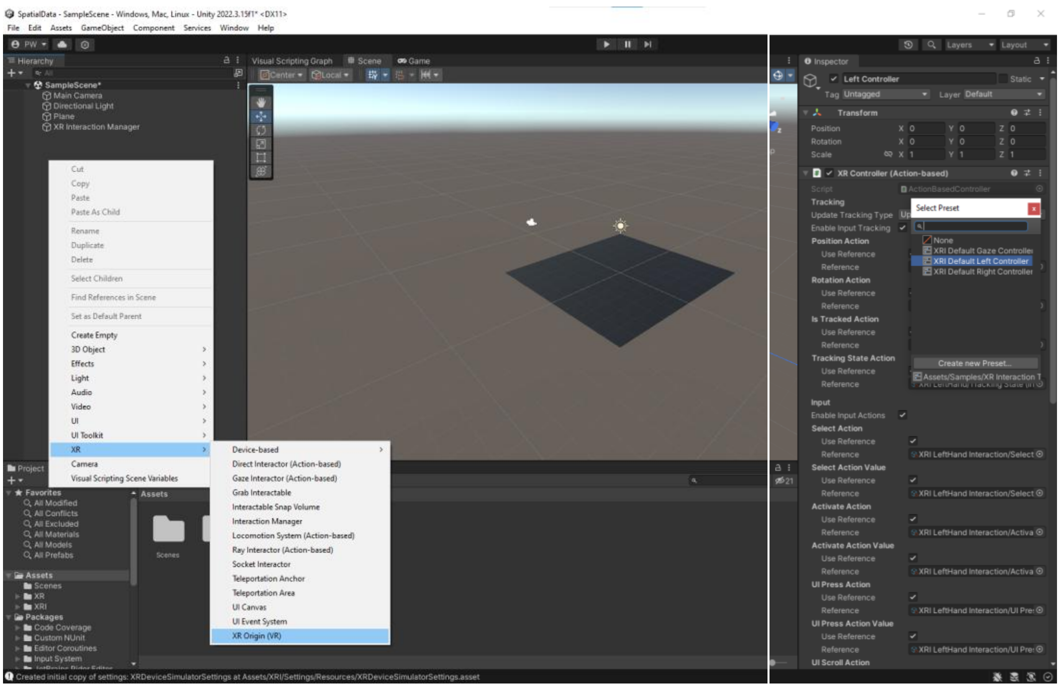


Figure WA-E3: Create XR Origin

Next, we need to set a preset for both the left- and right-hand controllers so that you do not have to configure the **XR Controllers** manually. In the scene hierarchy, select the **LeftHand Controller** and in the inspector, klick the slider (middle) button of the **XR Controller (Action-Based)** component, where you can then see the **Controller Input Preset Manager**. From the list of available presets, choose a suitable preset that matches your controller. Repeat the same process for the **RightHand Controller**.

Sample Experiment

To get your first experiment started you should follow at least these steps before running any experiments using spatial data:

1. Designing your research

Start with a clear definition of your research objectives. What questions are you trying to answer with this study? How will spatial data help you achieve these goals? Determine the variables you need to capture. These could include the position and orientation of the VR headset, the movement of hand controllers, movement of avatars, user interactions with the virtual environment, interactions between avatars, and physiological data like heart rate or eye-tracking metrics.

2. Preparing the scene

Ensure your scene is optimized and that you capture all the data needed to answer your research questions. Design your scene and add interactive elements or assets which are needed for your study and that will help you gather relevant data. For example, objects that users can pick up, buttons they can press, or areas they can explore. Make sure your data logging is robust and captures all necessary variables.

3. Running the experiment

Before running the actual experiment, conduct several tests and test studies. We suggest that you test early and often. It is often hard to fix problems which have been made early, later on as more and more complicated code and assets are added to your project. These smaller tests will help you identify any issues in your setup, ensure your data logging is accurate, and make necessary adjustments to your VR environment. Also, collect feedback from participants to understand any usability issues or confusing aspects of your 3D environment. Make sure the experiment runs smoothly to minimize external factors affecting your data. It is important to test your study with different people as people experience effects like motions sickness differently.

In the following sections, this tutorial will walk you through a sample experiment that demonstrates how to implement the three key steps. For this demonstration, we will use a virtual store shelf as the focal point of our study. The objective is to observe and analyze participants' behavior as they interact with this store shelf in a simulated environment. Specifically, this guide will illustrate how to determine whether participants are visually focusing on the shelf and whether they engage with it through interactions, such as grabbing or pointing. By following this example, you should gain a better understanding of how to set up and execute similar experiments using spatial data in your own research projects. We will start by defining the research objectives, identifying the variables that need to be tracked, and then proceed to prepare the VR environment by integrating the necessary 3D assets and scripting the interactions. This practical example will serve as a comprehensive guide, enabling you to replicate and adapt these steps for your own experimental needs.

Designing Your Experiment

To begin, the objective of this experiment is to understand how people visually explore and interact with a store shelf in a 3D environment. Variables are the position and orientation of the VR headset and interactions with the shelf. Hereby we can understand what and from where participants are looking at the shelf and if they are pointing with their hands at the shelf. We will start by learning how to collect positional and rotational data from the VR headset. We start by capturing data from the main camera, which represents the VR headset in Unity. This will allow us to record the position and rotation of the headset in the 3D environments. In the Unity editor, navigate in the scene hierarchy to the **Main Camera** of the **XR Origin (XR Rig)**. Click on **AddCompontent** and type in the name of the script **SpatialDataExtractor**. Then klick on **New script** as seen in Figure WA-E4.

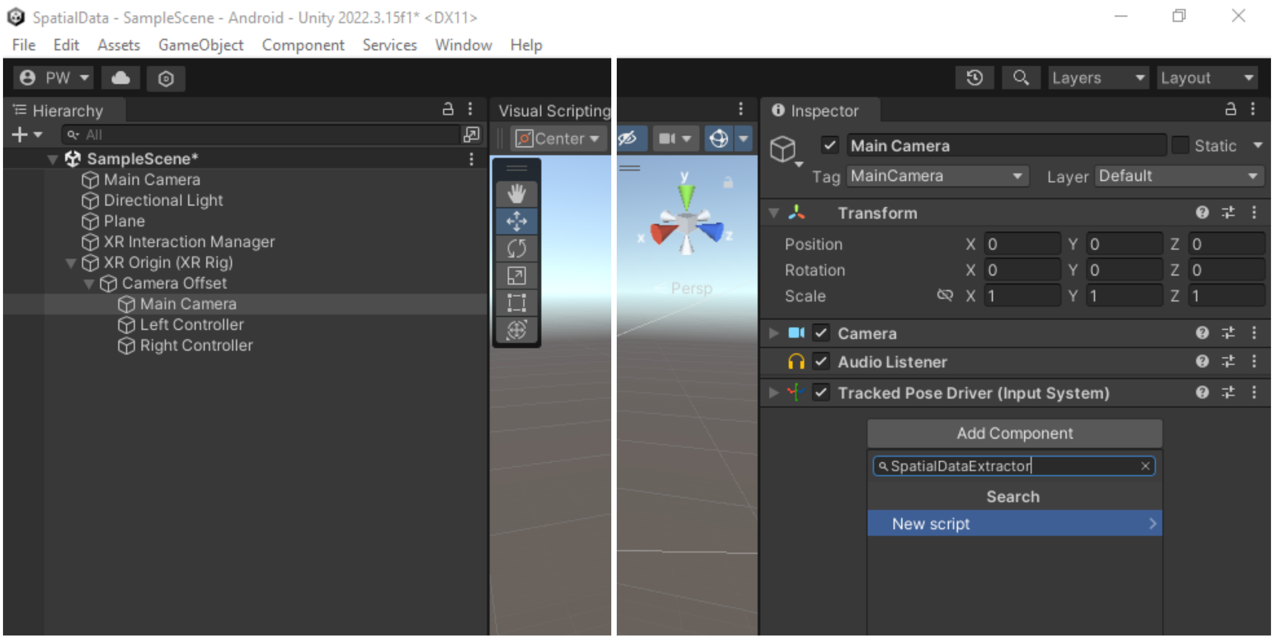


Figure WA-E4: Create Spatial Data Extraction Script

Now, open the **SpatialDataExtractor** script by double clicking and add the basic code from below to start capturing spatial data. For now, you can use a simple text editor to insert the code. Advanced users should switch to an integrated development environment for better syntax highlighting and additional features. You can set the logFilePath variable to a local file path of your choice, to save the spatial data at a designated location.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using System.IO;

public class SpatialDataExtractor : MonoBehaviour
{
    private string logFilePath; // Path to the log file
    private Camera mainCamera; // Reference to the MainCamera

    void Start()
    {
        // Set the path for the log file (e.g., in the Persistent Data Path
for cross-platform compatibility) The path can also be set to a fixed local
path "C:\\Users\\<<YourUser>>\\Desktop\\"
        logFilePath = Path.Combine(Application.persistentDataPath,
                      "CameraLog.txt");

        // Initialize the reference to the MainCamera
        mainCamera = Camera.main;

        // Check if the file exists, and create it if not
        if (!File.Exists(logFilePath))
        {
            File.WriteAllText(logFilePath, "Time, Position, Rotation,
            Direction\n");
        }
    }

    void Update()
    {
        // Get the current time
        string time = System.DateTime.Now.ToString("HH:mm:ss.fff");
        // Get the position and rotation of the MainCamera
        string position = mainCamera.transform.position.ToString("F3");
        string rotation = mainCamera.transform.
                          rotation.eulerAngles.ToString("F3");

        // Get the direction the MainCamera is looking at
        string direction = mainCamera.transform.forward.ToString("F3");

        // Create the log line
        string logLine = $"{time}, {position}, {rotation}, {direction}\n";

        // Write the log line to the file
        File.AppendAllText(logFilePath, logLine);
    }
}
```

This code snippet will track in each frame, where the VR headset is and which way it is facing. Then the script saves this information in the log file. To test the script, press the play button to start your Unity scene, while wearing your VR headset. You should see the black plane at the bottom and be able to move your head. This should result in tracking the movement and being saved to your selected path. The data captured now looks as follows:

```
Time,         Head-Position,            Head-Rotation,          Gaze direction
18:59:57.563, (-0.132, 1.020, -0.037), (6.107, 10.587, 0.190), (0.183, -0.106, 0.977)
18:59:57.574, (-0.133, 1.021, -0.038), (6.026, 10.481, 0.411), (0.181, -0.105, 0.978)
18:59:57.588, (-0.137, 1.024, -0.041), (4.934, 10.081, 0.664), (0.174, -0.086, 0.981)
18:59:57.602, (-0.138, 1.025, -0.042), (4.745, 9.979, 0.696),  (0.173, -0.083, 0.981)
18:59:57.617, (-0.139, 1.026, -0.042), (4.413, 9.875, 0.884),  (0.171, -0.077, 0.982)
18:59:57.631, (-0.140, 1.027, -0.043), (4.088, 9.748, 1.202),  (0.169, -0.071, 0.983)
18:59:57.646, (-0.141, 1.027, -0.044), (3.633, 9.567, 1.505),  (0.166, -0.063, 0.984)
18:59:57.660, (-0.142, 1.028, -0.044), (3.153, 9.258, 1.615),  (0.161, -0.055, 0.985)
18:59:57.674, (-0.143, 1.028, -0.045), (2.791, 8.951, 1.620),  (0.155, -0.049, 0.987)
18:59:57.689, (-0.144, 1.029, -0.045), (2.556, 8.680, 1.555),  (0.151, -0.045, 0.988)
18:59:57.703, (-0.146, 1.029, -0.045), (2.418, 8.358, 1.510),  (0.145, -0.042, 0.988)
18:59:57.717, (-0.148, 1.029, -0.046), (2.273, 7.928, 1.480),  (0.138, -0.040, 0.990)
```

Congratulations, you have extracted your first spatial data! We will now continue with the rest of the experiment. Insert a cube object, which serves as a mock-up for our store shelf. Follow the same steps as before to insert the 3D object. Place the cube in the scene at an appropriate location. It is important that the cube contains a **Box Collider** component, add this component to the cube if it is missing. Your scene should now look as depicted in Figure WA-E5.

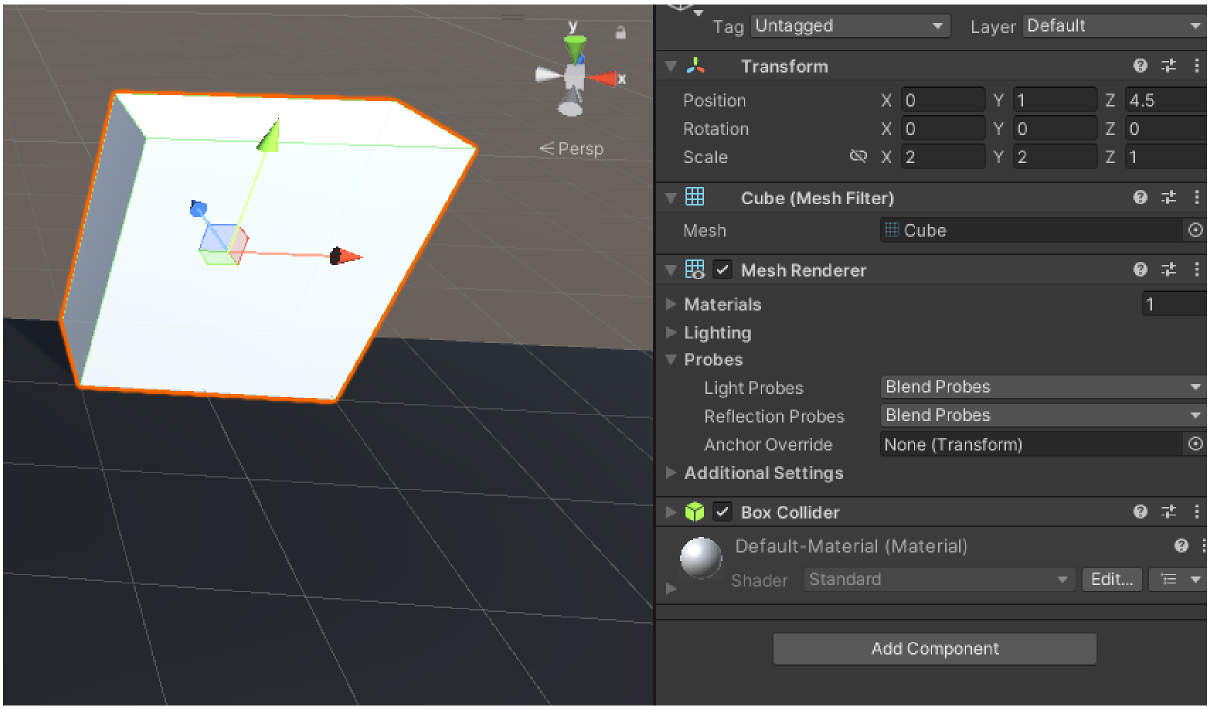


Figure WA-E5: Create Store Shelf Mock-Up

Preparing the Scene

Next, we need to set up our scene so that we can collect spatial data. For this we will use the same script we had earlier to track the **Main Camera** of the XR Rig. Then we want to capture whether the participant is looking at our shelf or not. For this we need to first configure the shelf and attach a collider to it. Select the shelf and go to **Add Component** and search for **Rigid Body**, add it to the store shelf.

Then we need to create a new script attached to the **Main Camera** which tracks if the gaze ray (the direction in which the main camera is facing) hits the shelf collider. We do this with the following code:

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using System.IO;

public class CameraRayColider : MonoBehaviour
{
    private string logFilePath; // Path to the log file
    private bool isLookingAtShelf = false; // To track if currently looking at
the shelf
    private Camera mainCamera;
    public Collider shelfCollider; // Reference to the shelf

    void Start()
    {
   // Set the path for the log file
   logFilePath = Path.Combine(Application.persistentDataPath, "ShelfLog.txt");
   // Initialize the reference to the MainCamera
   mainCamera = Camera.main;
    }

    void Update()
    {
   // Get the eye gaze direction from your eye-tracking solution
   Vector3 eyeGazeDirection = mainCamera.transform.forward;
   // Perform a Raycast to check if the gaze is hitting the shelf collider
   Ray gazeRay = new Ray(mainCamera.transform.position, eyeGazeDirection);
   RaycastHit hit;
   string time = System.DateTime.Now.ToString("HH:mm:ss.fff");

   if (Physics.Raycast(gazeRay, out hit) && hit.collider == shelfCollider)
        {
       if (!isLookingAtShelf)
            {
          isLookingAtShelf = true; // Update the state to looking at the shelf
          // Write the log line to the file
 File.AppendAllText(logFilePath, $"{time}, Started looking at the shelf \n");
            }
        }
        else
        {
         if (isLookingAtShelf){
           // Write the log line to the file
  File.AppendAllText(logFilePath, $"{time}, Stopped looking at the shelf \n");
            }
  isLookingAtShelf = false; // Update the state to not looking at the shelf
        }
    }
}
```

Figure WA-E6: Camera Ry Colider (Script) Configuration

After you have created the script go back to the **Main Camera** and configure the **Shelf Collider** variable as seen in Figure WA-E6. You can search for the cube by pressing the circle button on the right side of the variable.

The next script we need is to capture if one controller is touching or hovering the shelf. The hovering works in the same way with a controller ray and hit collider. If that is the case, we can also check if the controller is currently being clicked. Use the following script and add it to both controllers.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using System.IO;
using UnityEngine.XR.Interaction.Toolkit;
using UnityEngine.InputSystem;

public class ControllerShelfInteraction : MonoBehaviour
{
    private string logFilePath; // Path to the log file
    private bool isPointingAtShelf = false; //is currently looking at shelf
    public Collider shelfCollider; // Reference to the shelf
    // Reference to the controller input action (configured in Input System)
    public InputActionProperty selectAction;

    void Start()
    {
   // Set the path for the log file
   logFilePath = Path.Combine(Application.persistentDataPath, "ShelfLog.txt");

    void Update()
    {
     // Perform a Raycast to check if the gaze is hitting the shelf collider
     Ray ray = new Ray(transform.position, transform.forward);
     RaycastHit hit;
     string time = System.DateTime.Now.ToString("HH:mm:ss.fff");

        if (Physics.Raycast(ray, out hit) && hit.collider == shelfCollider)
        {
            if (selectAction.action.WasPressedThisFrame())
            {
 File.AppendAllText(logFilePath, $"{time}, Player interacts with shelf \n");
            }

            if (!isPointingAtShelf)
            {
isPointingAtShelf = true; // Update the state to looking at the shelf
// Write the log line to the file
File.AppendAllText(logFilePath, $"{time}, Started pointing at the shelf \n");
            }
        }
        else
        {
            if (isPointingAtShelf){
 File.AppendAllText(logFilePath, $"{time}, Stopped pointing at the shelf \n");
            }
 isPointingAtShelf = false; // Update the state to not looking at the shelf
        }
    }
}
```

Figure WA-E7: Controller Shelf Interaction (Script) Configuration

Lastly you need to configure both scripts for the controllers in the same way as before. In addition, you need to add an action which you want to track. For this select the **Use References** option, press the circle button, and search for **XRI LeftHand Interaction/Select** on the left-hand controller and **XRI RightHand Interaction/Select** for the right-hand controller.

Running the experiment

Start the application while wearing the VR headset. By moving your head and controllers you are generating spatial data in real time. You can complete our simple experiment with this set up and see if and for how long participants are looking at the shelf. The spatial data generated should look like this:

```
Time,         Action
12:48:39.332, Started pointing at the shelf
12:48:39.583, Started looking at the shelf
12:48:42.006, Player interacts with shelf
12:48:43.315, Stopped looking at the shelf
12:48:46.531, Stopped pointing at the shelf
```

```
Time,         Head-Position,           Head-Rotation,             Gaze direction
12:48:42.006, (-0.069, 1.003, -0.180), (12.064, 4.807, 358.614), (0.082, -0.209, 0.974)
12:48:42.019, (-0.069, 1.003, -0.180), (12.088, 4.829, 358.614), (0.082, -0.209, 0.974)
12:48:42.033, (-0.069, 1.003, -0.179), (12.087, 4.865, 358.608), (0.083, -0.209, 0.974)
12:48:42.048, (-0.069, 1.003, -0.179), (12.078, 4.880, 358.633), (0.083, -0.209, 0.974)
12:48:42.062, (-0.069, 1.003, -0.179), (12.067, 4.881, 358.665), (0.083, -0.209, 0.974)
12:48:42.075, (-0.069, 1.003, -0.179), (12.040, 4.884, 358.695), (0.083, -0.209, 0.974)
...
12:48:43.287, (-0.057, 1.003, -0.176), (12.021, 12.341, 0.185), (0.209, -0.208, 0.955)
12:48:43.301, (-0.055, 1.003, -0.176), (11.848, 13.703, 0.460), (0.232, -0.205, 0.951)
12:48:43.314, (-0.053, 1.003, -0.176), (11.669, 15.075, 0.733), (0.255, -0.202, 0.946)
```

Congratulations, you are now ready to conduct your first study with spatial data!

Web Appendix F – Spatial Data Showcase

This appendix demonstrates the visualization and analysis capabilities of spatial data. We use a brief sample 3VIS study to showcase how data can be replayed and analyzed. The methodology for collecting the underlying spatial and gaze data, which enables this, is detailed above in Web Appendix E.

The sample study required a participant to navigate a virtual environment and locate specific objects. The study was divided into two distinct phases:

- Phase 1: Familiarization. Participants first completed an onboarding task to acclimate to the virtual environment. This phase ensured they understood the movement and interaction mechanics within the VR space. A screen recording of this phase, captured from the perspective of the study supervisor, is available here: https://youtu.be/tEBCg5n2oBs.
- Phase 2: Object Search Task. Following the familiarization phase, participants performed a two-part search task. They were first instructed to locate a knight statue, approach it, and then proceed to find a basketball hoop located in another part of the room. A recording of the supervisor's perspective during this task is available here: https://youtu.be/kKe5xO6yLOc.

During the study, spatial data is continuously collected, including the participant's position, orientation, and gaze vectors. This rich dataset enables not only the analysis of behavioral patterns but also a complete, high-fidelity reconstruction of the experiment for post-study analysis. Figures WA-F1 and WA-F2 compare two visualization methods:

1. Screen Recording (Left Panels): A standard video capture of the session from a fixed perspective (in this case, the supervisor's view). This represents a traditional method of documenting an experiment.
2. Post-Study Gaze Simulation (Right Panels): A dynamic, 3D reconstruction generated from the collected spatial data. A key advantage of this method is the ability to change the viewpoint to any conceivable angle, providing a comprehensive overview of the participant's actions and attention within the 3D space. Gaze vectors can be rendered to visualize precisely what the participant was looking at over time.

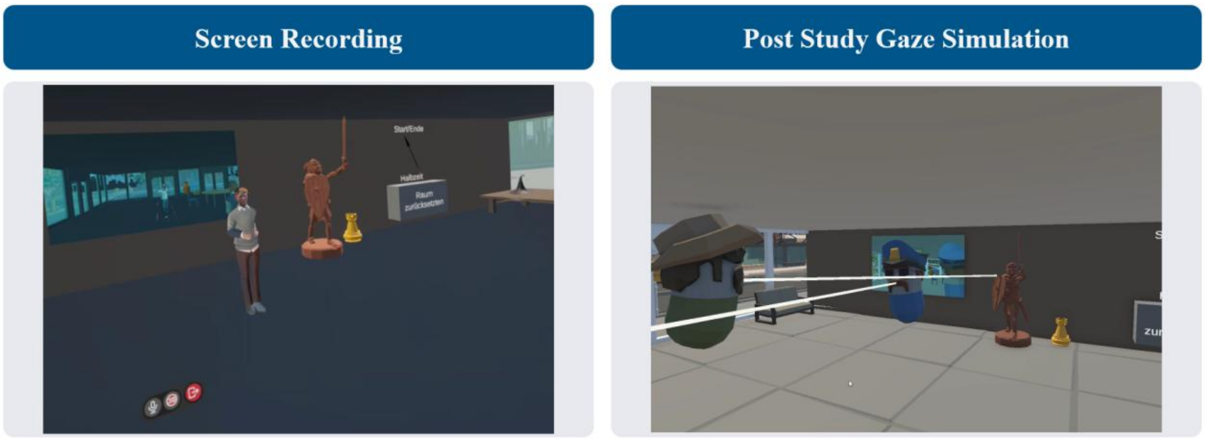


Figure WA-F1: Participant located next to the night statue

Comparison of a live screen recording and a post-study gaze simulation during the initial phase of the search task.

- **Left:** The screen recording from the third-person perspective of the experiment supervisor shows the participant (center-left) near the starting area.
- **Right:** The post-study simulation, reconstructed from spatial and gaze data. This alternative third-person view visualizes the participant's avatar (police officer) and their gaze vectors (white lines) directed towards the target knight statue, demonstrating the platform's ability to recreate and analyze visual attention from any perspective.

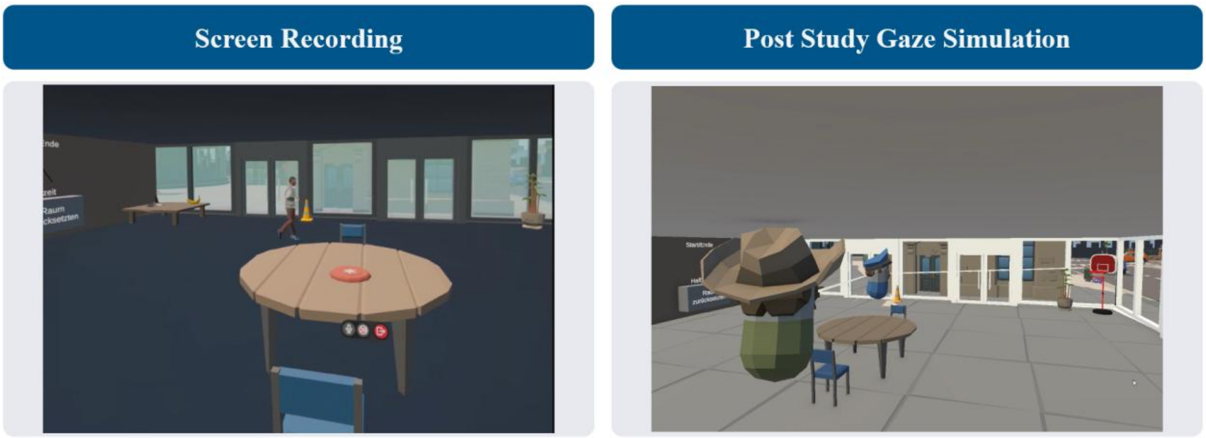


Figure WA-F2: Participant moving towards the basketball hoop

Following the first step, the participant further navigates through the environment.

- **Left:** The screen recording captures a moment of the participant's movement from the supervisor's fixed viewpoint.
- **Right:** The simulation provides a different overhead perspective, clearly showing the participant's position relative to the environment and the second target (the basketball hoop, far right). This dynamic viewpoint capability is a core feature of the analysis platform, enabling a more holistic understanding of user behavior in the virtual space.

Web Appendix G – Example Configurations of 3VIS Studies

Table WA-G1: Study Evaluation for Two Alternative Configurations of a 3VIS Study

	Key Consideration	Example: Metaverse Marketing	Example: VR Shopping Simulation
Research question		**Key RQ**: What is subjects' perceived value of social interactions in the metaverse?	**Key RQ**: What is the sales effect of repositioning product X from shelf position Y to position Z?
Validity demands			
Internal validity and external validity	What is the role of the 3VIS study within the overall empirical package?	Part of an empirical package	Sole empirical study
	What is the type of 3VIS study that we aim to conduct?	Virtuality 3VIS research	Physicality 3VIS research
Data needs			
Spatial data	How important is the access to time-stamped, high-frequency millisecond-level recordings of all participant actions for my research?	Not important	Very important
Data privacy	How important is it that all simulation data is collected and stored on local, private servers?	Not important	Moderately important
Resource constraints			
Budget	How many monetary resources do I have available for this study?	Low budget	Medium budget
Time	How long will I be able to wait for the results?	Fast execution	Have some time to set simulation up
Configuration of…			
3D environment		Closed virtual world	Semi-open virtual world
Interacting entity		Self-avatars	Generic entity
Access device		3D hardware	3D hardware

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