Facing the challenges of metaverse: a systematic literature review from Social Sciences and Marketing and Communication

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Abstract

The metaverse is the conjunction and optimization of the possibilities of the Internet and technology at their best. It is a consequence of the development and evolution of digital society. Technological innovation, fundamentally oriented toward virtual reality, augmented reality, and mixed realities, contributes significantly to the creation of a solid foundation on which to build an entire universe of virtual worlds. This is a universe that, in turn, requires the creation of backbone content for narratives that attract and retain users by capturing their attention to promote a specific ecosystem that transfers the activities of the real world to a virtual one, either projected or recreated. This research is based on a systematic review of 402 articles and a qualitative analysis of 125 publications indexed in *Scopus*. It examines the trends in technology, application, and methodology pertaining to the metaverse in the social sciences field, namely marketing and communication and neuroscience, areas that contribute to the understanding of the social dimension of the metaverse phenomenon. Although there is abundant academic literature on the metaverse in computer science, this is not the case in the aforementioned disciplines. Given that the metaverse is destined to become the next Internet revolution, there is a race among countries and brands to position themselves within it, which is expected to intensify in the coming years. The metaverse can contribute to a wide variety of applications of a social nature, which is why it is a highly competitive tool for nations, companies, and academia, as well as the public and private media. The results indicate a technological transformation proposing a future that includes neuro-technologies based on brain–computer interfaces and the metaverse as the setting. This will occur alongside the solidification of the virtual ecosystem thanks to the emergence of digital natives and Gen Z, as well as the convergence of many different technologies and immersive and participatory content, in which the consumer is the provider, owner, and beneficiary.

Keywords

Metaverse; Social Sciences; Marketing; Extended reality; Innovation; Social value; Neuromarketing; Neuroscience; Mixed reality; Augmented reality; Virtual worlds; Brands; Business; Mass media; Systematic review.

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1. Introduction

The metaverse is expected to be the next Internet revolution (**Harley**, 2022). Moreover, it is said that it will produce greater changes than those resulting from the emergence of the Internet. The metaverse is a space considered to be a "new plane of existence", a cyberspace free of monopolistic and governmental interests, (**Knox**, 2022) but with the related dangers (**Brownsword**, 2021; **Corballis**; **Soar**, 2022; **Dear**, 2022). Various voices indicate that the metaverse will have a great impact on the world we know, due to its capacity to create offshore economies; generate virtual states; compel a new type of geopolitical and military competence; and establish sovereign organizations apart from nations, resulting in new ideologies that will represent a revolution in the current *statu quo* (**Corballis**; **Soar**, 2022; **Dear**, 2022).

It is believed that the boom of the metaverse will have such an impact that the very economy in its realm will eventually exceed that generated outside it. Major technologies are investing important amounts of money in creating metaverse spaces, where the physical and virtual worlds blend together (**Riva**; **Wiederhold**, 2022). It is estimated that their platforms will contribute a market value of more than 1 trillion dollars over the next few years (**Lee**; **Kim**, 2022). In 2021, a key year for this phenomenon, *Google Trends* indicated an exponential increase in the interest in the term, coinciding with the public listing of *Roblox* on the stock market, the announcement of the creation of a metaverse by *Nvidia*, and the rebranding of *Facebook* as *Meta* (**Kim**, 2022; **Ning** *et al.*, 2021; **Rospigliosi**, 2022). Those companies that ignore its power, as in the case of marketplace, could suffer the same fate as those who ignored the power of the world wide web (**Dear**, 2022).

Younger generations, more interested in experiences and the possession of virtual rather than physical objects, promote the virtues of the metaverse (**Petit** *et al.*, 2022a). Nowadays, one out of every three people in the world is a gamer, which is to say, a large part of the population is already used to investing their time actively interacting with screens (**Márquez**, 2015). The video game industry is worth more than the film and music industries together (**Dear**, 2022). It is estimated that by 2026, 25% of the world's population will devote at least one hour per day to the metaverse for digital activities, purchases, social interaction, and entertainment (**Johnson**, 2022). The appearance of the metaverse will modify consumer behavior and policy-making. It is therefore necessary to study these changes (**Petit** *et al.*, 2022), just like it was in the past with the emerging graph of the Internet user.

Initially, the limitations of the technology and the cost required to operate in what we know as the metaverse made it necessary to restrict its use to simulations used in professional applications (in medicine, aviation, the military, etc.). Its current accessibility is favoring the mass experience (**Huggett**, 2020) and resulting in new phenomena and lines of research that are generating academic interest. The metaverse is at the center of the debate, even encouraging the appearance of pioneering journals dedicated to it, such as the *Journal of metaverse*, founded in November 2021.

There is a certain research baggage surrounding the metaverse, principally in relation to Computational and Computer Engineering, as seen below. A large part of the studies on the phenomenon are conceived of from a technological perspective; however, it should be emphasized that the metaverse has a very relevant social component (**Park**; **Kim**, 2022) that must also be analyzed. There are two large areas that will enable us to assess the value of the metaverse from the social domain, understood as individuals/consumers: the Social Sciences, where we find Marketing, and the Neurosciences. The first area supplies knowledge about the commercial application of the metaverse and the profile of the new consumers. At the same time, Neuroscience and Neuromarketing will allow for the creation of contents and efficient experien-

> "Younger generations, more interested in the experiences and the possession of virtual objects than physical ones, promote the virtues of the metaverse. The appearance of the metaverse will modify consumer behavior and policy-making. It is therefore necessary to study these changes"

ces and the better understanding of the human being in relation to the cognitive and emotional processes that determine human/consumer behaviors.

The current article analyzes the academic bibliography that exists on the metaverse, and at the same time, it synthesizes the main thematic approaches and current trends in the fields of the Social Sciences and Neuroscience. The objective is to show a better comprehension of the metaverse phenomenon in this regard.

2. Methodology

This study used the systematic literature review method as a strategy to search for, evaluate and synthesize the evidence from research on the metaverse phenomenon. This methodological focus facilitates a quantitative approach to the study objective; meanwhile, the so-called qualitative review offers an interpretative view of the phenomenon being analyzed (**Grant**; **Booth**, 2009). In our case, both perspectives will be applied. The review method was carried out in three phases, which are outlined below.

Phase 1. Planning the review and sample design

The heuristic stage consisted of designing the search strategy, based on the following selection criteria and guidelines.

Table 1. Heuristic phase: search parameters

Search resource	*Scopus* database. Previous bibliographic works on the metaverse have already been published in the *Web of Science* and *Scopus* (**Ning** *et al.*, 2021) databases, as well as in the bibliometric analysis of VR in the *WoS* (**Liu** *et al.*, 2022). The article has opted to use the *Scopus* database, as it is the first database to publish articles about the metaverse (1995). The first publication on the metaverse appears in the *Web of Science* in 1998 (**Ning** *et al.*, 2021).
Individual search term	Metaverse
Language	English
Search strategy	Title, abstract and keywords
Time period	January 1, 1995 to July 20, 2022
Type of document	Does not apply
Filter by discipline	Does not apply

Although based on the technique used, it is common to apply inclusion and exclusion criteria that filter the results, the very nature of the research questions that are indicated below has prevented this. The aforementioned search resulted in 402 articles. This documentary corpus made it possible to answer the following questions:

RQ1. How many studies are there about the metaverse in the *Scopus* database and how have they evolved over time?

RQ2. Which thematic areas have the largest volume of publications on the metaverse?

Given the interest that emerges from delving deeper into the social value of the metaverse, a qualitative approach was applied in the second stage. The results were filtered according to the set of inclusion and exclusion criteria described below. The results were filtered by discipline, in such a way that those articles were selected in *Scopus* that were published within the following areas of knowledge: Social Sciences; Business; Management and Accounting; Economics; Econometrics and Finance (n=146). In this work, we refer to this selection as the Social Sciences block. Bibliographic data were then downloaded for processing with the *Rayyan* software, used to identify articles based on the reading of their title and abstract, in order to select those that would later be analyzed in depth, i.e., examining the entire text. Articles were selected that: 1) approached the topic of the metaverse in relation to the Social Sciences, and in particular, marketing, 2) were written in English and 3) were in available in open access version. On the other hand, excluded were: articles in Chinese and German (languages found in the search, along with English); articles with restricted access; articles that included the word metaverse (in the abstract or keywords), but were not related to the subject of study, as it was seen that that some of the articles use the term without addressing it in the body of the text; and those entries corresponding to calls for papers.

The full text was analyzed for a total of 89 articles. The purpose of this approach was to consider the metaverse phenomenon from a conceptual and technological perspective, as well as to determine the trends and shortcomings with regard to its research in the field of the Social Sciences and Marketing. This second part of the research seeks to answer the following questions:

RQ3. How is the metaverse defined and what technologies belong to its universe?

RQ4. How has research into the metaverse evolved from the perspective of the Social Sciences?

RQ5. What topics and applications stand out in the field of the Social Sciences?

Finally, in order to determine the relationship between the metaverse and Neuroscience, the same process was conducted that was explained above. The discipline filter was applied in *Scopus* for Psychology, Medicine, the Decision Sciences, and the Neurosciences. This step allowed us to obtain a total of 68 publications. The articles were then screened in *Rayyan* according to:

- the availability of the article;
- the use of the English language; and
- the topic: the relationship between the metaverse and Neuroscience.

Excluded from the corpus were those articles that were found in the previous search in the Social Sciences, and which therefore overlapped, as well as the calls for papers. Once the articles were selected, we proceeded to give a full reading to a total of 36 articles.

The questions that guided this search are the following:

RQ6. What is the role of Neuroscience in the metaverse?

RQ7. What are the trending topics in research on the metaverse?

Phase 2. Conducting the study

The hermeneutic phase consisted of the collection and analysis of the documents. This took place in July 2022. As previously mentioned, the *Rayyan* software was used for the systematic review, since it allowed the data to be processed in a rigorous and transparent manner. This tool makes it possible to eliminate duplicate articles and those that are not of interest to the researchers and to categorize the documents.

The sum total of the articles found in *Scopus* was 403; after eliminating the duplicates, our base was 402 unique articles. The articles were then filtered and screened according to the above-mentioned guidelines and the results were extracted. As a complement to this, the *VOSviewer* software was used, which provided data of a quantitative nature and facilitated the display of information. For the qualitative processing of the selected articles, an analytical matrix of the contents was created based on our own categorization, which considered the definition of the metaverse, the origin of the metaverse, types of metaverses and applications. To complement the interpretation of the data, information recovered from the websites was accessed that was identifiable in the bibliographic references (n=5).

Phase 3. Report on the results

This phase consisted of the generation of the report and the interpretation of the results obtained. As previously stated, the present work has both a quantitative (RQ1, RQ2, RQ4) and a qualitative (RQ3, RQ5, RQ6, RQ7) approach.

3. Results

3.1. Metaverse: definition and characteristics

RQ3. How is the metaverse defined and what technologies belong to its universe?

The term metaverse first appeared in 1992 in the science fiction novel *Snow crash* by Neal Stephenson, in which its characters become avatars and work in a virtual reality environment (**Kelly**, 2018; **Kim**, 2021; **Kye** *et al.*, 2021; **Lee**; **Kim**, 2022). The term metaverse consists of the prefix "meta-" (meaning beyond) and "-verse", (which comes from universe) (**Dionisio**; **Burns**; **Gilbert**, 2013; **Kye** *et al.*, 2021). Even though the aforementioned work has become the historic reference, other narrative works (**Dionisio**; **Burns**; **Gilbert**, 2013), television series and films (**Murray**, 2020) have also laid the foundation for its construction.

There is no consensus regarding the conceptual approach to the metaverse, given the complexity of the phenomenon (**Guo**; **Gao**, 2022; **Smart**; **Cascio**; **Paffendorf**, 2007) and the many different technologies available (**Ning** *et al.*, 2021; **Rauschnabel** *et al.*, 2022a). Clarification of the concept and technology is therefore necessary (**Dincelli**; **Yayla**, 2022).

First, the metaverse cannot be considered to be a single space, but rather multiple metaverses. Accordingly, even a single universe can be made up of different metaverses (**Abeles**, 2007; **Papagiannidis**; **Bourlakis**; **Li**, 2008; **Smart**; **Cascio**; **Paffendorf**, 2007). It should be pointed out that, accord to the study, scholars preferentially use the singular term "metaverse" (n=334) as opposed to the plural "metaverses" (n=33), without the singular term implying the conception of the metaverse as a single entity (Graph 1).

Ever since Neal Stephenson shaped the metaverse from the perspective of immersive 3D worlds, its conception has evolved over time by virtue of a more complex and expansive notion in the form of an interconnected network of virtual worlds (**Dionisio**; **Burns**; **Gilbert**, 2013), which are characterized as being infinite, self-supporting, interoperable, decentralized, persistent and in real time (**Khan** *et al.*, 2022). This is true to the extent that it is commonly observed that contemporary definitions tend towards a confluence of technologies (e.g., immersive, 3D technologies) in shared virtual worlds (Table 2).

> "There is no consensus regarding the conceptual approach to the metaverse, given the complexity of the phenomenon. Contemporary definitions tend towards a confluence of technologies in shared virtual worlds"

Table 2. Definitions of the metaverse

Authors	Definition	Features							
		Avatar	3D	Virtual world	Virtual reality	Augmented reality	Mixed reality	Artificial intelligence	Immersion/subject interaction
(**Smart**; **Cascio**; **Paffendor**, 2007)	The metaverse is the convergence of 1) virtually improved physical reality and 2) physically persistent virtual space. It is a blending of both that at the same time allows users to experience it as either one.				X				
(**Leenes**, 2008)	The metaverse is a 3D computer-generated environment where players move as avatars.	X	X						
(**Lee** *et al.*, 2011)	Metaverse "services" is a collective term for services such as augmented reality, life recording, the mirror world, and the virtual world.			X		X			
(**Owens** *et al.*, 2011)	The metaverses are three-dimensional immersive virtual worlds (VW) where people interact with each other and with their environment, using the metaphor of the real world, but without its physical limitations.		X	X					X
(**Tomonori**; **Thawonmas**, 2011)	The metaverse is a 3D virtual world in which users can act freely, for instance by visiting museums or chatting with others, for their own purposes.		X	X					X
(**Vernaza**; **Armuelles**; **Ruiz**, 2012)	The metaverse is a virtual world where people can share and interact with one another, as if they were in the real world.			X					X
(**Dionisio**; **Burns**; **Gilbert**, 2013)	The metaverse refers to a three-dimensional digital environment that is totally immersive, unlike the more inclusive concept of cyberspace, which reflects the entire shared online space in all the dimensions of representation.		X						X
(**Ning** *et al.*, 2021)	The metaverse is the continuous digital space-time parallel of real human society.			X					
(**Kim**, 2021)	It is a persistent interoperated network of shared virtual environments where people can synchronously interact through their avatars with other agents and objects.	X		X					X
(**Di-Pietro**;**Cresci**, 2021)	A metaverse is a combination of persistent 3D virtual spaces that are both multi-user and shared, which are interwoven with the physical world and blend in with it to create a unified, perpetual virtual universe.			X	X				X
(**Jeon**, 2021)	The metaverse is a 3D virtual world with collapsed reality and virtual limits, together with technological developments, such as virtual reality and augmented reality (…); the metaverse refers to a universe beyond the physical world.		X	X	X	X			
(**Akour** *et al.*, 2022)	A world that has virtually improved the physical reality and space.			X					
(**Skalidi**; **Muller**; **Fournier**, 2022)	The metaverse is a three-dimensional (3D) digital environment where AR/VR and artificial intelligence (AI) serve as basic visual providers and where people can have social, financial, and other forms of interactions, using personalized digital avatars that imitate real life experiences.	X	X		X	X		X	
(**Lee**; **Park**; **Lee**, 2022)	A new world of digital means.			X					
(**Khan** *et al.*, 2022)	The metaverse is a three-dimensional virtual reality environment where users can interact with digital elements and with each other in an immersive environment.		X		X				X
(**Lee**; **Hwang**, 2022)	Emergent technology acts as a fully executed digital world.			X					X
(**Vidal-Tomás**, 2022)	The metaverse is defined as a shared and immersive virtual world where users are allowed to participate in different activities, represented by avatars.	X		X					X
(**Guo**; **Gao**, 2022)	The metaverse is building a virtual world that is mapped and independent of the real world in cyberspace, making use of the greater maturity of various digital technologies, such as virtual reality (VR), augmented reality (AR), big data and 5G.			X	X	X			
(**Kim**, 2022)	The main idea of the metaverse is to create a three-dimensional (3D) virtual space that appears and feels similar to the real world, with the help of special portable devices, and to allow many people to interact with it.		X	X					

Authors	Definition	Features							
		Avatar	3D	Virtual world	Virtual reality	Augmented reality	Mixed reality	Artificial intelligence	Immersion/subject interaction
(**Lee**; **Kim**, 2022)	The metaverse refers to the immersive, permanent, and mixed-reality world where people/people and people/objects can synchronously interact, cooperate and live within the limitation of time and space, using avatars and devices, platforms and infrastructures that support the immersion.	X					X		X
(**Park**; **Kim**, 2022)	The metaverse is a world combining the transcendence of meta and universe; it refers to a three-dimensional virtual world where avatars participate in cultural, social, economic, and political activities. It is widely used in the sense of a virtual world based on daily life, where both the real and the unreal coexist.	X	X	X					
(**Riva**; **Wiederhold**, 2022)	The primary characteristic of the metaverse is the blending of the virtual and the physical world.			X					

3.2. Metaverse technologies

The metaverse phenomenon consists of three elements*:* hardware, software, and contents (**Park**; **Kim**, 2022). In short, it is made up by the technology and the narrative. Technology is an essential part of the metaverse; in fact, a large part of the definitions (Table 1) point to technology as the central element to explain the phenomenon.

The metaverse is a "parallel universe" (**Lv** *et al.*, 2022) that uses many different technologies. The existence of terms like augmented reality (AR), virtual reality (VR), mixed reality (MR) and Web 3.0 complicate the comprehension of the phenomenon for both professionals and scholars (**Rauschnabel** *et al.*, 2022b; **Riar** *et al.*, 2022), and thus technological clarification is necessary (**Dincelli**; **Yayla**, 2022).

The emergence of the Web 3.0 opens the door to a more advanced version of the metaverse (**Smart** *et al.*, 2007; **Au**, 2005; **Boulos** *et al.*, 2008). The available virtual reality technology represents a step up in quality in terms of the level of presence and immersion that were achieved in the 3D proto-metaverses of the Web 2.0 (**Cagnina**; **Poian**, 2008; **Tasa**; **Görgülü**, 2010). *Second Life*, created in 2003, is a virtual 3D world where users can create, connect, and chat with others using voice and text in a PC-screen environment (**Lee**; **Kim**, 2022; **Sánchez-Mendiola**, 2022). There is a long tradition of their study in several different disciplines. The metaverse is a concept that has repeatedly been linked to *Second Life* in the academic research from 2005 until today (2022). This platform constitutes a sort of pioneering metaverse, (**Bourlakis**; **Papagiannidis**; **Li**, 2009; **Lee**; **Kim**, 2022; **Smart** *et al.*, 2007) which initially enjoyed relative popularity, only to see its success dampened over the years as the result of the limitations and obstacles of the time, such as 3D graphic support, problems with servers and staffing cuts (**Lee**; **Kim**, 2022), and the emergence of the social networks, which were simpler to use. However, recent statistics confirm signs of its recovery, thanks to the boom of the phenomenon of the metaverse (**Voyager**, 2021).

Current technologies allow the metaverse to create and evolve. There are several factors behind its current upsurge:

- the development of deep learning technology and virtual reality devices (**Lee**; **Kim**, 2022);
- the 5G boom and improved 3D technology (**Lee**; **Kim**, 2022; **Suh**; **Ahn**, 2022);
- the boom and influence of generation Z, digital natives, on consumption patterns (**Suh**; **Ahn**, 2022);
- the need to keep in touch face to face and teach classes as the result of the COVID-19 pandemic (**Guo**; **Gao**, 2022; **Kim**, 2022; **Lee**; **Kim**, 2022; **Suh**; **Ahn**, 2022);
- the ubiquity of mobile devices and changes in the types of content that facilitate access to the metaverse anytime, anywhere (**Suh**; **Ahn**, 2022);
- the existence of metaverse currency, cryptocurrency, and the possibility of trading with virtual goods through the use to non-fungible tokens (NFTs) and cryptocurrencies. Each metaverse has its own set of currencies (**Khan** *et al.*, 2022; **Lee**; **Kim**, 2022).

Today, the overcoming of technological limitations in relation to immersion, 3D and interactivity are guiding the launching of the metaverse in its social and commercial aspects and in the form of leisure platforms that are well known by young people, and which have great commercial potential (*Epic Games*, *Decentraland*, *Roblox*, etc.) (**Ning** *et al.*, 2021; **Rospigliosi**, 2022).

When many people think of the metaverse, they imagine immersive virtual reality experiences (**Gadalla**; **Keeking**; **Abosag**, 2013; **Rospigliosi**, 2022; **Smart** *et al.*, 2007) and massively multiplayer online role-playing games (mmporpg) (**Knox**, 2022; **Shin**, 2022), such as *Ready Player One* and *Roblox* (**Hollensen**; **Kotler**; **Opresnik**, in press; **Han**; **Heo**; **You**, 2021; **Rospigliosi**, 2022). There is little doubt that large technology companies have invested heavily in the construction of me-

taverses for leisure purposes. In 2016 alone, the investment by VR startups was 2.3 billion dollars (*Caict* 2017, cited by **Dincelli** and **Yayla**, 2022). It thus does not seem unreasonable to believe that their application is destined exclusively for leisure and entertainment purposes, despite the great possibilities that it has for commercial, educational, and social development (**Au**, 2005; **Smart** *et al.*, 2007). Such is the current potential of the metaverse that companies like *Meta* (previously *Facebook*) are already modifying their business model, focusing on hardware and software development to make their metaverse, *Horizon World* and *Horizon Workroom*, accessible to the general public at an affordable price and to make it applicable to the professional world (**Kraus** *et al.*, 2022).

> Large technology companies have invested heavily in the construction of metaverses for leisure purposes, despite the great possibilities that it has for commercial, educational and social development

The metaverse is synonymous with user immersivity, and thus virtual reality technology has traditionally been associated with the metaverse (**Kye** *et al.*, 2021). Virtual worlds strive to create an alternative reality, one that is different from the real world in which individuals are immersed. Proprietary technology is available for this immersivity in the form of virtual reality glasses, headsets, or HMDs (*head-mounted display*) (**Rauschnabel** *et al.*, 2022b). They provide a level of presence and immersion that is on a whole different level, thanks to the technology that permits the rendering of high-quality images and the freedom of movement in the virtual environment (**Dincelli**; **Yayla**, 2022). Their technological capacity is such that the frontier between the real and virtual world is blurred (**Murray**, 2020).

Augmented reality (AR), in turn, is an extended reality that strives to superimpose virtual information on the real world (**Rauschnabel** *et al.*, 2022b; **Riar** *et al.*, 2022). A large number and variety of devices exist for augmented reality, and they require both ubiquitous hardware, as in the case of smartphones, and specialized hardware, such as that used for retinal control screens, voice commands, eye-tracking, etc., which facilitate control over the human-computer interface or brain-computer interface (BCI) (**Lee**; **Kim**, 2022; **Park**; **Kim**, 2022; **Rauschnabel** *et al.*, 2022b; **Riar** *et al.*, 2022).

As can be inferred from the above, the physical environment, as part of the user experience, is one of the keys (together with the technology) to conceptualize AR and VR. Augmented reality (or AR) is conceived as an extended or augmented reality, while the VR is understood as a substitute or simulated reality that seeks the immersion of the individual in virtual worlds (**Rauschnabel** *et al.*, 2022b; **Riar** *et al.*, 2022). Mixed reality, in turn, integrates both augmented reality and virtual reality. Specifically, the technology allows objects created by AR to offer individuals an experience in a 3D environment through an immersive experience in the virtual environment (**Tayal**; **Rajagopal**; **Mahajan**, 2022). In addition to the dimensions of augmentation/simulation, there are two other types of user experiences in the world of the Internet: an 'external' and an 'intimate' approach. The intimate approach focuses on the privacy of the subject's actions, as opposed to the external approach, where the subject's actions are shared with the world (**Lee** *et al.*, 2011).

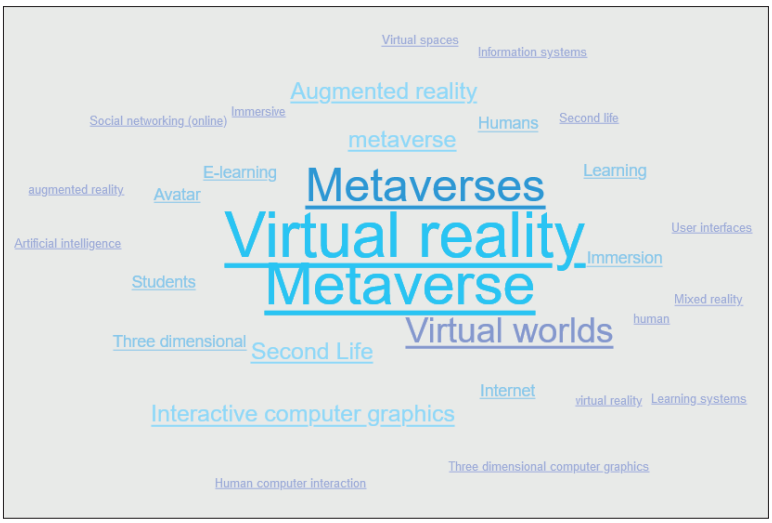
Pioneering research suggests that there are four types of metaverse that offer a very broad vision of the phenomenon, based on the combination of four dimensions (**Smart** *et al.*, 2007). This typology of metaverse is proving to be recurring and accepted in accordance with the literature review (**Bolger**, 2021; **Boulos**; **Burden**, 2007; **Cheng** *et al.*, 2022; **Choi**; **Kim**, 2017; **Márquez-Díaz**, 2020; **Guo**; **Gao**, 2022; **Jeon**, 2021; 2021; **Kim**, 2021; **Kye** *et al.*, 2021; **Lee** *et al.*, 2022; **Lee** *et al.*, 2011; **Lee**; **Kim**, 2022; **Mendiola**, 2022; **Suh**; **Ahn**, 2022) (Table 3).

Table 3. Metaverse typology

	Definition	Features	Examples
Augmented reality	Augmented reality (AR) is the superposition of digital information on the real world (or even a virtual world). It uses location-based technologies and networks that process and superimpose the information.	Augmented and external technology. Creation of an intelligent environment using location-based technology and networks. It uses front display screens or head-up displays (HUD), which provide information relevant to the context through a mobile screen (such as a smartphone screen or a car navigation device).	*Pokémon Go*
Life-logging	Technology that captures, saves, and shares everyday information about people.	Augmented and external technology. Recording of information about objects and people.	*Facebook*, *Instagram*, *Apple Watch*, *Samsung Health*, *Nike Plus*.
Mirror worlds	They are virtual models that try to reflect the real world as it is, but integrating and providing information from the external environment. These are digital representations of our world.	Simulation and intimate technology. Virtual maps and modeling using GPS technology.	*Google Earth*, *Google Maps*, *Naver Maps*, *Airbnb*, *Microsoft Virtual Earth 3D*, military systems.
Virtual reality	A virtual world by means of digital representations of any space, either imaginary or real.	Simulation and intimate technology. Activities based on the interaction between avatars that reflect the user's self. It uses virtual reality glasses.	Multiplayer online games. *Second Life*, *Minecraft*, *Roblox*, *Zepeto*.

Source: adapted from **Boulos** and **Burden** (2007), **Kye** *et al.* (2021), and **Smart** *et al.*(2007)

There is an important presence of the virtual reality and virtual worlds terms in our sample (Graph 1). A large portion of the studies about the metaverse revolve around VR and AR technologies. The metaverse is the Internet in VR and AR (**Guo**; **Gao**, 2022; **Park**; **Kim**, 2022; **Rauschnabel** *et al.*, 2022b; **Werner** *et al.*, 2022; **Ilyina** *et al.*, 2022). The metaverse relies on the combination and technological integration of VR, AR, and MR (mixed reality) in fulfilling its purpose of offering a complete interactive and immersive virtual world (**Ning** *et al.*, 2021). In the quest for mixed realities, the implementation of different devices that exploit the senses is central to the user's experience (**Tayal**; **Rajagopal**; **Mahajan**, 2022).



Graph 1. Word cloud of all the articles analyzed (n=402)

The metaverse joins together different elements of VR, AR, *life-logging,* and *mirror window*. These technologies overlap each other (**Huggett**, 2020). Examples are the existence of a mirror world map in a virtual world, or the use of AR devices in a virtual world, or the user life-logging in a mirror or virtual world (**Smart** *et al.*, 2007). Along these lines, we can see AR-HMD technology used in the field of training, manufacturing, and medical applications (**Cheng** *et al.*, 2022). The private and commercial sectors also make a combined use of the networking possibilities under the idea of the metaverse. This is the case of *Meta* and the use of the *Oculus Quest 2* (VR), which allows an avatar to represent us in a virtual world, where we can interact with others (**Lee**; **Kim**, 2022), and which would complement the experience with augmented reality (*CNET Highlights*, 2022). *Meta*, in cooperation with *Ray Ban*, already markets smart glasses that have multiple AR functions and in which the social networks are very much present.

3.3. Content

As mentioned earlier, the metaverse consists of three elements*:* hardware, software, and content (**Park**; **Kim**, 2022). The metaverse requires social engagement for its success. The content is provided by the organizations through storytelling, the objective of which is a more complete immersive experience, for which many different technological devices will be developed that accent the senses and emotions (**Tayal**; **Rajagopal**; **Mahajan**, 2022). Users will participate in the metaverse through avatars, as virtual representations of themselves. It is interesting to point out that several studies have dealt with the relationship between the physical properties of the avatars and the effects on their behavior and that of others (**Murray**, 2020). Users are key for the future of the metaverse, as they are active subjects in this space (**Park**; **Kim**, 2022). Parallel to the metaverse applications, the contents must be provided with formulas for interaction with the users (**Tayal**; **Rajagopal**; **Mahajan**, 2022). Users must be required to participate in the metaverse through the generation of personal proposals, in other words, through what is known as User Generated Content (UGC).

Metaverse platforms recognize that success depends on the users' innovation and participation in the platforms; this has led to the growth of open, accessible, and collaborative virtual platforms where the content creator obtains more control in starting businesses in which to offer products and services and to promote transactions (**Zhou**; **Lenders**; **Cong**, 2018). If the Web 1.0 connected us online and the Web 2.0 created an online community, then the Web 3.0 connects us in a virtual world belonging to/that is the property of the community (**Lee**; **Kim**, 2022; **Vidal-Tomás**, 2022).

Even though it is still in an early stage, virtual societies today are aimed at obtaining self-sufficiency and the promotion of trade and transactions as a formula to involve individuals in the virtual world. In this sense, the current legislation surrounding the metaverse is worthy of consideration. Property in the virtual world differs from that in real life, as property in the virtual world is inseparable from the platform. Currently, studies indicate that this interdependence is understood to be problematic for entrepreneurs, since the business model in the virtual world seems to favor the interests of platforms and jeopardizes the sustainability of the system itself, which is based on the centrality of the user (**Zhou**; **Lenders**; **Cong**, 2018).

"The metaverse requires social engagement for its success. The content is provided by the organizations through storytelling, the objective of which is a more complete immersive experience, for which many different technological devices will be developed that accent the senses and emotions"

4. Evolution of research on the metaverse

RQ1. How many studies are there in the *Scopus* database about the metaverse and how have they evolved over time?

RQ2. Which thematic areas have the largest volume of publications on the metaverse?

Ning *et al.* (2021) believe that the research on the metaverse has taken place in four stages:

- the embryonic phase (from the first publication in 1995 until 2007);
- the first boom (from 2008 to 2013);
- the declining stage when a decrease in publications occurs (from 2014 to 2019);
- the development stage, after 2021, when a large increase in research occurs, thanks to the development of the AI and blockchain technologies.

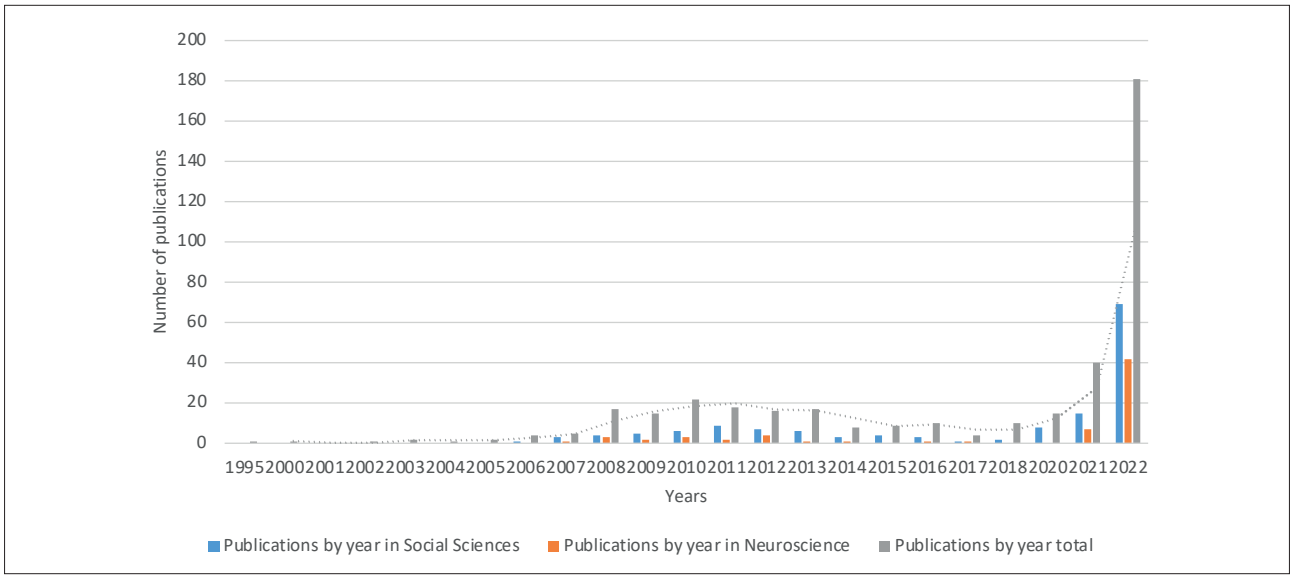
The metaverse and VR are considered the next major breakthrough for the Internet (**Harley**, 2022), and so it is logical that the main disciplines to address this phenomenon are primarily in the field of Computer Science and Engineering (Table 4). The review carried out allows us to confirm that during the period 1995-2000, the first articles are published in *Scopus* that consider the creation of languages for virtual reality and metaverses from the field of Mathematics and Computer Science. These early studies on the metaverse are focused primarily on the *Second Life* platform during the period between 2006 and 2020. This is followed by a boom, and then by a declining stage and, finally, a stage of great development, along the same lines as the proposal by **Ning** *et al.* (2021). This was also true for publications in the fields of Social Sciences and Neuroscience (Graph 2). However, due to the meager volume of articles on the metaverse in *Scopus* to date (n=402), this could be considered an embryonic stage in the research on the metaverse. Academic studies have only just begun, and there is a considerable amount of empirical work to be done (**Lee**; **Kim**, 2022), especially in the Social Sciences and the Neurosciences.

Table 4. Publications by area of knowledge

Areas of knowledge	Publications	Percentage
Computer Science	264	65.5
Engineering	115	28.5
Social Sciences	88	21.8
Mathematics	58	14.3
Business, Management and Accounting	42	10.4
Arts and Humanities	38	9.4
Decision Sciences	29	7.1
Physics and Astronomy	25	6.2
Psychology	23	5.7
Material Science	19	4.7
Medicine	16	3.9
Economics, Econometrics, Finance	14	3.4
Environmental Science	12	2.9
Energy	10	2.4
…		
Neuroscience	4	0.9

Source: *Scopus*, July 2022

The year 2022 saw exponential growth in the number of academic studies on the metaverse phenomenon from multiple areas of knowledge. Just midway into the present year, already a total of 181 documents have been indexed; this means that nearly 50% of all of the publications since 1995 have been concentrated in just the first six months of 2022 (Graph 2).



Graph 2. Evolution of the publications by area and year.
Source: *Scopus*, July 2022

The metaverse is present in all of the *Scopus* disciplines. It is interesting to note here that part of the research points to the construction of the metaverse in its many facets: economic, political, economic policy, social, educational, and commercial, etc. (**Knox**, 2022). It is even seen in the Environmental Sciences. The Social Sciences, Business, Administration and Accounting and Arts and Humanities make up the second block of disciplines with the most publications on the metaverse; meanwhile, trailing in the list are the Neurosciences, Medicine, Psychology, and the Decision Sciences (Table 4). However, the term metaverse has begun to spill over into publications on biomedicine in 2020 and 2021 in *PubMed* (**Huh**, 2022).

Some works analyze the relationship of the metaverse with governmental, economic, educational, and business policies. The metaverse is a state matter for countries such as the United States, China, Japan, South Korea, and the United Arab Emirates, and one they have been working on for decades (**Ning** *et al.*, 2021).

The metaverse also forms part of China's geopolitical strategy. In 2006, China had already turned its attention to virtual reality in the report *Development plan outline for medium and long-term science and technology development* (2006-2020) (**Dionisio**; **Burns**; **Gilbert**, 2013). There is an interest in this country to match its technological level with that of the United States, and different agents are involved in this effort. By the end of 2021, around 1600 companies had requested 11,000 trademarks with the Chinese word for metaverse (*Yuan Yuzhou*). Companies like *Tencent*, *Baidu* and *Alibaba* invest large sums of money in their development, so that they are already very well positioned to play a relevant role. Even so, and due to its own idiosyncrasies, China will follow a path that is predictably different in terms of the regulation or control over platforms, as compared to the West (**Knox**, 2022).

South Korea, whose government undertook the *Metaverse industrialization policy* (2022), understands that the metaverse constitutes an opportunity to improve national industrial competitiveness, while the challenge of building an entire ecosystem around areas such as tourism, culture, and arts; education, health, mass media, content creation, manufacturing and government are considered (**Kim**; **Lee**, 2022). The country already incorporates the metaverse in educational policies for primary and secondary school students (**Ning** *et al.*, 2021), and not just in higher education. This is proposed as a strategic tool to solve national problems, for example, in relation to teleworking and reducing the population pressure in megacities (**Choi**, 2022), social relations (**Jeon**, 2021), education and even the surgical training of its professionals (**Koo**, 2021; **Lee**; **Hwang**, 2022).

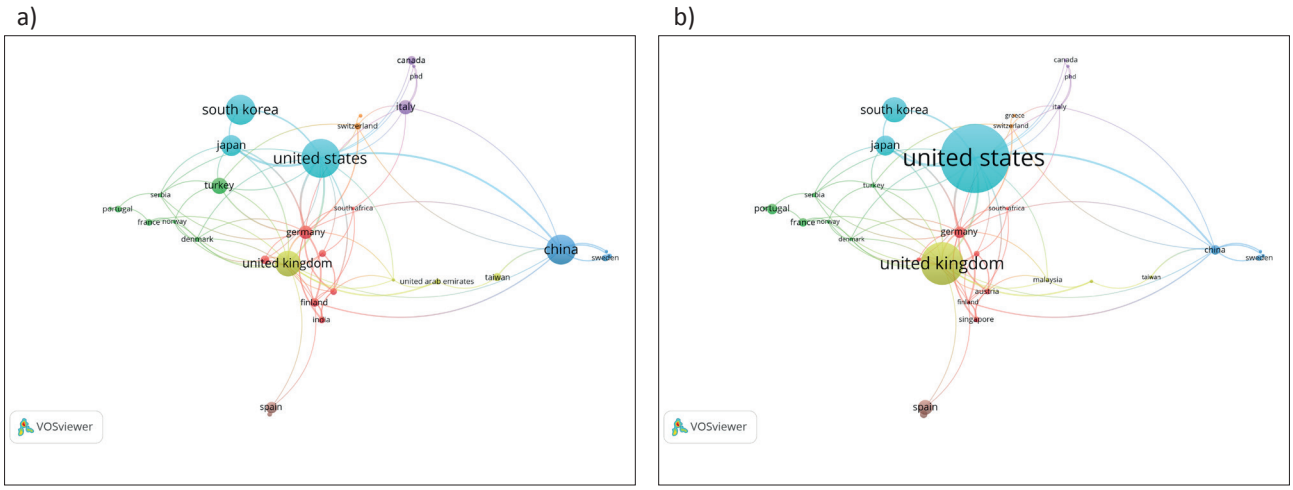
As early as 2007, Japan was already contemplating that the metaverse would be a technological priority for the 2025 horizon, while in 2008, the *National Academy of Engineering* (*NAE*) of the United States saw virtual reality as one of the 14 great challenges for the 21st century (**Dionisio**; **Burns**; **Gilbert**, 2013). The United Arab Emirates (UAE) also champions technological transformation, as the result of its capacity to contribute to the national economy and promote the investment. The *Virtual Assets Regulatory Authority* (*VARA*) of Dubai, in the UAE, became the first state institution to enter the metaverse, establishing its headquarters in the virtual world (*Swissinfo.ch*, 2022).

Our analysis points to the United States, China, South Korea, United Kingdom, and Japan as the top 5 countries with the greatest number of documents published in *Scopus*. This indicates a close link between the power conferred on the metaverse as a competitive tool and the research action for all the aforementioned countries, except for UAE, which does not make it into the top 10. The area of Computer Science and Engineering accumulates the greatest volume of publications, followed by the Social Sciences and Business. There are still not many results in the field of Neuroscience reflected in the *Scopus* multidisciplinary database (Table 5).

Table 5. Volume of publications by country, area of knowledge and citations

Countries	Total number of published documents	Citations	Documents on Social Sciences, Business, etc.		Documents on Neuroscience, Psychology, etc.		Documents on Computer Sciences and Engineering	
			n	Citations	n	Citations	n	Citations
United States	72	572	26	26	12	12	53	528
China	50	36	8	8	8	8	43	33
South Korea	50	139	16	16	7	7	33	113
United Kingdom	40	290	23	23	8	8	21	165
Japan	30	101	7	7	5	5	30	101
Turkey	21	13	7	7	2		19	13
Italy	18	9	10	10	5	5	13	5
Germany	16	45	6	6	4	4	8	34
Spain	13	66	6	6	1	1	11	66
Finland	9	6	4	3	2	2	4	3

Note: It is possible that several articles are found under different areas of knowledge, hence the total number of publications does not coincide with the sum of the areas. On the other hand, here the areas of Scopus that are of interest to the article are alluded to, excluding those that are not pertinent.
Source: *Scopus*, July 2022



Graph 3. Volume of publications by countries (a) *vs.* cumulative volume of citations (b). The United States is the country with the highest production and the most cited one. The size of the circles reveals the number of documents published (a) and the volume of citations accumulated by country (b). The proximity or distance between the circles denotes the degree of relationship between countries by co-authorship (a) and by citation (b). The colors identify the clusters that link countries.
Source: Graph produced with *VOSviewer*.

5. Metaverse and applications in Social Sciences

RQ4. How has research into the metaverse evolved from the perspective of the Social Sciences?

RQ5. What topics and applications stand out in the field of the Social Sciences?

The studies that were found consider many different metaverse applications in their broadest sense (VR, AR, etc.). Many articles allude to their application in relation to gaming, entertainment, training, marketing, tourism, fashion, manufacturing, retail trade, supermarkets (**Rauschnabel** *et al.*, 2022b), management and organization (**Dincelli**; **Yayla**, 2022), smart cities, remote offices and virtual meetings, psychotherapy, economics, and social aspects (**Ning** *et al.*, 2021).

Applying the Social Sciences filter, the journals with the largest number of works published on the metaverse are those related to the fields of computing, technology, psychology, and human behavior (Table 6).

Table 6. Journals with the largest number of publications under the keyword metaverse

Journal	Documents	Citations
Sustainability	5	7
Lecture notes in business information	4	0
Technological forecasting and social change	3	84
Computers in human behavior	3	5
Cyberpsychology, behavior, and social networking	3	3
Journal of educational evaluation for health professions	3	9
Smart innovation, systems and technologies	3	15

Source: *Scopus*, July 2022

There are many different disciplines that deal with the metaverse from the social perspective: Economics and Business, Psychology, Marketing and Advertising, studies in specific industries (e.g., music) (**Bourlakis**; **Papagiannidis**; **Li**, 2009), Religion (**Jun**, 2020; **Leone**, 2011), Theater (**Chen**; **Yao**, 2021; **Baía-Reis**; **Ashmore**, 2022) and Law (**Falchuk**; **Loeb**; **Neff**, 2018; **Leenes**, 2008). However, research on the possibilities of the metaverse as an educational tool predominates in *Scopus*.

5.1. Education

Of the articles filtered by disciplines in the Social Sciences, a total of 46 articles fit into the thematic category #learning, #teaching #students; 19 in the Business category, and 14 under the umbrella of Marketing. Virtual worlds have the capacity for education and training (Table 7). However, it appears that the VR applications for education are limited (**Dincelli**; **Yayla**, 2022). The interest in these studies lies in the creation of training programs in environments that are safe, accessible, and affordable, and which would be impossible in real life. Military and emergency applications stand out, as do industrial and maintenance applications; medical and surgical training applications and the educational applications in various disciplines (**Dincelli**; **Yayla**, 2022; **Koo**, 2021). The focus of these studies also seems to indicate the effectiveness of these technologies in learning, which in the area of the physical health, is focused on improving physical and cognitive performance and pain management.

> The metaverse is a state matter for countries such as the United States, China, Japan, South Korea and the United Arab Emirates, and one they have been working on for decades

Table 7. Articles by topic

Education	Articles	Marketing	Articles	Business	Articles
#Learning	36	#Marketing	9	#Business	14
#Students	28	#Brand	5	#Business model	1
#Teaching	19	#Advertising	2	#E-commerce	3
		#Positioning	1	#Fashion	2
				#Luxury	1
				#Tourism	2
Total articles (eliminating duplications)	46		14		19

Fuente: *Scopus*, julio de 2022

The metaverse as an active educational tool is analyzed from the perspective of gamification (**Park**; **Min**; **Kim**, 2021), classroom education (university, primary school, etc.) (**Makransky**; **Mayer**, 2022; **Sofianidis**, 2022), cognitive value (**Pigultong**, 2022) and oral health education, and it considers those with neurological problems (autism) and intellectual disabilities (**Lee** *et al.*, 2022). The monetization of education is another of the scenarios contemplated with regard to the virtues of the metaverse (**Knox**, 2022).

5.2. Marketing, business, and communication

Just as the metaverse will revolutionize the Internet, it will have a similar effect on Marketing and Communication. According to Hollensen, Kotler and Opresnik, the metaverse is intended to be the new marketing platform for brands, thanks to its potential to promote them and open up new formulas of communication among humans (**Hollensen**; **Kotler**; **Opresnik**, 2022). We must not forget that part of the content the metaverse offers is linked to economic activity, given that it creates and ecosystem that transfers it to a virtual level (**Park**; **Kim**, 2022).

An ever-increasing body of articles focuses on Marketing and Business. Private enterprise already has a history of investing in technologies, devices and brands that position them within the market (**Rauschnabel** *et al.*, 2022b). The use of different technologies is commonplace in museums: AR with smartphones, interactive kiosks, and VR (**Dincelli**; **Yayla**, 2022). However, research on the possibilities of the metaverse/VR in tourism is few and far between. Only one article is found that matches the discipline criterion (Social Sciences) and that seeks to understand how VR increases the intention to visit the destination (**Lee**, 2022), while the use of the metaverse in museums takes place almost entirely in the areas of Computer Science and Engineering (**Ando**; **Thawonmas**; **Rinaldo**, 2013; **Choi**; **Kim**, 2017; **Lee** *et al.*, 2022; **Thawonmas**; **Fukumoto**, 2011; **Thawonmas**; **Kato**, 2011; **Thawonmas**; **Shuda**, 2011).

In retail, the hedonistic perspective plays a greater role than utilitarian aspects (**Dincelli**; **Yayla**, 2022). The world of fashion is a sector that is expected to have a great capacity for consumption in the metaverse (*Morgan Stanley*; *PwC US*; *BEA*; *US Census Bureau*; *NCES*, 2022). Following the appearance of *Second Life*, companies like *Adidas* and *American Apparel* have joined it for marketing purposes (creating events, branding, etc.) (**Bourlakis**; **Papagiannidis**; **Li**, 2009). In the advanced version of the metaverse, it is common to see the creation of virtual shops, such as *Gucci*'s store in *Roblox*, and their use on the social platform *VR Chat*, as well as the sale of NFTs in *Decentraland* (**Dear**, 2022; **Han**; **Heo**; **You**, 2021; **Kim**, 2021; **Ning** *et al.*, 2021). Nonetheless, our sample only found three items for fashion and luxury items in the field of the Social Sciences (**Ayiter**, 2010; **Guo**; **Hou**, 2022; **Joy** *et al.*, 2022). Once again, fashion and cosmetics are mainly considered by other disciplines (**Lee**; **Kwon**, 2022; **Oh**; **Nah**, 2021). Furthermore, their consideration in the Social Sciences is not central, and it is limited to including examples of cases of companies that make use of the metaverse.

There is much to study in terms of designing services and what determines quality in the metaverse (**Gadalla**; **Keeking**; **Abosag**, 2013) , from the design of the atmosphere of virtual shops for greater commercial efficiency (**Hassouneh**; **Brengman**, 2015); to factors of influence in virtual online shopping worlds (**Lee** *et al.*, 2011). With this in mind, scholars offer a new terminology in reference to the phenomenon of the metaverse in relation to Marketing, its strategies and objectives, with proposals such as Augmented Reality Marketing or AR Marketing (**Rauschnabel** *et al.*, 2022a).

A total of 18 articles included the keyword *communication* in their abstract. However, it is necessary to mention that their use is also common in other disciplines, such us Engineering or Education, and therefore they distance themselves from the area of the mass media. It is also common to find references to the fact that the metaverse imposes challenges related to the communication process. The possibilities that the metaverse provides in relation to the reconfiguration of business models are not subject to analysis in the media context. The mass media are considered (n=2) and serve simply to illustrate in a very superficial manner the advances that the latter has made as compared to television as a persuasive and preterit medium, or to discuss virtues of immersive journalism in storytelling (**Vázquez-Herrero**; **Sirkkunen**, 2022). In spite of the pre-

> "Metaverse is intended to be the new marketing platform for brands, thanks to its potential to promote them and open up new formulas of communication among humans"

ponderance of storytelling and content in the creation of metaverse worlds, no articles have been found that consider the role of the mass media, either public or private, in this new scenario.

6. Neuroscience and the metaverse

RQ6. What is the role of Neuroscience in the metaverse?

RQ7. What are the trending topics in research on the metaverse?

The mass media and social networks are platforms with the capacity to influence the attitudes and behaviors of individuals, that is to say, they have a persuasive capacity. The metaverse proposes a substantial change related to the modulation of the cognitive and emotional processes of human beings. "The metaverse works like our mind," as they say. It has the potential to create alternative realities, induce basic and complex emotions and even to replace emotions with others. This takes us to a new level in terms of understanding the effect of virtual environments on the human brain (**Riva**; **Wiederhold**, 2022).

Neuroscience, which has paved the way for the interest in the comprehension of emotions, attention and memory in the entertainment industry, advertising, marketing, and the mass media, is not indifferent with regard to its potential in virtual environments, such as that proposed by the metaverse. However, there is little research on the impact of these affective states experienced in immersive virtual environments (**Mandolfo**; **Baisi**; **Lamberti**, 2022).

VR offers a great methodological opportunity, opening up a range of possibilities with regard to innovation in both techniques and metrics (**Dincelli**; **Yayla**, 2022). Biometric and physiological identification techniques could be extended from virtual reality and include gaze analysis, voice recognition and facial recognition (**Egliston**; **Carter**, 2021). The way is paved for adopting biometric sensors on headsets and peripheral devices: Electrocardiography (ECG), Electrodermal Activity (EDA), Electroencephalography (EEG), Electromyography (EMG), Electrogastrography (EGG), Electro-oculography (EOG), Respiration rate (RR) and Temperature (TMP) (**Angelini** *et al.*, 2022; **Dincelli**; **Yayla**, 2022; **Guo**; **Gao**, 2022).

The future of the metaverse is associated with technological innovation and the obvious adoption of the same by the general public. The development of accessories is aimed at boosting the user's senses and emotions, and so companies have begun to invest in the sense of touch through a skin, the *ReSkin*, created by *Carnegie Mellon University* and *Meta*, and to acquire various technologies: an *EMG Wristband*, by *Meta*, for hand movements; *Meta Gloves* by *Oculus*, which increase the sensory sensation; and the *Meta* bodysuit, by the Indian company *Holosuit*, for a complete sensory experience (**Park**; **Kim**, 2022; **Tayal**; **Rajagopal**; **Mahajan**, 2022). According to *Meta*, the next advance with regard to the metaverse is, among other things, the use of mixed reality, displays, haptic devices, hand tracking, eye tracking, graphic sensors, avatars, perception sciences and artificial intelligence (*CNET Highlights*, 2022).

Contemporary technology is leaning towards the use of the capacities of the human mind without their physical limitations. The next big step in technological transformation comes from Neuroscience and Computer Engineering in the form of technologies aimed at the brain-computer interface. The brain-computer interface encodes and decodes the brain's signals in the process and sends orders to the devices. Current technological developments allow for the interaction of the mind with technological devices in order to circumvent the physical barriers of humans beings. Classic Neuroscience technology, such as EEGs, is now used to speed up the development of BCI (**Ning** *et al.*, 2021; **Park**; **Kim**, 2022); this, combined with the metaverse as a metaverse scenario could give way to new lines of research that would be very interesting in order to understand the cognitive processes of human beings. This type of technologies is being developed by university laboratories and by private laboratories, such as in the case of the *Neuralink*, belonging to Elon Musk (**Lee**; **Kim**, 2022; **Park**; **Kim**, 2022; **Rauschnabel** *et al.*, 2022b; **Riar** *et al.*, 2022).

6.1. Human functions and VR

The convergence of the disciplines of Neuroscience and Computer Engineering provide continuous feedback for one another. Among the studies on HCI (human-computer interfaces), there is also growing interest in emotions and VR (**Dozio** *et al.*, 2022). HCI studies are focused on 1) the equivalence of primary human functions (cognition, emotion, physical movements, senses) in VR and physical reality and 2) the effect of VR on these functions (**Dincelli**; **Yayla**, 2022; **Riva**; **Wiederhold**, 2022).

The study on VR includes physical movement and facial expressions, given their relevance for the human cognition. The interaction with virtual characters or the level of realism of the faces is critical to understanding the communication between machines and humans (**Dincelli**; **Yayla**, 2022). **Riva** and **Wiederhold** (2022) offer a literary review regarding the effect that the metaverse has on our cognitive and emotional processes, based on multidisciplinary studies in the Computational Sciences and Neuroscience.

The collection of psycho-physiological data in real time provides information about the user's level of attention, concentration, stress, engagement and emotions that will make it possible to design effective VR applications (**Dincelli**; **Yayla**, 2022). These can also be used to improve social skills in persons with autism disorder (**Lee** *et al.*, 2022). There is a long tradition and a vast number of articles that deal with the use of physiological measurement in VR, mainly related to therapy, entertainment, training and simulation (**Angelini** *et al.*, 2022).

The manipulation of the senses and emotions will have effects on behavior (**Mandolfo** *et al.*, 2022). This is of interest for their potential application in various industries that employ sensory information, which can also be personalized (**Dincelli**; **Yayla**, 2022). Emotions and senses can affect attitudes, decision-making and attention. Studies have examined decision-making based on multiple stimuli in the metaverse (**Petit** *et al.*, 2022). VR must boost the emotional state of the individuals in order to provide high levels of presence; these high levels of presence, in turn, generate emotional involvement in VR. As we have previously seen, there is growing interest in integrating the senses into the VR experience through the use of auditory modalities; haptic interfaces for touch; movement and balance; auditory feedback for hearing; visual signals for sight; odor feedback for the senses of taste and smell; and usability, as they all affect the sensation of presence in VR.

The platforms can modify all types of visual and semantic aspects, as well as dynamic and interactive elements to produce certain emotions (**Dozio** *et al.*, 2022). There are many different mechanisms to boost user interest and engagement in the virtual environment, with personalization being a relevant factor. The use of avatars, peripheral devices and the manipulation of the virtual environment may affect the emotions and senses. Virtual agents and avatars may influence the emotions of individuals and increase the feeling of confidence and satisfaction (**Dincelli**; **Yayla**, 2022). There is still a great deal of research to be done on the enrichment of the emotional experience in the metaverse (**Angelini** *et al.*, 2022).

This study has detected a small number of articles in *Scopus* when using the search equation 'Neuroscience' AND 'metaverse' (n=2). Even though Computer Science and Engineering are the fields that most use the keyword metaverse, from a neuroscientific perspective, the articles on emotion, attention and cognition are written from an approach that addresses 'virtual worlds' and/or 'virtual reality', and thus would fall outside the studied sample (**Marín-Morales** *et al.*, 2018; **McCall** *et al.*, 2016; **Petukhov** *et al.*, 2020; **Pfeiffer** *et al.*, 2020; **Rockstroh**; **Blum**; Göritz, 2019; **Van-der-Ham** *et al.*, 2019).

6.2. Ethics and privacy

While the technology of physiological signals could improve future metaverse applications (**Angelini** *et al.*, 2022), alarms have sounded pertaining to privacy issues (**Egliston**; **Carter**, 2021). Contemporary virtual reality systems, including the most popular headsets offered by Oculus, or life-logging platforms like *Nike Plus*, have the capacity to track personally identifying biometric of users through wearable devices (**Egliston**; **Carter**, 2021; **Kye** *et al.*, 2021). Technology companies seek to acquire data concerning online and emotional behavior through biometric information that can be obtained by the various gadgets (**Knox**, 2022). Similarly, the technological innovation represented by neurotechnologies and BCIs opens up an ethical debate on mental privacy and the so-called neurorights, as well as neurosecurity. Once the current limitations have been circumvented, neurotechnologies, and in particular BCIs, could emerge in the consumer market. Future research may consider, in parallel to the development of the metaverse, the ethical and legal aspects that are represented by these advances (**Park**; **Kim**, 2022). Along these lines, the metaverse is called upon to become the setting for progress made in neurotechnology, and thus there remains a lot of unexplored territory to cover in the years ahead.

7. Conclusions

The metaverse is called upon to revolutionize the world as we know it. It is understood as a virtual world that is parallel to real life, which employs multiple technologies in order to provide immersion for users. However, the metaverse is not synonymous with virtual reality. It would be inappropriate to base its definition solely on hardware. It is necessary to discuss metaverses as a group of interconnected networks in which the user is central, and both the different technologies and the contents created for the platforms and the users themselves are necessary to build and maintain the ecosystem.

Nations are racing to position and prepare themselves for its adoption by the general public. Its capacity to generate a new type of *statu quo* must be kept in mind, and so countries will spend years analyzing the possibilities that are offered. Companies will also be affected by this new scenario. The metaverse promotes an ecosystem that transfers the economic activity to the virtual plane. Its emergence will modify consumer behavior and decision-making, as occurred with the emergence of the Internet. Nations, academia, companies and the mass media are called upon to reconfigure themselves in light of the possibilities of this technological future. To do this, it is necessary to advance in the knowledge and the implementation of innovative policies that do not lose sight of the social value of the technology and ethics.

Currently, research on the metaverse is mainly centered on the Computer Sciences and Engineering, and the platform *Second Life*. Due to the small number of articles on the metaverse in *Scopus*, it is possible to consider the research to be in its embryonic stage, especially in the fields of the Social Sciences, Marketing, Communication and Neurosciences. Academic studies have just begun and there is a lot of empirical work that lies ahead.

Once the limitations have been overcome for its advancement, research in the aforementioned fields will prove valuable in terms of allowing the adoption of technological innovations, efficient educational formulas, alternatives for consumption and new spaces for the knowledge and understanding of human beings. The results point to a technological transformation that posits a future with neurotechnology based on brain-computer interfaces and the metaverse as a possible scenario.

> "Technological innovation represented by neurotechnologies and brain-computer interfaces (BCIs) opens up an ethical debate on mental privacy and the so-called neurorights, as well as neurosecurity"

It should be pointed out that among the limitations of the study is the *Scopus* database itself, which despite being multidisciplinary, could have a bias in terms of publications in the field of Neuroscience, due to the existence of other specialized databases. However, the studies analyzed indicate that the use of the term metaverse, in the field of biomedicine, and specifically in PubMed, has expanded between 2020 and 2021 (**Huh**, 2022), and thus we can infer that the data provided in our research are in agreement with the evolution of this phenomenon in other databases.

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