Technium Vol. 8, pp.72-83 (2023)
ISSN: 2668-778X
www.techniumscience.com

The strategies for innovating with virtual reality and artificial intelligence: a literature review.

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Abstract. Metaverse, virtual reality, data science, and artificial intelligence are buzzwords that attract the attention of tech enthusiasts and corporate managers. The following article is a literature review that integrates the emerging domains of virtual reality/metaverse and artificial intelligence/data science into good use cases from a commercial perspective. As the result of the analysis, we propose four strategies that commercial organizations can use to harness the synergy of these domains for successful and effective Value Innovation management.

Keywords: Metaverse, Virtual Reality, Data Science, Artificial Intelligence, Value Innovation, Innovation Management

1. Introduction

Data science (DS), artificial intelligence (AI), metaverse, and virtual reality (VR) are considered critical drivers of innovation. These areas are listed as leading trends in the development of digitisation for the coming years. The primary motivation for reviewing this subject matter is to produce a comprehensive high-level map to help any commercial organisation decide on a new virtual media space strategy. A decision to leverage novel technological solutions should not be accidental. Consciously exploring the intersection of VR/metaverse and DS/AI could open significant new business opportunities. This publication aims to identify opportunities for innovation rooted in these two novel domains. We limited the research to innovations that have the potential to be used as prototypes or products in a natural business environment.

The terms VR/metaverse and DS/AI have many definitions. Since the metaverse as a phenomenon is not mature, its purpose, scope, and characterisation continue to evolve. This subject has caught the attention of many young and seasoned scientists. The knowledge base in this area is still being created. Is it reasonable to try to define this phenomenon?

On the other hand, scientists worldwide are studying this promising space intensely. A recent systemic review of metaverse definitions was provided by Weinberger [1]. The author proposes a unified and comprehensive description for future research: “The Metaverse is an interconnected web of ubiquitous virtual worlds partly overlapping with and enhancing the physical world. These virtual worlds enable users who are represented by avatars to connect and interact with each other and to experience and consume user-generated content in an immersive, scalable, synchronous, and persistent environment” [1].

The definition proposed by Weinberger incorporates the key features and aspects of the digital phenomenon – the metaverse. The definition describes the immersiveness and interpenetration of experiences of the digital and real worlds. It emphasises the unique aspect of a new type of synchronisation of experiences for users who meet in real-time in the unreal world. Their avatars increasingly reflect their behaviour.

The areas of AI and Data Science are nothing new. Many businesses have implemented some aspects of these novel technologies over the last several years. Ransbotham et al. demonstrate that over 80% of participating organisations perceive AI as a strategic opportunity, whereas almost 85% see artificial intelligence as an essential element of competitive advantage [2]. However, the return on investment from implementing and using AI can be challenging, especially concerning the time and resources invested [3-4].

We posed the following research questions to achieve the defined research objective:

RQ1. What research is conducted to implement and assess solutions combining metaverse and AI areas for new business value creation?

RQ2. In what areas has the combination of VR/AI successfully solved technical problems and provided new market opportunities in commercial use cases?

RQ3. Are there any recommendations for implementing solutions that combine VR and AI domains for commercial organisations?

We divided the article into four sections: 1) Definitions and assumptions of the Value Innovation Paradigm, 2) The method used to carry out the literature review, 3) A discussion of the findings broken down by research areas, and 4) Conclusions and further research questions requiring extensions.

2. The Value Innovation Paradigm

The Value Innovation paradigm shift was initiated in 1997 by Kim and Mauborgne, two pioneers in the field. Initially, it was based on the observation that high-growth companies differed from less dynamic competitors in defining market conditions. Less successful competitors perceived other players as the benchmark. They tried to outperform them within known, established criteria. In contrast, high-growth companies focused on identifying what customers valued the most and tailoring their service to those values rather than the broad market offer [5].

After seven years of research with more than 150 companies, the paradigm was refined into the Blue Ocean Strategy that underlined the need to identify customers' unfulfilled and sometimes unrecognised needs. The strategy meant adjusting the service so the organisation could create a new, uncontested market space instead of struggling to strengthen its competitive advantages within the existing saturated market [6].

With time, the Blue Ocean paradigm evolved into the modern jobs-to-be-done paradigm [7-8], which assumes that historical data analysis or general brainstorming on what customers value has moderate accuracy. More empirical methods are necessary to identify customer behaviour's actual, functional and practical drivers.

Although Bouwer (2017) states that Blue Ocean (initially, the Value Innovation) and jobs-to-be-done theories differ in the area in which they identify an opportunity for a new market niche, they both prioritise finding a new market with some unmet demand and lowering production/operation costs [9]. In both approaches, organisation continuity is rooted not in strengthening its position in the existing market but in sparking investments that would ideally discover uncontested markets and improve the cost-effectiveness of the company's portfolio [10]. For this analysis, their shared focus serves as a potential value definition.

3. Methods

Due to the nature of the research question, the content must be retrieved from a broad publication base across various disciplines. According to the literature review guidelines [11], meta-analysis or systematic literature review may not be the most suitable approach for two reasons. First, although most source materials are based on mathematics, computer science, and statistics, the authors assume that business, sociology, philosophy, and economy journals should also be screened. Additionally, specific, narrow domain-restricted sources, where VR or metaverse can happen to be a source of disruptive innovation, will also be evaluated. The domain is in the early phase of being defined. No well-characterised phenomenon or effect could undergo a formal and structured analysis, making the boundaries mere estimates across various studies. Therefore, this review simultaneously explores and integrates these yet-to-be-framed subjects. Second, the article selection underwent a two-tier screening process that demanded some creative\arbitrary judgement: 1) can the subject of the publication be a source of value or cost-effectiveness for an enterprise, and 2) is the domain related to or enriched with DS/AI? The articles were processed based on a critical judgment of combining perspectives across these subject matters to create a synthetic but versatile model. We used the integrative literature review method [11-12].
The screening process started with the search for publications that used at least one keyword from each pair (virtual reality/metaverse) and (data
science/artificial intelligence). Since the Google search engine and other
engines use semantic similarity tools based on a neural network within the search engine [13]. Only some articles returned by the search would describe the perfect synthesis of these two domains. Critical human judgment is necessary to decide on the inclusion criteria. The following rules served as the inclusion guidelines: 1) The publication should be of these three types: use cases (e.g., case study, prototype design), research report (e.g., algorithm design and testing, literature review), or idea (e.g., theoretical paper, especially in the field of social sciences or philosophy), 2) The article's content should be related to, a) preferably, VR/metaverse *and* DS/AI or b) to VR/metaverse application in the domain in which there are known and documented applications for DS/AI. For the second case (2b), these methods can likely be transferred to VR/metaverse use case. However, due to the recency of the domain, it has yet to be done, which indicates a potential adaptation or research gap. 3) The discovery should have a potential value driver (e.g., a new investment) from the Value Innovation perspective, enabling one or both: a) blue ocean discovery or b) company cost cut.

4. Results

Our research found that although there are many examples of the simultaneous use of machine learning/AI and VR technology, it was not possible to find a synthetic article that would serve as a map for a company interested in investing in innovation, e.g., VR technology in the context of a potential return on investment. We found various meta-analyses; for example, Beng et al., 2022 [14] and Cai, 2022 [15] aggregated multiple VR/AI interaction studies. However, these authors structured them from a technical perspective and identified technical challenges to overcome. In another publication [16], the results were structured from the use case perspective, describing scenarios in which VR/AI was reportedly technically successful with limited focus on technical challenges or market adaptivity potential. More philosophical studies were identified, envisioning the digitalisation of entire cities or societies [17]. Eventually, 27 articles were included for detailed review and conclusions (Table 1).

Table 1. Selected article list.

References	Publication type	Commercial potential	AI maturity	VR role
Aylett, 2000	Theoretical	No	Potential	Transferred/applied to VR
Beng et al., 2022	Meta-analysis	Yes	Potential	VR native
Birbi et al., 2022	Theoretical	No	Potential	VR native

Bisonette, 2019	Research report	Yes	AI/ML models	VR native
Cai, 2022	Theoretical	No	AI/ML models	Transferred/applied to VR
Carter, 2022	Theoretical	Yes	Quantitative metrics	Transferred/applied to VR
Chen, 2020	Meta-analysis	No	Quantitative metrics	Transferred/applied to VR
Ershad, 2018	Research report	Yes	Quantitative metrics	Transferred/applied to VR
Hong, 2022	Research report	No	AI/ML models	Transferred/applied to VR
Jovanović,_2022	Theoretical	No	AI/ML models	Transferred/applied to VR
Lin., et al., 2022	Research report	No	AI/ML models	Transferred/applied to VR
Meili, Lili, 2022	Research report	No	AI/ML models	Transferred/applied to VR
Nakahira, 2010	Research report	Yes	Quantitative metrics	Transferred/applied to VR
Nica, 2022	Theoretical	Yes	Quantitative metrics	Transferred/applied to VR
Reiners, 2021	Meta-analysis	Yes	AI/ML models	VR native
Ryan, 2022	Meta-analysis	Yes	AI/ML models	Transferred/applied to VR
Sadeghi, 2021	Research report	Yes	AI/ML models	Transferred/applied to VR
Schwind, 2018	Research report	Yes	Potential	Transferred/applied to VR
Shah, 2021	Research report	No	AI/ML models	Transferred/applied to VR
Shen, 2020	Research report	Yes	AI/ML models	Transferred/applied to VR
Talbot, 2012	Theoretical	No	AI/ML models	Transferred/applied to VR
Touran, 2019	Research report	Yes	AI/ML models	Transferred/applied to VR
Upadhyay, 2022	Theoretical	No	Potential	Transferred/applied to VR
Updyke, 2021	Research report	No	AI/ML models	Transferred/applied to VR
Valaskova, 2022	Meta-analysis	Yes	Quantitative metrics	Transferred/applied to VR
Wachsmuth, 2005	Theoretical	No	AI/ML models	VR native
Wang, 2022	Theoretical	No	Potential	VR native

ML – machine learning

There were three types of publications: five meta-analyses, 12 experimental research papers, and ten theoretical papers. 13 out of 27 publications described innovative use cases with commercial applications. The remaining 14 were too general to be labelled as a use case, or, if it was a use case, the paper described research applied to some improvement for a well-defined product or service, but none were considered innovative. 21 out of 27 articles described a solution that had been known or applied before metaverse/VR technology became widespread (the ideas were transferred to metaverse/VR). Only six papers described use cases that can be considered metaverse/VR native; that is, the product or services that could not exist without a virtual environment or would lose their advantages. Regarding

AI maturity level in the selected publications, in 15 out of 27 publications, machine learning (ML) or AI models were applied. In six papers, simple quantitative metrics were discussed, with the potential to extend to more complex models when enough data becomes available. The remaining six papers did not consider any ML/AI or quantitative data processing implementation but described data-rich use cases that can be refined with DS tools.

After critical and integrative analysis of identified articles, we categorised the findings into four areas: 1) Supporting the VR/metaverse, 2) Populating the VR/metaverse, 3) Operating in VR/metaverse, and 4) Understanding the VR/metaverse. The first describes the technical challenges that can be solved with the help of DS/AI tools that enable or facilitate the operation of VR. Confronting challenges can generate value innovation by delivering a product that would make VR/metaverse services easier and seamless to the broad market. The second describes the identified gap in building artificial agents, such as humanoid sales bots or artificial teachers for commercial applications. The third one describes use cases of VR/metaverse for solving identified problems in commercial areas and bringing innovation to these domains by jointly delivering new services and products using VR and DS/AI. The last section describes how the new value can stem from the quantitative analysis of complex systems' behaviour in virtual reality. The findings can be applied to evidence-based policy and process optimisation.

4.1. Supporting the virtual reality/metaverse

VR emphasises the need for solid convergence of real and virtual world data. An efficient network architecture that processes (i) quickly (ii) large amounts of data, such as real-time sensor feed and virtual reality visual layer generation, with (iii) fast distribution to provide seamless user interaction and metaverse state consistency for multiple users. Therefore, the metaverse will generate a solid push for bridge computing, communication, and mass storage. Such computing infrastructure has been treated and developed separately so far. Some authors envision the next generation 3C (computing, caching, and communication) to be highly distributed high-throughput networks combined with user device caching and computing on edge with network policy [15]. Such infrastructure would provide workload/resource optimisation and coordination of communication paths [15].

One of the characteristics of the metaverse from a data-centric point of view is continuous interaction, that is, the flow of data between the physical and virtual worlds [14]. The user's actions and behaviours in physical reality must be transferred immediately to the virtual world so that the virtual world can react and respond to them and so that the actions of multiple users can be synchronised in real-time. This domain can be broken down into eight areas. 1) Data fusion which demands fast and efficient data integration from multiple heterogeneous sources, such as head-mounted devices (sensors, cameras), social media, web pages, Wikipedia, and more. This integration demands not only simple data stacking but often must incorporate complex logical processing so that events reflected separately in these data sources can be represented consistently in virtual reality. 2) Data collaboration because virtual worlds are likely to be co-supported and co-created by multiple collaborators. There is also a space for collaboration that assumes data sharing between subjects to obtain more profound, comprehensive insights about participants. All these activities must be accomplished within the legal boundaries of user privacy. 3) Data consistency issues are a consequence of the existence of heterogeneous data sources and geographical dispersion of users and data centres. Network bandwidth limits the consistency of data. One solution is to prioritise data upload to distribute critical information first. At the same time, the less active parts of virtual reality are processed with less priority and higher latency. 4) Security and data privacy is becoming more complex due to multiple endpoints (data producers and consumers) and multidimensionally of data that can be used to identify or approximate sensitive information about users. 5) Database architecture(s) for collaborative, peer-to-peer data production and consumption can benefit from three modern data processing paradigms: decentralised, disaggregated, and serverless. 6) Query processing and optimisation are other system and database architecture concerns. Given the amount of data, the multiple data sources, and distributed data storage, queries run by applications must be high-speed and well-optimised to provide real-time information. 7) Database and AI integration must be re-engineered. The classical approach of building an AI layer on top of a database may not be the most optimal solution, given the amount and complexity of the data. AI algorithms could be run as an integral part of in-database data processing or be used to optimise the database processing itself. 8) Machine learning on data streams – AI algorithms are necessary to provide high-fidelity user representation. However, continuous reinforcement learning on the data stream may be necessary to provide smooth and seamless interaction between users and the environment, including autonomous agents.

4.2. Populating the virtual reality/metaverse

In their prophetic publication, Aylett and Luck describe three aspects that must be considered while designing autonomous agents [18]. First, the autonomy level should be defined. The authors notice that the higher the uncertainty about the environment, the more autonomy an agent needs to navigate. In artificial environments, where the agent is supplied with complete information, autonomy becomes unnecessary or a noise generator (minimal randomness). Thus, each artificial agent's autonomy level should be defined depending on the agent's purpose and available information. Second, the agency, understood as the ability to make nondeterministic decisions, should be distributed over its spectrum. There is no single agency threshold, and the agency can be different across the areas of operation, such as physical and cognitive. Physical agents can have high agency in the physical layer with little in the cognitive layer, e.g., the robot is set to act with a given result. Still, the exact sequence of steps can be delegated to its agency.

On the other hand, cognitive agents may be designed to have high agency in solving cognitive tasks, but the physical layer is strongly constrained to provide the best data collection. The third layer of agency relates to emotions. Emotion can be modelled as a cognitive state and treated as an input for cognitive processing or physical behaviour. However, there have also been attempts to model emotion as a function that takes interaction with the environment as an input. The agent's emotional state in VR seems inseparable from credible interaction with the virtual agent [19]. Disembodied agents' communication channels are restricted, for example, to written language. In VR, this communication will be of much higher dimensionality. Hence the emotional layer of communication, expressed by body language, gestures, and facial expressions, is necessary to provide smooth and seamless interaction.

The design of autonomous agents has been widely developed in the gaming industry under Non-Player Characters (NPCs). Since deep neural network training with GPU gained popularity, machine learning, especially reinforcement learning and generative adversarial networks, were harnessed for efficient and effective NPC training [20]. Since then, virtual agent training has become a DS/AI task. Current research focuses on efficient continuous NPC improvement based on data from interactions with real users with genetic algorithms [21]. One of the approaches is directly improving NPCs' behavioural decision-making in metaverse games with recursive neural networks [22]. Another method is to design frameworks for training virtual agents to minimise the difference between an agent and human behaviour performing the same task [23]. The interest in designing and training virtual animals [24] shows that autonomous agents in VR are not restricted to humanoid creatures. There is a straightforward application of virtual agent design in the gaming industry. However, they have also been successfully implemented in collaborative learning environments as virtual assistants [25].

4.3. Operating in the virtual reality/metaverse

We found that the most famous intersection of AI/VR domains was in medicine, with 37% of all articles included in a systematic literature review relating to this topic [16]. The most common application was incorporating machine learning models in medical training, primarily surgical. The research was conducted to create quantitative surgical expertise models that can be used as feedback for users trained in virtual environments [26-27]. Other applications included virtual patient simulations for the practical training of professionals [28] and using AI and VR in doctor-patient communication for risk management and shared decision-making [29]. There are studies discussing employing AI tools for advanced visualisation in VR. Complex anatomical structures can be visualised for lung surgery [30]. Immersive team collaboration is another area of VR/metaverse application [15]. Discussions suggest this approach may apply to digital workspace [31], immersive professional training [32], and collaborative learning in problem-based learning virtual environments [25, 33].

Interestingly, the last field combines gaming and learning, resulting in a gamified learning environment incorporating NPCs as virtual learning assistants. Detailed architecture of this solution has been developed under the name VoRtex [15]. In education and professional training, there are already significant developments in humanoid robots functioning as teachers and instructors with the ability to assess student skills [34]. Virtual environments and avatars are poised to become successful in these areas. Military professional training was mentioned as a strong domain in both literature reviews and included studying the use of artificial enemies for soldier training [16]. More visionary, significant battlefield use cases were found, with teams being trained in a physical environment on a small scale but with big-picture battlefields being simulated [14].

The second most popular study area [16] includes autonomous car-related applications, such as virtual environment design, in which algorithms used for autonomous car behaviour can be trained to make this process cheaper and faster [35]. Creating a virtual environment where reinforcement learning-based algorithms can be pre-trained is also applied in robotics. For example, Shen and colleagues designed a virtual environment of large-scale realistic homes, which included more than 100 rooms populated with objects with multidimensional properties, such as shape, size, and material for training virtual agents in navigation and manipulation tasks [36].

Another XR/AI interaction domain identified in the study [16] was the gaming industry. AI was also used to create NPCs and to build a virtual environment where NPCs could be trained [21-24]. The research also included generation techniques of virtual animals that resemble realistic behaviour [24, 37].

E-commerce, marketing, and customer behaviour analytics is a domain that employs DS and AI tools and shows a significant potential value source for commercial organisations. Research demonstrates that VR/metaverse enhances tailored product design, targeting or creating opportunities for precise consumer engagement metrics [38]. Another systematic literature review identified that analytical tools were used to trace digital shopping journeys in immersive environments to identify purchase intentions [39]. Navigating user experience and satisfaction with machine learning models has been proposed to assess the quality of services in a metaverse environment [40].

4.4. Understanding the virtual reality/metaverse

Wang et al. proposed the idea of MetaEnterprises and MetaCities [41]. The authors suggest that in the VR or metaverse environment, the entire organisation or city can have their digital clones inhabited by avatars or artificial agents. These complex systems can decrease uncertainty in decision-making by conducting experiments in VR before launching change into the real world. On the other hand, they could be living their own lives, different than their real-world counterparts, for the following reasons: 1) human needs and behaviour in virtual life will not be the same as in reality, 2) the virtual world will also be populated by artificial agents interacting with users 3) the principles of social coexistence and the law itself will be different in the virtual reality. MetaEnterprises and MetaCities will have a different dynamic than the normal ones. Therefore, the economy and sociology must be revised, adjusted, or reinvented.

This process would demand scientific studies of the new domain, enhanced by large amounts of behavioural data to the extent that it is rarely available in such detail and scale for social economy studies in the physical world. On one side, this data richness will enable extensive investigation and the building of detailed inductive models. Still, on the other side, large amounts of data will need sophisticated tools for statistical inference, which underlines the need for data science and AI algorithms to be employed. Wang et al. also envision that *MetaEconomies* and *MetaManagement* will stem from these experiments. The insights generated in such experiments can be used for the evidence-based strategy for enterprises and policy evolution for local governments. Another perspective links the idea of societies in the

VR/metaverse to the smart city paradigm. It postulates that a society in virtual reality will perfectly represent a data-driven smart city, with the data available to track the city's state and a quick and easy way to optimise the factors based on data-driven, AI-enabled decision-making [17]. At the same time, society's problems in the physical world, such as poverty, social exclusion, privacy erosion, minority marginalisation, hive mentality, surveillance, and control, will also manifest in the metaverse. Therefore, authors like Birbi [42] postulate substantial public participation and democratic control over the virtual life space, especially in early experimental phases when the changes are easier to induce.

5. Conclusions

This literature review assessed the current state of research and knowledge on XR/metaverse and AI, which is mature enough to be used as a source of innovation for commercial organizations. The main goal was to search for guidelines for enterprises that use these technologies to achieve competitive advantages in the field of value innovation paradigm. This review shows that, despite much research in this area, integrated, off-the-shelf implementation strategies that could serve as a roadmap have yet to be proposed.

The research mainly yielded low-level findings on implementing ML algorithms with VR data or using VR to train AI models better. Use cases that can be turned into products or services have been discussed but are most likely VR-adapted adaptations of solutions that are known and proven helpful in non-virtual reality. Some literature reviews integrating existing knowledge bases focus mainly on technical challenges and opportunities. However, they do not apply a critical analysis of factors affecting business value, which is a comparable subject of this analysis.

The identified requirements and technical challenges are primarily to ensure:

1. Convergence and synchronization of real-time data with the real world, i.e. more efficient network architecture and computing power than currently available.

2. Creating conditions for the simultaneous co-creation of virtual worlds by many entities (at various levels: companies and users).

3. Security and data protection in this real-virtual world.

From the complexity of these requirements and the coordination of data flows, ready-made services are likely needed to provide such protection for smaller economic entities. Not everyone will have the opportunity to invest in integrating complex IT environments, and not every company will be able to invest the time to create such integrations. When creating virtual entities, at least descriptions of the aspects of being relevant to the creation of agents are needed, e.g. a specific level of autonomy and agency of the agent (separately for the motor and cognitive layers).

The conversation engine area for NPCs is a continued decisive development phase requiring skilled personnel. Most companies that enter this area will play the role of technology users rather than integrators or creators. The scope of requirements will also expand over time from simulating humans (humanoids) to simulating other living things. Virtual means no limits, and the goal will quickly become a broad spectrum of possibilities to create a new digital experience to the point of being unnatural and impossible.

The demand for more straightforward tools to design and manage digital experiences will grow. Creating practical tools is a big challenge in the context of XR/metaverse. It makes sense to create different environments to work (and collaborate) and others to implement immersive business experiences. As for the existing patterns, most of them are in the medical industry. Combining 3D imaging and AI for analysis is the most desirable and common.

The second area is broadly understood robotics and autonomous vehicles/robots. It also seems that VR/metaverse is an ideal training environment in medicine, engineering, education, design and digital cities. By analogy with reality, new branches of MetaEconomics and MetaManagement are postulated.

Despite the trend in these areas, there is a need for research on the effectiveness of implemented solutions for the functioning of companies, customer service, user satisfaction and patterns of designing interaction with users. Also, research is required to predict long-term effects for the human being, with particular emphasis on human well-being, changes in behaviour patterns or even personality, and possible passivity as an effect of automation and taking over in activity, and the impact on the need for social interaction.

In the context of business implementations of innovations and solutions in XR, AR, metaverse and AI, more research is needed to help decide which implementation strategy to choose. Any company interested in creating an innovation strategy must determine how to incorporate VR/metaverse into its business model and value stream. In conclusion, based on the overview, four possible approaches can be described.

The first assumes the lack of direct representation of the company in VR/metaverse, but the extension of its offer with tools and services that help customers benefit from their presence in VR/metaverse (by providing infrastructure, tailor-made cloud solutions, security solutions or quick start services).

The second approach uses the automation and robotization of human work and focuses on developing AI agents to assist people in their lives or work. Given the lack of a physical layer, training a virtual assistant to interact with a client or student in VR is much easier than training a physical robot with such a function. This simplification could set new momentum for the trend if used wisely by the companies that want to implement it. In addition, it allows for easy and quick implementation of hyper-personalization of the user's experience, for example, based on his personality profile (see for example [43,44]). An exciting area is the development of hyper-personalization of experiences.

The third approach assumes that the company could offer and sell its services and products in VR. Some examples include shopping in VR or offering and selling products that use VR as a critical competitive advantage in areas such as medicine or the military industry.

The fourth strategy assumes that people's behaviour in VR matters more than in traditional reality. The difference can be better understood by doing VR-specific market research, measuring user preferences and predicting their behaviour, or educating them on creating effective VR content.

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