Asian Journal of Business Research Volume 8 Issue 2, 2018
ISSN 2463-4522 e-ISSN 1778-8933 DOI: 10.14707/ajbr.180051

Augmented Reality Trends to the Field of Business and Economics: A Review of 20 years of Research

Mafalda Teles Roxo
LIAAD/INESC-TEC and Faculdade de Economia, Universidade do Porto, Portugal

Pedro Quelhas Brito
LIAAD/INESC-TEC and Faculdade de Economia, Universidade do Porto, Portugal

Abstract

Augmented Reality (AR) is emerging as a technology that is reshaping the current society, especially the fields of Business and Economics (B&E). Therefore, the scientific studies produced on AR call for an interdisciplinary systematic review of the knowledge generated to structure an organized framework. Three main questions are addressed: How has the production of AR scientific knowledge evolved? What user-related aspects does AR affect? Also, which set of subtopics is associated with each motivation to develop an AR solution? The content of 328 papers produced between 1997 and 2016 in the field of AR is analyzed, unveiling 58 coding categories. There are 13 digital media characteristics that assume instrumental roles in addressing four major motivations to develop AR solutions. Technological topics dominate the research focus over behavioral ones. The investigations on AR in mobile displays show the highest increase. This research identifies the main scientific topics that have led researchers' agenda. Consequently, they contributed to develop and to adopt AR solutions and to forecast its future application in the organizations' strategies.

Keywords: Augmented Reality; Content Analysis; Digital Media; AR-User Interaction; Consumer Psychology; Digital Transformation.

Publication Details: Received 06 Sep 2018; Revised 17 Nov 2018; Accepted 23 Nov 2018

Introduction

Augmented Reality (AR), is a technology that allows the superimposition of computer-generated data registered in 3D to the real world, interactively, and in real-time (Azuma, 1997). The concept of AR represents one form of Mixed Reality (MR) and it is a blend between the virtual environment (VE) -virtual reality- and the real one, where elements from both environments are combined (Milgram & Kishino, 1994; Schmalstieg & Hollerer, 2016). AR is distinct from Virtual Reality (VR), because VR immerses its user in a complete digital and artificial world. Within the MR, AR calls for attention as it represents the first step into the virtuality continuum (VC), by adding virtual elements, being closer to the real environment (Schmalstieg & Hollerer, 2016). On the extremes of the VC, we found AR and the augmented virtuality (AV) (closer to the VE), where the VE is enhanced with real world elements (Milgram & Kishino, 1994; Tamura, Yamamoto, & Katayama, 2001).

AR has the potential to expand human perception and the ability to quickly adapt to different contexts, thus contributing to the creation of new platforms to deliver content to a global audience (Hugues, Fuchs, & Nannipieri, 2011). This technology also creates more transparent, flexible and fluid relationships, which leads to an increased productivity and the creation of immersive, context-aware and transparent experiences for people and businesses (Gartner Reports, 2017). Hence its wide application in domains like gaming or psychology (Bonus, Peebles, Mares, & Sarmiento, 2017). The Boston Consulting Group (BCG) estimated that more than 80 million of US citizens uses AR, i.e., around one third of smartphones users engage with AR technology at least monthly (Bona, Kon, Koslow, Ratajczak, & Robins, 2018). Moreover, BCG also found out that retail and fashion companies include/are prone to include AR in their marketing strategies, because advertisers believe that AR, in a 2 year period, will impact sales, purchase intent and engagement (Bona et al., 2018).

This specificity of AR causes a need for it to be studied more systematically. In this sense, some surveys were conducted, systematizing the use of this technology in assembly research (Wang, Ong, & Nee, 2016) or education (Sungkur, Panchoo, & Bhoyroo, 2016). Concerning consumer behavior research (CBR), Javornik (2016b) conducted a literature review about the potential media effects of AR on users. Although acknowledging the importance of this technology on consumer psychology few studies started to study the role of AR in consumer preferences and purchase intention (Beck & Crié, 2018). To the best of our knowledge, it has not yet been made an effort to systematically understand how the specific aspects of AR facilitate its influence on the consumer.

The objective of this study is to review the literature produced since 1997. We highlighted cross-analysed the variables identified by researchers related to the intrinsic aspects of AR technology that guided the development of AR solutions from a B&E perspective. Most of such scientific effort has been conducted in the fields of Education and Computer Sciences, and user research (Bacca, Baldiris, Fabregat, & Graf, 2014; Billinghurst, Clark, & Lee, 2014; Dey, Billinghurst, Lindeman, & Swan, 2018). However, little attention have been paid to those who use AR as a marketing tool to improve consumer-brands relationships (Scholz & Duffy, 2018; Scholz & Smith, 2016), or to develop new methods impacting consumers (Javornik, 2016a). We pay particular attention to the technical variables underlying AR development, specifically those relevant to the technology-user relationship, and MC.

To fill this gap in the literature, we conducted a content analysis, whose unit of analysis were scientific articles (journal and conference papers) retrieved from the Web of Science (WOS) and Scopus databases, published between 1997-2016.

The state-of-the-art of Augmented Reality

Technology-related aspects

Our first research question addresses a timeline perspective about the intensity of production but also the major applications of AR scientific knowledge.

RQ1: How has the production of AR scientific knowledge evolved?

Twenty years after the first systematization of AR (Azuma, 1997), its 'ecosystem' can be divided into interfaces, tracking systems, tracking techniques, displays, and augmented content (see Figure 1).

Interfaces enable the interaction between the user and AR content (Mihelj, Novak, & Begus, 2014). These may be tangible, collaborative, hybrid, or multimodal (Carmigniani et al., 2011). Tangibles allow interaction with the virtual content through physical objects and tools (Chao, Chiu, DeJaegher, & Pan, 2016), whereas collaborative involves multiple displays that allow several users to work simultaneously (Tait & Billinghurst, 2015). Hybrids combine complementing interfaces that create more interaction points in a flexible platform (Manuri, Piumatti, & Torino, 2015), and multimodal combines tangible with natural user interfaces (e.g. gesture) (Lv, Khan, & Réhman, 2014).

AR can be characterized according to its tracking system into marker-based (MB), markerless (ML), and extensible tracking. The tracking system relates to different tracking techniques because each tracking system has different tracking techniques associated (Lima et al., 2017). MB AR relies on the recognition of fiducial markers (Katiyar, Kalra, & Garg, 2015), whereas ML is more interactive than the MB, depending on natural features/3D models to perform the tracking (Xu, Chia, & Cheok, 2008). Alternatively, there is the extensible tracking where some fiducials are incorporated in the environment, although the tracking can continue even when there are no fiducials in the camera's field of view (Kim, Lee, Wang, & Kim, 2015).

In a review of the work presented in 10-year ISMAR/ISAR/ISMR and IWAR conferences, Zhou et al. (2008) divided such techniques into: sensor-based, vision-based, and hybrid. Since then, these techniques recognized by the tracking system were further refined and nowadays they can be divided into image-based, requiring the recognition of a 2D image/tag (Chehimi, Coulton, & Edwards, 2007). Location-based is a standard version for outdoor AR experiences involving GPS to determine the user's location (Chiang, Yang, & Hwang, 2014). Sensor-based tracking relies on information from the device sensors like gyroscopes (Nam, 2015), and model-based depends on 3D structures like computer-aided design models (Comport, Marchand, Pressigout, & Chaumette, 2006). Further, other tracking techniques exist like gesture-based (Lv et al., 2014) or paper-based (Ryu & Park, 2016).

AR displays, i.e, the components that allow users to have AR experiences, are organized into four groups. Head-worn displays (HWD) include head-mounted displays (HMD) (Kress & Starner, 2013) and glasses (Rauschnabel, Brem, & Ivens, 2015). Handheld displays regard portable technologies with adequate processing capability (e.g., smartphones, tablets) (Carmigniani et al., 2011). Spatial displays include projectors and holograms (Mihelj et al., 2014), and computer displays create AR experiences mediated by desktops and laptops with a webcam (Huang & Liao, 2015).

Ideally, AR would augment content from all five senses. However, the available AR solutions are related to the superimposition of visual artifacts, especially videos, images, and texts, and few involve a kinesthetic or haptic component (Craig, 2013).

Moreover, there has been an increased investment in mobile devices which makes AR hardware more accessible (Irshad, Rohaya, & Awang, 2016), and so developing mobile AR (MAR). MAR is essential in areas such as user interface (UI), user experience (UX), and app acceptance (Dacko, 2017; Olsson, Lagerstam, Kärkkäinen, & Väänänen-Vainio-Mattila, 2013).

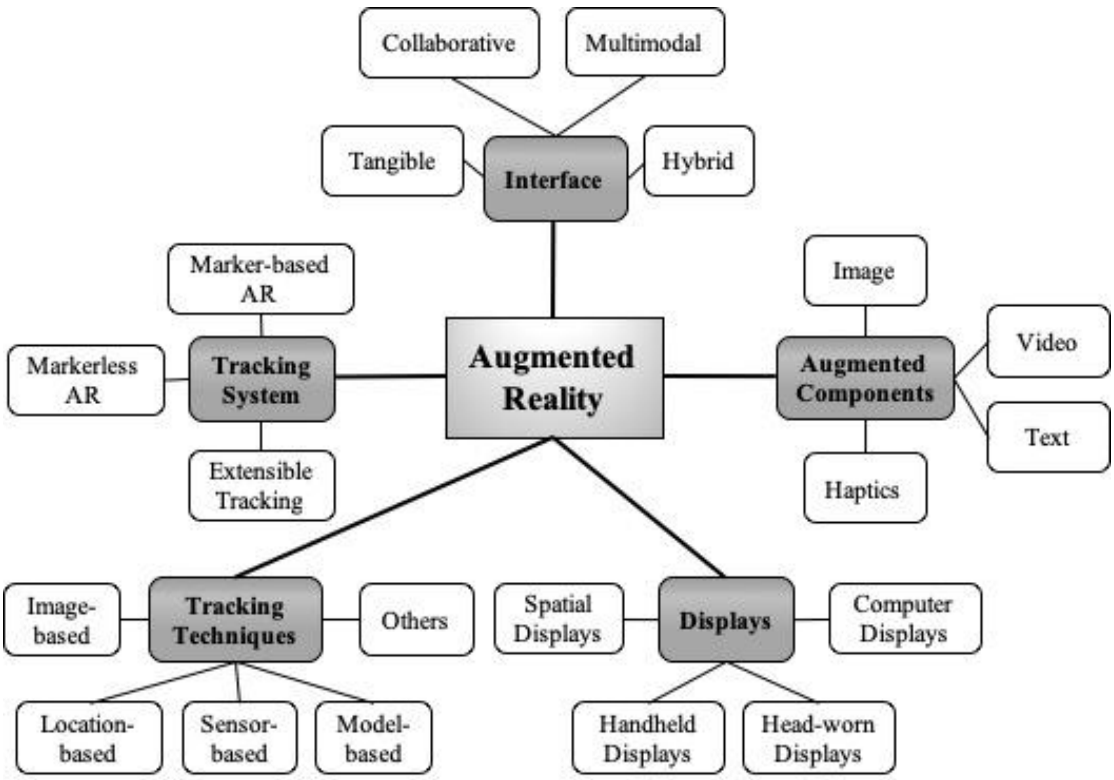

Figure 1: AR Ecosystem

Media Characteristics

The increasing sophistication and diversification of communication media lead to the need to measure their effect on users since ultimately its characteristics are associated with consumer behavior and management decisions (Hoffman & Novak, 1996; Stewart & Pavlou, 2009).

The framework of media characteristics (MC) include the following variables: interactivity, hypertextuality, modality, connectivity, location-specificity, mobility, virtuality, augmentation, flow, personalization, agency, and navigability (Blom, 2000; Javornik, 2016b) (see Table 1).

Table 1: Overview of MC

Media Characteristics	Definition	Authors
Interactivity	The degree to which two or more parties communicate in a technologically mediated environment synchronously or asynchronously by exchanging reciprocal messages.	(Kiousis, 2002)
Augmentation	The ability of technology to add additional virtual and dynamic capabilities/content to real systems.	(Billinghurst et al., 2014)
Flow	The result of MC that allows a holistic interaction experience with the environment leading to immersion in the activity performed within the medium.	(Csikszentmihalyi, 1990)
Telepresence	The experience of presence in an environment through a medium.	(Steuer, 1992)
Modality	It pertains to the way content is presented (e.g., image).	(Sundar, Xu, & Dou, 2012)
Hypertextuality	This is the number of available links. In AR, it is the connections between the different hyperlinks, devices, and applications.	(Javornik, 2016b)
Connectivity	It regards the kind of communication that can be established (one-to-one, one-to-many).	
Location-specificity	It concerns the geolocations of users that are relevant for AR as these data contribute to content production.	
Mobility	It relates to the ability to transport devices which is relevant, with the emergence of the MAR and wearable technologies.	
Virtuality	This is an inherent feature of AR that refers to the capability of the medium to overlap virtual elements to the real world.	
Personalization	Envisaged as the process of adapting the medium regarding functionality, content, and interface to increase personal relevance.	(Blom, 2000)
Agency	The degree to which the self feels s/he is a relevant actor in the interaction with the environment, which may influence the content.	(Sundar, 2008)
Navigability	The ability of the user to explore the mediated environment system and functions.	(Sundar et al., 2012)

AR-User Interaction

AR technology is implemented to affect the user and to solve specific problems. Our second research question tackles the issues about what users' need and their context. As can be observed in this section, these issues have been sensitive topics in the AR literature.

The AR-user relationship is a recently explored area in studies on UI and UX (Olsson et al., 2013) and technology acceptance studies (Rese, Baier, Geyer-Schulz, & Schreiber, 2017). However, it has not yet been systematized the user-related areas that AR can impact, i.e., there is no consensus regarding which theoretical concepts (TC) will AR impact. Concretely, which are the elements considered to be relevant to understanding the effect of AR on the user? Is AR influence reflected in the adoption of an attitude, in the decision-making process? How do users perceive the affordances carried by this technology? Does AR change an outcome? Alternatively, does it act in mediating any process, or even the value that the user perceives that AR has?

RQ2: What user-related aspects (TC) does AR affect?

Attitude concerns the psychological tendency to evaluate an entity on a scale of acceptability ranging from goodness to badness (Eagly & Chaiken, 1993) and regards cognitive (the beliefs and opinions that subjects knowingly have and form that relate to concepts like perception, memory); behavioral (a penchant for action or inaction that involves concepts like intention, referral); and affective factors (emotions and feelings triggered by a stimulus).

The process of **decision-making** regards problem recognition, search for information, and assessment of existing options before a decision (Solomon, 2018).

The concept of **affordances** is commonly employed in the areas of Psychology and Human-Computer Interaction (HCI) and is defined as the ability to use technology (Hartson, 2003). **Mediating** involves concepts that interfere in the human-technology relationship like risk, control, engagement. **Outcome** concerns concepts that lead to an objective assessment of the expected/verified effect of technology in satisfaction, performance, usability. **Value** regards measuring the worth of AR to the user (utilitarian, hedonic, or experiential) (Willems, Smolders, Brengman, Luyten, & Schöning, 2017).

Motivations to develop AR solutions

This topic explicitly drives the rationale underlying the development of AR applications.

RQ3: Which set of subtopics is associated with each motivation to develop an AR solution?

From an overview of the AR literature we learned that four main motivations lead to the study and development of AR solutions: hedonic, utilitarian, educational, and user-technology interaction.

Utilitarian motivations comprise rational features like the satisfaction of functional and rational needs and task accomplishment (Etemad-Sajadi & Ghachem, 2015).

Hedonic motivations are involved when AR aims at the satisfaction of leisure, entertainment, and affective needs and technological experience (Etemad-Sajadi & Ghachem, 2015).

Educational motivations regard AR as a tool to improve the educational process by providing new ways for learners to interact with and learn content (Candela et al., 2014).

The motivation can be to promote user-technology interaction, allowing them to create content (Liao & Humphreys, 2015) or to use different displays (Javornik, 2016a).

Method

A quantitative content analysis allowed for a systematic and replicable analysis of the scientific production content, because it is associated with statistical analysis, permitting to establish relations between the coded contents (Riffe, Lacy, & Fico, 2014).

Data Collection

Journal (JP) and conference papers (CP) on the topic of AR published between 1997-2016 were analyzed using a method similar to the one applied by ter Huurne et al. (2017). 1997 was the starting year because the first survey on the subject was published that year (Azuma, 1997).

A purposive sampling was used to search through the WOS and Scopus databases (Riffe et al., 2014). The set of keywords applied was: “augmented reality,” (as dependent variable) AND “marketing,” “consumer behavior,” “consumer psychology” and “business” (as study context), thus creating a sample of the knowledge built upon the field of AR.

An additional filter was the English language. The initial database consisted of 502 entries (346 from Scopus and 156 from WOS). This database was refined to eliminate duplicate entries resulting in 459 documents.

In line with the good practices established for this approach, two researchers conducted a thorough analysis of titles, abstracts, and keywords in the articles to eliminate any documents whose subject diverged from the purpose (Costa, Soares, & de Sousa, 2016). This process produced a final data set of 328 documents (166 JP and 162 CP) retrieved from 85 different publications and 109 conference proceedings.

Coding Process

The documents were coded relating to the salient aspects listed in figure 2 as relating to AR, using a phenomenological approach. This process resulted in the categorization of the articles accordingly to the following variables: domains of application, MC, tracking systems, tracking technologies, TC, displays, unit of analysis, augmented components, operating systems, and motivations to develop AR solutions.

The variable "domains of application" derived from the categorization created by the databases. "MC" concerned AR traits that create digital media experiences. "Tracking systems," "tracking techniques," "displays," and "operating systems" are intrinsic to AR technology development. "TC" represented the most common topics considered by the authors to explain the effect of AR on users. The variable "unit of analysis" reflects the scope of the databases' documents. The subtopic "augmented components" is the specific technical feature augmented by AR implementation.

The criteria for the coding process was the "absence" or "presence" of the subtopic in the article, i.e., if there was an explicit mention of the subtopic, or it addresses the definition considered for that subtopic we considered that the subtopic was present in the document. However, all topics were not exclusive, i.e., in some scientific papers, the authors discussed more than one subtopic belonging to the same category.

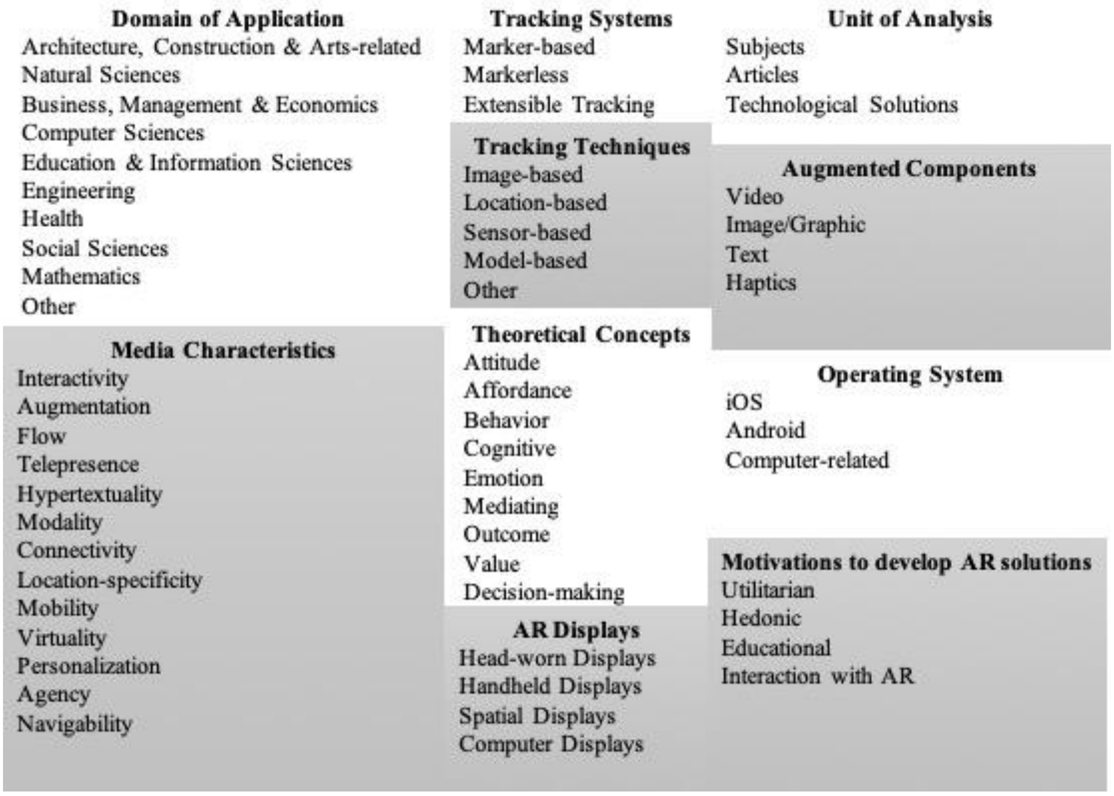

Figure 2: Topics and Subtopics

Intercoder Reliability

Two researchers conducted the coding solving the disambiguation issues, potential discrepancies regarding the coding meanings and the categories involved throughout the process (Krippendorff, 2004). The ultimate intercoder reliability for two coders was calculated for all documents using Krippendorff's alpha reliability measure (Hayes & Krippendorff, 2007). The values range from 0.82 to 0.97. The mean value was 0.89, which was acceptable.

Data Analysis

Two multivariate data analysis techniques were used to identify patterns in the AR literature: chi-squared automatic interaction detection (CHAID) and a cluster analysis.

The CHAID technique divided a sample into comprehensive, exclusive, and distinctive subgroups according to the dependency relation between a dependent variable (decision criteria) and the independent variables that were predictive of the criterion (Kass, 1980; Magidson, 1994). This algorithm profiles scientific articles based on the most statistically significant shared features through a decision tree that identified and profiled the underlying motivations to develop AR solutions.

The cluster analysis classified the documents contained in the database by the motivations to develop AR solutions, displays used, and MC so that we could examine the interdependent relations between the list of coded variables (Hair Jr., Black, Babin, & Anderson, 2014). This examination led to the identification and classification of specific sets of articles into groups with high internal homogeneity and high external heterogeneity (Hair Jr. et al., 2014).

A two-stage clustering approach was also followed. First, using Ward's method (Ward, 1963) of hierarchical clusters to determine the number of clusters to retain. Then, we used a nonhierarchical method (K-means algorithm) to overcome possible chaining effects and to fine-tune the results (Punji & Stewart, 1983).

The cluster analysis was complemented with a cross-tabulation analysis to statistically assess the cluster membership of the articles concerning the association between the following classifiers: "MC," "displays," and "motivations to develop AR solutions" (Hair Jr. et al., 2014; Lee & MacQueen, 1980).

Results

Evolution of the scientific production on AR between 1997 and 2016

The production of AR scientific literature has grown exponentially since 2013 (see Figure 3).

In 2000, 2004, 2006, 2008, 2010-2012, and 2015, the number of CP exceeded the number of articles published in journals. In 2007, 2009, 2013, 2014, and 2016, the number of JP exceeded the number of publications in conference proceedings.

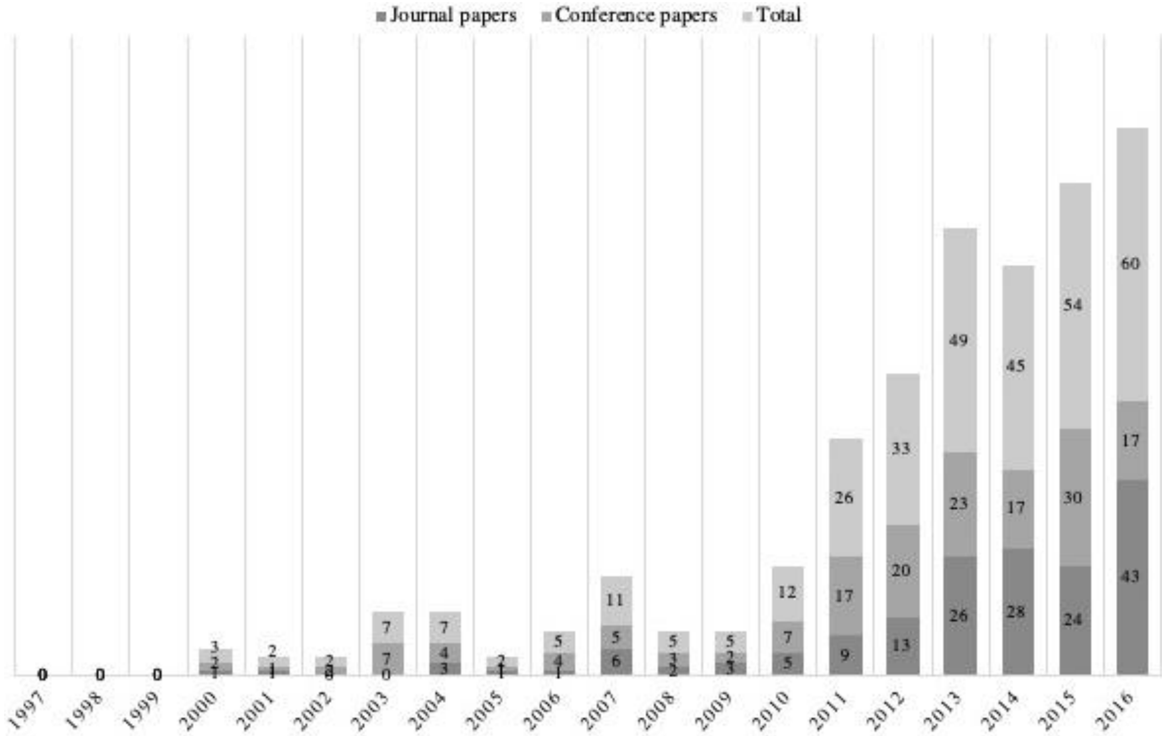

Figure 3: Evolution of the production of scientific documents between 1997 and 2016

Figure 4 shows the composition of the relevance of subtopics in four selected main topics of our research aggregated into five-years period groups, illustrating the evolution of academics' interest devoted to specific research subjects that are relevant for the B&E literature.

Regarding the motivations to develop AR solutions, a great bulk of the research produced is dedicated to the development and study of applications that promote user-AR interaction.

Concerning the domains of application, "Computer Sciences," followed by "Engineering" represent around 60% of the studies conducted. Also, "Health" accounts for 6% of the research done since. The number and diversification of areas of study has also increased over that period of time.

Within the topic of MC, "Augmentation" and "Interactivity" are the most dominant researched topics in the period under analysis. In contrast, from 2007 onwards, we assist to a decrease in research interest about topics such as "Agency" and "Personalization", favoring the study of "Connectivity", "Telepresence", and "Navigability".

Finally, concerning, researchers have been paying an increased attention to the type of displays such as handheld displays. Since 2007, research on HWD and computer displays have dropped, whereas the interest on spatial displays has been kept constant, despite the decrease observed between 2002 and 2006.

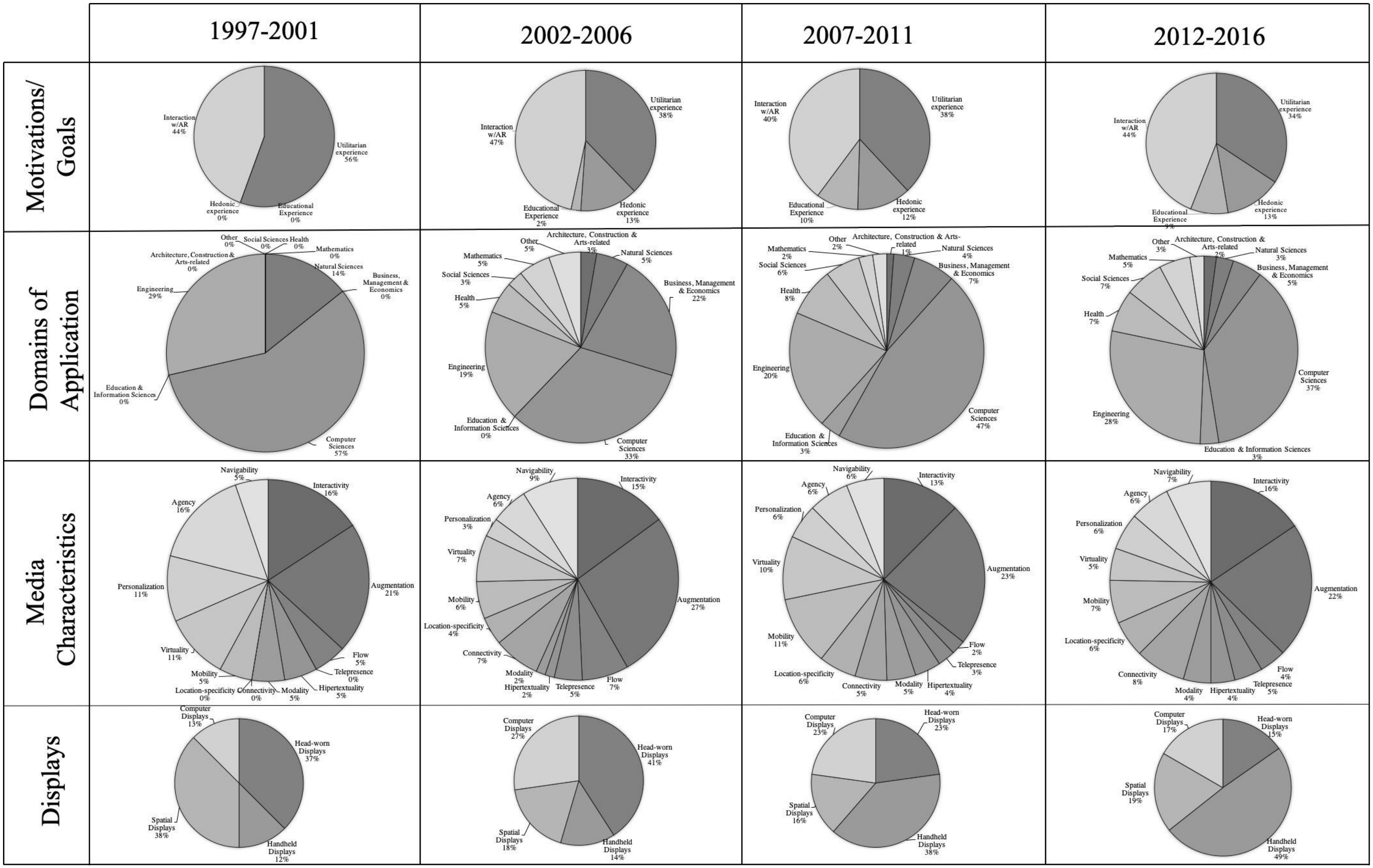

Figure 4: Evolution of the topics “motivation,” “domains of application,” “MC,” and “displays” over 20 years.

The user-related aspects that AR affects

Figure 5 shows the most common TC studied in the literature related to the effect of AR on users. "Affordances" (technology characteristics) is the most present subtopic (157/328), which indicates that these features are meaningful to the development of AR solutions. The subtopic "outcome" (72/328) expresses what might be expected from AR concerning performance in the promotion of collaboration and co-creation between people and technology.

The subtopic "mediating" aggregates several concepts that involve the relationship between people and technology (51/328), followed by the cognitive effect on the user (49/328). Subtopic "value" represents 11.3% of the articles, "behavior" is presented in 9.1%, "attitude" in 8.8%, whereas "decision-making" represents 5.5%. The subtopic "affective" accounts for only 4.0% of the TC used to study AR phenomena. Overall, the presence of the above-mentioned subtopics in the literature addresses the type and frequency of AR concepts affecting users in the period between 1997 and 2016.

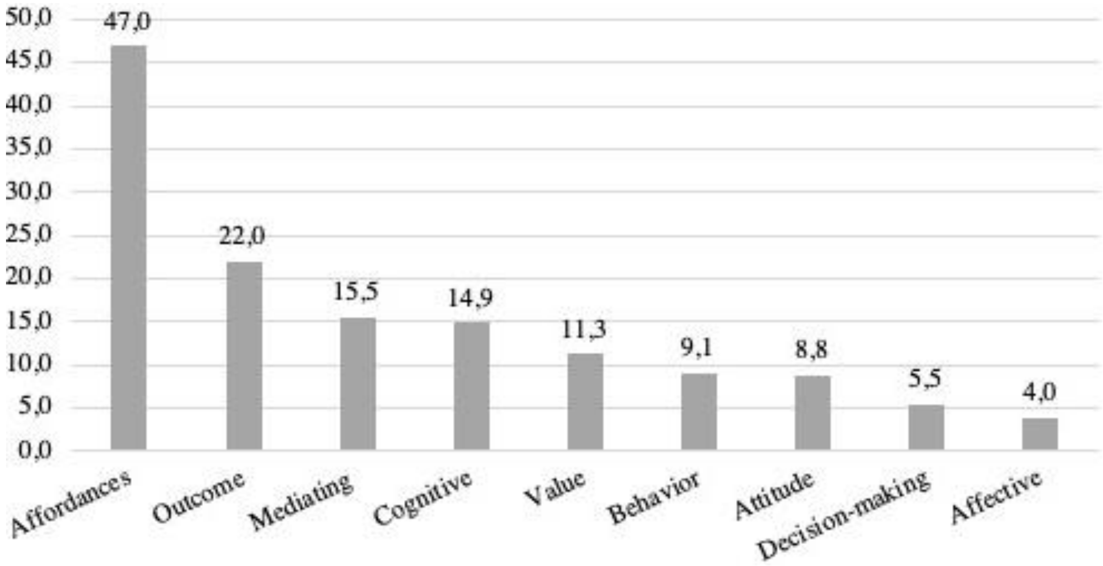

Figure 5: Distribution of the TC in the database (%)

Motivations to develop AR solutions

We predefine a dependent variable placed in the root node. The connections of the other subtopics to that leading variable are evaluated by the distance to the root. Within a continuous hierarchical mode, the closest predictors to the initial node in the tree are more statistically related to it. Using the "motivation to develop AR solutions" as the starting focal point, the CHAID algorithm processes the set of predictor/subtopics (see figure 2) to explain each one of the four motivational goals to apply AR according to its degree of influence in each successive node/subtopic.

We estimate four models where each one focuses on the main rationale behind the development of AR solutions (see

Figure 6): (1) Utilitarian experiences; (2) Hedonic experiences; (3) Educational experiences; (4) Interactions with AR.

From the 58 potential attributes/subtopics, only 10 have predictive power in the CHAID estimation. Since the dendrogram partitions are based on a binary input (0=absence;1= presence of that subtopic in the article), they also highlight the relevant nodes of the tree accounting for absence.

For each motivation or subtopic, the algorithm classifies both the statistically relevant subtopics mentioned in the articles in connection with the previous node benchmark subtopic and those also significant but absent subtopics.

Six subtopics are structurally associated to each one of the "motivations to develop AR solutions." However, we focus our analysis on those subtopics systematically present in articles devoted to the main motivation and rooted on successive nodes of each partition.

The CHAID dendrogram shows that the most likely predictor associated with the "utilitarian experience" motivation is the MC "augmentation." From the initial predictor, two nodes are extracted; 59.5% of the articles of that initial node mention another MC: "modality." Furthermore, issuing from "modality," 85.7% of the articles discuss the "personalization." In three nodes, all subtopics present are significantly associated with the dependent variable: "utilitarian experience."

Two out of the four CHAID models share a common trait: the first and best predictor concerning the topic of the development of AR solutions is always considered a MC, except for the "hedonic experience," and "educational experience." Still, even in those motivations, at least one MC ("navigability" and "connectivity", respectively) is present in 9.4% (8/85) and 11.3% (6/53) of the scientific production, respectively.

In general, the scientific studies on AR solutions mainly discuss MC that pertain to several domains of application (five subtopics mentioned) and one theoretical concept ("value"). The references to AR augmented content ("image/graphic") and unit of analysis ("subjects") marginally appear in a structurally consistent association with some AR development motivations.

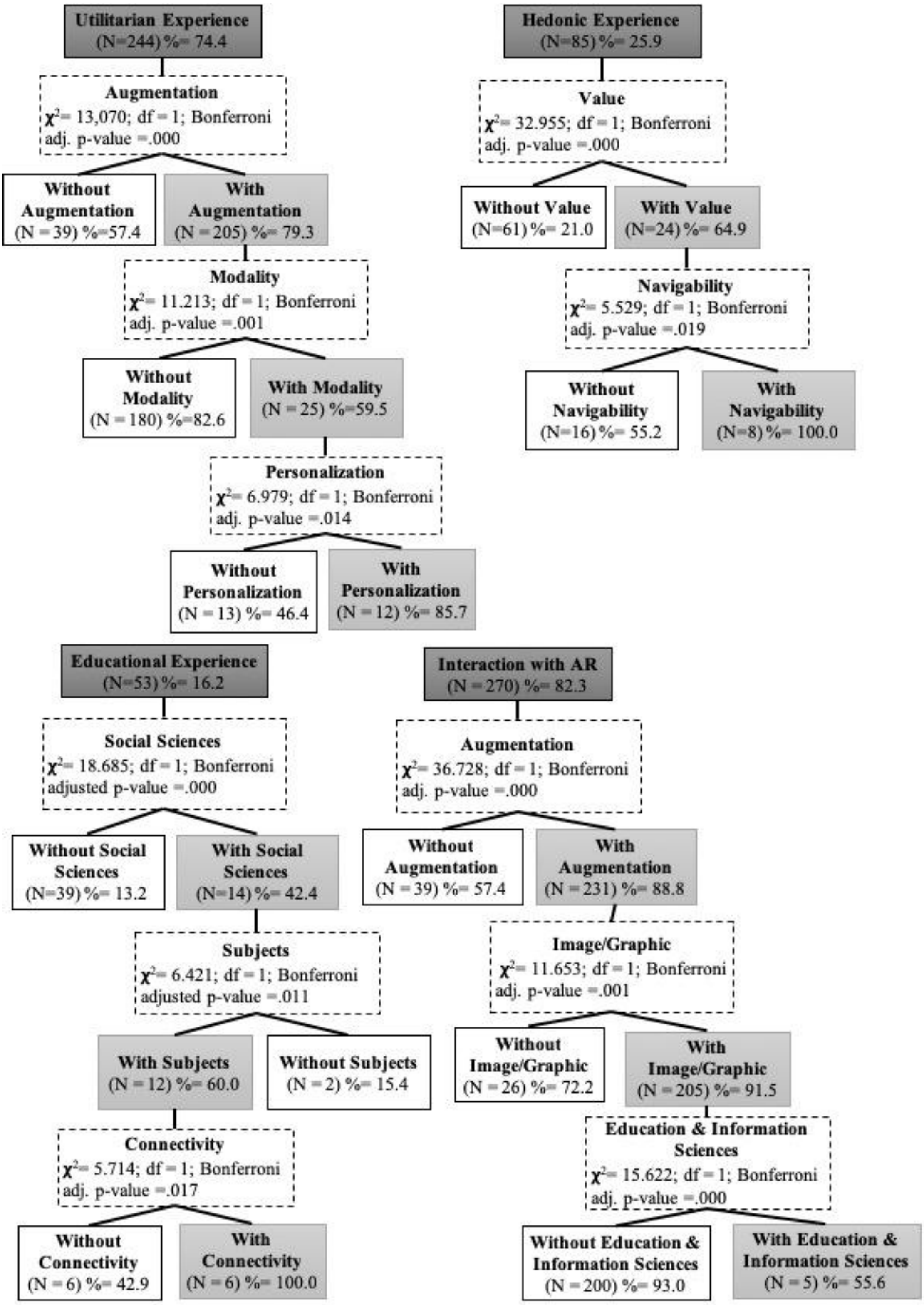

Figure 6: CHAID charts

The cluster analysis groups the articles of our database of scientific production if all variables used for classification have a similar status (Hair Jr. et al., 2014). No predefined structure was defined. We selected three major topics to categorize into homogeneous clusters of scientific studies.

The rationale for selecting “MC,” “displays,” and “motivation to develop AR solutions” as inputs in that numerical taxonomy program are the following:
(1) Statistical: the sample size compromises the validity of the output if we try to include several variables. The selected three topics already bring 21 subtopics to the estimation;
(2) Interpretability of the clusters: the output should make sense and be meaningful. The conflict of potential overlapping among clusters would upsurge as the number of variables increase;
(3) Compatibility with our research Focus.

“MC” embody the digital media substance of AR. Moreover, the “motivation to develop AR solutions” defines the logic behind the implementation of AR, and “displays” captures the technological dimension. In fact, the displays are the most tangible representations of AR that everybody physically interacts with.

Table 2 shows the degree of presence for each subtopic in the cluster. The corresponding statistic – chi-square – that was estimated through the cross-tabulation analysis allows the measurement of the extent to which the subtopic is significantly discriminating in each cluster.

As expected, the MC “augmentation” is the omnipresent issue in all scientific studies and reaches at best a minimum incidence rate of 87% (79.3% average). Similarly, on average 82.3% of the articles emphasize the “interaction with AR” behind applying AR. We precede below with a brief characterization of the AR scientific production clusters’ compositions that are labeled according to the most prominent subtopic.

Cluster 1: Headset AR

This cluster assembles the AR publications with the highest incidence of “displays” subtopics “HWD” (69.6%) and “spatial displays” (47.8%). All papers focus on “interaction with AR” (100.0%) as the main motivation to apply AR. The MC “mobility” (78.3%) and “navigability” (52.2%), besides “interactivity” and “augmentation” are predominant in this cluster.

Cluster 2: General

None of the papers belonging to this collection of publications shows a predominantly specific subtopic. They list all subtopics but at the lowest levels of presence compared to the other clusters, except the MC “modality” and “connectivity” that are absent.

Cluster 3: Mobile AR

Cluster 3 concentrates almost all publications studying “handheld displays” (97.7%) under the subtopic of “location-specificity” (83.7%) in MC.

Cluster 4: Utility-related AR

Cluster 4 is characterized by a strong prevalence of publications studying “computer displays” (38.6%) paired with the research motivation “utilitarian experience.” In contrast, “location-specificity” “and “mobility” are the MC subtopics not referred to in the papers devoted to AR belonging to this cluster.

Cluster 5: Multi-featured medium

Driven by the “hedonic experience” motivation to develop AR (60.5%, the highest incidence rate among all clusters), this cluster aggregates articles predominantly mentioning several MC: “augmentation” (97.4%), “flow” (39.5%), “telepresence” (50%), “connectivity” (73.7%), “virtuality” (57.9%) and “personalization” (52.6%).

Cluster 6: Educational promoter

Compared to other groups, the most frequent articles dealt with the “educational experience” AR application in this cluster. “Interactivity” (95.6%) is the most representative MC.

Cluster 7: User-adaptable medium

The articles mentioning subtopics like “augmentation” (97.0%), “navigability” (81.8%), and “agency” (75.8%) have a strong prevalence of the MC. The most common drive to apply AR is “utilitarian experience” (90.9%) that uses “spatial displays” as the most representative AR display (45.5%).

Table 2: Subtopic presence within cluster regarding MC, displays and motivations to develop AR solutions

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5		Cluster 6		Cluster 7		Total per cluster	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Interactivity (χ^2= 138.284)	20	87.0	11	19.0	15	34.9	29	33.0	35	92.1	43	95.6	2	6.1	155	47.3
Augmentation (χ^2= 225.763)	20	87.0	4	6.9	41	95.3	84	95.5	37	97.4	42	93.3	32	97.0	260	79.3
Flow (χ^2=55.177)	8	34.8	5	8.6	0	0.0	4	4.5	15	39.5	10	22.2	0	0.0	42	12.8
Telepresence (χ^2= 62.039)	3	13.0	4	6.9	1	2.3	5	5.7	19	50.0	9	20.0	1	3.0	42	12.8
Hypertextuality (χ^2= 85.748)	11	47.8	2	3.4	2	4.7	3	3.4	0	0.0	18	40.0	1	3.0	37	11.3
Modality (χ^2= 68.634)	11	47.8	0	0.0	6	14.0	5	5.7	3	7.9	17	37.8	0	0.0	42	12.8
Connectivity (χ^2= 155.223)	5	21.7	0	0.0	2	2.7	3	3.4	28	73.7	30	66.7	4	12.1	72	22.0
Location-specificity (χ^2= 161.878)	7	30.4	4	6.9	36	83.7	0	0.0	1	2.6	9	20.0	2	6.1	59	18.0
Mobility (χ^2= 161.479)	18	78.3	5	8.6	30	69.8	0	0.0	0	0.0	19	42.2	0	0.0	72	22.0
Virtuality (χ^2= 68.708)	9	39.1	3	5.2	2	4.7	9	10.2	22	57.9	10	22.2	2	6.1	57	17.4
Personalization (χ^2=44.428)	9	39.1	3	5.2	6	14.0	15	17.0	20	52.6	10	22.2	2	6.1	65	19.8
Agency (χ^2=98.742)	10	43.5	2	3.4	9	20.9	5	5.7	19	50.0	8	17.8	25	75.8	78	23.8
Navigability (χ^2=149.868)	12	52.2	2	3.4	23	53.5	1	1.1	5	13.2	2	4.4	27	81.8	72	22.0
Head-worn Displays (χ^2=50.815)	16	69.6	12	20.7	3	7.0	17	19.3	7	18.4	1	2.2	6	18.2	62	18.9
Handheld displays (χ^2=136.952)	7	30.4	22	37.9	42	97.7	27	30.7	8	21.1	43	95.6	1	3.0	150	45.7
Spatial displays (χ^2=52.634)	11	47.8	4	6.9	0	0.0	21	23.9	12	31.6	2	4.4	15	45.5	65	19.8
Computer displays (χ^2=48.171)	1	4.3	8	13.8	1	2.3	34	38.6	14	36.8	1	2.2	10	30.3	69	21.0
Utilitarian experience (χ^2=65.493)	20	87.0	26	44.8	37	86.0	77	87.5	33	86.8	21	46.7	30	90.9	244	74.4
Hedonic experience (χ^2=53.065)	11	47.8	7	12.1	8	18.6	15	17.0	23	60.5	19	42.2	2	6.1	85	25.9
Educational experience (χ^2=34.469)	2	8.7	6	10.3	5	11.6	10	11.4	3	7.9	21	46.7	6	18.2	53	16.2
Interaction with AR (χ^2=72.307)	23	100.0	27	46.6	41	95.3	72	81.1	38	100.0	38	84.4	31	93.9	270	82.3

Discussion

From the pool of scientific publications developed between 1997 and 2016, we have tried to understand what the main topics and the logic underlying the associations within the 328 articles are. The categorization process identifies 10 major topics covering several attributes such as domains of AR application, theoretical framework, digital media aspects, motivations to develop AR solutions, and technical dimensions (displays, components, operating systems, tracking and system techniques). We deliberately select the subtopics of "motivations to develop AR solutions" and try to understand the network of connections the researchers considered in their studies when investigating AR.

A substantial part of the scientific corpus of the literature produced in the studied 20 years involves CP from Computer Science and Engineering which are the main areas of investigation of AR. However, JP is almost reaching the CP status with an equal distribution of the publications (an aspect that we highlighted by emphasizing JP over CP).

CP typically addresses novel and innovative research dimensions. In general, the publication process involving CP is faster than other topics and might be further transformed into JP (Bar-Ilan, 2010; Montesi & Owen, 2008). Additionally, CP is a primary source of feedback that researchers have access before submitting they studies to journals (Drott, 1995).

Concerning the domain of application, the academic research topics have become more diversified due to the multiple applications that AR has started to offer.

The results from the multivariate analysis show the instrumental role of the "MC" topic in motivating the creation of AR solutions. Regardless of the intensive presence of this topic in academic studies on AR, we naturally detect 13 subtopics that show the relevance of the topic.

"Augmentation" is the most representative MC in AR research and omnipresent in the main motivations to invest in AR solutions (Javornik, 2016b). Moreover, since 2007 the research interest in MC like "telepresence" increased. The manipulation of the level of presence introduced by visual assistance in a consumption experience, or in the context of location-based AR settings may explain the amplification of "telepresence" as a relevant research topic (Georgiou & Kyza, 2017; T. L. Huang & Hsu Liu, 2014). Although we verify a decrease in the research of the MC of "flow", some sound studies have worked on the topic of the flow experience in e-shopping contexts using AR technologies (Huang & Liao, 2017).

The technological features of AR remain directly or indirectly the dominant concern of the investigations between 1997 and 2016. The interests of researchers have switched from computer to handheld displays in tune with the growing availability of those products in the professional and entertainment markets. We observe a tendency to focus on MAR solutions and wearable, which is a consequence of its increasing importance (Tarute, Nikou, & Gatautis, 2017).

Additionally, despite our database indicates otherwise, the use of HMD is a trend that is projected to rise in the next few years (e.g.: the studies of Liao, 2016; Rauschnabel et al., 2015, that did not appeared at the time of the data collection) due to the applications of headsets in the healthcare and industrial jobs. Within the tracking technologies, image is still the most used tracking technique. Nonetheless, we witness an increased use of sensor, location, and gesture-based techniques, which is in line with the investment in the development of ML AR solutions (Kasapakis & Gavalas, 2017).

Among the user-related aspects, “affordances” is the most investigated subtopic, because they allow researchers to understand which capabilities of the AR can influence one’s behavior (like the fact that AR allows to see something that is not present in the real world). The second most researched subtopic is outcome, since it supports the employment of AR to fulfill users’ needs (e.g., in collaboration processes) (Poppe, Brown, Johnson, & Recker, 2012). The intellectual investment in subtopics related to CBR (attitude; cognitive, behavior, and affective factors) seems to be in its infancy. Only in this decade the research interest started to increase thus presenting a venue for future research.

Apparently, AR studies have not stimulated the development of a new and more precise theoretical framework. We do not notice a dominant theory or theoretical concept that is consistently discussed in association with any main motivation to develop AR solutions or other technical dimensions.

Limitations and Outlook

AR plays an important role as a new medium and technology, that could be used as a tool to generate and communicate new content in a wide range of contexts, e.g. marketing (Liao, 2015) or surgery (Bourdel et al., 2017).

This study provides a focused overview of 20 years of research on AR, showing how this technology is being incorporated in our society, focusing on the type of AR solutions that have been developed in the fields of B&E.

This study has some limitations that justify further research. The first is the phenomenological limitations derived from using a content analysis as the method. When filling the gap between technical aspects of AR and their effect on the user, it was developed a coding system based on the analysis of previous studies in other areas. Therefore, despite reaching acceptable values of intercoder reliability, there is always the risk of biased interference from the researchers.

Secondly, this study is based on two databases: WOS and Scopus. This could be complemented by using other databases (e.g., ProQuest), which might broaden the scope of the investigation, creating a larger data set, and increasing the validity of the results.

It would be interesting, the conduction of a citation analysis to our database to detect whether there are any relationships among documents regarding its authorship, and the potential connections between the articles and the major conferences, similar to the approach followed by Dey et al. (2018), on the topic of AR user studies. Moreover, it could be used a hybrid (human and computer) approach to content analysis (Su et al., 2017).

Thirdly, since our goal was to understand the inferences that might be drawn from AR applications in digital media, future research could adapt the search keywords to other research goals.

In summary, despite these limitations, this study clarifies some important questions about the technology of AR, thus constituting a benchmark for researchers and companies interested in AR as a communication medium.

Acknowledgements

This research was financed by the European Regional Development Fund (ERDF) and the North Portugal Regional Operational Programme in the framework of the project "NORTE-01-0145-FEDER-000020", and by Portuguese Public Funds through Fundação para a Ciência e Tecnologia (FCT) in the framework of the Ph.D. grant SFRH/BD/131191/2017.

References

Azuma, R., (1997), "A survey of augmented reality", *Presence: Teleoperators and Virtual Environments*, vol. 6, no. 4, pp. 355–385.

Bacca, J., Baldiris, S., Fabregat, R., and Graf, S., (2014), "Augmented reality trends in education: A systematic review of research and applications", *Educational Technology and Society*, vol. 17, no. 4, pp. 133–149.

Bar-Ilan, J., (2010), "Web of Science with the Conference Proceedings Citation Indexes: the case of computer science", *Scientometrics*, vol. 83, no. 3, pp. 809–824.

Beck, M., and Crié, D., (2018), "I virtually try it…I want it! Virtual Fitting Room: A tool to increase on-line and off-line exploratory behavior, patronage and purchase intentions", *Journal of Retailing and Consumer Services*, vol. 40, pp. 279–286.

Billinghurst, M., Clark, A., and Lee, G., (2014), "A survey of augmented reality augmented reality", *Foundations and Trends in Human-Computer Interaction*, vol. 8, no. 2–3, pp. 73–272.

Blom, J., (2000), "Personalization - A Taxonomy", in *Extended abstracts of the CHI2000 Conference on Human Factors in Computing Systems*, pp. 313–314.

Bona, C., Kon, M., Koslow, L., Ratajczak, D., and Robins, M., (2018), *Augmented Reality: Is the Camera the Next Big Thing in Advertising?*, Retrieved from https://www.bcg.com/publications/2018/augmented-reality-is-camera-next-big-thing-advertising.aspx

Bonus, J. A., Peebles, A., Mares, M. L., and Sarmiento, I. G., (2017), "Look on the bright side (of media effects): Pokémon Go as a catalyst for positive life experiences", *Media Psychology*, vol. 21, no. 1, pp. 263–287.

Bourdel, N., Collins, T., Pizarro, D., Bartoli, A., da Ines, D., Perreira, B., and Canis, M, (2017), "Augmented reality in gynecologic surgery: Evaluation of potential benefits for myomectomy in an experimental uterine model", *Surgical Endoscopy and Other Interventional Techniques*, vol. 31, no. 1, pp. 456–461.

Candela, E.S., Pérez, M.O., Romero, C.M., Pérez López, D.C., Herranz, G.S., Contero, M., and Raya, M.A.(2014). HumanTop: A multi-object tracking tabletop. *Multimedia Tools and Applications*, *70*(3),1837–1868.

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., and Ivkovic, M., (2011), "Augmented reality technologies, systems and applications", *Multimedia Tools and Applications*, vol. 51, no. 1, pp. 341–377.

Chao, J., Chiu, J. L., DeJaegher, C. J., and Pan, E. A., (2016), "Sensor-augmented virtual labs: Using physical interactions with science simulations to promote understanding of gas behavior", *Journal of Science Education and Technology*, vol. 25, no. 1, pp. 16–33.

Chehimi, F., Coulton, P., and Edwards, R., (2007), "Augmented reality 3D interactive advertisements on smartphones", in *Proceedings of the International Conference on the Management of Mobile Business*.

Chiang, T. H. C., Yang, S. J. H., and Hwang, G. J., (2014), "Students' online interactive patterns in augmented reality-based inquiry activities", *Computers and Education*, vol. 78, no. 2, pp. 97–108.

Comport, A. I., Marchand, É., Pressigout, M., and Chaumette, F., (2006), "Real-time markerless tracking for augmented reality: The virtual visual servoing framework", *IEEE Transactions on Visualization and Computer Graphics*, vol. 12, no. 4, pp. 615–628.

Costa, E., Soares, A. L., and de Sousa, J. P., (2016), "Information, knowledge and collaboration management in the internationalisation of SMEs: A systematic literature review", *International Journal of Information Management*, vol. 36, no. 4, pp. 557–569.

Craig, A. B., (2013), *Understanding augmented reality: concepts and applications*, Elsevier.

Csikszentmihalyi, M., (1990), *Flow: The Psychology of Optimal Experience*, Harper Collins.

Dacko, S.G., (2017), "Enabling smart retail settings via mobile augmented reality shopping apps", *Technological Forecasting and Social Change*, vol. 124, pp. 243–256.

Dey, A., Billinghurst, M., Lindeman, R. W., and Swan, J. E., (2018), "A systematic review of 10 years of augmented reality usability studies: 2005 to2014", *Frontiers in Robotics and AI*, vol. 5, no. 37, pp. 1–28.

Drott, M. C., (1995), "Reexamining the role of conference papers in scholarly communication", *Journal of the American Society for Information Science*, vol. 46, no. 4, pp. 299–305.

Eagly, A. H., and Chaiken, S., (1993), *The psychology of attitudes*, Harcourt Brace Jovanovich College Publishers.

Etemad-Sajadi, R., and Ghachem, L., (2015), "The impact of hedonic and utilitarian value of online avatars on e-service quality", *Computers in Human Behavior*, vol. 52, pp. 81–86.

Gartner Reports (2017), *Hype Cycle for Emerging Technologies 2017*, Gartner.

Georgiou, Y., and Kyza, E. A., (2017), "The development and validation of the ARI questionnaire: An instrument for measuring immersion in location-based augmented reality settings", *International Journal of Human-Computer Studies*, vol. 98, pp. 24–37.

Hair Jr., J. F., Black, W. C., Babin, B. J., and Anderson, R. E., (2014), *Multivariate Data Analysis*, Pearson.

Hartson, R., (2003), "Cognitive, physical, sensory, and functional affordances in interaction design", *Behaviour and Information Technology*, vol. 22, no. 5, pp. 315–338.

Hayes, A. F., and Krippendorff, K., (2007), "Answering the call for a standard reliability measure for coding data", *Communication Methods and Measures*, vol. 1, no. 1, pp. 77–89.

Hoffman, D. L., and Novak, T. P., (1996), "Marketing in hypermedia computer-mediated environments: Conceptual foundations", *Journal of Marketing*, vol. 60, no. 3, pp. 50–68.

Huang, T. L., and Liao, S. L., (2017), "Creating e-shopping multisensory flow experience through augmented-reality interactive technology", *Internet Research*, vol. 27, no. 2, pp. 449–475.

Huang, T. L., and Liao, S.,(2015), "A model of acceptance of augmented-reality interactive technology: The moderating role of cognitive innovativeness", *Electronic Commerce Research*, vol. 15, no. 2, pp. 269–295.

Huang, T. L., and Hsu Liu, F., (2014), "Formation of augmented-reality interactive technology's persuasive effects from the perspective of experiential value", *Internet Research*, vol. 24, no. 1, pp. 82–109.

Hugues, O., Fuchs, P., and Nannipieri, O., (2011), *New augmented reality taxonomy: Technologies and features of augmented environment*, in B.Furht(Ed.), Handbook of Augmented Reality, pp. 47–63.

Irshad, S., Rohaya, D., and Awang, B., (2016), *User perception on mobile augmented reality as a marketing tool marketing tool*, in Proceedings of the International Conference on Computer and Information Sciences, pp. 109–113.

Javornik, A., (2016a), "It's an illusion, but it looks real!" Consumer affective, cognitive and behavioral responses to augmented reality applications", *Journal of Marketing Management*, vol. 32, no. 9–10, pp. 987–1011.

Javornik, A., (2016b), "Augmented reality: Research agenda for studying the impact of its media characteristics on consumer behaviour", *Journal of Retailing and Consumer Services*, vol. 30, no. 1, pp. 252–261.

Kasapakis, V., and Gavalas, D., (2017), "Occlusion handling in outdoors augmented reality games", *Multimedia Tools and Applications*,vol. 76, no. 7, pp. 9829–9854.

Kass, G. V., (1980), "An exploratory technique for investigating large quantities of categorical data author", *Journal of the Royal Statistical Society. Series C(Applied Statistics)*, vol. 29, no. 2, pp. 119–127.

Katiyar, A., Kalra, K., and Garg, C., (2015), "Marker Based Augmented Reality", *Advances in Computer Science and Information Technology*, vol. 2, no. 5, pp. 441-445.

Kim, M. J., Lee, J. H., Wang, X., and Kim, J. T., (2015), "Health smart home services incorporating a mar-based energy consumption awareness system", *Journal of Intelligent and Robotic Systems: Theory and Applications*, vol. 79, no. 3-4, pp. 523–535.

Kiousis, S., (2002), "Interactivity: A concept explication", *New Media and Society*,vol. 4, no. 3, pp. 355–383.

Kress, B., and Starner, T., (2013), *A review of head-mounted displays (HMD) technologies and applications for consumer electronics,* in Proceedings of SPIE8720, Photonic Applications for Aerospace, Commercial, and Harsh Environments IV.

Krippendorff, K., (2004), *Content analysis: An introduction to its methodology*, Sage Publications.

Lee, H. B., and MacQueen, J. B., (1980), "A K-Means cluster analysis computer program with cross-tabulations and next-nearest-neighbor analysis", *Educational and Psychological Measurement*, vol. 40, no. 1, pp. 133–138.

Liao, T., (2015), "Augmented or admented reality? The influence of marketing on augmented reality technologies", *Information, Communication and Society*,vol. 18, no. 3, pp. 310–326.

Liao, T., (2018), "Mobile versus headworn augmented reality: How visions of the future shape, contest, and stabilize an emerging technology", *New Media and Society*, vol. 20, no. 2, pp. 96–814.

Liao,T., and Humphreys, L., (2015), "Layar-ed places: Using mobile augmented reality to tactically reengage, reproduce, and reappropriate public space", *New Media and Society*, vol. 17, no. 9, pp. 1418–1435.

Lima, J. P., Roberto, R., Simões, F., Almeida, M., Figueiredo, L., Teixeira, J. M., and Teichrieb, V., (2017), "Markerless tracking system for augmented reality in the automotive industry", *Expert Systems with Applications*, vol. 82, pp. 100–114.

Lv, Z., Khan, M. S. L., and Réhman, S. U., (2014), "Hand and foot gesture interaction for handheld devices", *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM) - Special Issue on Multiple Sensorial (MulSeMedia) Multimodal Media : Advances and Applications*, vol. 1, no. 1, pp. 621–624.

Magidson, J., (1994), *The CHAID approach to segmentation Modeling: Chi-squared automatic interaction detection*, in R.P. Bagozzi(Ed.), Advances Methods of Marketing Research, pp.118–159.

Manuri, F., Piumatti, G., and Torino, P., (2015), *A preliminary study of a hybrid user interface for augmented reality applications*, in Proceedings of the International Conference on Intelligent Technologies for Interactive Entertainment, vol.17, pp. 37–41.

Mihelj, M., Novak, D., and Begus, S., (2014), *Augmented reality*, in Virtual Reality Technology and Applications, pp. 195–204.

Milgram, P., and Kishino, F., (1994), "A taxonomy of mixed reality visual displays", *IEICE Transactions on Information Systems*, vol. E77–D, no. 12, pp. 1–15.

Montesi, M., and Owen, J. M., (2008), "From conference to journal publication: How conference papers in software engineering are extended for publication in journals", *Journal of the American Society for Information Science and Technology*, vol. 59, no. 5, pp. 816–829.

Nam, Y., (2015), "Designing interactive narratives for mobile augmented reality", *Cluster Computing*, vol. 18, no. 1, pp. 309–320.

Olsson,T., Lagerstam, E., Kärkkäinen, T., and Väänänen-Vainio-Mattila, K., (2013), "Expected user experience of mobile augmented reality services: A user study in the context of shopping centres", *Personal and Ubiquitous Computing*, vol. 17, no. 2, pp. 287–304.

Poppe, E., Brown, R., Johnson, D., and Recker, J., (2012), *Preliminary evaluation of an augmented reality collaborative process modelling system*, in International Conference on Cyberworlds, pp. 77–84.

Punji, G., and Stewart, D. W., (1983), "Cluster analysis in marketing research: Review and suggestions for application", *Journal of Marketing Research*, vol. 20, no. 2, pp. 134–148.

Rauschnabel, P. A., Brem, A., and Ivens, B. S., (2015), "Who will buy smart glasses? Empirical results of two pre-market-entry studies on the role of personality in individual awareness and intended adoption of Google Glass wearables", *Computers in Human Behavior*, vol. 49, pp. 635–647.

Rese, A., Baier, D., Geyer-Schulz, A.,and Schreiber, S., (2017), "How augmented reality apps are accepted by consumers: A comparative analysis using scales and opinions", *Technological Forecasting and Social Change*, vol. 124, pp. 306–319.

Riffe, D., Lacy, S., and Fico, F., (2014), *Analyzing media messages: Using Quantitative content analysis in research*, Routledge.

Ryu, H. S., and Park, H., (2016), "A system for supporting paper-based augmented reality", *Multimedia Tools and Applications*, vol. 75, no. 6, pp. 3375–3390.

Schmalstieg, D., and Hollerer, T., (2016), *Augmented Reality: Principles and Practice*, Addison-Wesley Professional.

Scholz, J., and Duffy, K., (2018), We are at home: How augmented reality reshapes mobile marketing and consumer-brand relationships", *Journal of Retailing and Consumer Services*, vol. 44, pp. 11–23.

Scholz, J., and Smith, A. N., (2016), "Augmented reality: Designing immersive experiences that maximize consumer engagement", *Business Horizons*, vol. 59, no. 1, pp. 149–161.

Solomon, M. R., (2018), *Consumer Behavior: Buying, having, and being*, Pearson.

Steuer, J., (1992), "Defining virtual reality: Dimensions determining telepresence", *Journal of Communication*, vol. 42, no. 4, pp. 73–93.

Stewart, D. W., and Pavlou, P. A., (2009), *Social cognitive theory of mass communication*, in J., Bryant and D., Zillmann (Eds.), Media Effects: Advances in Theory and Research, pp. 362–401.

Su, L. Y. F., Cacciatore, M. A., Liang, X., Brossard, D., Scheufele, D. A., and Xenos, M. A., (2017), "Analyzing public sentiments online: Combining human- and computer-based content analysis", *Information, Communication and Society*, vol. 20, no. 3, pp. 406–427.

Sundar, S. S., (2008), *Self as source: Agency and customization in interactive media*, in E. A., Konijn, S., Utz, M., Tanis, and S. B. Barnes, (Eds.), Mediated Interpersonal Communication, pp. 58–74.

Sundar, S. S., Xu, Q., and Dou, X., (2012)., *Role of technology in online persuasion: A main model perspective*, in S. Rodgers., and E., Thorson (Eds.), Advertising Theory, pp. 355–372.

Sungkur, R. K., Panchoo, A., and Bhoyroo, N. K., (2016), "Augmented reality, the future of contextual mobile learning", *Interactive Technology and Smart Education*, vol. 13, no. 2, pp. 123–146.

Tait, M., and Billinghurst, M., (2015), "The effect of view independence in a collaborative AR system", *Computer Supported Cooperative Work*, vol. 24, pp. 563–589.

Tamura, H., Yamamoto, H., and Katayama, A., (2001), "Mixed reality: Future dreams seen at the border between real and virtual worlds", *IEEE Computer Graphics and Applications*, vol. 21, no. 6, pp. 64–70.

Tarute, A., Nikou, S., and Gatautis, R., (2017), "Mobile application driven consumer engagement", *Telematics and Informatics*, vol. 34, no. 4, pp. 145–156.

ter Huurne, M., Ronteltap, A., Corten, R., and Buskens, V., (2017). "Antecedents of trust in the sharing economy: A systematic review", *Journal of Consumer Behaviour*, vol. 16, no. 6, pp. 485–498.

Wang, X., Ong, S. K., and Nee, A. Y. C., (2016), "A comprehensive survey of augmented reality assembly research", *Advances in Manufacturing*, vol. 4, no. 1, pp. 1–22.

Ward, J. H., (1963), "Hierarchical grouping to optimize an objective function", *Journal of the American Statistical Association*, vol. 58, pp. 236–244.

Willems, K., Smolders, A., Brengman, M., Luyten, K., and Schöning, J., (2017), "The path-to-purchase is paved with digital opportunities: An inventory of shopper-oriented retail technologies", *Technological Forecasting and Social Change*, vol. 124, pp. 228–242.

Xu, K., Chia, K. W., and Cheok, A. D., (2008), "Real-time camera tracking for marker-less and unprepared augmented reality environments", *Image and Vision Computing*, vol. 26, no. 5, pp. 673–689.

Zhou, F., Duh, H. B., and Billinghurst, M., (2008), *Trends in augmented reality tracking , interaction and display : A review of ten years of ISMAR*, in Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality, pp. 193–202.