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Sustainable Value Co-Production and Co-Creation in Virtual Reality: An Exploratory Research on Business-to-Business Interactions

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Abstract: The objective of this study is to identify the environment for business interactions in virtual reality in the value co-production and co-creation process and to understand how such an environment enables the sustainable development of co-creational activities. This paper takes the concepts of value co-production and co-creation and presence and the Actors, Resources, and Activities Model as conceptual references for the exploration of interactions in virtual reality. Using ten in-depth interviews with senior managers, this paper takes an exploratory case analysis perspective. Results show how the sense of presence—level of immersion to which a medium that produces seemingly accurate representations of objects, events, and people, can submerge the perceptual system of a user—is the primary technical resource enabling the performance of value co-production and co-creational activities inside VR simulations. Additionally, the VR consultants and the hiring firms become the actors, organizing the value-co-production and co-creation practices; those customers and employees are the actors performing five co-creational activities that can result in valuable outcomes for the VR consultants and the hiring firms. Virtual reality is one of the newest vehicles used for the co-production and co-creation of value, for innovating existing products, for sustainable creation of new marketing offerings, or for managing network relations. This study contributes to existent literature by showing the process and practice of value co-production and value co-creation taking place in virtual reality simulations in B2B settings.

Keywords: virtual reality; value co-creation; value co-production; business-to-business; business interactions; ARA

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1. Introduction

Virtual Reality (henceforth VR) offers companies a chance to move away from traditional interaction and provide customers with value-added experiences through immersive simulations [1]. VR is also an enabling technology for the passive and active co-production and co-creation of value since it allows real-time, media-rich, and highly interactive collaborations between firms, institutions, and customers, leading to innovation breakthroughs [2]. This uniquely immersive platform on the one hand offers individuals the opportunity to experience the different facets of a product through a fully sensorial experience, rather than just focusing on the enhancement of specific features [3]. On the other hand, it enables organizational actors, machines, and resources to communicate and collaborate intensely in production and innovation ecosystems [4].

VR has received academic and business attention as a technology that allows sustainable prototype preparation and testing as it delivers analysis of different scenarios without taking a significant amount of time and resources [5]. It also helps in reducing the cost and emission of personal travel in case of maintenance or training in remote or hazardous

locations [6]. The interplay of sustainability and application of VR technology has been studied in a variety of contexts, e.g., building/construction engineering [7], smart cities [5] manufacturing in Industry 4.0 [8], chemical laboratories [9], pollution [10], or corporate management [11].

Those studies focused on technology and its implementation into firms' processes. Researchers examining virtual computer-mediated environments, such as Kohler et al., [2] have analyzed the technical setup and design principles required for VR co-creation systems. However, little has been studied about how firms should utilize VR for the joint co-creation of value with other firms, customers, partners, and any other stakeholder, and even less about how the value co-creation process unfolds within these systems and is measured [12]. In this vein, Kothamati and Rajala [3], found that co-creation studies in B2B settings give very limited insight into the sustainable practice perspective on value creation. Thus, further exploration of a virtual environment is required, so firms operating in fast-changing dynamic environments can develop the right strategy to fully capitalize on the opportunities offered by VR in value co-production and co-creation.

This research wants to contribute to the scarce empirical research exploring the environment for business interactions in virtual reality in the value co-production and co-creation processes and to understand how such an environment enables the sustainable development of co-production and co-creational activities. In this sense, major contributions of the work are the highlight of the features of the virtual environment for value co-production and co-creation, an environment full of a sense of presence and immersion; the identification of essential variables for successful development of VR simulations beyond the sense of presence; the observation of a circular rather than a linear process involved in the development and implementation of a VR simulation, and the way in which the sustainable virtual environment for value is co-produced and co-created.

In the same vein and related to the scope of this journal, the application of EX technologies, such as VR, allows to eliminate the consumption of resources and waste generation in prototype and environment design and construction. Furthermore, working in a virtual environment reduces maintenance costs and waste, as well as learning travels for employees and managers. As far as we know, those sustainable aspects of VR technology have been not explored before with a focus on business interactions in the B2B context.

As for the conceptual basis for this research, the analysis draws from the value co-production and co-creation concepts [13] its linkage with the Actors, Resources, and Activities Model (henceforth ARA) developed by Håkansson and Johanson [14] and adapted by Gadde and Håkansson [15] to explain interactions in the business landscape. Although focused on service and industrial settings respectively, we have adapted this conceptual framework to a virtual context, and we argue that it provides a suitable structure to explain how the value co-production and co-creation process unfolds in VR simulations.

The present work is structured as follows: first, we will provide an overview of the key concepts involving virtual immersive systems and how it works, value co-production, and co-creation. Second, we adapt the ARA model from Håkansson and Johanson [14] and Gadde and Håkansson [15] to a virtual setting and we establish four research questions to explore the value co-production and co-creation process that takes place in VR simulations. The four research questions are related to, respectively, the role played by the sense of presence in VR simulations, the role played by VR companies as the organizing parties behind the co-creation activities in VR simulations, how customers, company employers, and other partners perform co-creational activities and, how the virtual environment is perceived by actors involved in value co-production and co-creation. Next, we justify the research method used, and finally, we present the findings. Lastly, we suggest a conceptualization of a virtual environment for value co-creation and co-production, point out its contribution and propose the next steps for future investigation.

2. Literature Review

2.1. Virtual Reality Immersive Systems

Virtual Reality is currently one of the most promising emerging technologies in terms of business innovation. The technological developments embedded in these systems certainly allow for greater interactivity, simultaneity, and sensory involvement.

It can be defined as the construction of a virtual world, where through the integration of computer-supported reflections of real-world environments, exhibiting augmented objects, elements, and additional valuable information, and interaction with, the users feel immersed and present [16,17]. Virtualization Technologies are used as marketing communication or distribution channel toll tool, to innovate and enhance their offerings as well as savings in terms of costs, time, and man-hours [18], as well as highly interactive collaborations between firms, institutions, and individuals, which can lead to innovation breakthroughs [2]. Summing up, the key distinguishing feature of VR is that it is digitally simulated so does not need the real presence of the user in the real environment or the user can be present in an artificial environment [19].

According to Lombard and Ditton [20], presence can be conceptualized in three different ways. The extent to which a medium is perceived as sociable, warm, and sensitive, the degree to which a medium can produce seemingly accurate representations of objects, events, and people, and the level of immersion to which a medium can submerge the perceptual system of a user. All these definitions share the central concept of an enabling medium. Although, paradoxically, the illusion of non-mediation, that is, that users fail to acknowledge the existence of a medium, is what encourages their natural responses, just as they would in a real-life context [21]. Therefore, the primary technological goal of VR is to create perception through natural sensorimotor contingencies (such as turning our head, moving our eyes, bending down, looking under, looking over, looking around, reaching out, pushing, and so on) performed simultaneously or all at the same time, while experiencing familiar environments depicted in this technology [22]. Through the accomplishment of these natural movements, the user has the illusion of "being there" despite knowing that he or she is partaking in a simulation. This is called "place illusion" (PI), which is used to describe the sensation experienced by VR users when they can move in a stereo-displayed scenario. Moreover, when their actions can change the events occurring in a simulation, it creates the illusion that the events are happening. This is referred to as "plausibility" (Psi), which is imperative for interactions inside VR. Successful VR simulations need to evoke realistic responses from users, consistent with behaviors shown every day not in a contrived testing environment, but in an environment that simulates the real world [23].

In B2B settings, this technology can replace the traditional, laborious hand-calculations, drafting, physical testing, and model building approach to many design tasks and, consequently, reducing costs, development time, and uncertainties involved in the engineering and design of projects. With the inclusion of VR into the value co-creation practice, users can improve the prototyping, production, and evaluation processes in the manufacturing stage of products [24]. As virtual prototypes of new products are created during the development phase, it is only a minor step to allow users to virtually interact with these products and to co-construct the experience that best suits their context [25]. Indeed, the participation and the input received from individuals, on the one hand, increase product functionality, quality, and service life, on the other hand, helps to create a more competitive portfolio of offerings tailored to customers' needs [26].

2.2. Value Co-Production and Co-Creation

The systemic process of value creation considers the collective efforts of interdependent actors, in which all actors are enterprises, benefiting themselves while integrating and transforming resources [27]. Value co-creation strategies have been vastly employed in different areas and sectors, ranging from automotive [28], to consumer durables [29], to knowledge-intensive business services [30], and to fast-moving consumer goods [25]. All thanks to the participatory roles of customers, communities, and crowds, collaborating as

innovators [31]. This organizational practice continues to evolve, especially with the use of new interactive technologies such as VR. The highly dynamic, synchronous, and constantly changing nature of digital interactions, calls for special attention to the co-productional and co-creational activities performed in highly immersive systems [2].

Ramaswamy and Ozcan [31] point out that value co-creation requires interactions and causes interdependence of resources of various actors. Regarding resource integration or how an individual or firm combines available operant resources or where an activity can be carried out and operand resources or those used by an organization or customer to use the operant ones such as knowledge, skills, imagination, or experiences, is a means of value co-creation by reciprocal exchange [27]. In this line, value creation is based on interaction, and co-creation of value is defined as joint activities by actors involved in dyadic direct interactions [32]. This interaction among actors generates experiences that, according to Ramaswamy [33] are central to value creation. Thus, the customer is an active participant in service or product shaping and the perception and creation of value experience based on the interaction [27]. Kohtamäki and Rajala [3] stated that the prefix "co" indicates shared work among actors within dyadic relationships, multilateral networks, and ecosystems. Value is co-created when a solution is used, and it is seen as different from the co-production of value which comes from collaborations between actors (i.e., developing a VR setting) [13]. Thus, co-production refers to practices, which enable a customer's influence on a supplier's resources, processes, products, services, or solutions, which are co-produced in the interaction between the supplier and the customer.

Studies show that digital technologies significantly influence the way value is co-produced and co-created. Integration of resources and processes can be highly complex [34,35]. Skylar et al. [36] point out the ambiguity of digital technology that simultaneously can increase resource complexity and facilitate coordination of that complexity in value co-creation or co-production. The role of digital technologies in value capture is also discussed in recent studies. Some authors show that implementation of such technologies increases costs of IT infrastructure and outsourced IT services [37] and require new competencies [38] while others report improvement of revenue streams due to digital technologies in value co-creation [39]. Paiola and Gebauer [40] conclude that in the case of digital technologies, value co-creation happens beyond the boundaries of individual organizations and involves various actors.

So far, two studies are related specifically to value and immersive technologies in the B2B context. First, Nussipova, Nordin, and Sörhammar [41] examined how value is generated in Virtual Reality. They show that physical activities trigger the emotional responses of users which can cause negative implications in the case of novice users. Then, Battisti and Brem [42] identified success factors for the implementation of Virtual Reality as a tool that increases positive shopping impressions. Regarding value co-creation and value co-production, we perceive VR as digital technology that creates an immersive environment for value-added experiences that allows real-time, real consumption simulations, pseudo-real settings, and highly interactive collaborations between companies and customers' value. The co-production and value co-creation overlaps during the product co-development process in such an environment (see Figure 1).

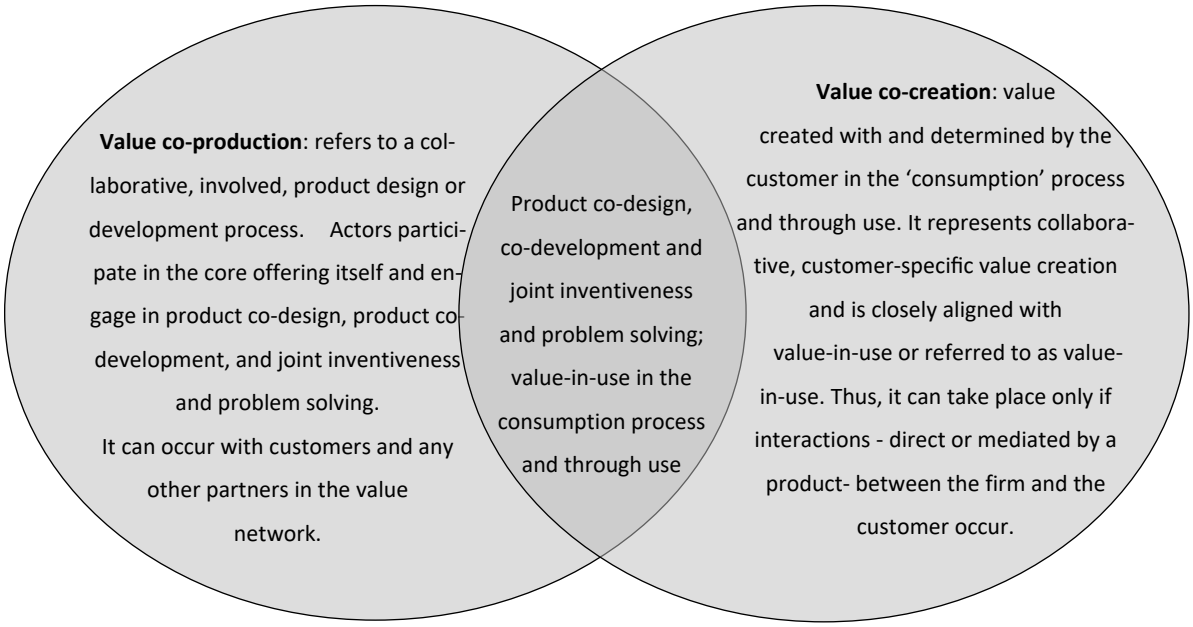

Figure 1. Value co-production and co-creation overlapping in VR settings. **Source:** Own elaboration based on Vargo and Lusch [27], Grönroos and Ravald [32] and Terblanche [43].

2.3. The Value Co-Creation Process in Virtual Reality Systems: The ARA Model and Research Question Setting

Studies on B2B marketing identify business interactions as the key elements of value co-creation and co-production [44]. They allow short-term exchange episodes and long-term institutionalization and adaptation which leads to the development of relationships, which is described by the Interaction Model [45]. The interaction process is embedded in a general business environment described by market structure, dynamism, internationalization, the market position of actors, and the social system. Interactions take place and an atmosphere is created by power, dependence, cooperation, closeness, and expectation of interacting organizations and individuals. Researchers show that the environment and atmosphere of business interactions were deeply changed by digitalization. Technologies increase data and information exchange, transparency, and support actors' participation in common activities [46], and can even remove human actors from business interactions [47]. Gligor et al. [48] point out some negative aspects of digital technology for value co-creation. However, these studies identify the digitalization of exchange episodes or products or services as the subject of exchange but do not describe the environment of those episodes. They do not identify the environment enabled for business interactions in Virtual Reality.

To stress that business interactions involve not only humans, the ARA model was originally developed by Håkansson and Johanson [14]. This model, commonly used to describe the different interactions taking place in industrial settings, suggests that a business exchange can be described in terms of three components: actors, those who perform activities and control resources; activities, where actors use and exchange resources in different ways; resources, the means used by the actors when performing activities.

These three circular components create a network of actors, a network of activities, and a network of resources, all related to each other [14]. However, the adoption of immersive digital technologies such as VR has transformed these interactions, affecting how value is co-created with the different actors of their network [49]. Thus, we adapt the ARA model and its components to a virtual context and use it to explain how the utilization of VR in firms' strategies can raise new forms of business exchanges to ultimately co-create value. Such an approach has been criticized for paying too much attention to complexity and uniqueness, which has had narrowing consequences for research [50]. However, the ARA model has been profitably applied to focus on business interactions, i.e., in solution

networks [51], innovations in co-creation, and network ties [52], digitalization of business networks [53], and the role of Artificial Intelligence in business networks [54].

According to Lenney and Easton [55] resources can be of high value or worthless, physical, or digital, depending on the configuration. Resources are combined with other resources, more or less systematic, conscious and active, and the generation of value while using these resources is dependent on how they fit together [15]. Therefore, the system capabilities embedded in VR are, according to the ARA model, considered the resource that enables the delivery of authentic experiences in a simulated environment [23]. As mentioned earlier, considerable evidence shows that the sense of presence in the physics of VR, a system capability that gives rise to an illusory sense of place (Pi) and an illusory sense of reality (Psi), which enables participant interaction inside VR simulations. Thus, the first research question is formulated:

RQ1. *How the sense of presence (place illusion and plausibility) embedded in VR simulations is an essential technical capability for participants to intuitively perform co-production and co-creational activities?*

Gadde and Håkansson [15] suggest that resource-combining efforts are a large extent [56] of the organizational processes (an activity organizing other activities), and how well these resources are linked is in fact a value-generating process driven by the actors. Actors in the ARA model are identified as individuals and organizations coordinating activities beyond the dyad [14], that can be of any kind and organized in different layers [49]. If actors in the ARA model are the entities, connecting resources and organizing other actors' activities, therefore, we identify VR providers, namely VR developers and VR consultants, as the organizing parties behind the brand value co-creation practice inside VR simulations. A second question then arises:

RQ2. *How VR providers are the organizing parties behind the co-production and co-creational activities performed by users participating in VR simulations?*

Similarly, Lenney and Easton [55] point out that actors carry out activities, but these activities can include the transformation or transfer of resources to benefit the more aggregated actor, namely the organization to which they belong. The relationship between actors and organizations is the central characteristic of business networks and may appear in various forms, such as collaborative product development, synchronized delivery system, and openness in information exchange Gadde and Håkansson [15]. Hence, we identify actors as individuals in their role of customers (part of other organizations), employees, or any other stakeholder engaging in co-creational activities with firms. If so, a third question must be addressed:

RQ3. *How customers, employees, and partners partaking in VR simulations are the performers of co-production and co-creational activities that can result in potential value?*

The numerous interactions of these actors, and the outcome of their activities performed jointly, may have a widespread impact on the evolvement of the business Gadde and Håkansson [15]. Firms as organizational entities, determine what is considered of value following their business objectives, ideals, or values shared with others [57]. In the case of digital technologies, their characteristics significantly define the environment for marketing activities [58]. Therefore, understanding the attributes of the VR device that shape actors' perception of the virtual environment for value co-creation and co-production leads to the last question:

RQ4. *How do the actors involved in VR value co-creation and co-production perceive the virtual environment for VR simulations?*

3. Research

A case study method enables the description of an occurrence and the exploration of the focal phenomenon in its natural context [59]. Conducted under a positivist approach,

a case study facilitates the objective examination and account of the event in question but abstracts the researcher from the context [60]. The inherent flexibility of this method allows the examination of prior theoretical evidence, typically combining multiple data collection methods, either qualitative (e.g., words), quantitative (e.g., numbers), or both [61], providing a stronger validation of constructs and a richer description of the phenomenon.

This technique is commonly used in the field of B2B, especially characterized by rapid changes triggered by technological advances [60]. The selection of a small number of illustrative cases can source a great number of qualitative data that can offer insights into the nature of a phenomenon [62] and advance our exploration of new and innovative practices in B2B settings. This methodological approach has been significantly applied to understand business interactions [50]. Consequently, we decided to perform a multiple case study, to enable the reflection of each particular case in its context and to identify patterns and commonalities [59]. What may be particularly useful is to claim some level of analytical generalizability, leading to more robust and justified findings [60].

Business-to-business exchanges can vary from one firm to another, and as stated in the ARA model, firms as actors control resources to change other resources in various ways, so the possibility of resource combinations is endless [63]. Thus, a multiple case study enables the reflection of the particular results of each case studied and the identification of commonalities, which helps to claim a level of analytical generalizability in the findings [64]. The study focused on three units of analysis or SMEs (small and medium-sized enterprises) considering that they play an important role in the exploitation of innovations (technology solutions) that will later be commercialized by larger firms [65], all in the B2B sector, providing VR-related services. Finally, the companies selected provided a broad spectrum of what can be accomplished with VR in terms of research, marketing communications, training, and product development.

The first unit of analysis was Innoarea Projects, a young consulting company specialized in providing ad hoc solutions through virtual reality and augmented reality systems for clients in the 4.0 industrial sector. The second unit was The Institute for Research and Innovation in Bioengineering (i3B) of a Polytechnic University. The institute integrates R+D+I activities with multidisciplinary teams of about 60 researchers from different disciplines working towards the improvement of human skills using 4.0 technologies. The i3B Institute consists of five research units. One of those is the European Laboratory for Immersive Neurotechnologies (LENI), and Quatechnion is its spin-off. The third unit is Oarsis, a venture builder company focused on creating partnerships with entrepreneurs from different industries with deep expertise in virtual and augmented reality. Table 1 describes the relevant characteristics of the companies.

Table 1. General information about companies.

Unit of Analysis	Company Age	Turn Over	HHRR	Technology	Number of Employees	Service Offered/Experience in VR/AR
Innoarea	4 years	<0.5 M	EX Technics and Engineers	State-of-the-art EX technology	<30 (12)	Technological solutions based on VR/AR for the industry 4.0
i3B (LENI)	8 years	<0.5 M	Business Consultants; EX Technics and Engineers; Psychologists and Neuroscientists	State-of-the-art EX technology and consumer and organizational neuroscience technics	<30 (5–20)	Technological solutions based on consumer neuroscience, VR/AR and AI
Oarsis	5 years	<0.5 M	Business Consultants and EX Technics and Engineers	State-of-the-art EX technology	<30 (28)	Business incubator (startups) based on VR/AR/MR

Source: Own elaboration based on empirical data.

A total of ten interviews were conducted over nine months between July 2017 and March 2018 with key informants from these firms, including senior managers such as the

CEO, CTO, business development managers, lead researchers, and marketing managers. Adjusted during the research process to ensure that the questions better reflected the experience of the interviewees. The interviews provided an opportunity to explore different environments, highlighting the particular features of the organization and individual managerial approaches to using VR technologies (see Table 2). The length of the interviews varied from 45–70 min, either conducted face-to-face or over video calls, all recorded and transcribed.

Table 2. Characteristics of respondents.

Resp.	Gender	Position	Unit of Analysis	Market Focus
1.	Female	Chief Marketing Executive	Innoarea	4.0 Industry
2.	Male	Lead Business Developer	Innoarea	4.0 Industry
3.	Male	Chief Executive Officer	Innoarea	4.0 Industry
4.	Male	Director of Research	iB3	Research, FMCG & 4.0 Ind.
5.	Female	Lead Researcher CBR	iB3	Research, FMCG & 4.0 Ind.
6.	Male	Lead Researcher DUX	iB3	Research, FMCG & 4.0 Ind.
7.	Male	VR/AR Experiential Marketer	OARSIS	Telecom & Entertainment
8.	Male	VR Expert & Promoter	OARSIS	Telecom & Entertainment
9.	Male	VR Marketer	OARSIS	Telecom & Entertainment
10.	Male	VR Expert & Promoter	OARSIS	Telecom & Entertainment

Source: Own elaboration based on empirical data.

To lead and control the interviewing process, the script was structured in four sections: general information about the interviewee and the firm's description; the VR system functionality and its most common uses in business, and research; the role of the participants performing various tasks inside the VR simulations and, the criteria used by firms and VR consultants to determine the level of success obtained (in-depth interviews script is available from authors under request).

The constant dialogue was encouraged, and respondents' answers were complemented with follow-up questions to deepen and further explore concepts, patterns, and interrelations [66]. The thematic analysis allows the researcher to identify, and report patterns that surfaced from the data collected [67]. A deductive, driven by our RQ, thematic analysis was applied in which the six steps by Braun and Clark [68] were followed. First, to become familiar with the data, the transcripts were read and checked against the audiotapes, then some concepts or codes were identified and examined to generate initial themes. The themes are concepts that appear repeatedly throughout the data and represent a kind of information summary that helps to answer the RQ. In this research, transcripts extracted with statements -in which concepts or codes appear- made by the interviewees were selected to fit with the narratives addressing the research questions. The themes were reviewed against the codes, the data set, interviewer notes, and academic literature and finally defined (see Table 3).

Table 3. Codes and themes related to RQ1.

Codes or Concepts	Theme Identification and Definition
Real life; reality; real; authentic experience; rich environments; multisensory environment; move naturally; real room; realism; realistic behaviors	VR design easy to use & know how to use it
Learning; learning curve; cognitive workloads; distraction; lack of attention; attention; spatial abilities; memory; experience; distress; locomotion metaphors; awareness; dizziness	Other VR design variables to pay attention to

Source: Own elaboration based on empirical data.

The inferences presented resulted from the process of analysis and theme interpretation. Additionally, an extensive set of secondary data was collected, such as presentation material, videos, live simulations, and websites, to support and provide validity to the findings [64].

4. Findings

The first RQ1 asked how the sense of presence (place illusion and plausibility) embedded in VR simulations is an essential technical resource for participants to intuitively perform co-production and co-creational activities. Resources in the ARA model (in this case, the system capabilities afforded by VR) are means combined with other resources, and the generation of value while using these resources is dependent on how they fit together [63]. Digitally generated environments would never replace a real-life context, but place illusion and plausibility are very achievable, however, this is entirely determined by how the technology is used. As explained by the Lead Business Developer at Innoarea: "*you can create, shape or model a room that will continue to look digitally generated. But the use of rich environments, textured backgrounds, shadows, volumetric dimensions, and vivid colors, can result in the creation of a multisensory environment. This will encourage participants to move naturally as if they were in a real room, the perception of realism is brutal*".

Two lead researchers from iB3 and one VR expert from Oarsis concurred that in VR you could easily transgress the physical laws and the metaphors of locomotion to provide a more sensorial experience. As one of them stated, "*VR is a powerful tool to achieve an authentic experience, evoking realistic behaviors, even if the events depicted in the simulation are quite unreal*". Complying with Håkansson et al. [63] that actors dispose and combine resources with other resources to perform specific activities, how successful it will be, depends on how these resources fit together. For example, a simulation was developed replicating a manufacturing plant, where the potential customers were able to operate two types of machinery used in an assembly line. It did not exactly look like a real-life plant, quite the opposite; it had a very clean layout with dynamic elements but complied with real-life dimensions and placements. The machinery stood out, sort of "floating in the air", and became the main focal point of the simulation. As one of them said, "*This made it easier for customers to know where to go and which buttons to click to see how the machinery worked*." As it was suggested earlier, a sense of presence (PI and Psi) is an essential element to encourage participants' co-creational activities and to be able to understand it firsthand, we had the opportunity to participate in a simulation designed for a tiling firm. While wearing a very potent stereo head-mounted display (HMD), we were able to move around the digitally recreated room, and with the use of commands placed in both hands, we were able to transfer objects, open doors, and choose color options to change the titles. However, to achieve this level of realism and presence, The CEO and The Lead Business Developer from Innoarea conducting the demonstration, indicated, "*We had to execute several preliminary tests. These tests have to consider not just the system features to evoke a sense of presence, but also contemplate other variables relate to simulation design and the participants*".

Complying with the Director of Research at iB3 that mentioned, "*Participants could experience different cognitive workloads, attention processes, spatial abilities, and memory when they are asked to perform tasks. Their learning curves may differ, and their locomotion metaphors may vary. Moreover, the number of sensorial stimuli and information presented in the simulation can cause participants to show dizziness*".

It was indicated then those participants who have more experience with VR are less likely to present any distress and adapt more quickly to simulation. However, the main goal traced by the hiring firm is to implement VR simulations for their target customers, who may be non-avid users of VR. Therefore, prior testing is imperative to reduce any stimuli that may cause cyber discomfort in users and affect the co-production and co-creational activities.

RQ2 concerned how VR is the organizing party behind the co-production and co-creational activities performed by users participating in VR simulations. Most of the

respondents agreed that, most of the time, firms' executives are not sure of what exactly can be done to start developing a VR simulation that helps them accomplish their business objectives. According to Håkansson et al. [63], actors are defined as those who perform activities and combine and control resources, hence, it is the VR consultant's job to detect the system capabilities and design requirements needed to develop simulations adjusted to the firm's business objectives. The CEO from Innoarea gave us an example of one client requesting the virtual recreation of a production plant where, whenever he wanted, he could add a new machine model to the simulation. However, as he explained, "*This cannot be done instantly; some previous meetings are needed to training and guide our customers which takes a significant amount of time, . . . VR consultants and developers also perform formative and guiding roles to ensure that the hiring firms have realistic expectations*".

This explains why some of the VR consulting firms like iB3 and Oarsis, prefer to have the first meeting at their offices, as they stated, "*This way the firms' executives get to experiment with VR and become more familiar with the technology . . . once they have a real notion of what VR can do, both parties proceed to schedule a second meeting, namely a briefing session*". Here is when the hiring firm lays out the strategy and the target segment that they want to approach and requests a simulation that helps them accomplish their business goals, which can include: sales growth, enhancing customer experience, increasing customer engagement, and improving training processes with employees.

A simulation design is presented by the VR consulting firm, considering the budget, the target audience, and the product and visual standards given by the hiring firm. If the hiring firm accepts the proposal, the VR consulting firm proceeds to develop a simulation, conducting various tests with a broad sample of users (with characteristics in line with the firm's target segment). The sample receives a short induction on how to move and the tasks that need to be completed inside the simulation. These tests are implemented for three main reasons: First, to evaluate the level of immersion and sense of presence evoked in the simulation. Second, to assess the cognitive workload, the locomotion metaphors, and the sections within the simulation that are more difficult to handle for the participants. Third, to determine if the brand elements are noticeable and if the commercial dialogues presented are relevant for the sample. Once the VR simulation is approved by both parties, the hiring firm proceeds to implement the simulation with the target user. However, as one of the CEOs stated, "*the development of a successful VR simulation is not a linear process. On the contrary, it is a back and forth set of inputs given by the VR consultants, the VR developers, the sample users, and the executives from the hiring firms, during all stages of the development process*". Therefore, the process integrates operand and operant resources, generating value propositions during the co-production and use of the VR simulation that rather than a linear process is a back and forth of interactions in which the value propositions and value in use appear.

RQ3 regarded the role of actors partaking in VR simulations in co-production and co-creational activities that can result in potential value. Following the ARA Model [14] individuals, firms, parts of firms, and a group of firms can be considered actors, and the performance of activities occurs when one or several actors develop relationships with each other while combining, developing, or exchanging resources while using other resources [63]. Therefore, we have identified five different ways where the different actors have performed co-creational activities that can result in value co-production and co-creation. In the first place, and based on the implementation of several simulation tests implemented with managers and final users successful development and implementation of VR simulations are achieved. The VR developers and VR consultants can identify the elements that enhance or impact the level of immersion and interactivity achieved by the participants. According to both Lead Researchers of iB3, "*these tests are valuable since they help to evaluate if the sensorial stimuli, information codes, and locomotion metaphors are adequate if the participants can correctly perceive the brand cues and commercial dialogues presented to them, and if these are in line with the objectives traced by the hiring firms*". Thus, the users become not

only enterprises performing co-creational activities, but also the co-producers of successful simulations delivered to the hiring firms.

Second, participants that have a highly interactive experience inside a VR simulation enhance prototyping. When they can assist in the development of new value propositions that result in value co-production. Here, the user's contributions to co-production can include common preferences and features that can be later included in the design or the development of the goods or services. For example, The CMO (Chief Marketing Officer) of Innoarea described how they had been working with the plastic provider of a chain supermarket in Spain, developing a "gaming experience" for customers and experts in supermarket planimetry, "*They had to make several decision-making processes regarding five plastic bottles placed in shelves and exhibitions, the inputs include color, shape, size, cap and label designs. The customers and experts' responses helped us to co-produce and co-design the best bottle in terms of brand image and space efficiencies*".

Third, to speed up the learning processes, employees can be treated as sources of information and insights, especially in training simulations. In this line, Innoarea and iB3 develop VR training solutions simulating the assembly tasks involved in the manufacturing chain of new vehicles for two different companies. Every time a new model is launched, a three-month training is imparted to the operators in a pilot production plant, to learn all about the new production processes. As researchers said, "*The advantage is that with VR this is no longer needed, with the use of a five-square-meter space, a helmet and commands, the training session could be held anywhere and anytime, while registering the operators' task completion at each stage of the VR training simulation*". The recordings of the activities performed by the employees participating in the simulation will help to accelerate learning curves for new processes, identify bottlenecks and make new processes implemented in the value chain more efficient. Firms on the other hand will save time and space and significantly reduce costs of configuration and execution. Thus, again, the users become the value co-producers and value co-creators of successful simulations delivered to the hiring firms.

Fourth, the development of VR simulations for experiential activations like concerts, sports events, and store openings not only drives positive awareness towards the brand sponsoring the VR simulation but also captures the attention of the public for the co-production, co-creation, and *viralization* of the branded content. The VR Expert and the Experiential Marketer from Oarsis explained, "*People want to be part of the simulation and share their experience in all of their social media apps. For example, we filmed 1600 consumers participating in a VR simulation and gave them the clip as a gift along with some merchandising. Here participants personalized the branded content and shared different posts on various social media platforms, reaching more than half a million impacts in the first 10 days and becoming a form of indirect advertising at no cost for the hiring firm*". They also commented that beyond the free publicity that can be accomplished, the participants tend to have a very positive inclination towards VR and that this creates a higher affinity towards the firm that allows them to experiment with this technology. This experience in use and interaction with the company clearly show value in co-creation.

Fifth, VR allows for the enhancement of commercial strategies used in B2B sales. For example, when a potential customer—meaning a firm purchasing machinery from another firm—interacts in a VR simulation showcasing a catalog of products, they can examine the machine and its parts. As the CEO of Innoarea explained, "*the firm and its sales managers can take notice of the customers' preferences and suggestions, which can help them to identify the features and functionalities that are of primary importance to them to make a purchasing decision*" and, "*Customers decide which commercial messages are of their interest when requesting specific information off certain products presented in the simulation, eliminating the excess of visual stimuli*". Hence, customers are not only the beneficiaries of targeted marketing efforts but also the co-producers and co-creators of more persuasive and assertive commercial dialogues that can be used for future potential customers.

Our last research question, RQ4, deals with the perception of the virtual environment for business interaction. The interviews led us to identify two stages or moments where the

inputs obtained from the VR simulations influence the perception of the virtual environment. The first one is during the simulation testing. The Lead Researchers and The Research Director from iB3 noted that "*some VR consulting firms are more rigorous about performance and tracking metrics compared to other, younger firms currently offering similar services*". The Director of Research stated, "*There is a lack of rigorous guidelines in the methodology used to analyze VR as a new means of communication. There is a lack of unified protocols and standardized parameters to be used in the development of a simulation, and even less tracking metrics to measure engagement, immersion, sense of presence, and so on*".

It was noted that only the VR consulting firms with strong research and academic background, such as iB3, have been using tracking systems to measure behavioral variables, which allows them to give certain scientific support and success guarantees in the simulations delivered to the hiring firms. Some of these tracking systems include Neurometrics, Human Behavior tracking (HMT), body or brain response (EEG and MRI), Heart Rate Variability (HBT), or skin conductivity, all commonly used to gather insights from the participants' interactions in the VR simulation. The resulting quantitative data obtained is combined with other qualitative information, which is sourced from focus groups and questionnaires applied to the sample participants. The VR developers and consultants assess both inputs to identify the adjustments that need to be made in the virtual reality-based setting.

The second one is during the implementation of the VR experience with the target user. All the respondents concurred that firms use both objective and subjective arguments to measure the value obtained from these simulations. As the Innoarea explained, "*some firms use VR simulations at industrial fairs to display and commercialize their products, . . . international settings like these are pricey, of high demand, with reduced space, complex logistics and with high-security standards, these constraints can be controlled or reduced with the utilization of VR, where the potential customers can experience and manipulate the real size heavy machinery in a VR recreated environment*". These VR simulations are reusable and adaptable, as they can be modified at any time for future needs. Consequently, cost efficiencies, synergies, increase in potential customers, and increase in sales are some of the objective arguments used by hiring firms to measure value. The CME from Innoarea suggested that "*the insights gathered from customers interacting in their VR solutions, could be considered objective arguments as well since firms can identify customers' preferences and adapt products to their needs. Similarly, firms can identify the commercial messages that resonate better with the customers, thus helping their sales representatives in the development of more persuasive commercial dialogues to close a sale*".

Additionally, the VR Experiential Marketer from Oarsis mentioned that "firms use other metrics to measure value, these include awareness, engagement and the social media impressions achieved with the content co-created with users during the experiential simulation". However, most of the respondents expressed that firms use their criteria to assess the level of the value obtained from a VR simulation. As it was indicated by the Lead Developer from Innoarea, "None of the numeric data proving success is relevant unless the executives of the hiring firm have a clear knowledge of what the technology is, and what it can accomplish concerning their expectations and business objectives. They have to believe in its potential to deliver value". Thus, we can observe that the virtual environment has the potential to set controlled and measurable conditions for business interactions related to value co-creation and co-production.

5. Discussion

This research considered the virtual environment for value co-creation and co-production following the conceptual frame of business interactions [45] and presence [20]. It applied the ARA model as an illustrative structure to explain the value of co-production and co-creation processes taking place in VR simulations. This allowed to answer research questions in an attempt to shed some light on the process behind the co-creational activities that take place in VR simulations in a B2B context and the environmental setting for this process.

Examining business interactions between actors, resources, and activities, our research highlights the features of the virtual environment for value co-creation and co-production. Its conditions are generated by the provider and client who mobilize their resources and link activities to produce visualizations and simulations for the environment full of a sense of presence and immersion. In some cases, they also try to make it measurable. When they manage to induce sensory stimuli, information codes, visualizations, locomotion metaphors, and tracing, they use these conditions for developing value propositions, training, and working on product parameters and aspects of communication. This contributes to Kannan's [58] understanding of the digital environment by showing how deeply it is defined by the attributes of VR technology.

Our study extends the discussion on immersive VR simulations by pointing out the variables that are essential successful development of value co-creation and co-production beyond the sense of presence (place illusion and plausibility). Users' learning curves, attention and cognitive processes, spatial abilities, memory, and executive functions [69], and their propensity to cyber discomfort are some of the additional implications that need to be assessed and considered to develop VR simulations that entice value propositions that result in value co-production and co-creation.

We were able to trace the non-linear process involved in the development and implementation of a VR simulation. A back-and-forth set of inputs is given by the VR consultants, the VR developers, the sample users, and the executives from the hiring firms, during all stages of the development process. That, with the appropriate skills and awareness of the limitations of the technology and the engagement of interested parties, designers can have confidence in the appropriateness, accuracy, and efficacy of their solutions [70]. We were able to classify the five different ways where the co-creational activities performed inside the VR simulation can result in potential value for the hiring firm and the VR consulting firm. These are: (1) For the successful development and implementation of VR simulations; (2) To enhance the user experience or for prototyping; (3) To speed up the learning curve associated with new processes; (4) For the co-creation and *viralization* of branded content; (5) To enhance commercial strategies used in B2B sales.

This study presents the way the sustainable, virtual environment for value is co-created and co-produced [5]. The application of digital technologies eliminates the consumption of resources for prototype construction as was presented in the case of Innoarea and testing virtual plastic bottles instead of material ones. Working in a virtual environment can also favor the limitation of maintenance and learning travels of professional personnel, as suggested by [6]. To the best of our knowledge, those sustainable aspects of VR technology have been not explored before with a focus on business interactions in the B2B context.

6. Conclusions, Limitations, and Future Research

Our explorative work leads to relevant contributions that can be regarded as a starting base for understanding how value is co-produced and co-created settings when using VR. First, we enriched the literature on value co-production and co-creation in the B2B context by exhibiting how the virtual environment is generated by the joint activities of provider and customer. Second, we extended the discussion on the interactive approach by characterizing the virtual world as the environment for business interactions. We also contributed to research on VR by identifying variables that are essential for the successful development of cooperation and by classifying five ways of co-creational activities in an immersive environment. Finally, our findings add a contribution to the existing state-of-the-art literature on the impact of technology on sustainability. By exploring virtual co-production and co-creation in a virtual environment, we show how consumption of resources can be limited.

Our observation and interpretation are based on qualitative data, and what qualitative methods enable us to do is primary. In addition to the interviews, websites, articles, seminars, and videos addressing the topic were assessed. Thus, all sorts of information obtained were considered of value, but its trustworthiness must be properly appraised.

Moreover, the few cases used for evaluation can place doubt on the objective substantiation of the dynamics involved in the value co-production and co-creation inside VR simulations. The units of analysis and their offerings, ethics, and how they interact with other companies might differ from others in the same sector. Observing and gathering information from managers may lead to a better appreciation of what these technologies can objectively accomplish for companies. Another limitation of this research is that we applied the ARA model which can lead to an overestimation of the complexity and uniqueness of studied cases [50].

Furthermore, being aware of the explorative character of this study suggests some research directions for future studies. First, it was noted that some VR consulting firms are more rigorous about performance and tracking metrics compared to other firms providing similar services. Only the VR consulting firms with complementary neuroscientific resources—iB3/LENI—have been developing and using tracking systems to measure the various cognitive and behavioral variables influencing participants' performance in VR simulations. Thus, further research could elaborate on the ways of standardization of guidelines and protocols that guarantee the success of value co-production and co-creation of the simulations delivered to the clients. Second, as the virtual environment is jointly generated, it is dynamic and can be heterogeneous. Thus, clients' expectations and perception of it can evaluate as they experience it more and more in different settings. Understanding the consequences of the dynamic character of VR for business interactions could attract the interest of researchers too. Finally, while virtual reality is discussed as a more sustainable environment for co-creation and co-production than using real materials for tests and prototypes, it also uses high calculative power for sophisticated graphics, so it contributes to some energy consumption and causes some carbon emissions. These parameters could be controlled in further research for a better understanding of the virtual environment in the future.

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