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RESEARCH ARTICLE

Characterization of Quality Attributes to Evaluate the User Experience in Augmented Reality

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ABSTRACT This study proposes a characterization of quality attributes for applications that use augmented reality. This classification is done from the perspective of the user experience. The attribute identification was based on primary studies of the IEEE Xplore, Scopus, and ACM repositories. From an initial set of 1165 papers, 101 documents were selected. The document proposes two categories: objective and subjective. In the objective category 4 subcategories and 40 attributes were found, and in the subjective one 5 subcategories and 54 attributes were found. This is the first time that all these criteria are presented in a single document, which is the input for designing a comprehensive quality assurance tool for user experience in augmented reality.

INDEX TERMS Augmented reality (AR), category, quality attributes, user experience (UX), user interface (UI).

I. INTRODUCTION

Augmented Reality (AR) is a concept that has been studied for more than 40 years. Recently, due to hardware and software developments that have enabled substantial cost reduction to implement AR-based solutions, there has been an increase in demand for these services in different areas: training of staff in industry and academia, health, support in plant work activities, support for users in equipment use, and entertainment, among others.

A key element for companies adopting AR is identifying which features influence the proper use of this technology and how it can improve the user experience and the processes it aims to impact positively [1]. Most recent research has focused on defining quality indicators for this type of application [2]. However, there is no consensus on which elements should be comprehensively analyzed when evaluating an AR solution. The scope of this study addresses concepts about AR, the user experience (UX) in AR, and a systematic search for features that affect the user experience to build a characterization of quality attributes for AR from the perspective of the UX. Before addressing the evaluation criteria, it is important to know the concept of AR on which this article is based. For Azuma [3], Augmented Reality (AR) is ''a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world'' (p. 7).

A crucial element in AR is the experience it gives the user. This concept is critical in this study as it allows identifying what characteristics affect the quality of the user experience in applications with augmented reality that should be measured to evaluate how the user feels.

Therefore, it is relevant to describe the UX notion proposed by Jakob Nielsen & Raluca Budiu [4] that guides this research. In Nielsen's text Mobile Usability, he suggests that although usability is a quality attribute that measures the ease

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of use of designed interfaces (UI) when the users interact with them, the UX would be everything that the user perceives, thinks, and feels by experiencing such ease. If the UX anticipates what users will experience in the interaction instances, it is obvious that these experiences are determined by UI designers [5] and developers who implement AR as a motivational resource. Thus, extrinsic motivations [6] are planned in the present moment and projected by the creators of the interfaces, so that the user lives or experiences them in the future when they come into contact with AR-assisted digital products. The sensations or reactions created in advance by and for users have been achieved thanks to collaborative and participatory work dynamics between interdisciplinary teams and samples of those future users. The determinism implicit in this generation of experiences, based on a predestined logic, makes the cause and the effect the extrinsic and the intrinsic motivation respectively [6].

Hence, the characterization performed in this study is supported by a systematic literature review that allows defining the UX as a person's perception of the use of a product, a service, or a system. The measurement of the user's perception is based on the analysis of instrumental and non-instrumental elements. Instrumental elements include usability and utility, and non-instrumental elements include aesthetics, ergonomics, and biometrics, among others. Both instrumental and non-instrumental elements can be measured using integral user experience indicators. The research questions that serve as the basis for the systematic literature review are presented below.

II. REVIEW PROTOCOL

A. RESEARCH QUESTIONS

PICOC methodology, presented in [7], allows the definition of research questions in a literature review. In this study, the population was defined as the set of studies that address the AR topic from the quality criteria perspective. The intervention is the quality criteria for the user experience. The comparison refers to the work done by others to collect quality attributes. The result is referred to how the characteristics are organized. The context comprises the entire literature review carried out. The analysis was done with the PICOC methodology to define the following research questions.

Q1: How is the user experience measured in AR applications?

Q2: What are the user experience quality metrics used in augmented reality applications?

B. DIGITAL REPOSITORIES AND SEARCH STRING

The review protocol starts with the selection of repositories. This selection was made based on the work proposed in [8]. The repositories used in this study were: IEEE Xplore, SCOPUS, and ACM. The generic search string was set: "augmented reality" and "user experience". Table 1 presents the string execution in the selected digital repositories.

TABLE 1. Chain execute.

Repository	Found
IEEE Xplore	220
SCOPUS	774
ACM	171
Total	1165

C. APPLIED FILTERS

After the execution of the search string, two filters were applied: 1) duplicate documents and 2) observation window after 2009. 2009 is used as a milestone because that year unified developers, manufacturers, researchers, and other stakeholders around the concept of Augmented Reality. A standardized seal emerged and allowed to establish the work path of this technology in areas such as geolocation, video games, and even the use of web browsers with augmented reality support. As a result, 856 studies were obtained as follows: 207 for IEEE, 600 for Scopus, and 49 for ACM.

D. PRESELECTION

For the shortlisting of the studies, the process of verifying the metadata was carried out: title, abstract, and keywords. The applied preselection criterion included studies that addressed the AR topic, defining concepts and variables that affected the user experience. The relevant aspects found in each repository after the search string are described below.

IEEE: 58 studies out of the 207 papers were pre-selected, equivalent to 28% of this repository. The relevant aspects found in the works were:

- Feature descriptions to improve the interfaces of AR applications.
- AR evaluation models.
- AR applications with the aim of training workers.
- Visual optimization techniques.
- Description of the UX in games.

SCOPUS: 95 studies out of the 600 works were preselected, the equivalent of 16% of this repository. The relevant aspects found in the works were:

- Prototype usage assessments.
- Case studies where the user experience is described.
- AR design requirements.
- Mobile Augmented Reality (MAR) challenges.
- Comparison of AR technologies, virtual reality (VR), and Mixed Reality (MR).

ACM: 24 studies out of the 49 works were pre-selected, the equivalent of 49% in this repository. The relevant aspects found in the works were:

- Algorithms to customize a user's preferences.
- Touch interaction techniques.
- Test applications for head-mounted devices (HMDs).

Finally, 177 studies were pre-selected corresponding to 58 IEEE papers, 95 SCOPUS, and 24 ACM works. The analyzed observation window shows a significant increase in publications with topics related to user experience assessment in AR applications in the previous three years. Fig. 1 presents

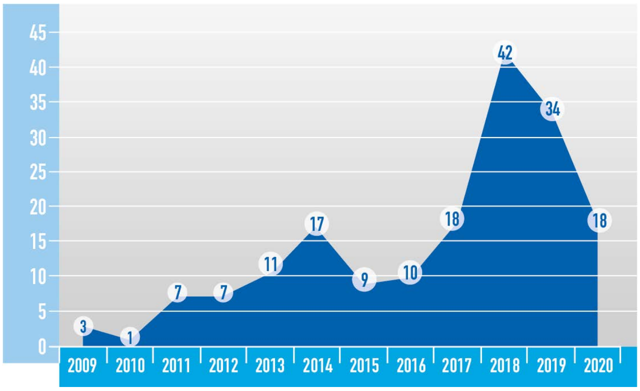

FIGURE 1. Pre-selected studies per year of publication.

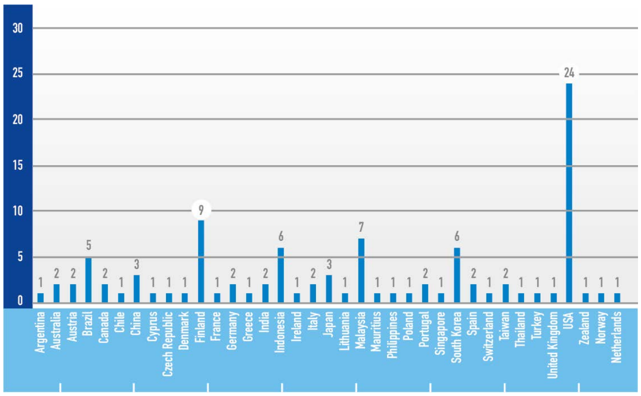

FIGURE 2. Studies per country.

the number of articles published per year. The 2020 cut was made in August, which is why only 18 studies were found.

E. QUALITY ASSESSMENT

As mentioned by Kitchenham in [9], after having the initial work sample, the relevance of the study for research should be verified. For this reason, quality criteria were established to decide whether a study was a candidate to enter the primary study base of this research. The quality criteria defined were the following: 1) the study presents evaluations of AR applications, 2) the study describes criteria associated with user experience, and 3) the work describes the results of research and/or application. After applying the quality criteria to the 177 studies resulting from the preselection process, the following results were obtained: IEEE 32, Scopus 52, and ACM 17. The total number of studies that met the quality criteria was 101.

F. DATA EXTRACTION

From the 101 studies that approved the quality assessment phase, relevant information was collected on the following topics: AR basic concepts, UX quality criteria, trends and challenges. According to Fig. 2, it can be seen that the country with the most publications on the subject of user experience with augmented reality applications is the United States, followed by Finland and Malaysia.

It is important to highlight the validity of the selected sources for this research. Therefore, tables 2 to 5 are presented where it can be visualized what type each work is, and in what H-Index, quartile, and Web of Science Categories/Index it is located.

TABLE 2. Studies by document type.

Document Type	Quantity
Journal Article	46
Proceedings Paper	55
Total	101

TABLE 3. Studies by H-Index.

H-INDEX	Quantity
No index	1
Between 1 - 50	59
Between 51 - 99	19
Between 100 - 199	13
Greater than 200	9
Total	101

TABLE 4. Studies by SJR metric.

Quartile Scopus	Quantity
Q1	15
Q2	16
Q3	6
Q4	7
No quartile	57
Total	101

TABLE 5. Studies by web of science index.

Web of Science Index	Quantity
Emerging Sources Citation Index	7
Science Citation Index Expanded	17
Social Sciences Citation Index	3
No index	74
Total	101

The H-Index presented by the SJR ranking (Scimago Journal Rank) evidences the citation and referencing of the sources of the articles linked to this research. As can be seen in table 3, 99% of the works are relevant to the academic community.

Table 4 presents the SJR impact metric according to the site Scimago Journal & Country Rank.

The Web of Science is made up of the basic Core Collection that includes the indexes of Sciences, Social Sciences and Arts, and Humanities. In addition, it includes the Proceedings of both Sciences and Social Sciences, and Humanities together with the tools for analysis and evaluation, such as the Journal Citation Report and Essential Science Indicators. Table 5 presents the distribution of the papers of this research in this collection.

The web of science categories was obtained from the official website of the Web of Science. The most common categories found are:

- Computer Science, Cybernetics with 6 studies.
- Computer Science, Theory & Methods Engineering, Electrical & Electronic with 5 studies.
- Chemistry, Multidisciplinary Engineering, Multidisciplinary Materials Science, Multidisciplinary Physics, Applied with 4 studies.
- Computer Science, Artificial Intelligence Computer Science, Theory & Methods with 4 studies.

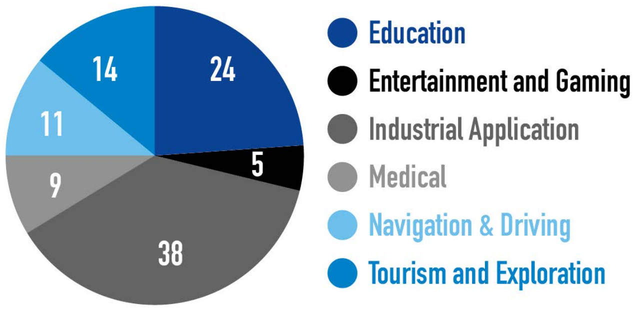

FIGURE 3. Areas of application in AR.

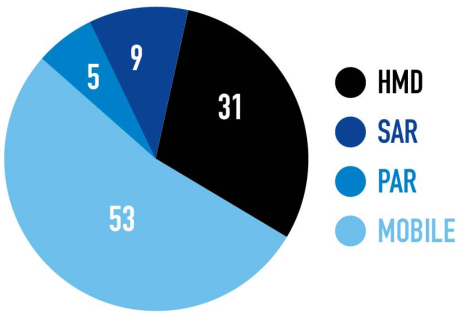

FIGURE 4. AR types identified in the studies.

- Computer Science, Information Systems Computer Science, Software Engineering Computer Science, Theory & Methods Engineering, Electrical & Electronic with 3 studies.
- Computer Science, Information Systems Telecommunications with 3 studies.

Based on the studies of [10], [11], [12], and [13], six areas of application of augmented reality technology were identified: Medical, Education, Entertainment and Gaming, Industrial Application, Navigation and Driving, and Tourism and Exploration. Taking into account these areas, it was identified that the most widespread application area among the analyzed studies is Industrial Application (Fig. 3).

The most studied AR type in the works was Mobile, as shown in Fig. 4.

III. WORKS RELATED TO THE AR AND UX CONCEPTS

The standard concept of augmented reality is described by [3]. However, it is important to keep in mind other more current definitions of the concept. According to [14], the AR presents a view of the real and physical world that incorporates additional information to increase this view. The world can be analyzed through views. A tacit intuition indicates that the first view, whether direct or canonical, can be treated as reality and from that augmented with additional information. The increase, in reality, allows information to be injected into a view, this information being true or false, and in turn, any type of data can be expressed.

Reference [15] define AR as a technology used to increase the user's visual field with the necessary information in the performance of the current task. AR is an experience that complements the real world and provides a virtual layer of information [16], [17]. The most common versions of AR so far have used the cameras and screens on mobile devices such as smartphones and tablets. A typical scenario is that the user observes a part of the real world through the screen on his/her device, and then the application overlays digital information.

Reference [18] define AR as the improvement in the user's perception with additional sensory information generated artificially to create a new experience that includes, among others, improving human vision by combining natural and digital offerings. Augmented reality generally has three characteristics: 1) it combines the virtual with the real world; 2) objects are recorded from both the real and virtual world in a coordinate system; and 3) the interaction between the objects of both worlds is possible in real-time.

Reference [19] propose AR as a set of technologies that can be applied to extend different modalities of the human senses.

In the work of [13], the evolution of AR is presented as an exploratory experiment for the supplementation of sensory channels in a controlled environment to a generalized enabling technology for a variety of interactive applications. This progression is partly due to advances in tracking, logging, and displaying device fields and associated software. Concerning the concept of UX, in addition to that by Nielsen [4], [20], the following definitions are proposed: 1) the user experience is considered a subjective and a universal concept that defines the experience of the product or technological service; 2) it is a vision and response of people as a result of the intended use of a system, a product or a service. Most instrumental elements in the analysis of the UX, such as usability, utility, and non-instrumental elements such as joy and aesthetics, are addressed in depth in [20].

In [21], [22], and [23] the authors categorize the user experience as a person's perceptions and responses that result from the early use of a product, a system, or a service. UX perceptions involve an individual's experience with feelings that address the significant aspects of human-computer interaction.

For [24], the user experience refers to the addition of all the experiences in the user interaction with products, services, and companies that provide them. In addition, user experience assessment refers to surveying exploration issues to develop or improve user interfaces that allow users to easily and usefully use product or service features.

IV. UX QUALITY METRICS IN AR

The topic of quality criteria for the user experience is addressed by Brancati, Caggianese, Frucci et al. in [25]. The International Organization for Standardization ISO developed the standard 9241-210 Ergonomics of human-system interaction - Part 210: Human-centered design for interactive systems, in order to establish the human, ergonomic, and usability factors of the systems. The main element defined in the standard is the machine's communication with the person, to help those responsible for managing the design of hardware and software, and redesign processes to identify and plan timely and effective human-centered design activities [26].

Some international organizations, such as IEEE, are working on standards for AR [27]; however, the issue of user experience has not been addressed so far.

In general, the 101 revised studies present information related to how UX-related characteristics are evaluated in AR applications. The contributions from the analyzed works are described below. In [28], a comparison of user experience is presented in 5 immersive AR environments. The virtual environment, graphic design, and the perception of navigation were evaluated using a questionnaire and open questions. The perception of pleasure and emotions was combined with questionnaires, open questions, and biofeedback measurements such as heart rate, skin conductivity, and breathing patterns. The mental effort to perform tasks was measured through the NASA Task Load Index [29].

In [30], the authors describe an AR application designed for testing and research scenarios where the requirements were established with a group of 50 users. The characteristics highlighted by the participants in the study were the aesthetics, ergonomics, durability, and usability of the application. They expressed that the design should be ergonomic to limit the possibility of injuries related to repeated use. This includes making the device flexible to accommodate all users, regardless of their height or gender.

The work in [31] presents a mobile app to search for places, people, and events within a college campus. The feature that stands out in [31] is navigability, as well as in the study presented by Skinner, Ventura, and Zollmann in [32], where they propose an indirect browser for AR. Voice-based interfaces represent a breakthrough in the user experience, [33] propose a framework for generating voice-based interfaces to control AR applications on wearable or usable devices. The characteristics to be measured are divided into objective and subjective. Objective characteristics include:

- True positive. When a feature is activated, and it was the one that the user wanted to activate.
- True negative. When the system does not assign the issued command to any functionality.
- False positive. When the enabled functionality is not the one the user expected.
- False negative. When the user tries to activate a functionality correctly, but the system does not recognize it.

The subjective characteristics that are measured are system response accuracy (9 items), likeability (9 items), cognitive demand (5 items), annoyance (5 items), habitability (4 items), and speed (2 items).

In [15], the authors describe a comparative test between two instruction systems for an industrial assembly: augmented reality (group 1) and on paper (group 2). The collected measures were task completion times and the number of errors made when performing the task. The workload perceived by participants was measured with the NASA-TLX questionnaire. The evaluated variables were mental demand (MD), physical demand (PD), temporal demand (TD), user performance (P), effort (E), and frustration (F). The SUS questionnaire was used to measure the usability of each training system [34]. To measure the user experience, the short version of the UEQ [35] was used measuring: pragmatic quality (PQ), hedonic quality (HQ), and overall quality (OQ). Another important variable measured in group 1 was inter pupillary distance (IPD) to calibrate the HMD device.

According to [17], one of the developments in this new area of AR is the visualization of the light field that projects a complete 3D image on the retinas, which can be focused in the same way as a real object. Another improvement in the technology that can impact AR is the incorporation of sensors. In addition, the author highlights aesthetics as one characteristic that should be accounted for.

In [36] and [37], a test scenario is presented to measure image quality in augmented reality applications. The quality of experience (QoE) is generally measured using a Likert [38] categorization of acceptance of a service, based on intrinsic cognitive and emotional human states mixed with the delivery characteristics of the services. In this contribution, the authors consider QoE prediction for spherical images in augmented binocular vision scenarios. The metric used is called BRISQUE, an unreferenced quality image metric. The BRISQUE metric determination provides good overall performance when used as a target Quality of Service (QoS) indicator to predictively determine subjective QoE. A second contribution is EEG-signal-based on QoE prediction(Pan et al., 2016). There is a background on the integration between QoS and QoE [39], which presents an approach to improving the UX with respect to QoS of AR and VR sessions together.

Usability issues such as navigation, occlusion, selection, and text readability affect the proposed 3D visualizations to support developers in software engineering tasks. In [40], a controlled experiment is developed to check whether using immersive AR in visualizations could improve the process. The test group consisted of 9 participants, and the visualizations were 3D cities presented on a Microsoft Hololens device. The tests measured: user performance, which includes completion time, correctness and recollection, and user experience, including difficulty and emotions. The results showed that immersive augmented reality facilitates navigation and reduces occlusion.

In [41], an exploratory analysis of the user experience in parents was performed when reading an AR book with their children. The test group was 47 parents and their children. Each parent was interviewed to understand their experience qualitatively reading the AR-type book, and their intention to use AR books was also quantitatively measured. Considering the information of the measurements and perceptions of the test group, the authors propose a model to build books with AR. They suggest that the UX expectations oriented to user content are at the core of development problems to be considered. In addition, the developers should pay attention to UX perceptions such as the emotional, cognitive, and negative aspects of users.

In developing applications for augmented reality, the hardware to be used is important. In [18], it is described the experience of a group of users when using Microsoft HoloLens glasses. The authors claim that user satisfaction is defined as a combination of different factors associated with the use of the AR application and the associated delivery device. These factors include a sense of power and achievement; efficient use of time, effort, and other resources; meaningful content; a better view of the training environment; natural interaction; a feeling of astonishment; a performance that exceeds expectations; joy; the invocation of positive feelings and pleasant memories; immersion and commitment; transparent interaction; the feeling of participation in a community; a sense of privacy of user content; inspiration, encouragement, and motivation; and finally, artistic creativity. AR user satisfaction depends on both the user interface (UI) design and the choice of AR hardware. In this work and others like [42], [43], and [44], they used QUIS as a tool to evaluate the subjective satisfaction of users in specific aspects of the interface. Additionally, in [18], the Smart Glasses User Satisfaction (SGUS) questionnaire was used. SGUS is a method and a measure to analyze aspects such as improved environment perception, augmented environment interaction, location and object awareness implications, user-created AR content and new AR features that users typically use.

In [18] and [45], it is focused on the quality of the user experience on the selection of the appropriate hardware. In [45], the authors propose an evaluation using two devices: Microsoft Hololens and Epson Move - RIO BT-200. The performance evaluation for AR input devices uses 3 different input methods: mouse, touchpad, and gestures. The test group evaluated the following categories on a scale from zero to ten: overall comfort (easy to use), learning (the effort to learn how to operate), efficiency (after-test evaluation), precision (after-test evaluation), frustration (description of the level during the test), mental demand (description of the level during the test) and physical demand (description of the level during the test). Another field of application of augmented reality is in naval operations. Two application case studies are described in [19]: Tactical-AR and THEMIS-AR [46]. The evaluation was carried out with two questionnaires: UEQ - User Experience Questionnaire, which measures: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. The System Usability Scale (SUS) Questionnaire was used for usability testing.

An evaluation in [47] is conducted to see if AR applications are commercially accepted and in which areas they would work better. It was found that consumers consider AR more useful in the areas of education (case applied in [48]), medicine, and tourism. The survey results confirm that the hedonic and utilitarian aspects of the user experience are important for AR adoption.

A framework for evaluating MAR applications is proposed in [49]. The framework consists of 2 main components that are instrumental and non-instrumental quality attributes of MAR. These attributes are subdivided into categories: satisfaction, usability, and aesthetic measurements.

Mixed Prototype evaluation (MP) is also an area of research addressed in [50]. The users evaluated objective aspects of MP related to its performance (time to complete tasks and number of errors) and usability, as well as subjective aspects (time to complete the task; ease of use; and feeling after performing the task) related to satisfaction and user experience. The SUS questionnaire was used for the evaluation.

Research on devices, such as glasses, is also relevant to improving user experience A test case with the Zungle Panther device to evaluate the user experience is presented in [24]. It is proposed an evaluation model with 8 criteria: useful, usable, desirable, findable, accessible, credible, valuable, and audible.

In [22], an evaluation of two tourist applications is presented by measuring how the tracking technique affects the navigation of the AR application. The evaluation criteria they measure are Performance, Time to task completion and Error counts. Perception: expected quality of user experience based on context awareness, quality of experience, self-expressiveness and cognitive efforts. Usability: performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, habit, and behavioral intention.

Montuwy, Cahour and Dommes describe in [51] how to improve an adult user experience through the design and navigation recommendations for glasses and headphones. The variables evaluated were message perception, attention to the message, attention to surrounding, situation understand, feeling of efficacy, emotion, comfort and utility. The authors of [52] propose a model to evaluate the user experience in applications with AR in the tourism sector. The product features are content, presentation, functionality and interaction and product appearance characteristics: pragmatic attributes and hedonic attributes.

The work in [49] describes the development and the progress in MAR from the point of view of UX. In addition, it presents a systematic study on measuring user aesthetics as non-instrumental quality attributes for measuring UX for existing MAR applications. The non-instrumental quality attributes measure user needs beyond usability and satisfaction, which means aesthetics or product appeal. The evaluated characteristics were excitement, captivity, exclusiveness, innovation, interest and impression. The challenges of MAR are addressed in a complementary manner in [53].

In [54] and [55], it is described how AR is a field that offers many benefits in the automotive industry. In [55], the user experience evaluation was performed after the subjects experienced three contents using a mobile device or HoloLens glasses. The items for evaluated usability were Awareness: GUI element and degree of recognizing information. Comfort: the comfort of eyes in the visual aspect. Functionality: structural stability or clarity of distinction. Space Perception: distinction (depth) between real and virtual objects.

TABLE 6. Trends in metrics.

Application area	Common metrics	AR Type	Common metrics
Education	Engagement	HMD	Usability
Entertainment and Gaming	Enjoyment	Mobile	Aesthetics
Industrial Application	Space perception	PAR	Engagement
Medical	Image quality	SAR	Novelty
Navigation and Driving	Navigability	Indoor	Usability
Tourism and Exploration	Navigability	Outdoor	Navigation

In [56], a literature review on metrics is conducted to measure UX in AR applications in education. Metrics for MAR are presented: service quality, pragmatic quality, hedonic quality, stimulation, hedonic quality, identity, attractiveness and emotion. Two aspects of the UX are categorized: pragmatic and hedonic. In addition, it is concluded that AR technology is developing and interacting with new equipment. Therefore, UX measurement is not only limited to products in the form of applications and users, but also includes the available service and infrastructure. Performance metrics, self-informed metrics, and behavioral and psychological metrics are mentioned, as well. The measured UX aspects include the pragmatic which involves the completion of assigned tasks and the hedonic that includes user satisfaction when interacting with applications.

A detailed study is presented in [57] which includes evaluating of experience using different prototypes employing three UX evaluation methods. SUXES: a subjective method commonly used to evaluate the user experience of speech-based multimodal systems. It brings together nine types of user service statements and comments: speed, pleasantness, clearness, ease of use, robustness, learning curve, naturalness, usefulness, and future use. Emocard: a method consisting of 16 faces of drawings. The faces represent emotions. AttrakDiff, contains 28 attributes which are classified into three main groups:

- Perceived hedonic quality identification: presentable, integrating, creative, inviting, good, stylish y predictable.
- Perceived hedonic quality stimulation: attractive, straightforward, connective, professional, inventive, simple, likeable, pleasant and practical.
- Perceived pragmatic quality: appeal, structure, manageable, captivating, novel, innovative and motivating.

The investigation presented in [58] describes the behavior of a test group that uses an HMD application to perform an industrial task. Quantitative measures are evaluated such as accuracy, task completion, consistency, and time taken. From the analysis of the 101 works used as the primary source of this research, it is relevant to identify the trend in UX metrics in AR applications according to the area of application and the type of AR (Table 6).

V. AR TRENDS AND CHALLENGES

AR is an ever-evolving technology due to the demands of the productive environment. Therefore, researchers propose advances in the study of this concept. The studies that refer to AR trends and challenges are listed below. The concept of MAR, Mobile Augmented Reality, is described in [20]and [49]. MAR is defined as augmented reality generated and recovered with mobile devices in mobile environments. Various enabling technologies such as mobile processing, image recognition, object tracking, visualization, and sensors are used to measure location and orientation in smartphones that enable AR to become mobile.

The challenge that MAR technology faces is the performance of applications, because their performance depends in part on the device type and connectivity, that is, key features to be considered in test scenarios by application developers, especially mobile app developers [59], [60].

The Pervasive Augmented Reality (PAR) concept is described as a continuous and a context-aware experience [61]. The authors present a taxonomy based on three domains: context sources, context targets, and context controllers. The main difference with AR is the continuous use in PAR.

The Interactive Spatial Augmented Reality (SAR) subject is presented in [62]. The case study is the programming of industrial robots [63]. Gesture control is the preferred input mode to set parameters for common industrial tasks. Another input method used is a touch table. The user interface must be minimalist, because interface elements must share space with real-world objects in the workspace such as tools, parts, among others. However, the design of the elements should allow convenient touch control.

Regarding PAR and SAR technologies, space perception becomes their most important feature. Through this attribute the user can be aware of its location in the environment and the position of the objects relative to it, a primary indicator when using applications of this type.

According to [28], AR developers should pay close attention to the time users invest in understanding the device correctly to allow them to engage with the AR application in a better way. This can be done through elements such as the positional user interface and minimal user input. Alternative elements such as locomotion and the field of vision create barriers that often destroy the sense of commitment. The highest levels of interaction require engaging content, along with a greater sense of "being interactive" with the environment. Poorly designed user interfaces with few indications on how to interact are worrying.

Over the past decade, AR has increasingly been used for several training applications, such as medical education, rehabilitation engineering, automotive safety, task assistance and manufacturing [18], [64].

Although technology takes big steps forward, the evaluation metrics indicate a need for improved human input devices. New input methods, such as gestures or touch devices, arise in AR. However, most of them are far from traditional input methods such as the mouse.

Hence, the characterization of attributes elaborated in this research focuses on the liminal elements of two types of technologies that implement Augmented Reality: 1. The AR Headset, and 2. The AR Mobile. In the AR Headset (AR Glasses or Smart Glasses) users can perceive the real environment in which they are present, and at the same time, they can interact with the Augmented Reality that emerges in a floating manner on the device. This generates fixed proximity between the head-mounted object and the senses. However, in Mobile AR (tablets, cell phones, and smart watches, among others) such proximity is variable, due to the distances between the upper limbs holding the devices, and the senses focused on perceiving the AR [65], [66]. Although in both, the real environment and the AR are perceived at the same time, the characterization is based on the common aspects of these two technologies arising from haptic, sound, and visual gestures.

On the other hand, AR generates emotional links between digital products and users. The results of this study indicate that AR, in general, is also attractive to consumers that are the basis for increasing the competitiveness of companies by implementing AR solutions in their products, services, or business processes, especially marketing. Hedonic and utilitarian aspects of user experience are important for adopting AR [47].

In [17], [20], [28], and [67], the design of AR applications is presented as a challenge for developers. With so many real-world environment challenges, such as light, shadow, distance, precision, among others, AR has many obstacles to overcome. Meeting application design objectives depends to a large extent on the successful design of these components. These will only be resolved through experimentation and exploration [68].

In [69], the authors comment that there are numerous challenges for UX design in MAR such as ensuring the physical interaction of the user, reducing the mental effort to use those applications, technologies that allow the construction of prototypes, technical challenges such as battery consumption, processing power, screen size, type of tracking with or without markers, design of appropriate interfaces, and time to use applications. Despite these challenges, the authors present the opportunities that exist with this technology.

The existence of questionnaires for the subjective evaluation of the user experience such as QUIS [44], UEQ [35], [70], SUS [34] was evident. However, these questions do not cover the full characteristics of AR applications, so the work presented in this research mixes various evaluation techniques.

VI. PROPOSED CHARACTERIZATION

After the identification and analysis of the user experience quality attributes in augmented reality applications, the organization of knowledge towards a proposal for the characterization of these 94 attributes was developed. The classification is divided into two categories: objective and subjective, this corresponds to the first level with 40 objective attributes and 54 subjective attributes. The objective attributes are those that measure the user extrinsic motivations, whereas the subjective attributes describe the characteristics of the user intrinsic motivations [6]. The second level corresponds to the subcategories and the third level contains the attributes. The segmentation by subcategories was carried out taking into account the affinity of the attributes.

The process of generating the characterization proposal for this study was carried out by using the Delphi Method. The Delphi is a method of structuring a group communication process that allows a group of individuals to work on a complex problem.

The prediction capacity of the method is based on the systematic use of an intuitive judgment issued by a group of experts [71].

The phases applied to the context of user experience quality attributes in augmented reality applications are described below:

1. Definition of objectives. The initial problem is that there is no consensus in the organization of user experience quality attributes in augmented reality applications. For this reason, the objective of organizing the largest number of attributes identified from the systematic literature review based on the criteria of experts in software development is proposed.

2. Selection of experts. The experts needed for this study must meet the following criteria: 1) more than 5 years of experience in the field of UX/UI and AR, 2) having been assigned to fields of research and academia, and 3) having belonged to three recognized universities.

3. Preparation and launch of the questionnaires. The instrument sent to the experts contains 87 attributes with their names, descriptions, a field for observations and two columns to classify the attribute as objective or subjective. At this stage, the role of the expert is to decide whether the attribute is objective or subjective. The responses of the experts were reviewed, weighted and consolidated in another general instrument.

4. Exploitation of the results. In the general instrument, there were various attributes to which there was no consensus that the attribute was objective or subjective. To solve this finding, the consolidated instrument is sent again to the experts to review the opinion of their peer regarding the classification initially given to the attribute.

In this phase, a consensus must be reached on the location of all the attributes in a category. Additionally, the experts can suggest adding attributes according to their expertise. Two rounds were necessary to achieve the unification of how to locate the attributes in the categories.

When there is consolidation and unification of the attributes into objective/subjective, a new instrument is sent that consists of: attribute name, description, type of attribute (objective/subjective) and possible subcategory. At this stage, the expert can suggest more subcategories or rename the suggested ones. The objective of this stage is for the expert to place the attribute into a single subcategory.

This stage required 4 rounds to achieve the consolidation of the subcategories. In the end, an instrument with 94 attributes was achieved, 4 objective subcategories, 5 subjective

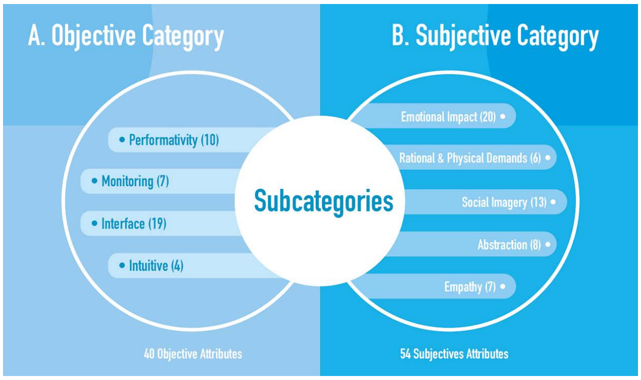

FIGURE 5. Proposed characterization of AR UX quality evaluation criteria.

TABLE 7. Performativity subcategory.

Name	Related work
Accessibility	[73]
Dependability	[42], [46], [74], [70], [75], [76]
Effectiveness	[48], [77], [78]
Efficiency	[42], [46], [48], [74], [70], [75], [76], [77], [79]
Interactivity	[73]
Navigability	[22], [31], [32], [40], [51], [74], [77], [80], [81], [82], [83], [84]
Perspicuity	[42], [46], [74], [70], [75], [76]
Practicality	[85]
Usability	[14], [19], [22], [24], [34], [39], [43], [50], [55], [86], [87], [88], [89], [90], [91], [92], [93], [41], [94]
Usefulness	[90], [95]

subcategories, where each attribute was located in an objective/subjective category and in a subcategory: performativity, monitoring, interface, intuitive, emotional impact, rational & physical demands, social imagery, abstraction, or empathy. The proposed categorization is presented in Fig.5.

A. OBJECTIVE CATEGORY

The objective category consists of the attributes presented in Table 7, Table 8, Table 9 and Table 10. The studies referred to in each characteristic present their explanation and/or functioning. Table 7 defines the subcategory called PERFORMATIVITY [72]. These attributes are related to the use of a system that must achieve clear and efficient objectives, explicit functionalities and safe interaction scenarios on a specific context of use.

As shown in Fig. 6 the most cited attribute is Usability, followed by Navigability. This indicates that these are the most used attributes in augmented reality applications in the observation window.

In the objective category, a subcategory called MONITORING, presented in Table 8, refers to attributes focused on the behavior of the application, based on the number of errors, the execution/completion time of the task and the successful procedures.

Fig. 7 shows the attributes referenced in the Monitoring subcategory, the most cited are: Task completion, Performance and Correctness.

Table 9 groups the Interface subcategory and collects the attributes associated with space perception, image quality and

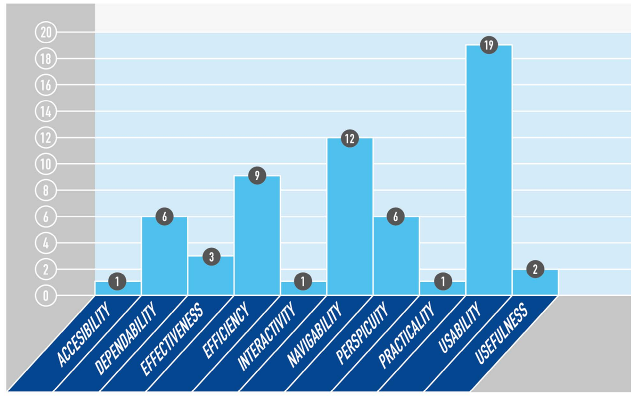

FIGURE 6. Performativity subcategory.

TABLE 8. Monitoring subcategory.

Name	Related work
Accomplish the task	[43], [96]
Accuracy	[58], [97]
Consistency	[58]
Correctness	[22], [25], [32], [33], [40], [98], [48], [51]
Performance	[15], [22], [45], [50], [56], [58], [77], [96], [99], [100]
Task completion	[15], [22], [28], [40], [50], [56], [58], [77], [83], [96], [101]
Time taken/task completion time	[58], [96]

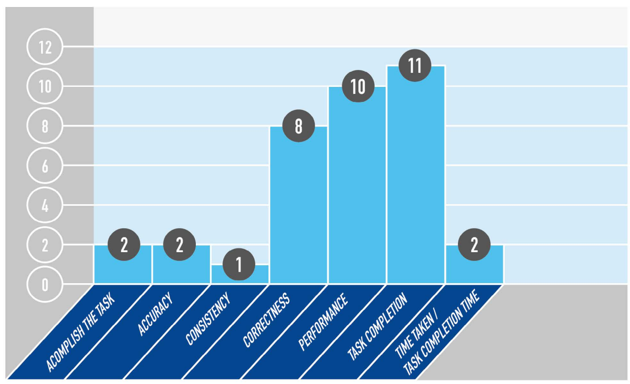

FIGURE 7. Monitoring subcategory.

clarity, camera technical characteristics, position, clarity in the identification and representation of interface elements and the level of transparency related to the Hardware to which the user will be exposed. Also, it establishes the design parameters from human factors such as ergonomics, anthropometry [102], and aesthetics in its two senses, perception and sensitivity. With all this, it projects the ease of interaction with the elements of the application.

In the Interface subcategory, the most cited attribute is Space Perception, followed by Attractiveness as shown in Figure 8.

The next subcategory is called Intuitive, and it is presented in Table 10. It relates the attributes to the ability to understand how to use the product, understanding of terminology, signaling, orientation aids, the ability to remember orientation information, and the level of information processing.

TABLE 9. Interface subcategory.

Name	Related work
Actor behavior	[103]
Aesthetics of Perception	[104]
Aesthetics of shape and color	[104]
Anthropometry	[105]
Attractiveness	[42], [46], [74], [70], [75], [76], [79]
Camera height	[103]
Coefficient of thermal spreading	[106]
Easy to use	[57], [95]
Ease-of-Interaction	[97], [67]
Ergonomics	[30], [50], [107], [91]
Identifiability	[52], [73]
Innovation	[57], [79]
Image quality	[16], [36], [37], [108]
Proportion	[104]
Representation	[95]
Space Perception	[17], [28], [30], [40] , [53], [55], [61], [62], [109], [110]
Transparency	[111]
Viewer position	[103]
Visual clarity	[73]

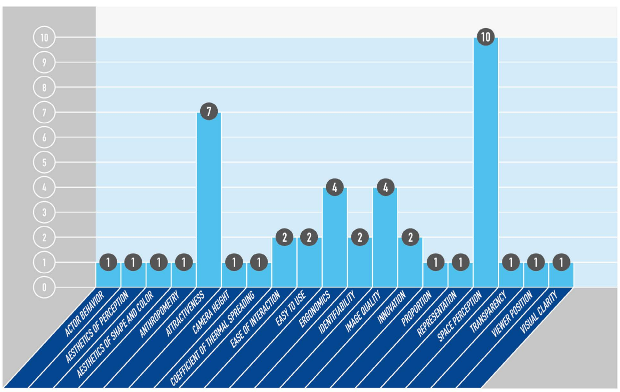

FIGURE 8. Interface subcategory.

TABLE 10. Intuitive subcategory.

Name	Related work
Comprehensibility	[79]
Comprehensivity	[73]
Information Processing	[107]
Memorability	[73]

The four attributes of the Intuitive subcategory are mentioned only once in the 101 studies reviewed. Therefore, these attributes are not as widely used in augmented reality applications (Fig. 9).

B. SUBJECTIVE CATEGORY

From Table 11 to Table 15 the attributes that are part of the subjective category are presented. The first subcategory presented in Table 11, Emotional Impact, has 20 characteristics, being the one that groups the majority of the attributes. These attributes are related to the emotional reactions of the application users, such as joy, anxiety, frustration, the ability to connect with other players, heart rate, skin conductivity, breathing patterns and the effect of continuity of the application use.

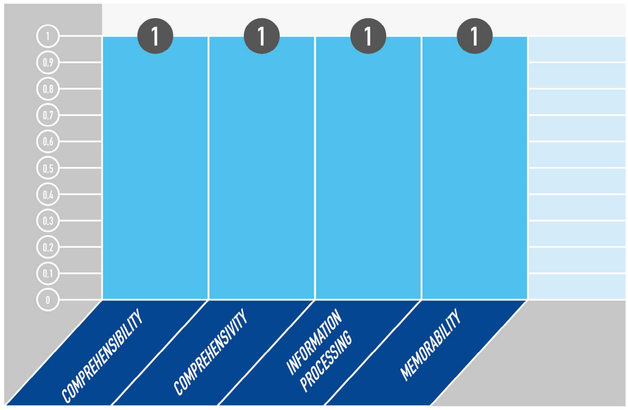

FIGURE 9. Intuitive subcategory.

TABLE 11. Emotional impact subcategory.

Name	Related work
Arousal	[112], [113]
Biofeedback	[21], [28], [56], [61]
Comfortability	[28]
Competence	[107]
Connectedness	[114]
Continuance intention	[115]
Engagement	[18], [28], [40], [47], [48], [49], [56], [87], [61], [112], [69], [116], [117], [118]
Enjoy	[113]
Enjoyment	[115], [119], [120]
Frustration	[77], [99], [120]
Importance	[111], [113]
Impressed	[113]
Perceived ease of use	[121], [122]
Perceived satisfaction	[119]
Pleasant	[92]
Reliability	[73], [79], [114]
Safety	[107]
Satisfaction	[18], [44], [45], [48], [49], [50], [56], [77], [78], [87], [90], [95], [123], [121]
Stimulation	[42], [46], [52], [74], [70], [75], [76], [79]
Valence	[112], [113]

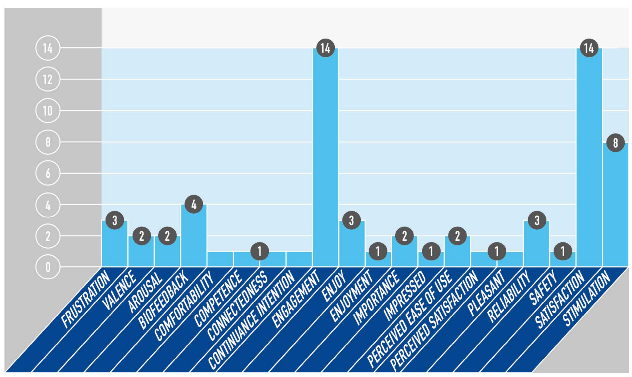

FIGURE 10. Emotional impact subcategory.

Fig. 10 presents Engagement and Satisfaction as the most used attributes of the Emotional Impact subcategory.

The subcategory Rational and Physical Demands is presented in Table 12, and groups the attributes focused on mental and physical effort and the ability to learn when using an AR application.

TABLE 12. Rational & physical demands subcategory.

Name	Related work
Cognitive demand	[15], [28], [33], [45], [77], [99], [69], [120]
Cognitive load	[124]
Effort	[77], [99]
Learning performance	[19], [119], [125]
Physical Demand	[77], [99], [121]
Temporal demand	[77]

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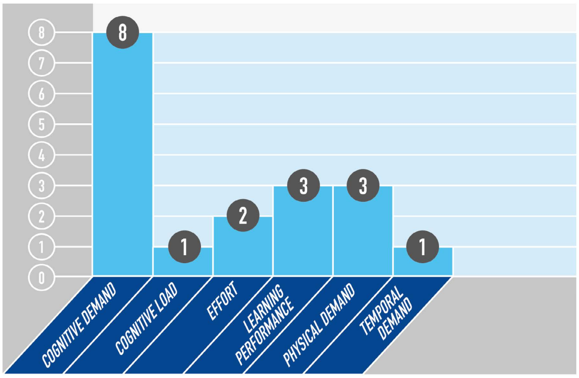

FIGURE 11. Rational & physical demands subcategory.

TABLE 13. Social imagery subcategory.

Name	Related work
Achievement	[115]
Self-presentation	[115]
Social behavior	[119]
Social interaction	[115]
Social presence	[87], [115]
Social Realism	[87]
Social Richness	[87]
Self-realization	[126]
Affordance	[127]
Perceived usefulness	[121], [122]
Novelty	[42], [46], [74], [70], [75], [76], [85]
Price Value	[22], [23]
Willingness to Use	[87]

In the Rational & Physical Demands Subcategory the most mentioned attribute is Cognitive demand (Fig. 11).

The Social Imagery subcategory, presented in Table 13, focuses on characteristics related to how the user experiences interacting with others. Such attributes are more visible in entertainment and/or games applications, where it is important how the player introduces itself, how it can compete with its peers, and where its presence in the game is visible. This subcategory also focuses on the characteristics that describe how the user perceives the application in terms of use, availability, the possibility of action and price value.

Fig. 12 presents Novelty as the most used attribute of the Social Imagery subcategory.

The attributes related to the ability of the system to abstract the user from the real world and present an alternative vision to escape from their daily routine, were subcategorized under the name of Abstraction and are presented in Table 14.

The use of the criteria in the Abstraction subcategory are balanced, as can be seen in Fig. 13.

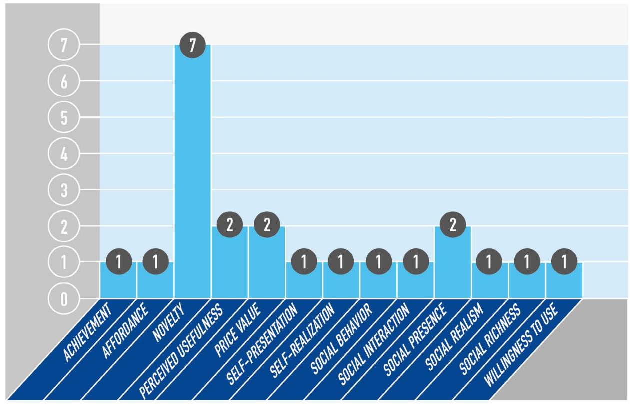

FIGURE 12. Social imagery subcategory.

TABLE 14. Abstraction subcategory.

Name	Related work
Attention	[113], [124]
Captivation	[114]
Escapism	[115]
Fantasy	[115]
Immersion	[123]
Immersion aspect	[88]
Kinesthetic	[128]
Reality Isolation	[128]

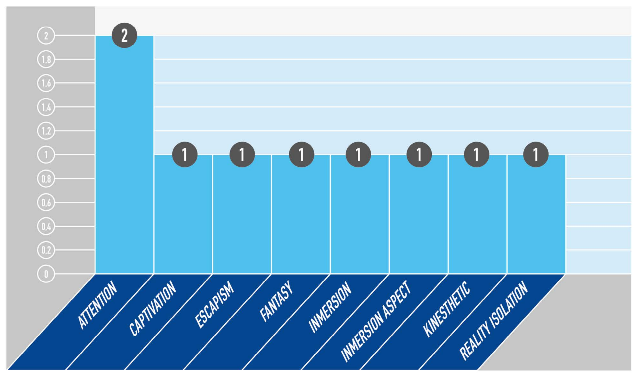

FIGURE 13. Abstraction subcategory.

The Empathy subcategory can be seen in Table 15. It contains attributes related to the feeling of naturalness and human likeness when interacting with AR information. In addition, it groups the attributes that superimpose the real world and allows the feeling of choice, that is, how realistic the application is.

Fig. 14 highlights two attributes as the most used: Intuitiveness and Naturalness.

The characterization presented in this study is a new proposal, in the form of a consensus, that organizes knowledge around augmented reality in the topics of quality attributes from the user experience. Through this classification, it is expected that the different actors related to the AR subject will have a conceptual basis to focus their efforts on the subcategories they require, according to their needs and the nature of their applications.

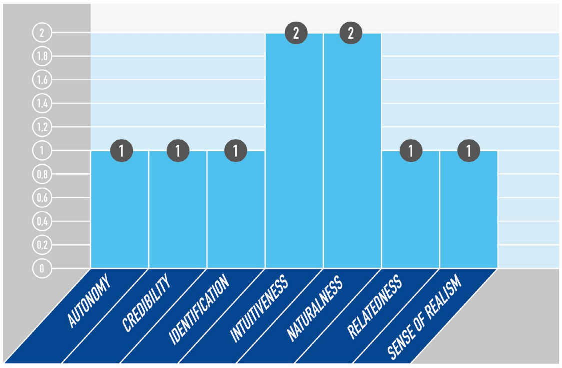

FIGURE 14. Empathy subcategory.

TABLE 15. Empathy subcategory.

Name	Related work
Autonomy	[107]
Credibility	[123]
Intuitiveness	[99], [114]
Naturalness	[57], [123]
Relatedness	[107]
Sense of realism	[97]
Identification	[126]

VII. DISCUSSION

The concept of usability as an attribute represents the primary concern of any project which envisions the creation of products with AR focused on satisfying the needs of various user profiles that emerge from any research. Human needs, which contain aspirational aspects, desires and biological requirements in an integrated way, arise as a challenge for designers and developers to find and typify, from them, the heterogeneous requirements that will be translated into interfaces. These interfaces are created as the potential solution to those needs, and for this, it is usually thought within the fields of interface design (UI) and User Experience Design (UX) that the search for objectivity is the key factor in order to make that usability or ease of use fulfill its mission. Although, usability can be defined as a unit of measurement that should monitor the satisfaction that a user experiences when interacting with AR products based on a kind of ease of use, it is necessary to go beyond operational factors to validate the scope of this aspect. Given that the satisfaction a user must achieve is subject to rational and emotional responses, factors linked to the reactions they generate in response to the stimuli behind the logic of any product designed for them must be systematically evaluated. The Interaction Design Foundation -IDF- [129] defines usability as follows: ''Usability is a measure of how well a specific user in a specific context can use a product/design to achieve a defined goal effectively, efficiently and satisfactorily. Designers usually measure a design's usability throughout the development process''.

As well defined by the IDF, in order to measure and know the level of satisfaction that a user experiences when immersed in a particular context, the process that supports the design and development of AR products involves the human factors that arise from a previous investigation, which is part of the initial sphere of every design process. In the initial research, not only the profiles of the users are known, but also the scope of how they think and feel can be measured [102].

However, usability translated as the ease of use, an aspect that could then be classified as an objective requirement, cannot always be so, which is a valuable point that this discussion demonstrates. Currently, the development of products that combine digital and analog interfaces, such as smart TVs, vehicle dashboards, cell phones, and tablets, among others, have touch screens that, also combined with haptic access buttons, enable people to carry out tasks in an increasingly efficient and fun way; which promises a high degree of satisfaction for the user. Then, it could be said, that each task that an AR product must fulfill in a simple and straightforward way arises as a translation of a kind of relationship between the finding and the human need to be satisfied, which, when it becomes a requirement, objectively gives rise to the functionality of the products. However, nowadays, the functions of the products that tend to be very evident for the user to achieve the expected efficiency, sometimes hide hidden functionalities to invite the user to discover them, in a kind of game that traces an affective bond with products, which goes beyond the pleasure caused by their acquisition, possession and daily use.

The hidden functionalities in the products are drawn not based on the practical, aesthetic and symbolic functions that generate affirmative emotions in their users, using the triad of the German designer Bernd Löbach [130] so that they can be elucidated by their users, it is to say for the specific tasks with which they were created. Contrary to this, they emerge as a turning point on the part of designers and software developers to stimulate emotions and reactions in the users which are at another level of decoding. Curiosity, as an activator of playful rituals or challenges, is one of them, and they have little or nothing to do with the basic functions for which they were created. These functionalities are monitored so they can no longer measure the, efficiency from the cognitive and emotional responses traced by the functionalities that if they are evident and although they also stimulate cognition and emotions, are not so hidden. In this sense, the concept of usability as an attribute is relativized and begins to assume a high role of subjectivity, as long as the hidden functionalities are experimentally at stake and are projected by their creators by and for the users, as the hypothesis that guides and supports this discussion. Within this context, usability as a necessary attribute in the design and development of digital products can assume these two roles, that of objectivity and that of subjectivity, understanding that the second is usually improperly attributed only to users and not to developers. All this, depending on the two dimensions that the functionalities can possess when being imbued in the products, as Max-Neef [131] argues, can operate as satisfiers of the needs.

On the other hand, the debate that the satisfaction of users using AR products does not only depend on the design of the interface and the hardware that generates the AR. Aspects such as accelerometer, gyroscope, GPS, and Eye

Tracking, may be present in the hardware, to a greater or lesser extent, depending on the category to which the digital product belongs. Among the products that make use of Augmented Reality addressed in this research it is possible to find: HoloLens-type Head Mounted Devices, HUD (Head-Up Display) Dashboards from the automotive industry, and various mobile devices such as tablets, cell phones and smart watches. In each of them, the combinations of hardware and sensors vary and do not respond to the same configuration. A HUD, although it makes use of GPS, does not need Eye Tracking because users tend to manually adjust values such as height and focus. This is not the case with mobile devices, where the coordination between screen and vision constantly changes angle, orientation, position and reading distance, leading to the use of gyroscope, accelerometer and GPS. This shows that depending on the category in which the device using Augmented Reality is framed, different combinations of technologies will be implemented. Hereafter, aspects that relativize the visualization of information coming from Augmented Reality, depending on the usability, content consumption and the distinctive hardware configuration in these technologies will be described.

Merenda et al. [132] manages to demonstrate that the fatigue generated in the sight, due to to the use of digital products with AR in the automotive industry, through the HUD (Head-Up Display) in the dashboards, appears when the visualization of the volumetric graphics is presented in different positions and in a complex way. This phenomenon requires a greater degree of brain activity while driving, increasing the risk of accidents due to the percentage decrease in the waking state. In the cases analyzed by Merenda et al. [132], on scenarios where the real environment remains in motion due to the movement of the user in the vehicles, the aspects that are part of the real world when combined with the emergent objects that arise from the AR, generate significant visual fatigue due to the focal overstrain that three-dimensional information requires, because it demands that the sense of sight focus at different distances and positions, and that the brain process a greater degree of information.

However, within the design parameters established by the new interfaces, it is possible to avoid that the displayed information is shown in different positions by superimposing the objects generated with AR on the real environments as if they effortlessly were part of them. This resource takes into account aesthetic factors such as perspective, vanishing points, proportion, textures, and lighting so that the three-dimensional modeling of objects, subject to Eye Tracking (ET), not only appears more real but also more natural and simpler to perceive. This ET concept, as explained by Sag, A. and Moorhead, P. [133], operates through the following of the visual trajectory in order to achieve that the experience with AR can simulate a sensation much closer to the modeled object or from the information superimposed on the environment, which requires less perceptual and cognitive efforts. In order to achieve a high degree of efficiency with ET, reduce eye fatigue, and satisfy the needs of content consumption with AR, it is necessary to make use of technological resources that current devices already have, including the gyroscope, barometer, GPS and accelerometer as argued by Sag and Moorhead. The systematic operation between these resources, which enable ET, leads to the user experience being easy to perceive and process, since it allows objects to interact more naturally with them, an effect that does not diminish the conscious waking state. This systemic operability that follows the senses is called by Sag and Moorhead device awareness, which is defined by them as "the compression of its position and environment coordinated with the user and the consumption of content" (p. 1). This is how they explain it: "Device awareness–a device's understanding of its position and environment in context with the user and content-is improving which in turn improves user experience by addressing users' needs sooner. Features such as touch display, GPS and barometer for location, gyroscopes, accelerometers for movement, fingerprint sensors for faster security, and voice for authentication and control have all improved device awareness. Moreover, eye tracking takes device awareness to a whole new level because it enables devices to understand where users spend their most valuable resource, their attention, at any given point in time" [133] (p. 1). With the current use of ET, the hypothesis of Merenda et al. [132] can be relativized in those digital products oriented to the transmission of knowledge in various disciplines, among which paleontology stands out specifically, with the simulation of extinct animals in current and static natural environments where the sensation of movement is generated when the user moves alongside the AR simulated object. The object simulated with AR and managed by ET appears on the environment in a natural way and interacts with the user in such a way that it does not over-demand the senses to appreciate the emerging aspects produced by the interfaces (UI); the latter, generators of sensitive experiences (UX). A case is exemplified within this particular area of the user experience with AR offered by NatGeo® in agreement with the social network Instagram. This NatGeo experience designates it as experience dinosaurs in your living room. Walk among the giants using Nat Geo's engaging interactive on Instagram [134]. Although the thesis of Merenda et al. [132] is assertive in some situations where the effort to try to capture the sum of real aspects together with those of AR presented in different positions, and in environments where the waking state is greater, does not happen even when the AR is superimposed taking into account conditioned aesthetic aspects that lead to said information reaching a high degree of reality to the point that the user thinks that it is part of the environment where it is displayed naturally.

VIII. CONCLUSION

Based on the research questions in this article, it can be said that regarding question 1: How is the user experience measured in AR applications? The evaluation is carried out through questionnaires such as QUIS [44], UEQ - User Experience Questionnaire [35]. No evidence was found from the evaluation of the UX integrated into the AR application. For question 2: What are the user experience quality metrics used in augmented reality applications? Evidence of works addressing augmented reality issues was found in different areas such as industry, commerce, medicine, education and tourism. The growing interest of organizations in improving their processes and generating profitability in their businesses influences the development of new technologies.

Measuring the characteristics of AR applications can be analyzed from two approaches: the performance and capacity of the technologies used, and the ability of people to adapt to technology and use it appropriately. The 94 attributes identified in the review of the 101 works described in section VI evidence the attributes used to measure the user experience.

Studies that describe how the user experience can be measured in augmented reality applications do not present unification in the characteristics to be measured, or in the way they do it. This means that multiple metrics are found according to the study area. Despite finding evidence of studies in user experience, there are opportunities to explore this field of knowledge in the industrial sector, because the use of AR in training, instruction and automation processes is important.

As future work to continue this research, the comprehensive classification of metrics, as well as their description through quantitative and qualitative indicators, is proposed. In addition, the development of instruments to measure characteristics is proposed when a user interacts with augmented reality.

Although the review of the seminal works of Azuma and Merenda appear as the referents of AR and UX, the investigations carried out by Nielsen [4], Revellino [72], Sag and Moorhead [133], among others, relativize the meanings of AR, HUD, UX, UI, and performativity from the new semantic edges that these concepts are assuming. All this, because the emerging technologies evidenced by these authors deduce new contributions regarding the dual and/or heterogeneous role that the concepts of Usability, Aesthetics and Interface can assume (to project how the other thinks and feels for the design focused on the user). This argument relativizes the singular position of objectivity or subjectivity raised in the seminal works.

The main contribution of this research reveals new subcategories around the 94 attributes used in the fields of AR, UI and UX. This new classification enriches previous studies in these areas, which designers and developers of digital products and/or services constantly consult, since they enrich the roles that these attributes are assuming in current technological developments. This classification proposes the consensus between the aspects that must be analyzed when fully evaluating an AR-based solution.

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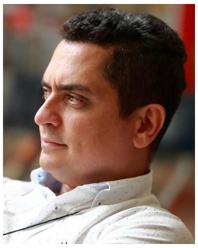

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