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Research article

Virtual Reality Technology: Analysis based on text and opinion mining

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Abstract: The purpose of this research is to highlight the importance of periodically analyzing the data obtained from the technological sources used by customers, such as user comments on social networks and videos, using qualitative data analysis software. This research analyzes user sentiments, words, and opinions about virtual reality (VR) videos on YouTube in order to explore user reactions to such videos, as well as to establish whether this technology contributes to the sustainability of natural environments. User-generated data can provide important information for decision making about future policies of companies that produce video content. The results of our analysis of 12 videos revealed that users predominantly perceived these videos positively. This conclusion was supported by the findings of an opinion and text analysis, which identified positive reviews for videos and channels with many followers and large numbers of visits. The features such as the quality of the video and the accessibility of technology were appreciated by the viewers, whereas videos that are 100% VR and require special glasses to view them do not have as many visits. However, VR was seen to be a product which viewers were interested in and, according to Google, there are an increasing number of searches and sales of VR glasses in holiday seasons. Emotions of wonder and joy are more evident than emotions of anger or frustration, so positive feelings can be seen to be predominant.

Keywords: virtual reality; sustainable tourism; sentiment analysis; text mining; LDA; MaxQDA

1. Introduction

Constant market changes and the need for timely information force companies to use

appropriate differentiation and growth strategies that fit the needs of customers. The disruptive aspects of information and communication technologies must be taken into account in order to improve the adaptability of companies to unexpected events such as pandemics. It is also essential that companies consider improving traditional market research processes by using both intentional user-generated content (UGC) from sources such as social media, as well as unintentional user-generated content (UGB) like images and information from geolocation applications, etc. This study analyzes comments on videos on virtual reality (VR) technology and its applications in tourism and other fields.

This study analyzes user feedback on VR videos. These comments are an important source of information about user emotions and feelings which can be written [1–3] or conveyed with symbols such as emojis [4]. Comments allow the data to be analyzed to identify a range of emotions that are expressed with language that is not always expected.

It is important to use technology in the process of analyzing feelings expressed with online comments, such as content on social networks, and analyzing and optimizing resources with technology that incorporates collaborative economies [5].

Recent studies explore research conducted on virtual reality in the context of tourism, concluding that "VR has been applied in planning, managing, promoting, educating, and creating or transforming tourist experiences" [6], (p.17). [7] analyze the dimensions of online customer engagement and associated concepts in online customer reviews, finding a high impact of cognitive processing of engagement, dimension and hedonic experience on the customer review effort, highlighting the importance of companies listening to feedback and aligning with these expectations and turning them into competitive advantages. The adoption of virtual reality technologies promotes economic growth by creating new market opportunities, can shorten the product innovation cycle, increase product quality, reduce time to market, and consider consumer expectations in a joint process of continuous improvement [8].

The use of mobile technologies in stores has led to new services, where VR applications are part of technologies that have led to what is known as electronic commerce [9]. These practices improve the user's shopping experience, even making it possible to dispense with staff at points of sale. Marketing despite not being a new concept, there is a phenomenon that we are interested in knowing, the feedback from the customer of the product or service offered, even if it is tacit, we seek to address this gap through the use of technological tools that allow one to improve decision making and improve the B2C relationship, through the analysis of text and sentiment obtained from comments on social networks [10].

Moro et al. 2019 [11] believe that there is a lack of research adopting Big Data/machine learning approaches based on secondary data. Specifically, we have selected from a list 12 virtual reality videos from the social network YouTube, which allows users to upload or comment on the content of the same, through the use of technological tools allows us to a systematic analysis of the information provided.

An important aspect that becomes a limitation to cover in detail important aspects of feedback, mainly the one obtained from videos and making it difficult to turn it into competitive advantages, are the differences between the real environment and the online environment, the latter lacks some factors such as temperature, smell, texture, or people [12]. These stimuli of the senses have marked the progress of VR from its beginnings to the present day, factors that can become stimuli for reality scenarios with the evolution of technology.

We expect to find implicit or explicit factors in user comments, reviews that can be classified as positive or negative opinions about VR technology, infer which features of videos influence favorable or unfavorable customer perceptions, visualizing suggestions for companies that generate VR content can create or change the focus of company strategies [13].

Knowing the user's feelings about the product allows the changes that increasingly demanding technological consumers expect to be quickly incorporated while respecting sustainability, which is a great challenge facing the world [14]. Technology platforms help reduce the number of resources, seek to reduce the environmental impact, and are considered a driver of sustainability [15]. An increasing number of users prefer green or sustainable products [16], leading to the emergence of green consumers that incorporate all dimensions of sustainability into their experiences [17].

The present study attempts to: (i) highlight spontaneous verbal reactions to videos conveying positive or negative emotions, as well as the language used; (ii) understand which attributes of virtual reality are most effective in terms of VR video user satisfaction; (iii) identify emotions in the messages generated by users after watching VR videos; and (iv) check in the comments to the videos if it is evident that virtual reality can be a substitute for a real tourist experience. To address these objectives, we used text mining using R software, we consider it the best way to analyze the content of more than 14,000 comments expressed by users for the set of selected videos, and we also performed an opinion mining and trend analysis, in search of timely information for the objectives set. This technique allows us to process a large amount of unstructured text, by categorizing and grouping text and sentiment analysis (attitudes, opinions, and general emotions of customers about a product or service), among others [18]. These analyses are performed considering reviews and comments published online [19]. This study addresses the following research question:

RQ 1: What are the feelings and opinions of the viewers of VR nature videos about using virtual reality?

RQ 2: What are the perceived components of VR in video feedback?

RQ3. What is the trend in virtual reality in relation to real life experiences?

RQ4. What are the predominant emotions?

RQ 5. What are the topics around which the comments are grouped?

This article aims to contribute to the academic literature with research work on the role of virtual reality in a better understanding of the life of nature. Virtual reality videos on a public social network like Youtube can help users feel virtual experiences in virtual reality technology such as 4K, 360, VR180 and others. Furthermore, this VR technology would preserve a national park and would not disturb wild animal life, and therefore would award deterioration of natural spaces.

This article is organized as follows. The theoretical basis is presented in Section 2. Section 3 describes the methodology used in this study. Section 4 presents the results, which are discussed in Section 5. The conclusions are set out in Section 6.

2. Materials and methods

2.1. Virtual Reality

VR is a technology that allows for an immersive experience of two different realities, through the use of a helmet with stereoscopic screens [20]; achieving the user to interact with a virtual

environment through the multiple devices available, ranging from a keyboard, to suits, which seek to deceive our brain to stimulate the senses and perceive as real that environment.

For the purposes of this research, VR is defined as "A computer-simulated environment where one interacts within the environment similar to how one would in the real world" [21].

This technology brings with it a history of success and applications in multiple fields such as e-Commerce [22]; in education [23]; and many others. What makes it particularly interesting in our view is its ability to lead us to a parallel world through devices that are frequently enhanced [24]; and to the extent that more senses are stimulated, a greater sense of immersion is achieved through multisensory experience [25]; achieving the sensation of interacting in that virtual environment.

The origin of virtual reality technologies dates back mainly to the work of Morton Heilig and Ivan Sutherland from 1960 [26]; although we find important data that precede it, such as the creation of the stereoscope by Sir Charles Wheatstone in the year 1838, this invention consisted of a device that presents a double image that our brain mixes and visualizes as one. The term Virtual Reality emerged in the 1980s, coined by Jaron Lanier who used the expression "virtual reality", it consisted of a head mounted display (HMD), data suit, and gloves attached to a computer.

The use of images generated through this medium has been commonly used, which increasingly enables the emergence of new and improved VR devices that are affordable for the user [27,28].

In 2014 virtual reality is growing, after the birth of Oculus, prototypes of virtual reality glasses start to be developed by large companies, and by 2016 new and improved devices were launched in the market, such as: Samsung Gear VR, in addition, important brands announce their devices with a wide amount of options to be used in different fields such as medicine [29]; optimizing complex products in process design [23]; military training [30]; and tourism, seeking to understand how to effectively market tourist destinations [31]; among others.

2.2. Data Mining

The term data mining refers to a set of techniques and technologies that make it possible to explore large databases, automatically or semi-automatically. Its objective is to find repetitive patterns that explain the behaviour of these data.

These techniques are used in many scientific and technological fields, such as the use of comprehensive classification and evaluation systems with lexicographic genres, such as WiPO Pearl [32], which is a complex terminology tool that supports ontological tools for searching terms in addition to traditional linguistic search methods.

Other research, software as MaxQDA, data in text form is processed, it allows qualitative data analysis, providing a lexical approach with the evaluation of metrics for opinion extraction, being able to organize and categorize any type of unstructured data, search for information, test theories and create illustrations [33]. Previous studies have used the software to download and analyze the dataset, converting unstructured text into codes, memos, categories that allow text mining and opinion mining, for example, [34–37].

We have focused our interest on the context of tourism, seeking to understand consumer behavior, through reviews and recommendations in our case comments on VR videos, especially if we want to influence the purchase decision of a destination, which is related to any positive or negative statement made by potential, actual, or former customers about a product / service or company, and is available through the Internet [38].

Several publications applied context analysis and data mining in different researches, such as

online feedback and satisfaction in hotels [39,40], startups [41], retail [42,43]. Other articles demonstrate the role of social networks in the development of recruitment actions that favor user interface design and conversions in mobile applications [44], especially in thought apps from the tourism sector [45].

Feedback is a way to interact with the company in the improvement or co-creation of products; it is an unstructured language that must be transformed into knowledge by management, technologies create value through new customer experiences and through interactions between customers [10].

Social networks allow companies to communicate with their potential customers, hence the importance of creating social content considering creativity, emotion, and passion, attributes that engage users of social networks [33]. People can share their experience and information with other users; this can affect purchase intention [46].

Online comments expose the emotional states and thoughts of consumers when they think about the company or the brand (product) [47]. Recent studies have used videos from the social network YouTube, [48] study whether virtual reality affects behavioral intention, for this they use a K-Pop video on YouTube, they highlight that virtual reality videos of celebrities on YouTube influence users' engagement processes, and in addition, virtual reality videos on YouTube have the potential to connect with celebrities (immersion and telepresence). [49] study virtual reality experiences in nature, such as watching wolves on YouTube, investigate aspects such as presence, emotions, and attitudes in immersive and non-immersive environments, find that immersive technology could induce interest in a test-related nature experience, and the findings suggest that 360° videos using immersive technology provide experiences with positive affective learning outcomes. [1] used the titles of videos uploaded to YouTube, since, on social networks, information about the law to force children to have mandatory vaccinations for school attendance, this fosters a fierce discussion between pro-vaccination and anti-vaccination people. Sentiment analysis shows that the intense vaccination campaign also promoted by physicians pushed sentiment to shift polarity from a negative to a positive opinion. [50] use YouTube content for analysis of cannabis vaping videos and [51] use YouTube content to explore trends in nursing start-ups, using text mining in one of their stages, finding that to foster nursing start-ups, business skills such as finance and budgeting need to be strengthened and active political support needs to be established.

Social networks help users establish friendly relationships and informal communication, as well as instantly and easily share their thoughts, feelings, and opinions [52]. Through user comments on products, spam, or news dissemination, online opinions have a high potential for information analysis on a topic or product of interest [53]. There is evidence that the user-generated customer reviews are more trusted than those posted by the seller [54]. Consequently, users' opinions have been studied using sentiment analysis (SA) and text mining (TM), both of which are popular methods to discover the valence of written texts [55,56]. The amount of information available online is immense and it is difficult to obtain valuable information without a relevant technique that analyzes patterns [57]. In this respect, both SA and TM are very useful. TM searches for automatic data patterns while processing the language used; it also enables evaluating the degree of association, keywords, keyword phrases, concept hierarchy, semantic networks, classification rules or prediction [58]. In its turn, SA can help identify and classify emotions in the analyzed texts as positive, negative, or neutral [55].

The TM approach involves a process of organizing, editing, and analyzing large amounts of unstructured text information to discover associations between features, provide specific information

for users who need it, and to find and extract knowledge from the data [58]. In essence, TM consists of extracting data from documents to obtain useful information from those documents [59]. The data are then converted to a document using the matrix (DTA) where each column represents a term, each row represents a document, and each cell shows the frequency of a given term in the analyzed document [60]. In an analysis of social network data using TM, [61] found three main groups and explored the sentiments for each group. The TM approach was also used effectively to analyze unstructured online reviews [62], production output, as well as chemical, biological and patent information [63].

The SA approach is used to explore emotions in written texts. Typically, SA is based on one of the following two approaches: (1) automatic sentiment classification using an algorithm or (2) lexicon-based classification using dictionaries for sentiment classification in text [64]. These approaches are used to describe the attitudes, experiences and opinions of users about a product, and these insights generate valuable information for companies in terms of identifying potential buyers [65]. Using the SA approach by monitoring social networks or online discussion forums can change the way companies measure consumer opinions [58]. For example, [66] used SA to measure sentiments expressed in reviews of online content. Similarly, [67] used SA to better understand public attitudes towards autonomous vehicles.

3. Methodology

We followed the procedure previously developed by [68] and [69] to study user-generated content in the tourism industry. The data was collected from YouTube videos that are freely available to the public. Our specific focus was on videos with informative VR topics related to tourism, sustainability and high-quality VR content, as these videos attract a large number of viewers from different countries or regions, and the results were expected to have high external validity [70]. To find the videos, the following keywords were used: virtual reality tour, VR travel, sustainable tourism, VR 360, VR experiences, virtual vacation, virtual tourism, sustainability, changing planet, VR nature. Relevant videos are selected according to the number of views, topic of interest, and number of comments. The final data set consisted of a total of 12 videos. Selection criteria are summarized in Table 1. The videos included in the analysis are shown in Table 2.

For this research was important in the first term topic of interest. Virtual reality videos with different focus on nature, wild animals, special protect species, natural monuments or planets were discarded because they did not provide real life experiences. However, the number of views and comments was very important because the applied method requires a sample. The results were better with a lot of comments. The number of views was a quality of the criteria related to popularity. The length of video is a critical question to avoid abandonment of video pages. Finally, users prefer short videos, and this criterion is a condition for obtaining successful visits.

Video data mining was performed between November 2020 and March 2021. To ensure that the comments analyzed were related to the information contained in the videos, rather than the thoughts and feedback of the users to the conversation threads, we used two software programs MaxQDA 2020 and R.TeMiS. The collected data set of comments consisted of 5857 comments posted between March 2014 and March 2021. The comments were processed using MaxQDA 2020 software [71], which performs qualitative data analysis and derives quantitative information through a series of metrics [72]. To this end, the categories form codes. These codes and categories facilitate the evaluation of texts, videos, audio files, and images in the opinion-mining or sentiment analysis

process. The main codes for the virtual reality category were as follows: nature, environment, tourism, heritage, accessibility, age, education, awareness, simulation, physical disability, love, glass, quality, experience. The categories obtained were opinion on videos, language, sustainability, ecology, among several others.

Table 1. Search criteria for video selection.

Search strings	Filters			
	Length of the video	VR Technology	Sort by	Channel
"virtual reality nature" OR "virtual reality tourism nature" OR "virtual reality sustainability nature"	< 4 mins.	5.7K OR 4K OR 360º OR VR180 OR 3D	Relevance AND Views	> 50000 followers

From the searches, we classified the results into the following types of videos (see Tables 2–3).

Table 2. Video nature VR classification.

Main channels	Nature Classification			
	Subject	VR Technology	Followers	Comments
Balu	Niagara falls, forest wildlife or birds lagoon	VR180, 3D	464,000	207
Airpano VR	Salto Angel, Venezuela	360º	302,000	2,758
ECOVR	Dive great barrier reef	5.7 K for oculus quest	42,100	27
National Geographic	Animals at risk of extinction: Tigers, Lions, Elephants, Orangutans, Forest: Giant sequoias… Waterfalls: Victoria Extreme places: Antarctica	360º	17,2 millions	5,876
Animal Planet	Elephants	4K, 360º	4,99 millions	86
At home in Wild Spaces	Giant forest sequoia	360º	130,292	169
BBC Hearth	Tourism Nature: forest in the Scottish highlands, baby turtles or bears brave	VR180	9,25 millions	498
Qantas	Hamilton Island	360º	102,000	731

Table 3. Environmental classification of videos.

Main channels	Environmental Classification			
	Subject	VR Technology	Followers	Comments
We the curious	Astronomy: Tour of six real exoplanets	4K, 360º	90,000	5,221
David Addis	Chernobyl VR	VR180	6,052	27

As a second evaluation criterion, text mining was used. To the end, online comments were preprocessed by removing nonrelevant words such as "the" or "and", numbering, punctuation, white spaces, HTML tags, as well as by converting words to lowercase and using the root for words with the same meaning, but with different suffixes and prefixes to avoid noise in the dataset [73,56]. Since we sought to establish patterns from an unstructured collection of comments on videos after the debugging process, this analysis included not only natural language searches with the support of Boolean operators, but also information behind text, keywords and phrases [74]; our purpose was to find useful information for decision making that is not explicit and has minimal human intervention or interference [75].

For text mining analysis, we used a free software program called R-Text Mining Solution (R.TeMiS) [76,77]. This package R makes it possible to create text sets, analyze and manipulate them [78]. Additionally, the R-Code libraries 'syuzhet' [79,80] for emotion analysis and 'sentimentr' [81,82] for sentiment analysis were used. The classification of topics was supported with 'LDA' [83].

Through, the use of algorithms and statistical techniques, this approach enables obtaining the first data to later verify and evaluate the results [84]. Table 4 shows the videos selected based on our search processes.

An important aspect to consider when analyzing VR video feedback is consumer behavior in terms of how they view the videos, which is difficult to clearly identify in the information provided by users. There are many options on the market, both for beginner and expert consumers, the differences go beyond price, although the higher the cost of the device, the better the immersion and interaction with VR. Many high-end virtual reality glasses use a six-degrees-of-freedom (DoF) tracking system, allowing you to move freely, crouch, jump, dodge objects, walk in different directions, interact with things in the virtual world even with both hands, offering a better experience.

They are models with important features to highlight, such as sound quality, isolation from the real world, and better resolution, allowing a sharper and more realistic image, ability to know the scale of the room and hand tracking, allowing the location in that space which makes the images are seen immediately and the fluidity of movements in the parallel virtual world is achieved in a natural and realistic way, the major manufacturers in the market offer us many options and constant innovation, as an example, two high-end models are Oculus Quest 2, HTC Vive Pro. Table 5 shows general data by video type on Youtube.

Table 4. Videos selected for the study according to VR type on YouTube.

Name	VR Type	Date	Visits	Comments	Like	Dislike
5.7K, 180º VR video set						
VR180 Virtual Dive Great Barrier Reef Underwater for Oculus Quest	5.7K, 180	06/03/2020	68,126	27	918	44
5.7K, 360º VR video set						
Virtual Nature Meditation for Oculus Quest	5.7K, 360	20/05/2017	6,061,118	1635	87,716	4,922
4K, 360º VR video set						
Surrounded by White Lions - 4K 360° VR	4K, 360	26/11/2018	11,776,037	1,921	63,548	8,449
Travel Without Leaving Home	4K, 360	08/07/2018	513,008	1,026	9,530	374
Take a Virtual Reality tour of six REAL exoplanets	4K, 360	22/09/2017	12,832,154	4,938	184,514	7,486
360°, Salto Ángel, Venezuela. Video aéreo en 8K	4K, 360	10/04/2017	145,000,000	2758	134,888	7,608
Visit Hamilton Island Virtual Reality with Qantas	4K, 360	29/08/2015	6,076,458	731	17,778	2,076
4K, 180º VR video set						
The Amazing Niagara Falls in VR180! - 3D Virtual Reality Experience	VR180	18/07/2019	598,563	117	4.632	413
Peaceful Lake Views in VR180 - Relaxing 3D Virtual Reality Experience with Calming Music	VR180	28/08/2019	185,044	50	1,276	159
Beautiful Forest Wildlife in Deer & Elk - Relaxing 3D Virtual Reality Experience ES	VR180	24/08/2019	520,449	90	3,422	413
VR 180 virtual reality tourism nature Unwind In A Forest In The Scottish Highlands	VR180	12/12/2019	104,364	82	1,607	130
Virtual tour of the reptile zoo!! All my reptiles!!	VR180	28/07/2019	128,195	1,075	5,578	229
Total			**183,863,516**	**14,450**	**515,407**	**32,303**

Table 5. General data by video type on Youtube.

360º video
360º videos do not include virtual reality. To enjoy VR it is necessary to have a specialized device, which includes the option to visualize in all directions within this parallel world. To move the images in the 360º video, it is necessary to move the cell phone or move the image with the finger. While in VR technology, you can interact with all the internal resources of that reality, going through the different places shown in the fictitious environment. The 360º videos consist of images or videos that show our surroundings, they do not allow complex movements or at different angles. This format collects the images from the camera to all the surrounding directions. In a 360-degree video, all pixels form the whole scene, therefore, the field of view covers a part of these pixels.
4K, 180º VR video
It is a virtual reality format where content is limited to offering a 180-degree field of view, focusing attention on what is in front of the viewer. VR180 cameras capture videos and photos in 3D, but they can be shared in 2D or 3D and can be viewed with inexpensive glasses, for example, Google Cardboard headset, To record these videos, one of the options is to use a monopod as a camera support, some of them have 250º of amplitude so it is important to avoid distorting the videos with vertical shots.
4K, 360º VR video
The most relevant feature is basically the resolution of 4096×2048 pixels. 1K=1000 pixels. The pixels are divided among the entire horizontal plane. If our field of view is an angle of 120 degrees within that horizontal plane of 360, we have vision of a third part, with a resolution of only 1.33K pixels, so we need a resolution of 12288 x 6144 pixels or 12K to obtain in each field of view the 4K pixels and a better quality of the image in the video. These formats are generally presented with 30 FPS, this measure represents the frames per second, that is, the amount of images that we need to join one from another to create a second of video, so that our eyes can perceive a smooth and fluid movement in the video; it is required to distinguish individually amounts greater than 12 images per second. Another aspect to consider is that the 30 FPS that make up the minute of video may have different shutter speed, that is, the amount of time we expose each of the images that make up a minute of video, for example, 1/30 means that we expose 30 images per second, if we use a higher amount 1/60 we can only expose 30 images per second. At the end we obtain an equirectangular image (flat representation of a spherical view), with the help of software it is transformed into videos with this format.
5.7K, 360º VR video
This format achieves a resolution of 5760 X 2880 (about 16.58 million pixels). It allows recording at 60 FPS.

4. Results

4.1. Sentiment analysis

First, we explored the data set to identify the feelings expressed by users through their comments. Specifically, we look for positive (favorable), negative (unfavorable), or neutral (neither for nor against) opinions towards VR videos. Figure 1 shows the results on the opinions of the users. Most users positively evaluated the videos, as suggested by a total of 44,559 positive comments on the analyzed videos. Relevant positive terms to convey users' feelings about the videos were 'amazing', 'wow', 'awesome', 'fascinating', 'this is so cool", "love it"; similarly, words and expressions that highlighted users' experiences with 360-degree videos included 'it' possible, 'this was a great experience', 'I love 360 videos'. Users who negatively evaluated the videos argued that they did not perceive them as more realistic content or did not like it. Examples of relevant expressions were as follows: "the video shows how it would look like not how it actually looks like", "see the same with fake images of home", "I felt strange watching it, "it was uncomfortable", mentioned that they are unable to appreciate the quality on their devices, "I expect higher quality", "this is not a vr video", "bad quality, even though it is 4k", "no it is not even split screened", "this should have thumbs down".

This negative evaluation of the videos by some users may be due to differences in the access of users to technology: While some users used their cell phones, others had glasses. Furthermore, a small group mentioned having VR technology and accessories such as headsets and helmets, and these users experienced frustration (e.g., "not running... How do i move the angle of view?", 'bc it's not loading"), anger (e.g., "even if we were in a VR, who cares?"), questioning (e.g., "how can you have a VR tour of something real? Why VR? Today You don't have to imagine"). Some users mentioned that they would rather look at the stars than experience something they did not consider real or that some parts of the video content made them feel nauseous. Users in a neutral position indicated that they did not perceive a realistic feeling, mainly in the videos that were not 360 degrees, but recognized the quality of the content, mentioning that they did not like the voice or the accent, but that the content provided them with a VR experience that motivated them to know the destination (e.g., 'Never tried VR but manually spinning the screen is already BA', 'you can also have a phone, but it will depend on what kind of Divac you have").

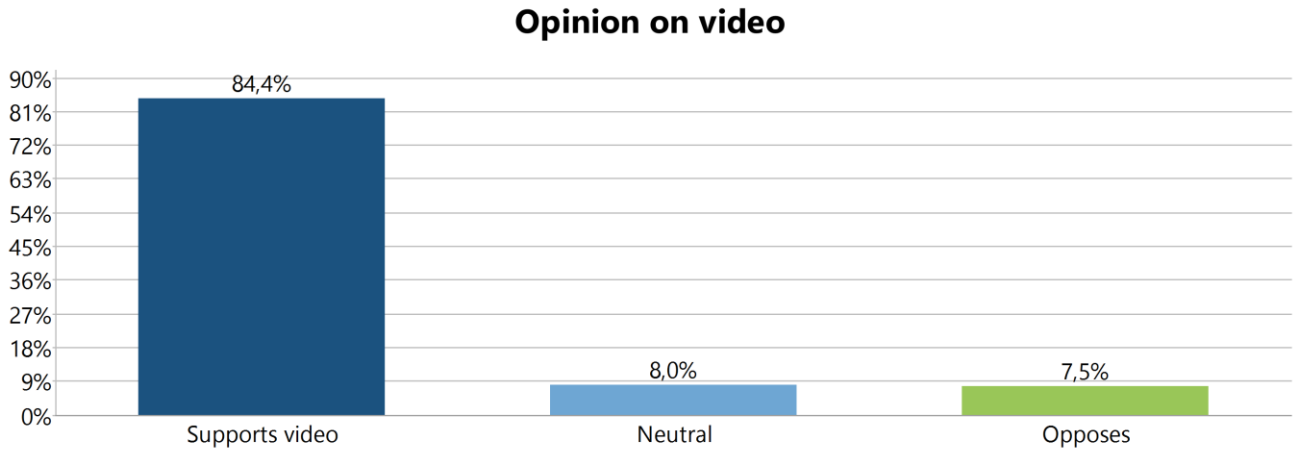


Figure 1. Polarity in Video Feedback.

Second, we analyzed the language used in the comments. As can be seen in Figure 2, the most frequent category of user comments was questions related to videos. For instance, users asked

whether the content was possible in real life or whether it was more simulation; some users asked how such a realistic sensation could be achieved, and what accessories they could use considering their possibilities and location. The second most frequent category of comments was jokes. Some users joked about perceived sensations such as being in hell, added links indicating that they had millions of views, or suggested stretching the images to 360 degrees in lower quality videos. The third group of comments consisted of reasoning statements. In relevant comments, users argued about immersive experiences, as well as whether glasses like cardboard could work with 360 videos; they also wondered why people disliked videos with excellent content and quality, or whether users were only interested in watching strange content, rather than informative content; some users also considered possible reasons for their negative experiences with videos (e.g., "the screen does not rotate when i turn the phone but it only rotates with the finger", "need to have gyroscope sensor", "have to swipe the screen to look around"). The fourth group of comments included insulting statements that expressed the disapproval of VR users.

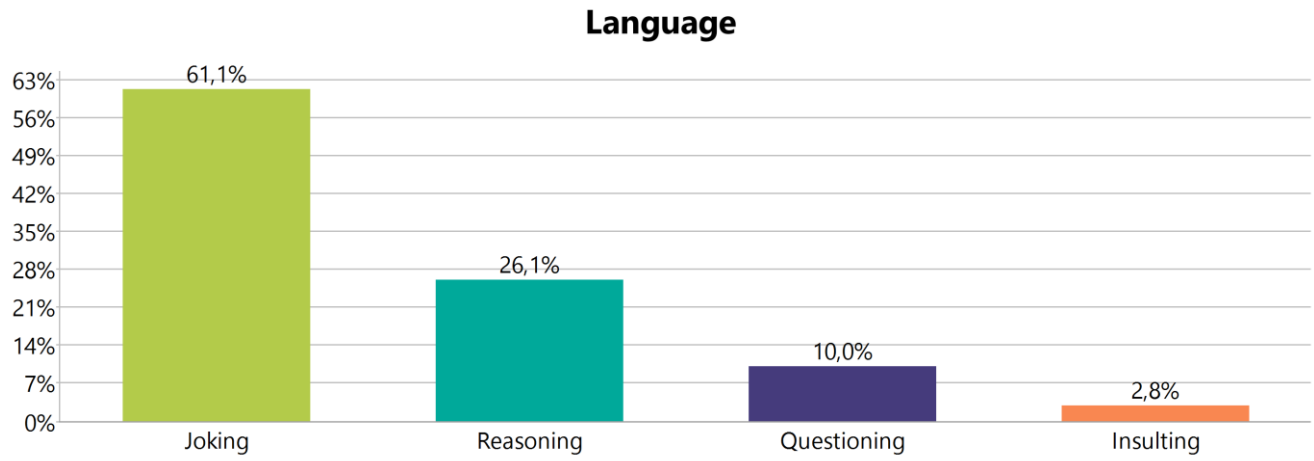


Figure 2. Language used by video users.

The third aspect we analyzed was the importance of sustainability for VR videos; here, our objective was to find out how users' feelings about the videos would influence their tourism activities or their interest in the protection of nature. The results revealed users' feeling of responsibility for national park conservation, their interest in raising awareness of the importance of virtual reality for the protection of nature, and users' desire to start more sustainable businesses. There were also users who expressed concerns about sustainable economic development and tourism (Figure 3).

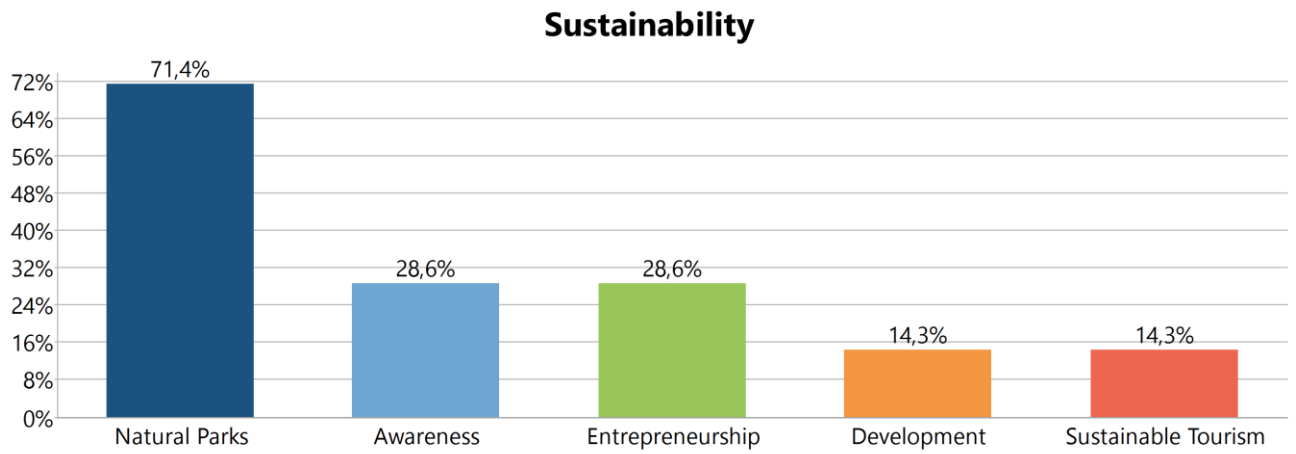


Figure 3. Perception of sustainability in video feedback.

The fourth aspect we analyzed was the main components of VR that users perceived and discussed through their comments. As shown in Figure 4, education, defined here as the desire to learn more about this technology, was of greater importance, followed by user experiences, which they found incredible. As for the simulation of virtual environments, most users through that, a great job was done to recreate scenarios. The quality of the videos was perceived mostly positively. As for access to technology, the evaluation of users varied greatly between regions: While some users considered the cost very high and unaffordable, others considered that it could be obtained for very low prices; therefore, users' perceptions of the affordability of technology varied depending on the country of origin of the user. The use of virtual reality for the promotion of tourism was not among the components mentioned most, but many users wanted to know more about their towns and their attractions; finally, some users felt that the videos of their country did not show the places that were important to them.

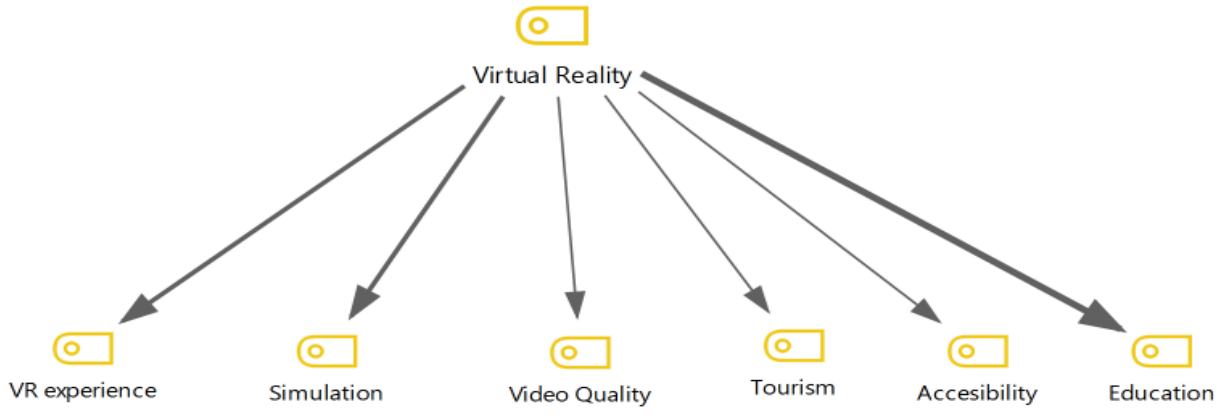


Figure 4. Perception of VR components in video feedback.

4.2. Trend Analysis

The first stage of this analysis consisted of querying search terms typed by users in the Google

engine [85]. It is commonly assumed that user searches on Google, their activity on the Web, and their use of various applications can be a very rich source of information for text mining analysis. Consequently, once we typed 'Can virtual reality...', the Google continuation suggested was '... be a substitute for real life experiences' (see Figure 5). This indicates that there have been many searches related to these research objectives.

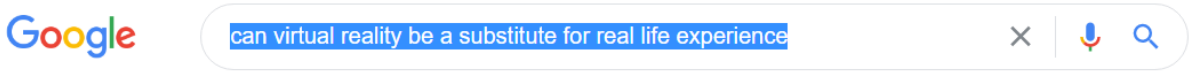
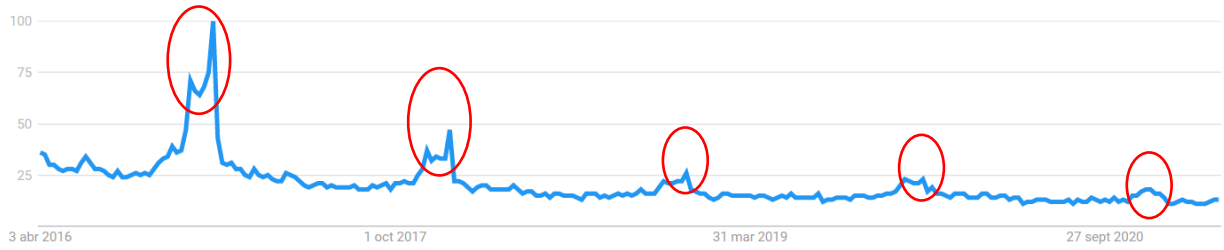


Figure 5. Results of the use of Google Search Engine as a predictive tool.

We also used Google Trends to see trends in searches for the term 'virtual reality' in the period 2016-2021 (see Figure 6).



Source: Google Trends

Figure 6. Searches for the term “Virtual Reality” in the world (March 2006-2021).

As can be seen in Figure 6, the peaks in the searches for this term occurred on December 25-31, 2016, December 24-30, 2017, December 23-29, 2018 and (with less intensity) in the following two years. This result is directly related to the Christmas holidays, when Oculus Quest sets are frequently presented as gifts. The words associated with the searches were in the following order: "oculus quest", "dream vision virtual reality", "utopia 360 virtual reality", "cynoculars virtual reality", and "oculus quest 2".

The countries where the most searches were made included USA, Canada, New Zealand, Australia, St. Helena, United Kingdom, Denmark, Man Island, Netherlands, Singapore, Zimbabwe, Ethiopia, Ireland, China, Bahamas, Malta, and Jamaica. This suggests that countries with huge natural areas are very interested in VR. Interestingly, the four countries with the highest number of searches were St. Helena Island, Man Island, Zimbabwe, Ethiopia, or Jamaica. We attribute this result to the fact that island countries have VR videos on their coasts and natural spaces, and also to the fact that Zimbabwe or Ethiopia have developed wildlife nature tourism.

In addition, we also analyzed Wikipedia searches (see Figure 7). Although the results were correlated with the Google trends results (Figure 6), an interesting finding was obtained for the period of the COVID-19 pandemic. While, in September 2020, there was a drop in the number of searches, since then, the interest of users in VR has skyrocketed (see the red arrow in Figure 7).

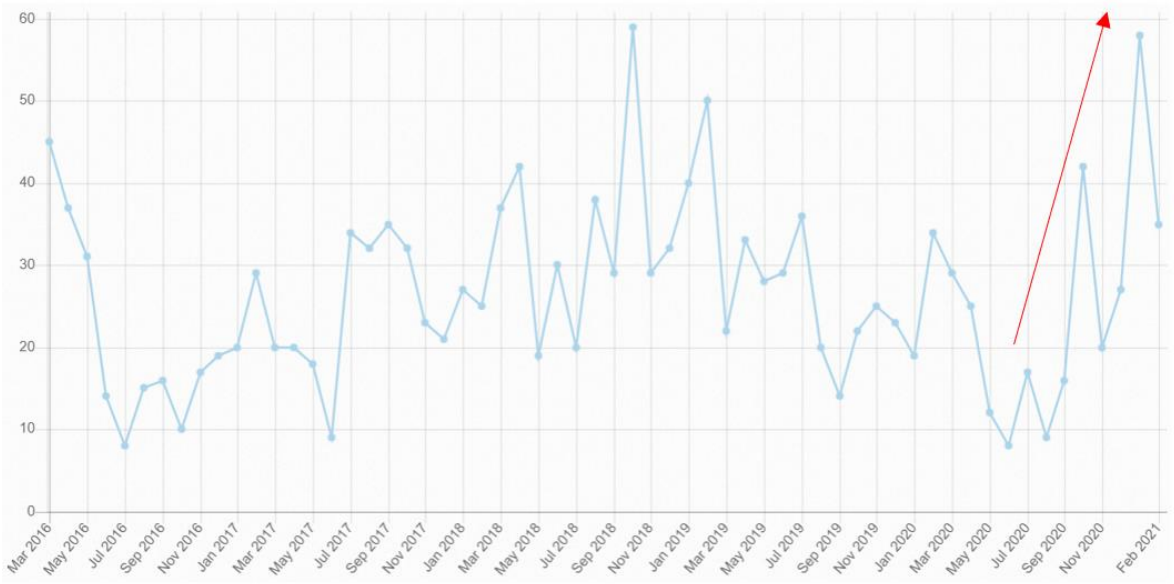
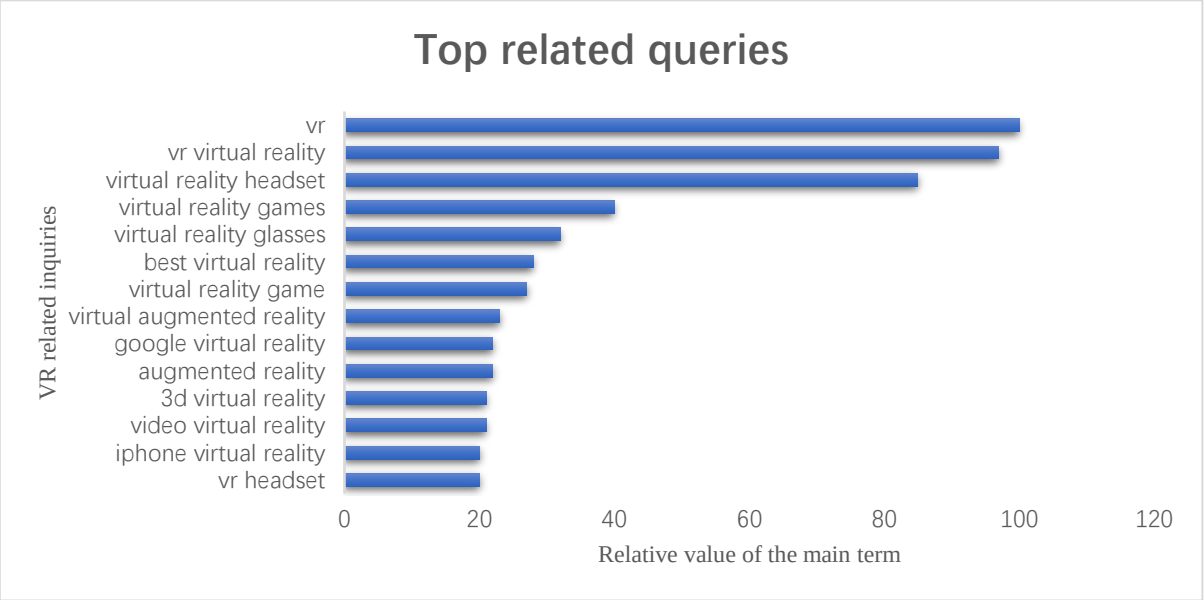


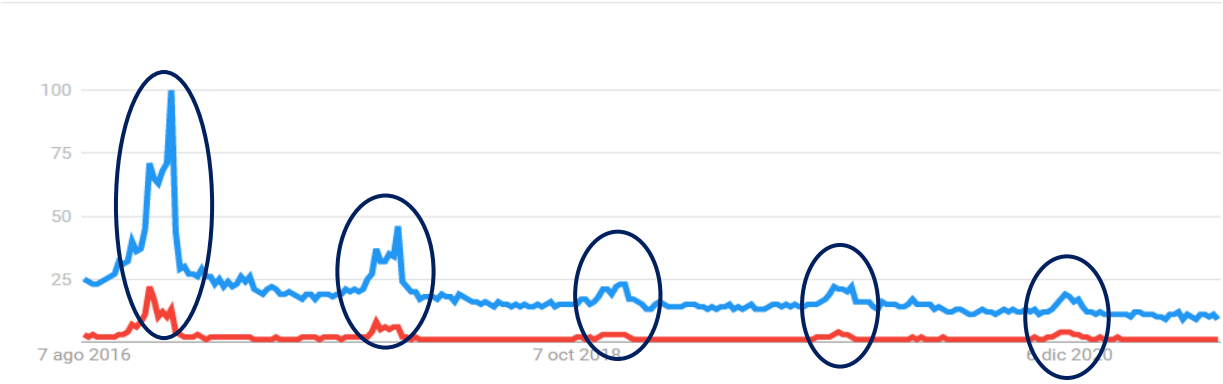
Figure 7. Wikipedia searches for the term 'Virtual reality' (March 2016-2021).

Trying to find other alternative explanations for these correlational results, we analyzed the main searches related to the term VR; these results are shown in Figure 8, highlighting the searches related to VR equipment as a headset and those related to video games. Games like "Skyrim" or "Fallout", or virtual reality versions of "Doom", have driven the advancement of technology, but some of the VR viewers with greater capacity to achieve an immersive environment, have been somewhat slow; this, together with the constant innovation and launch of devices from major manufacturers, may influence the relationship that we see in Figure 9.



Source: Google Trends

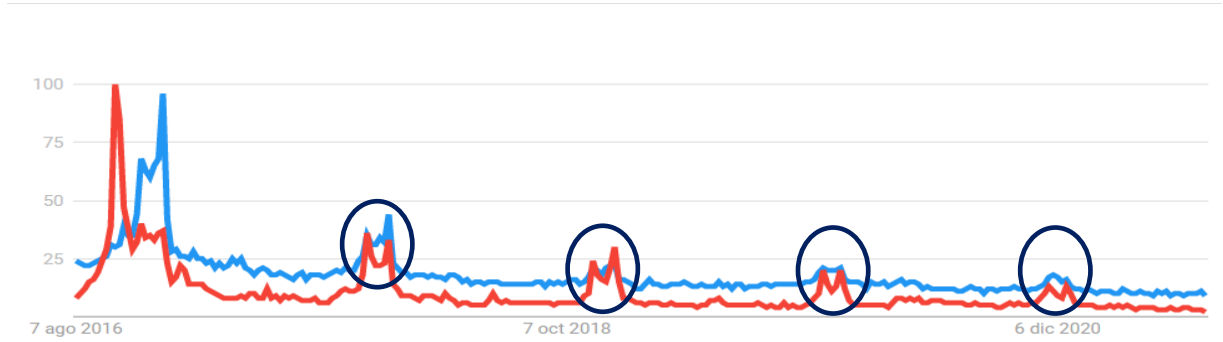
Figure 8. Searches of VR related inquiries in the world (August 2016-2021).



Source: Google Trends

Figure 9. Searches for the term 'Virtual reality' in blue and 'Virtual reality headset' in red, all over the world (August 2016-2021).

In the gaming industry, PlayStation VR has an advantage thanks to its lower cost, compared to market options such as the Oculus Rift system, games on social networks, computers, consoles or mobile devices. use devices that seem futuristic, due to the various means of interaction (special glasses, motion sensors, virtual headsets). It is a growing market that involves electronic sports, even with the opportunity to compete and interact in championships with prizes that exceed $100 million and whose public is anywhere in the world, hence the importance of offering the latest applications, and the generational change of consoles. And the recent launches such as Sony's PS5 and Microsoft's Xbox Series X, without leaving aside the advances of the last years of the main industries such as Samsung, Apple, GoPro, Nintendo Co. Ltd., HTC, among others. The VR in Gaming and AR in Gaming market is present in five major regions, Europe, North America, Latin America, Asia Pacific, and the Middle East and Africa. In some of these regions, with the arrival of winter in December, people plan their vacations to travel to warmer destinations, or take advantage of the time at home for relaxation and entertainment, with VR videos and games being an excellent alternative. In Figure 10, we see the historical searches for virtual reality and PlayStation, one of the main consoles in this industry.



Source: Google Trends

Figure 10. Searches for the term 'Virtual reality' in blue and 'PlayStation VR' in red, throughout the world (August 2016-2021).

4.3. Text Mining Analysis

Using textual analysis [76], we can perform operations typical of lexical statistics (e.g., measurement of occurrences and cooccurrences of terms) and textual data analysis (e.g., hierarchical ascending classification and factor analysis of correspondences). With TA, we can also construct a matrix of documents (rows) and terms (columns) so that the frequencies (occurrences) of each term in each document are observed in the cells [86].

We performed the classification of the corpus documents as follows. We used the text of the "comments" field of the analyzed YouTube videos, thus using the text of each comment and statistically analyzing the remaining fields, such as "channel name", "number of likes", "number of answers", "superior level" and "date". The superior level field allowed us to establish whether each comment was a first-level comment or a reply. The multivariate techniques used to classify the research topics were hierarchical clustering and correspondence analysis.

Cluster analysis is a multivariate technique that aims to group elements (or variables) to achieve maximum homogeneity in each group and the greatest difference between groups [87]. The dendrogram is the graphic representation used to interpret the results of the cluster analysis.

The steps followed to compile the video comments using MaxQDA are shown in Figure 11.

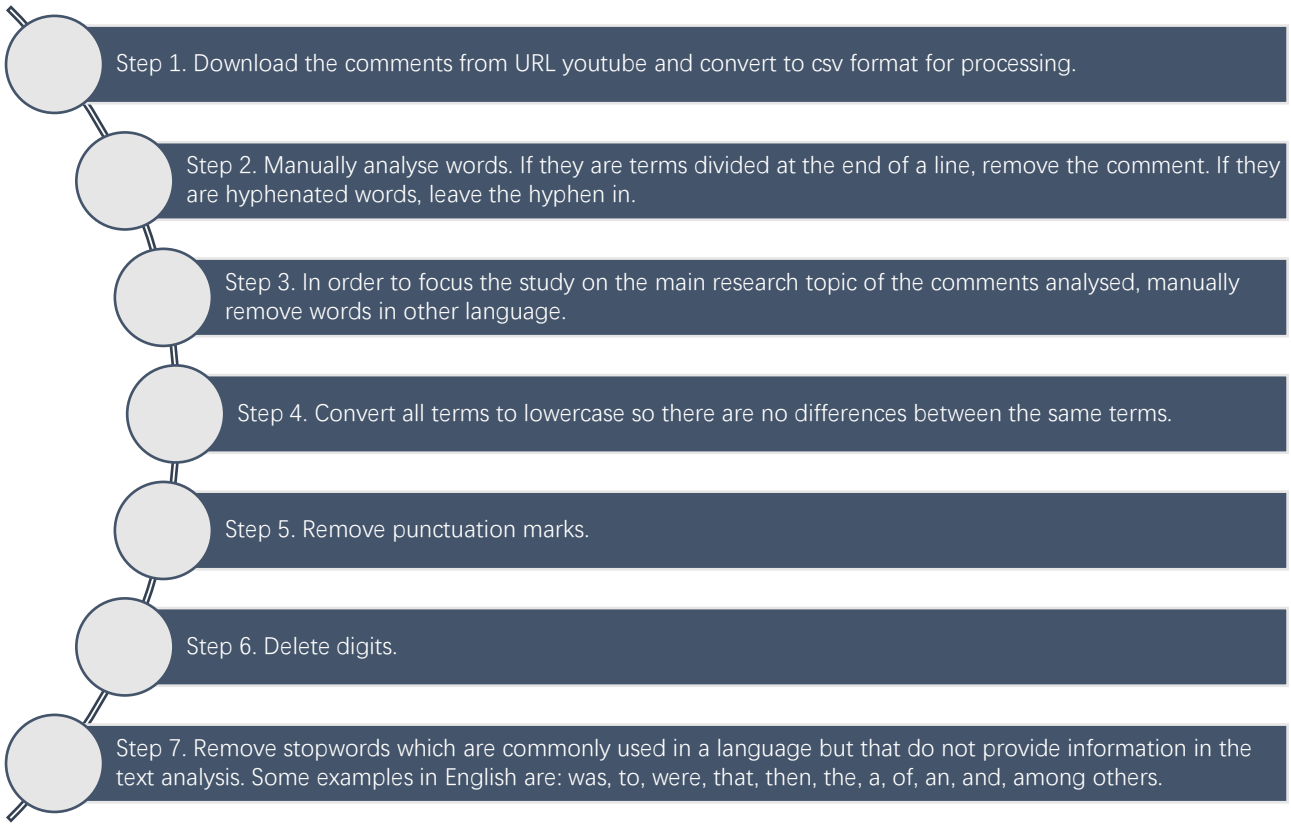


Figure 11. Steps of the Data Collection Process.

4.3.1. Field analysis of comments

The complete corpus downloaded from YouTube included a total of 5,857 comments/documents

for the 12 selected videos. Table 6 shows the complete corpus, while Figure 12 shows the distribution channels.

Table 6. Complete corpus.

Non-/sparse entries	Sparsity	Maximum term length
31684/30752708	100%	94

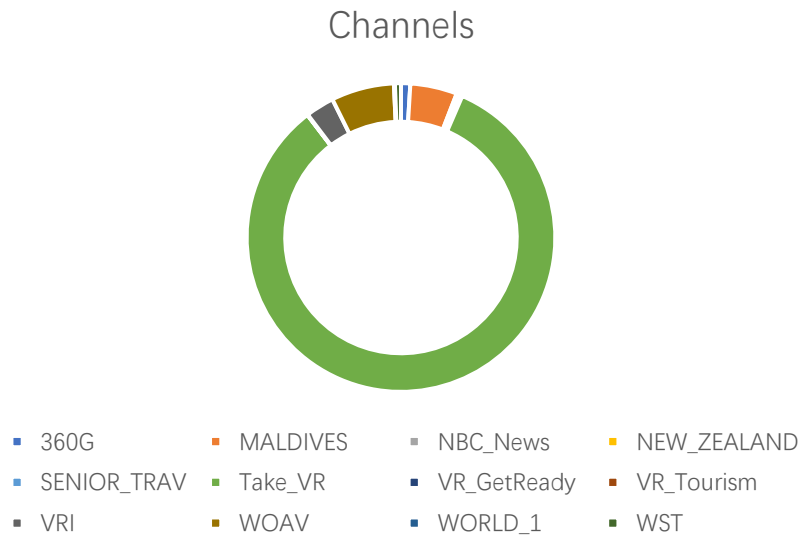


Figure 12. Channel distribution.

4.3.2 Hierarchical clustering

Hierarchical clustering was performed on the data set. Hierarchical ascending clustering, also called agglomerative or cumulative hierarchical clustering, was performed according to Ward's minimum variation method, which uses the chi-square distance [77], a procedure that joins, at each step, the two clusters for which there is the smallest increase in the total value of the sum of the squares of the differences within each cluster from each individual to the centroid of the cluster [88]. Terms appearing in more than 99% of cases were eliminated, and two dimensions were identified. We then eliminated 1,603 comments that did not meet this requirement.

The bar graph obtained using hierarchical clustering is shown in Figure 13.

Of the total number of documents, 6 groupings were created according to the following parameters (see Table 7).

Table 7 shows the validation statistics for the maximum number of clusters, a step after the detection of the most frequent terms, where we obtained 6 clusters applying Ward's minimum variance method with the chi-square distance [89]. Table 7 shows the most interesting groups from the point of view of the number of comments and the quality of the results. The clusters in Figure 13 represent the opinions, feelings, and emotions of the most frequent users in the comments of the analyzed videos.

Figure 13. Clusters of the total set of comments.

Table 7. Clusters Summary.

Topic	Comments	Frequency	Mean
1	723	16.48%	Vitality
2	883	20.12%	Perceived enjoyment
3	763	17.39%	Spirituality
4	627	14.29%	Virtual reality industry
5	672	15.31%	Representation of reality
6	720	16.41%	Planets and Earth (space)
total	**4,388**	**100.00%**	

The results obtained for cluster 1 have been interpreted as vitality: loving things in life. Cluster 2 represents perceived enjoyment, due to the association of words such as 'video' or 'planet' with 'cool', 'amazing', 'use', or 'watch'. Cluster 3 represents 'Spirituality' (“video',”god'"amazing', 'love', 'mean', 'hell', etc.). Cluster 4 was associated with the virtual reality industry (“video”, “work”,”world”, “see”, “make”…). Ir is a more professional cluster. Cluster 5 obtained high beta values with the following words: 'look', 'think', 'real', 'watch', 'something', etc. and represented reality. Finally, Cluster 6 was closely related to 'planet' and 'earth' and was understood as 'planets and earth: the space.'

The most interesting clusters with related terms are shown in detail in Figure 13 and Table 8.

Table 8. Cluster means.

Cluster	1	2	3	4	5	6
	Love, life, will, thing, live, universe	Video, Planet, Cool, Use, Watch,	Video, God, Amazing, Love, Good, Make, Mean	Video, work, world, see, move	Look, think, real, something, reality, wow	Planet, video, Earth, look, watch

Figure 14 shows the word cloud. The words 'video', 'amazing', 'watch', 'see', 'wow', 'reality', 'cool', 'think', 'space', or 'water' appear in more size due to the high frequency.

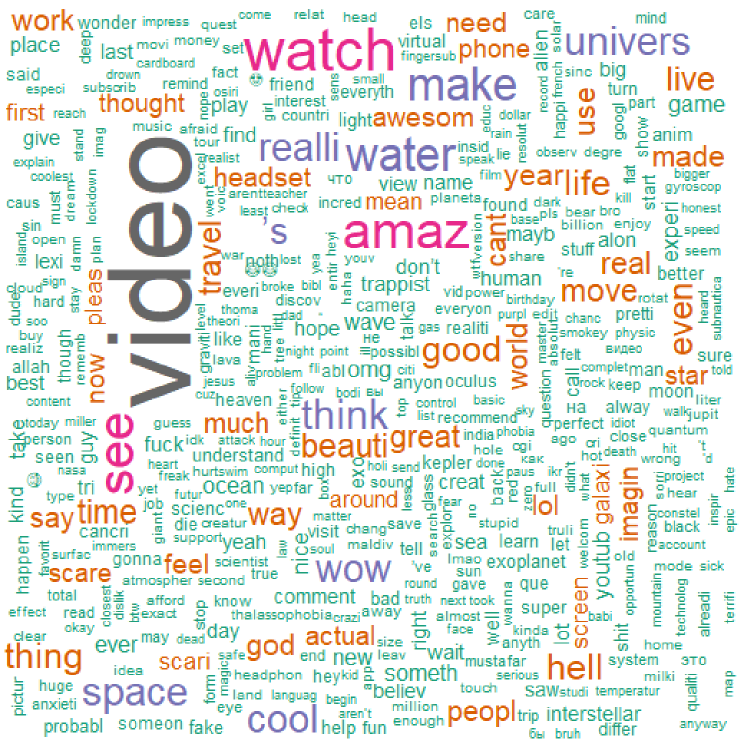


Figure 14. Word cloud.

Figure 15 represents the analysis of emotions from comments. This figure shows 8 emotions. The main emotions detected were trust, fear, and anticipation. However, the 'surprise' obtained less value. Users felt these emotions when they wrote these comments on Youtube, and the number of positive and negative comments (polarity) was very similar: positive (50.62%) and negative (49.37%).

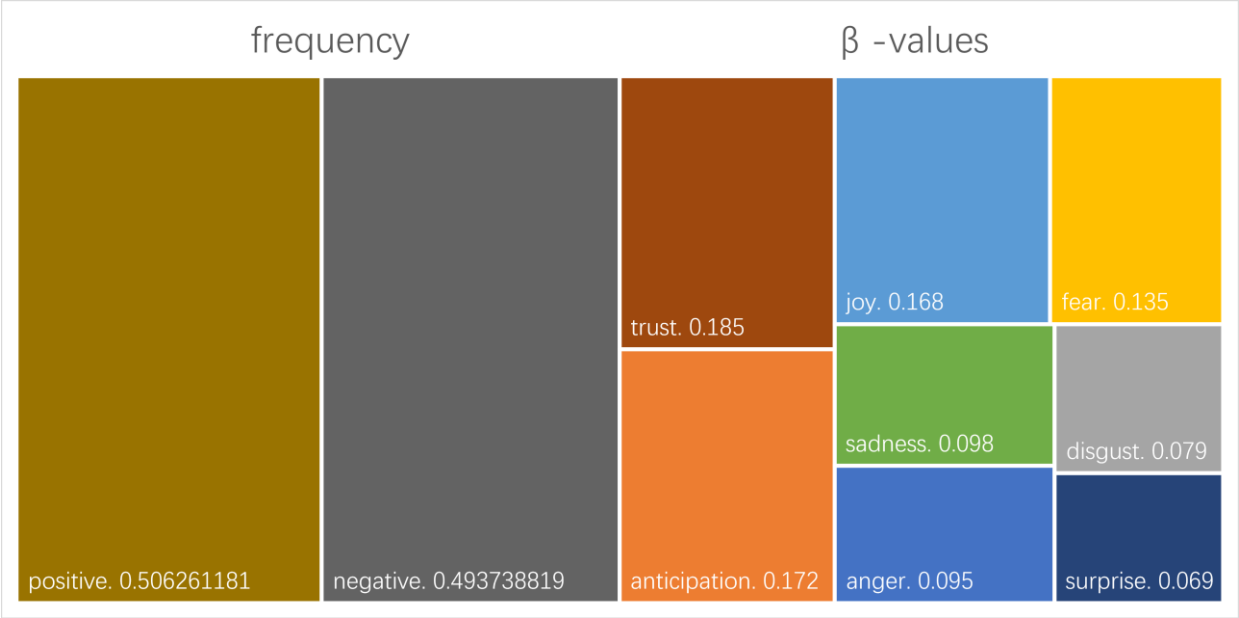


Figure 15. Analysis of associated emotions (β).

5. Discussion

On the basis of the results, we can now formulate answers to the research questions addressed in the present study.

Concerning our first research question ("*What are the reactions of VR video viewers to nature, as manifested through users' feelings and opinions associated with virtual reality*?"), we found that video viewers most experienced trust, fear, anticipation, and sadness. In addition, the results of the cluster analysis technique allowed to verify the thematic differentiation when structuring the set of terms according to the 6 clusters previously obtained in the hierarchical classification. As the bar graph reveals, the dispersion of the clusters was scarce, since the 6 clusters represent percentages of comments ranging from 14.29%–20.12%. Which indicates that they are sufficiently symmetrical.

It should be noted that the topics identified based on words with higher beta coefficients are consistent. Cluster 6 alone represents one of the VR videos that has the most comments (Take a Virtual Reality tour of six REAL exoplanets). This also explains the appearance of the word wáter in cluster 2 and 4, given that the most commented video is '360°, Angel Falls, Venezuela. Aerial video in 8K.'

This means that, for VR video viewers, it is necessary to have a greater production of contents with this technology of representation of reality. However, viewers considered that this representation technology was the best they had ever seen. Other clusters incorporated comments with emotions such as surprise (*wow*), love, gratitude (thanks), and amazement. In addition, there were also comments that expressed doubts about VR technology, as some videos that were indexed VR in YouTube 360º videos were VR 180.

With regard to our RQ1, check in the comments to the videos if it is evident that virtual reality can be a substitute for a real tourist experience. A significant number of comments (e.g., those in Cluster 5 that agglutinated more than 15.31% of all comments) indicated that the VR experience was perceived by the viewers as very real and authentic. In fact, many real tourism experiences were

rated with similar emotions (e.g., *amazing, awesome, nice,* or *lovely*). There is no evidence of contrasts of VR destinations with real visits of users, perhaps they have not made these trips for various reasons or limitations.

In relation with RQ 2 (*What are the perceived components of VR in video feedback?*), evidence was found indicating that VR Experience, Simulation, Video Quality, Tourism, Accessibility and Education are the perceived components.

With regards on RQ3 (*What is the trend in virtual reality in relation to real life experiences?*), it was found that search engine searches focus on launch dates of technological products, VR videos or video games. In addition, a continuing trend can be observed in the interest in related terms on Wikipedia.

The results obtained are in line with other similar research works on Youtube [90,91]. The predominant emotions were experienced trust, fear, anticipation, and sadness. Trust' shows that VR users trust the degree to which these videos represent reality ($\beta = 0.185$). Likewise, 'anticipation' appears with high values (($\beta = 0.172$) which means that users have a positive outlook on the future and believe that many protected species and natural spaces will continue to be preserved for future generations. Also, the emotion 'joy' ($\beta = 0.168$) was high, indicating the degree of enjoyment and satisfaction of the VR. Also, 'fear' appears among the group of emotions with the highest values ($\beta = 0.135$). This is caused by many comments that harshly criticize the fact that the making of these videos prevents the normal life of the animals filmed and that they have even been kept in captivity in order to make the videos. The rest of the emotions such as 'sadness' ($\beta = 0.980$), 'anger' ($\beta = 0.950$), 'disgust' ($\beta = 0.790$) and 'surprise' ($\beta = 0.690$) are less emotionally intense in the comments studied. Question RQ4 is therefore answered.

With reference to RQ5 (*What are the topics around which the comments are grouped?*), Figure 13 explains the results. Cluster 6 contains values ($\beta > 0.100$) for 'planet' and is therefore very definitive, followed by clusters 2 (Perceived Enjoyment) and 5 (Representation of Reality) with high values ($\beta > 0.05$). Other clusters such as 1 represent 'Vitality' or 'how users love things in life', cluster 3 'spirituality' and 'Virtual reality industry'.

6. Conclusions

6.1. Theoretical Contributions

This research work applies text mining techniques to analyze messages generated by users after watching virtual reality videos. As suggested by the minimal variability between clusters, the degree of differentiation in this new scientific field remains low.

To date, 100% VR videos that require special glasses have not had many views. As suggested by a Google Trends graph (Figure 6), virtual reality goggles are a holiday gift product. A similar trend was found based on Wikipedia searches of users (Figure 7).

We also found that the total inertia of the axes, factors, or dimensions is low in all of them, i.e. the contribution of each of the dimensions is so low that the interpretation of each of the two dimensions is complicated.

On the other hand, our results also demonstrated that the channels of companies with many followers get a significant number of visits and that the variety of VR videos helps to get more visits (see the case of Balu, National Geographic, BBC Hearth, etc., as shown in Table 2). These results support recent research on the feasibility of applying VR in national parks as a way to make tourists

more eco-friendly [92].

Sentiment analysis is an important approach used to analyze massive amounts of data produced by users of social networks. Consumers are increasingly expressing their opinions about different products and services. In this context, YouTube reviews and comments are an excellent way to understand which attributes of virtual reality are the most effective in terms of user satisfaction. Fortunately, these reviews generate a large volume of data recorded in digital form for subsequent analysis. Although short, these comments are spontaneous verbal reactions to videos and convey genuine users' emotions. Videos' likes and dislikes can also be informative.

Lexical statistics and textual data analysis are the basis for the development of the so-called knowledge systems, i.e. expert systems resulting from knowledge engineering, widely used in text mining.

The results of our sentiment analysis of the comments of VR video viewers revealed that most users have a positive opinion of this technology and a great interest in learning more about it. The viewers' emotions included admiration, joy, gratitude, as well as anger, frustration when there are accessibility problems to VR and even stress and fear in very realistic immersive content that highlights their phobias or helps them overcome them. Importantly, our results also suggested that, through simulation of natural environments, VR videos can be used as a means to promote the protection of national parks and raise users' awareness about environmental problems.

6.2. Managerial Implications

VR video content must be adjusted to the progress of the leading companies in the market, such as Oculus and HTC, among others, due to constant change, innovation and greater immersion and interaction, are features that are improved to incorporate our senses more and more. Even though we cannot generalize the results, there is a knowledge that must be taken full advantage of by decision makers, we refer to the comments that are an unstructured language where their position towards the product is reflected, but also their emotions, way of expressing themselves, and expectations of improvement that must be treated with greater care.

Despite the fact that VR is at a more advanced stage than other similar technologies, a potential market for VR video consumption devices is evident, in addition, few comments refer to the availability of equipment and accessories to enjoy VR technology, on the contrary, many access through their computer, without the use of accessories such as headphones or glasses, and some comments refer to the difference in costs and purchasing power from one country to another. Another viewing option is the low-end glasses, which use the smartphone and its resources such as accelerometer, compass, screen division for stereoscopic vision, limiting the advantages of this technology to the characteristics of the display device and the phone.

What does not go unnoticed is the quality of the VR videos that the user has visualized, it is evident the positive feelings towards the technology that can be used with the available resources, highlighting attributes such as immersion, telepresence, interaction, are the most effective in terms of user satisfaction. Although these feelings and emotions are present in the different formats, comments regarding resolution and quality are more common in 4K, VR360 formats, therefore, advertising and promotion efforts considering the quality and acceptance of this format results in a good opportunity for marketing strategies.

The sharpness and fluidity of the movements allowed by 5K, VR360 and very possibly the new formats, allow in-depth tours of tourist or commercial destinations; this is useful as a means of visual

information, brand positioning, loyalty, promotion, training, and development, among many options, but the way in which the videos are displayed reflects that the efforts that some manufacturers have made to provide low-cost devices, which are capable by themselves of providing a VR experience, without using the options available on your smartphone, should be continued.

6.3. Limitations and future research

It is expected that people with interest and experience with virtual reality nature, ecotourism and sustainability are the people who provide comments on VR videos, but we do not know the consumer profile of VR video content, so it is impossible to assess the representativeness of the sample or the generalizability of the findings.

Important limitations of using SA to analyze video comments include the need for data cleaning and the insufficient development of theoretical frameworks and recommendations on how to get the most out of these tools. As demonstrated in the present study, there are few high-quality VR videos. One of the reasons behind this trend is the low popularity of visualization devices and the scarcity of specialized channels.

Future research may include some experimental control and modality manipulation (e.g., 360 VR vs. conventional video vs. still photos) so that they can test the impact of the VR format on viewer experience and future intentions and behavior. In the lab, an experiment can be conducted with a control group viewing the VR videos on their computer or whatever device they have and another group with access to high-end devices to compare the results that can be obtained.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

1. A. Porreca, F. Scozzari, M. Di Nicola, Using text mining and sentiment analysis to analyze YouTube Italian videos concerning vaccination, *BMC Public Health,* **20** (2020), 1–9. https://doi.org/10.1186/s12889-020-8342-4
2. Z. Li, R. Li, G. Jin, Sentiment analysis of danmaku videos based on Naïve Bayes and sentiment dictionary, *IEEE Access,* **8** (2020), 75073–75084. https://doi.org/10.1109/ACCESS.2020.2986582
3. G. S. Chauhan, Y. K. Meena, YouTube video ranking by aspect-based sentiment analysis on user feedback, *Soft Comput. Signal Process.*, (2019), 63–71. https://doi.org/10.1007/978-981-13-3600-3_6
4. T. Tomihira, A. Otsuka, A. Yamashita A, T. Satoh, Multilingual emoji prediction using BERT for sentiment analysis, *Int. J. Web Inf. Syst.,* **16** (2020), 265–280. https://doi.org/10.1108/IJWIS-09-2019-0042
5. R. Botsman, R. Rogers, What's mine is yours, The rise of collaborative consumption. New York: HarperCollins, (2010).
6. S. M. C. Loureiro, J. Guerreiro, F. Ali, 20 years of research on virtual reality and augmented reality in tourism context: A text-mining approach, *Tour. Manag.,* **77** (2020), 104028. https://doi.org/10.1016/j.tourman.2019.104028

7. R. G. Bilro, S. M. C. Loureiro, J. Guerreiro, Exploring online customer engagement with hospitality products and its relationship with involvement, emotional states, experience and brand advocacy, *J. Hosp. Market. Manag*., **28** (2019), 147–171. https://doi.org/10.1080/19368623.2018.1506375
8. S. M. C. Loureiro, J. Guerreiro, S. Eloy, D. Langaro, P. Panchapakesan, Understanding the use of Virtual Reality in Marketing: A text mining-based review, *J. Bus. Res.,* **100** (2019), 514–530. https://doi.org/10.1016/j.jbusres.2018.10.055
9. M. Wedel, E. Bigné, J. Zhang, Virtual and augmented reality: Advancing research in consumer marketing, *Int. J. Res. Mark.,* **37** (2020), 443–465. https://doi.org/10.1016/j.ijresmar.2020.04.004
10. F. Velicia-Martin, J. A. Folgado-Fernández, P. R. Palos-Sánchez, B. López-Catalán, mWOM Business Strategies: Factors Affecting Recommendations, *J. Comput. Inf. Syst*., (2022), 1–14. https://doi.org/10.1080/08874417.2022.2041504
11. S. Moro, P. Rita, P. Ramos, J. Esmeraldo, Analysing recent augmented and virtual reality developments in tourism, *J. Hosp. Tour. Technol.*, **10** (2019), 571–586. https://doi.org/10.1108/JHTT-07-2018-0059
12. S. M. C. Loureiro, H. Roschk H, Differential effects of atmospheric cues on emotions and loyalty intention with respect to age under online/offline environment, *J. Retail. Consum. Serv.,* **21** (2014), 211–219. https://doi.org/10.1016/j.jretconser.2013.09.001
13. X. Xu, Y. Li, The antecedents of customer satisfaction and dissatisfaction toward various types of hotels: A text mining approach, *Int. J. Hosp. Manag.,* **55** (2016), 57–69. https://doi.org/10.1016/j.ijhm.2016.03.003
14. L. Serrano, A. Ariza-Montes, M. Nader, A. Sianes, R. Law, Exploring preferences and sustainable attitudes of Airbnb green users in the review comments and ratings: A text mining approach, *J. Sustain. Tour.,* **28** (2020), 1–19. https://doi.org/10.1080/09669582.2020.1838529
15. X. Wu, Q., Zhi, Impact of shared economy on urban sustainability: From the perspective of social, economic, and environmental sustainability, *Energy Proced.,* **104** (2016), 191–196. https://doi.org/10.1016/j.egypro.2016.12.033
16. H. Han, B. Meng, W. Kim, Emerging bicycle tourism and the theory of planned behavior, *J. Sustain. Tour.,* **25** (2017), 292–309. https://doi.org/10.1080/09669582.2016.1202955
17. C. Midgett, J. S. Bendickson, J. Muldoon, S. J. Solomon, The sharing economy and sustainability: A case for Airbnb, *Small Bus. Inst. J.,***13** (2018), 51–71.
18. A. N. Srivastava, M. Sahami, Text mining: Classification, clustering, and applications, New York, NY, Chapman & Hall/CRC, (2009).
19. C. Koltinger, A. Dickinger, Analyzing destination branding and image from online sources: A web content mining approach, *J. Bus. Res.* **68** (2015), 1836–1843. https://doi.org/10.1016/j.jbusres.2015.01.011
20. S. M. C. Loureiro, J. Guerreiro, F. Ali, 20 years of research on virtual reality and augmented reality in tourism context: A text-mining approach, *Tour. Manag.,* **77** (2020), 104028.
21. S. Rangelova, E. Andre, A survey on simulation sickness in driving applications with Virtual Reality Head-mounted displays, *Presence V. Augmented R.,* **27** (2019), 15–31. https://doi.org/10.1162/pres_a_00318
22. J. Martínez-Navarro, E. Bigné, J. Guixeres, M. Alcaniz, C. Torrecilla, The influence of virtual reality in e-commerce, *J. Bus. Res.,* **100** (2019), 475–482. https://doi.org/10.1016/j.jbusres.2018.10.054

23. K. Zhang, J. Suo, J. Chen, X. Liu, L. Gao, Design and implementation of fire safety education system on campus based on virtual reality technology, *Federated Conference on Computer Science and Information Systems (FedCSIS)*, (2017), 1297–1300.
24. C. Anthes, R. J. García-Hernández, M. Wiedemann, D. Kranzlmüller, State of the art of virtual reality technology, *IEEE Aerospace Conference*, (2016), 1–19.
25. C. Flavián, S. Ibáñez-Sánchez, C. Orús, Integrating virtual reality devices into the body: effects of technological embodiment on customer engagement and behavioral intentions toward the destination, *J. Travel Tour. Mark.,* **36** (2019), 847–863. https://doi.org/10.1080/10548408.2019.1618781
26. M. A. Gigante, Virtual Reality: Definitions, History and Applications, in *Virtual Reality Systems* (eds. R. A. Earnshaw, M. A. Gigante and H. Jones), Boston, Academic Press, (1993), 3–14.
27. P. Disztinger, S. Schlögl, A. Groth, Technology Acceptance of Virtual Reality for Travel Planning, in *Information and Communication Technologies in Tourism 2017* (Eds. R. Schegg and B. Stangl), Cham, Springer International Publishing, (2017), 255–268.
28. I. P. Tussyadiah, D. Wang, T. H. Jung, M. C. Tom Dieck, Virtual reality, presence, and attitude change: Empirical evidence from tourism, *Tourism Manage,* **66** (2018), 140–154. https://doi.org/10.1016/j.tourman.2017.12.003
29. M. Fagan, C. Kilmon, V. Pandey, Exploring the adoption of a virtual reality simulation: The role of perceived ease of use, perceived usefulness and personal innovativeness, *Campus-Wide Inf. Sys.,* **29** (2012), 117–127. https://doi.org/10.1108/10650741211212368
30. M. Mihelj, D. Novak, S. Beguš, Virtual Reality Technology and Applications, Dordrecht, Springer Netherlands, (2014).
31. Y. C. Huang, K. F. Backman, S. J. Backman, L. L. Chang, Exploring the implications of Virtual Reality Technology in tourism marketing: An integrated research framework, *Int. J. Tour. Res.*, **18** (2016), 116–128. https://doi.org/10.1002/jtr.2038
32. D. M. Tamás, Introduction to the WIPO Pearl patent terminology database, Fordítástudomány, 23 (2021), 49–62. https://doi.org/10.35924/fordtud.23.1.3
33. D. Babčanová, J. Šujanová, D. Cagáňová, N. Horňáková, H. Hrablik Chovanová, Qualitative and quantitative analysis of social network data intended for brand management, *Wirel. Netw.,***27** (2019),1–8. https://doi.org/10.1007/s11276-019-02052-0
34. Z. T. Osakwe, I. Ikhapoh, B. K. Arora, O. M. Bubu, Identifying public concerns and reactions during the COVID-19 pandemic on Twitter: A text-mining analysis. *Public Health Nur.,* **38** (2021), 145–151. https://doi.org/10.1111/phn.12843
35. A. Brait, Attitudes of Austrian history teachers towards memorial site visits, *Eine Analyse mithilfe von MAXQDA zeitgeschichte*, **47** (2020), 441–466. https://doi.org/10.14220/zsch.2020.47.4.441
36. P. Kowalczuk, Consumer acceptance of smart speakers: a mixed methods approach, *J. Res. Interact. Mark.*, **12** (2018), 418–431. https://doi.org/10.1108/JRIM-01-2018-0022
37. R. P. S. Kaurav, K. Suresh, S. Narula, R. Baber, The new education policy 2020 using Twitter mining, *J. Content Community Commun.*, **12** (2021), 4–13. https://doi.org/10.31620/JCCC.12.20/02
38. D. H. Choi, A. Dailey-Hebert, J. Simmons Estes, Emerging Tools and Applications of Virtual Reality in Education: IGI Global, (2016).
39. M. A. Ríos-Martín, J. A. Folgado-Fernández, P. R. Palos-Sanchez, P. Castejón-Jiménez, The

impact of the environmental quality of online feedback and satisfaction when exploring the critical factors for Luxury Hotels, *Sustainability,* **12** (2019), 299. https://doi.org/10.3390/su12010299

40. J. R. Saura, P. R. Palos-Sanchez, M. A. R. Martín, Attitudes expressed in online comments about environmental factors in the Tourism sector: An exploratory study, *Int. J. Environ. Res. Public Health*, **15** (2018), 553. https://doi.org/10.3390/ijerph15030553
41. J. R. Saura, P. R. Palos-Sanchez, A. Grilo, Detecting indicators for startup business success: Sentiment analysis using text data mining, *Sustainability,* **11** (2019), 917. https://doi.org/10.3390/su11030917
42. J. R.Saura, A. Reyes-Menendez, P. Palos-Sanchez, Are Black Friday deals worth it? Mining Twitter users' sentiment and behavior response, *J. Open Innov. Tech., Market Complex.,* **5** (2019), 58. https://doi.org/10.3390/joitmc5030058
43. J. R. Saura, A. Reyes-Menéndez, P. R. Palos-Sanchez, A Twitter sentiment analysis with machine learning: Identifying sentiment about #BlackFriday deals, *Revista Espacios,* **39** (2018).
44. P. R. Palos-Sanchez, J. R.Saura, F. Debasa, The influence of social networks on the development of recruitment actions that favor user interface design and conversions in mobile applications powered by linked data, *Mob. Inf. Syst.*, **2018** (2018). https://doi.org/10.1155/2018/5047017
45. P. R. Palos-Sanchez, J. R. Saura, M.B. Correia, Do tourism applications' quality and user experience influence its acceptance by tourists? *Rev. Manag. Sci.,* **15** (2021), 1205–1241. https://doi.org/10.1007/s11846-020-00396-y
46. D. Gefen, Reflections on the dimensions of trust and trustworthiness among online consumers, *ACM SIGMIS Database: The Database for Advances in Information Systems,* **33** (2002), 38–53. https://doi.org/10.1145/569905.569910
47. A. C. Calheiros, S. Moro, P. Rita, Sentiment classification of consumer-generated online reviews using topic modeling, *Hosp. Market. Manag.,* **26** (2017), 675–693. https://doi.org/10.1080/19368623.2017.1310075
48. S. Kang, S. Dove, H. Ebright, S. Morales, H. Kim, Does virtual reality affect behavioral intention? Testing engagement processes in a K-Pop video on YouTube, *Comput. Hum. Behav.* **123** (2021), 106875. https://doi.org/10.1016/j.chb.2021.106875
49. E. Filter, A Eckes, F. Fiebelkorn, A. G. Büssing, Virtual reality nature experiences involving wolves on YouTube: Presence, emotions, and attitudes in immersive and nonimmersive settings, *Sustainability,* **12** (2020), 3823. https://doi.org/10.3390/su12093823
50. C. C.W. Lim, J. Leung, J. Y.C. Chung, T. Sun, C. Gartner, J. Connor, et al., Content analysis of cannabis vaping videos on YouTube, *Addiction,* **116** (2021), 2443–2453. https://doi.org/10.1111/add.15424
51. J. Y. Lim, S. Kim, J. Kim, S. Lee, Identifying trends in nursing start-ups using text mining of YouTube content, *Plos One,* **15** (2020), e0226329. https://doi.org/10.1371/journal.pone.0226329
52. N. Öztürk, S. Ayvaz, Sentiment analysis on Twitter: A text mining approach to the Syrian refugee crisis, *Telemat. Inform.,* **35** (2018), 136–147. https://doi.org/10.1016/j.tele.2017.10.006
53. A. Alarifi, M. Alsaleh, A. Al-Salman, Twitter turing test: Identifying social machines, *Inf. Sci.,* **372** (2016), 332–346. https://doi.org/10.1016/j.ins.2016.08.036
54. R. Filieri, S. Alguezaui, F. McLeay, Why do travelers trust TripAdvisor? Antecedents of trust towards consumer-generated media and its influence on recommendation adoption and word of mouth, *Tour. Manag.,* **51** (2015), 174–185. https://doi.org/10.1016/j.tourman.2015.05.007

55. M. M. Mostafa, More than words: Social networks' text mining for consumer brand sentiments, *Expert Syst. Appl.,* **40** (2013), 4241–4251. https://doi.org/10.1016/j.eswa.2013.01.019
56. C. L. Santos, P. Rita, J. Guerreiro, Improving international attractiveness of higher education institutions based on text mining and sentiment analysis, *Int. J. Educ. Manag.,* **32** (2018) 431–447. https://doi.org/10.1108/IJEM-01-2017-0027
57. S. Lee, J. Song, Y. Kim, An empirical comparison of four text mining methods, *J. Comput. Inf. Syst.,* **51** (2010), 1–10.
58. R. S. Lu, H. Y. Tsao, H. C. K. Lin, Y. C. Ma, C. T. Chuang, Sentiment analysis of brand personality positioning through text mining, *J. Inf. Technol. Res.,* **12** (2019), 93–103. https://doi.org/10.4018/JITR.2019070106
59. A. Z. Hamdi, A. H. Asyhar, Y. Farida, N. Ulinnuha, D. C. R. Novitasari, A. Zaenal, Sentiment analysis of regional head candidate's electability from the national mass media perspective using the text mining algorithm, *Adv. Sci. Technol. Eng. Syst.,* **4** (2019), 134–139.
60. K. Hornik, B. Grün, Topic models: An R package for fitting topic models, *J. Stat. Softw.,* **40** (2011), 1–30.
61. M. Isik, B. Öztaysi, K. H. Fenerci, A sentiment analysis as a tool to identify the status of universities: The case of ITU, *Procedings of the International Conference on Industrial Engineering and Operations Management*, (2012), 3–6.
62. A. C. Calheiros, S. Moro, P. Rita, Sentiment classification of consumer-generated online reviews using topic modeling, *J. Hosp. Market. Manag.,* **26** (2017), 675–693. https://doi.org/10.1080/19368623.2017.1310075
63. Y. Yang, L. Akers, T. Klose, C. B. Yang, Text mining and visualization tools–Impressions of emerging capabilities, *World Pat. Inf.,* **30** (2008), 280–293. https://doi.org/10.1016/j.wpi.2008.01.007
64. B. Liu, L. A. Zhang, A survey of opinion mining and sentiment analysis, *Mining text data*, Boston, MA, Springer, (2012), 415–463. https://doi.org/10.1007/978-1-4614-3223-4_13
65. F. Zhou, J. R. Jiao, X. J. Yang, B. Lei, Augmenting feature model through customer preference mining by hybrid sentiment analysis, *Expert Syst. Appl.*, **89** (2017), 306–317. https://doi.org/10.1016/j.eswa.2017.07.021
66. Z. P. Fan, Y. J. Che, Z. Y. Chen, Product sales forecasting using online reviews and historical sales data: A method combining the Bass model and sentiment analysis., *J. Bus. Res.,* **74** (2017), 90–100. https://doi.org/10.1016/j.jbusres.2017.01.010
67. T. Li, L. Lin, M. Choi, S. Gong, J. Wang, YouTube AV 50k: An annotated corpus for comments in autonomous vehicles, *International Joint Symposium on Artificial Intelligence and Natural Language Processing (iSAI-NLP*), (2018), 1–5.
68. J. Wen, C. E. Yu, E. Goh, Physician-assisted suicide travel constraints: Thematic content analysis of online reviews, *Tour. Recreat. Res.,* **44** (2019) 553–557. https://doi.org/10.1080/02508281.2019.1660488
69. C. E. Yu, J. Wen, S. Yang, Viewpoint of suicide travel: An exploratory study on YouTube comments, *Tour. Manag. Perspect.,* **34** (2020) 100669. https://doi.org/10.1016/j.tmp.2020.100669
70. Y. Guo, S. J. Barnes, Q. Jia, Mining meaning from online ratings and reviews: Tourist satisfaction analysis using latent Dirichlet allocation, *Tour. Manag.,* **59** (2017), 467–483. https://doi.org/10.1016/j.tourman.2016.09.009

71. MAXQDA 2020, computer software, Berlin, Germany, VERBI Software, 2019.
72. U. Kuckartz, S. Rädiker, Introduction: Analyzing qualitative data with software, *Analyzing Qualitative Data with MAXQDA*, Cham, Springer, (2019), 1–11. https://doi.org/10.1007/978-3-030-15671-8_1
73. J. Guerreiro, P. Rita, D. Trigueiros, A text mining-based review of cause-related marketing literature, *J. Bus. Ethics,* **139** (2016), 111–128. https://doi.org/10.1007/s10551-015-2622-4
74. K. N. Lau, K. H. Lee, Y. Ho, Text mining for the hotel industry, *Cornell Hotel Restaur Admin. Q.,* **46** (2005), 344–362. https://doi.org/10.1177/0010880405275966
75. F. R. Lin, D. Hao, D. Liao, Automatic content analysis of media framing by text mining techniques, *49th Hawaii International Conference on System Sciences,* (2016), 2770–2779.
76. M. Bouchet-Valat, G. Bastin, RcmdrPlugin. temis, a graphical integrated text mining solution in R, *The R J.,* **5** (2013), 188–196.
77. G. Bastin, M. Bouchet-Valat, Media corpora, text mining, and the sociological imagination-A free software text mining approach to the framing of Julian Assange by three news agencies using R, *TeMiS Bull. Sociol. Methodol.,* **122** (2014) 5–25. https://doi.org/10.1177/0759106314521968
78. J. Pino-Díaz, Tutorial de R-Text Mining Solution, *Universidad de Málaga*, (2016), 2–56. http://hdl.handle.net/10630/11924
79. M. L. Jockers, Syuzhet: Extract sentiment and plot arcs from text, R Package Version, 2017.
80. M. Jockers, Msyuzhet: Extracts Sentiment and Sentiment-Derived Plot Arcs from Text, 2020.
81. T. Rinker, sentimentr: Calculate Text Polarity Sentiment, 2021.
82. M. Misuraca, A. Forciniti, G. Scepi, M. Spano, Sentiment analysis for education with R: Packages, methods and practical applications, *arXiv*, **27**, (2020). https://doi.org/10.48550/arXiv.2005.12840
83. J. Chang, Lda: Collapsed Gibbs Sampling Methods for Topic Models, (2015). http://CRAN.R-project.org/package=lda
84. S. A. García, M. I. M. Menéndez, Applications of statistics to framing and text mining in communication studies, *Inform. Culture Soc.,* **39** (2018), 61–70. https://doi.org/10.34096/ics.i39.4260
85. P. R. Palos-Sanchez, M. B. Correia, The collaborative economy based analysis of demand: Study of Airbnb case in Spain and Portugal, *J. Theor. Appl. Electron. Commer. Res.,* **13** (2018), 85–98. https://doi.org/10.4067/S0718-18762018000300105
86. J. Pino Díaz, J. Minguillón Campos, Application of the Simple Linear Regression technique to the Contribution-Quality relationship in correspondence analysis in data mining with R, *Fiabilidad Industr.*, (2016). http://hdl.handle.net/10630/11102
87. M. Terrádez Gurrea, Lexical frequencies and statistical analysis, How do you comment on a colloquial text?, *Ariel*, (2000), 111–124.
88. R. Gutiérrez, A. González, F. Torres, J. A. Gallardo, Multivariate data analysis techniques, *Universidad de Granada,* 1994.
89. P. Carracedo, R. Puertas, L. Marti, Research lines on the impact of the COVID-19 pandemic on business, A text mining analysis, *J. Bus. Res.,* **132** (2021). https://doi.org/10.1016/j.jbusres.2020.11.043
90. A. Porreca, F. Scozzari, M. Di Nicola, Using text mining and sentiment analysis to analyze YouTube Italian videos concerning vaccination, *BMC Public Health*, **20** (2020), 1–9.

https://doi.org/10.1186/s12889-020-8342-4
91. H. K. Ko, An analysis of YouTube comments on BTS using text mining, *The Rhizom. Revol. Rev.,* **10** (2020).
92. M. Sánchez, P. R. Palos-Sánchez, F.Velicia-Martin, Eco-friendly performance as a determining factor of the Adoption of Virtual Reality Applications in National Parks, *Sci. Total Environ*., **798** (2021), 148990. https://doi.org/10.1016/j.scitotenv.2021.148990

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