Is There More Than Pokémon Go? – Exploring the State of Research on Causal Modeling in the Field of Augmented Reality

Julia Bräker
University of Hamburg
julia.braeker@uni-hamburg.de

Martin Semmann
University of Hamburg
martin.semmann@uni-hamburg.de

Abstract

The paper explores how scholars apply causal modeling to gain an understanding of augmented reality as innovative technology and its potential for application. To do so, we conducted a structured literature review and applied a graph database-driven approach to analyze how scholars research augmented reality. Such an approach enables in-depth analysis of the body of knowledge that is not accessible in traditional ways of exploring literature. The results help to understand where we as a community stand and how directions for future research can help reshape the understanding of augmented reality and its application.

Keywords: Augmented Reality, Conceptual Model, Structural Equation Modeling, SEM, Literature Review

1. Introduction

The rise of augmented reality (AR) as a technology that bears the potential to impact everyday life is also mirrored in the scientific discourse. We have come far from early prototypes of AR head-mounted displays (HMDs) (Sutherland, 1968) to more recent developments toward mobile AR and AR glasses applied in several use cases. In consumer environments, mobile AR applications such as Pokémon Go have become popular in recent years, leading to research addressing health implications (Laato et al., 2020) or motivations that drive the use of Pokémon Go (Ernst & Ernst, 2015). In organizational contexts, research concentrates, for example, on AR use in technical services (Niemöller et al., 2019), infrastructure services (Osterbrink et al., 2021), logistics (Rauschnabel & Ro, 2016), and healthcare (Klinker et al., 2019). Other research systematizes interactions within AR (Bräker et al., 2022; Hertel et al., 2021). Conceptualizations that seek to explore a multitude of aspects related to AR, its use and applicability, and niche aspects like privacy (Rauschnabel et al., 2018) can also be found. Such conceptualizations seek to specify real-world phenomena (Weber, 2021) while bridging the gap between theory and measurement of phenomena as it is focal in information systems (Burton-Jones & Lee, 2017). Based on this perspective, we seek to broaden our understanding of how conceptual research on AR is done and if there are directions future research should address. However, until now, there seems to be a lack of AR-specific constructs that help shape its application. Consequently, we answer the following research questions within this paper: *(1) What constructs are applied to model causalities regarding AR? (2) Which theoretical perspectives guide research on AR?*

To answer these research questions, we structure the remainder of the paper as follows: first, we introduce related work by laying out the foundations of augmented reality. Then, we present the methodology based on a structured literature review combined with a graph database-driven approach (Song et al., 2021a; Song et al., 2021b). We present our results on current research on causal AR models and discuss them in detail afterward. Our results show that research on causal AR models is broad and studied by various communities. However, there is a focus on mobile AR, primarily consumer-oriented applications. Theoretical models of technology acceptance are overrepresented, although they are not the only theoretical lens. The paper concludes with a summary and opportunities for future research.

2. Foundations of augmented reality

Although research on AR dates back to the 1960s (Sutherland, 1968), the awareness of AR in the consumer environment increased in the last few years. The famous mobile application Pokémon Go, released in 2016, made AR accessible to almost everyone (Chapple, 2022). AR is part of the virtuality continuum (Milgram & Kishino, 1994) that describes different nuances of virtuality – from complete reality with no virtual aspects to complete virtuality in an immersive virtual reality (VR). AR is located between these two extremes, as it augments reality with virtual computer-generated objects. A commonly used definition accents

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three main characteristics of AR (Azuma, 1997). First, real and virtual objects are combined. This means that reality is still present but extended or overlaid with virtual objects. Second, the user can interact with the AR system in real time. And third, the virtual elements have a registered position in the three-dimensional reality, which makes them feel more like real objects.

The implementation of AR is possible using different hardware approaches (Bimber & Raskar, 2006). First and foremost are HMDs or AR glasses. AR glasses allow the user to either look through a transparent display (optical see-through) that blends holograms to reality or enrich video-generated images streamed on the glasses (video see-through). Because AR glasses such as the Microsoft HoloLens 2 are still quite expensive and rare, a more inexpensive and accessible way is mobile AR. Hand-held displays like smartphones or tablets can use the integrated camera to capture reality and overlay it with virtual objects. An example of mobile AR is the mobile game Pokémon Go. Apart from head-attached or hand-held devices, AR can be implemented with projectors, called spatial or projection-based AR. This way, virtual content can be directly projected onto real objects.

3. Methodology

In the following, we present the paper's methodology, which consists of three steps (see Figure 1). We began with a systematic literature review (Brocke et al., 2009; Webster & Watson, 2002). Subsequently, we followed the causal model analysis approach to literature reviewing by Song et al. (2021b), coding relevant publications using Cypher language and performing query-based knowledge extraction and synthesis in Neo4j (neo4j.com).

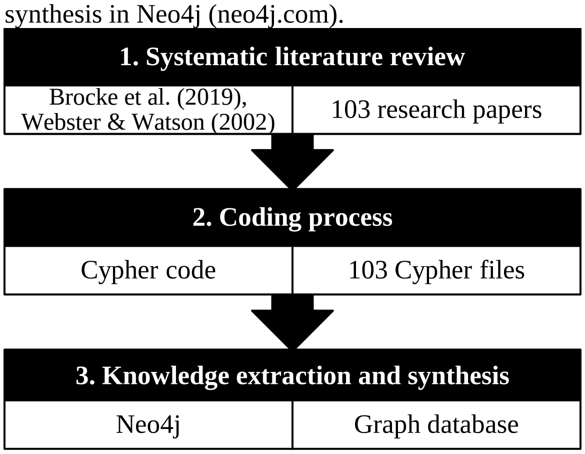

Figure 1. Research process.

3.1. Literature review

To assess the current state of research, we conducted a structured literature review following Webster and Watson (2002) and Brocke et al. (2009). We were interested in papers focusing on AR technologies and involving structural equation modeling (SEM) or causal modeling. Our query for the keyword search combines these two domains: *("causal model*" OR SEM OR "structural equation model*") AND ("augmented reality" OR "smart glass*")*. Because we wanted to paint the big picture, we did not limit our search and searched within full text. We did not set time restrictions or publication filters. When possible, we filtered for peer-reviewed articles in English. We searched the databases ACM Digital Library (ACM DL), (2) AIS Electronic Library (AISeL), (3) EBSCO Business Source Complete (EBSCO), (4) IEEEXplore, (5) ProQuest ABI/INFORM (ProQuest), (6) ScienceDirect (SD), and (7) ScholarSpace (SchS). The tool Litsonar (litsonar.com) helped generate the database queries.

Table 1. Literature review.

Database	Initial results	1st round	2nd round	3rd round/ relevant
ACM DL	181	7	7	1
AISeL	83	35	19	10
IEEEXplore	9	8	7	3
ProQuest	44	29	25	22
SD	786	184	79	47
SchS	24	2	0	0
Total	**1149**	**286**	**157**	**103**

The results of the literature review are shown in Table 1. Our search query initially yielded 1149 papers. We scanned the literature with two independent researchers, and in the first round, we made sure that AR was addressed in the paper and that an SEM or causal model was included. After the first round, 286 papers were potentially interesting for further processing. In the second round, we looked more closely at these 286 papers and sorted out any publications that used AR only as an example in the introduction or discussion but had no relevance to the SEM or causal model. Thus, after the second round, we had 157 papers that contained an SEM or causal model with an AR reference. In a third round, we read the papers in detail and kept only papers whose models had a direct AR focus. We sorted out papers in which AR was only a part of the model or if the results were just applicable to AR. In doing so, we ended up with 103 relevant papers for the further research process.

3.2. Coding process

The second step in our research design is coding relevant literature from the literature review. Following the argumentation of Song et al. (2021b), the existing knowledge is fragmented and difficult to synthesize and analyze manually. The causal model analysis approach provides a guideline for this by coding the core knowledge of the articles in the form of a graph and storing it in a database. This simplifies knowledge analysis and synthesis using database queries and allows for a more focused representation of data, which makes this approach an advantage over previous approaches to literature review.

The database represents a paper as a graph with nodes (circles) and relationships (arrows) between these nodes. We slightly adapted the original approach to our needs and added two new constructs – technology and topic – in addition to the constructs publication, element, theory, and author, as proposed in the original approach (see Figure 2). We defined a node type for each of the six constructs and further specified seven distinct types of relationships. In Cypher language, the node types are specified as labels. Each publication node can relate to one or more author, theory, topic, technology, or element nodes. For simplicity, we omit the proposed definition node as we do not consider it relevant to the big picture. We do not implement the model node because we assume that each publication has only one relevant SEM or causal model. If a publication describes more than one model, we refer to the final or revised model with only significant hypotheses. Consequently, the relationships in our graph differ from the original framework. Since we eliminated the model node, the elements are directly depicted by the publication nodes, and the publication applies a theory. The nodes and relationships can have different attributes, e.g., within each publication node, the Digital Object Identifier (DOI), citation, and a universally unique identifier (UUID) are stored.

The Codasaurus tool (https://t-rex-graph.org) developed by Song et al. (2021b) assists researchers in the coding process. Codasaurus is an R application with a graphical user interface that automatically generates Cypher code files for a graph. Using Codasaurus, we generated a Cypher code template that we customized as described above and created a Cypher code file for each of the 103 publications by inserting the information into the template. We normalized some inputs by aligning author names (e.g., different abbreviations of middle names), theory names, and element names – e.g., matching plural and singular if it did not change the meaning. These Cypher code files can be imported to Neo4j, which is a graph database, in the next step.

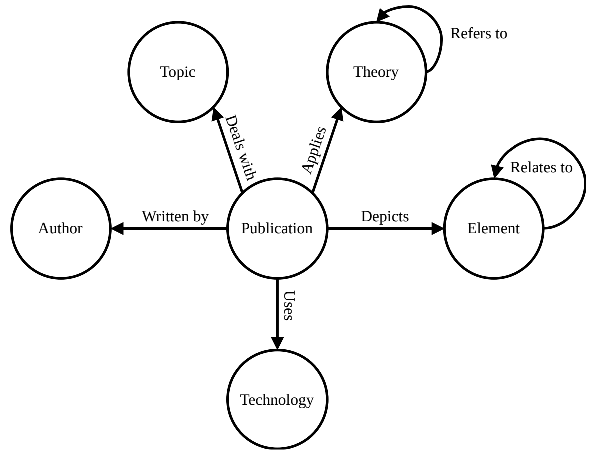

Figure 2. Nodes and relationships (adapted from Song et al., 2021b).

3.3. Knowledge extraction and synthesis

Song et al. (2021b) recommend using the graph database tool Neo4j for knowledge synthesis. In Neo4j, graphs coded as Cypher files can be visualized, and networks of multiple graphs can be created. Knowledge can then be extracted and synthesized using queries, such as known from relational databases. Knowledge extraction includes, for example, the extraction of node or relationship frequencies in a graph. Knowledge synthesis encompasses merging multiple graphs or calculations within a network of graphs to gain a deeper understanding of the coherences between publications. The results from the knowledge extraction and synthesis are presented in the following.

Table 2. Labels and number of nodes.

Label	Number of nodes
Publication	103
Author	269
Element	450
Technology	6
Theory	56
Topic	20
Nodes total	904
Relationships total	2299

4. Result

After coding and importing the publications to Neo4j, the graph database contains 103 publication nodes, 269 different author nodes, 450 element nodes, six AR technology type nodes, 56 theory nodes, and 20 topic nodes. In sum, there are 904 nodes with 2299 relationships (see Table 2). Each paper is visualized as exemplarily shown in Figure 3. The blue node in the center represents the publication by Harborth and Pape (2017), with the citation as the display name. The publication node also holds the DOI and a UUID as attributes. Although the DOI is unique, we added a UUID because not all publications have a DOI. The author nodes are visualized in light green, and the WRITTEN_BY relationship holds the authors' order. In this case, the USED_TECHNOLOGY (orange node) is mobile AR, and the publication DEALS_WITH Pokémon Go (red node). The publication APPLIES UTAUT2 as a theory (dark green node), which is partly reflected in the SEM elements. The publication DEPICTS the elements (pink nodes) of the model, which can relate to each other. The RELATES_TO relationship between elements can store a description of the relationship and the hypothesis to which it belongs.

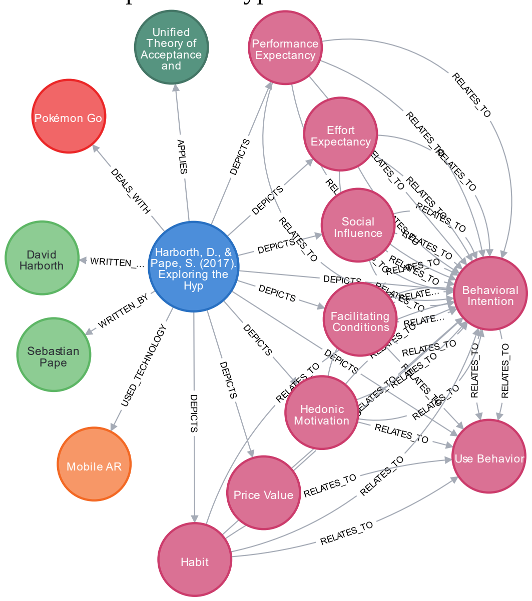

Figure 3. Example graph visualization of a publication (Harborth & Pape, 2017).

4.1. Elements

The element nodes represent the actual SEM or causal model. They are central to knowledge extraction and synthesis. Of the 103 publications, the most commonly used element and "hidden champion" among them is *Perceived Usefulness*, which is, e.g., used in the Technology Acceptance Model (TAM) (Davis, 1989). The same applies to *Perceived Ease of Use*, *Attitude*, and *Behavioral Intention*, indicating the relevance of TAM and acceptance models. Table 3 shows the ten most used elements in terms of the number of publications in which the element is used.

To analyze the elements of the graph network in more detail, following Song et al. (2021b), we calculate outdegree centrality, indegree centrality, and betweenness centrality, which provide information about the influence and importance of certain elements. The outdegree centrality counts the number of outgoing relations of a node, i.e., how many other nodes are influenced by it. If the outdegree centrality of a node is high, it means that it has a significant impact on other nodes and is a fundamental antecedent in models.

Table 3. Top ten elements and the number of publications that contain the element.

Element	Number of publications
Perceived Usefulness	26
Perceived Ease of Use	24
Attitude	14
Perceived Enjoyment	13
Behavioral Intention	12
Flow	10
Enjoyment	10
Satisfaction	9
Purchase Intention	8
Intention to Use	8

The outdegree centrality of the elements with more than ten outgoing relations is shown in Table 4. *Perceived Ease of Use* and *Perceived Usefulness* are antecedents for 34 and 33 other nodes, respectively, indicating that they have a high impact on the graph network. This is consistent with our findings that *Perceived Ease of Use* and *Perceived Usefulness* are the elements used by most publications, and TAM – to which they belong – is the most used theory. Taking a closer look at the TAM, these two elements tend to be at the beginning, i.e., on the left-hand side of the model, which underlines our results. Moreover, *Flow* as part of Flow Theory (Csikszentmihalyi & LeFevre, 1989; Montgomery et al., 2004) is an essential and influential element for other nodes. *Anthropomorphism* is also noteworthy because it is only used in three publications but is one of the most predictive elements with twelve outgoing relations.

Table 4. Element outdegree centrality.

Element	Outdegree centrality
Perceived Ease of Use	34
Perceived Usefulness	33
Perceived Enjoyment	19
Interactivity	16
Attitude	15
Flow	14
Anthropomorphism	12
Enjoyment	11
Satisfaction	11

Indegree centrality describes how many ingoing relations a node has, i.e., whether the node is a frequent outcome element (Song et al., 2021b). Table 5 shows the most influential outcome elements with more than 16 ingoing relations. *Behavioral Intention* is the element with the highest indegree centrality with 52 ingoing relations. This is consistent with the TAM, as the behavioral intention stands on the model's right side as an outcome. The *Intention to Use*, for example, is an outcome of a model because the indegree centrality (18 incoming relations) is higher than the outdegree centrality (3 outgoing relations).

Table 5. Element indegree centrality.

Element	Indegree centrality
Behavioral Intention	52
Perceived Usefulness	39
Attitude	34
Flow	24
Satisfaction	24
Perceived Ease of Use	22
Attitude Towards Using	18
Intention to Use	18
Enjoyment	18

Betweenness centrality describes the degree to which a node stands between two other nodes in the graph. A high betweenness centrality, therefore, means that the node is highly influential because it explains the flow of causality (Song et al., 2021b). The ten elements with the highest betweenness centrality are listed in Table 5. In our case, *Perceived Usefulness* and *Flow* achieve the highest value with a betweenness centrality of over 5000.

After focusing on the most used and influential elements, the question arises if there are unique elements that are only used in one research model. Our results show that 97 elements are used by more than one publication. Conversely, 353 elements are only used by one single publication and research model.

Table 6. Element betweenness centrality (rounded to whole numbers)

Element	Betweenness centrality
Perceived Usefulness	5341
Flow	5203
Achievement	4727
Attitude	3930
Satisfaction	3385
Intention to Use	3241
Enjoyment	2974
Trust	2087
Perceived Value	1790
Gender	1785

4.2. Technologies

The technologies used in the publications match the AR technologies described in the related work section. It is noticeable that mobile AR is by far the most used technology, with 70 publications (see Table 7). The second most publications do not specify the technology and describe independent concepts such as touchless interaction performance independent from hardware (Habibi & Chattopadhyay, 2021). AR glasses are only mentioned in eight out of 103 publications, followed by desktop AR and projection-based AR. One publication thematizes a comparison of different technologies.

Table 7. Technologies and the number of publications that contain the technology.

Technology	Number of publications
Mobile AR	70
Not specified	15
AR Glasses	8
Desktop AR	7
Projection-Based AR	2
Comparison	1

4.3. Theories

Regarding theories, there are a few outstanding ones that are used in multiple publications. Table 8 shows the theories that are used in at least three publications. The most popular is the TAM (Davis, 1989), with 29 publications applying it. With distance behind is the Stimulus-Organism-Response (S-O-R) Theory (Bitner, 1992; Jacoby, 2002) being used by eleven publications. The Uses and Gratifications Theory (UGT) (Sheldon, 2008), as well as Flow Theory (Csikszentmihalyi & LeFevre, 1989; Montgomery et al., 2004), are each used eight times. The acceptance theories Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) and the further developed Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) (Venkatesh et al., 2012) are used four times. This again speaks for the high relevance of technology acceptance in AR-related SEMs. Further, the Experience Economy Theory (Pine & Gilmore, 2013) and the Cue Utilization Theory (Olson & Jacoby, 1972; Richardson et al., 1994) are used in three publications.

Table 8. Theories and the number of publications that contain the theory.

Theory	Number of publications
TAM	29
S-O-R Theory	11
UGT	8
Flow Theory	8
UTAUT	4
UTAUT2	4
Experience Economy Theory	3
Cue Utilization Theory	3

4.4. Topics

In sum, nine topics are used in at least two publications. The most popular topics are shopping or retail thematic publications, with 43 publications (see

Table 9). Pokémon Go is the use case for 18 publications, followed by education and training cases. Only three publications consider gaming aside from Pokémon Go. Privacy and health care are each subject of two papers, and two publications deal with AR content visualization in general.

Table 9. Topics and the number of publications that contain the topic.

Topic	Number of publications
Shopping/ Retail	43
Pokémon Go	18
Tourism	11
Education	8
Training	4
Gaming	3
Privacy	2
AR content	2
Health care	2

4.5. Authors

Out of 269 authors, only a few wrote more than two publications. This shows that the field of SEMs and causal modeling regarding AR is wide-ranging and diverse authors contribute to it. Only one author (Philipp A. Rauschnabel) is part of six publications (Hinsch et al., 2020; Rauschnabel et al., 2015, 2017, 2018, 2019; tom Dieck et al., 2018). In four publications, David Harborth cooperated with Sebastian Pape (Harborth & Pape, 2017, 2019, 2020, 2021). Tseng-Lung Huang published three papers (Huang, 2019, 2021; Huang & Liu, 2021) and 21 authors have two publications. The remaining 244 authors are only related to one publication.

4.6. Synthesis of technologies, theories, and topics

When taking a closer look at technologies, it is interesting to understand which theories apply in the context of which technologies. Table 10 shows the theories that are at least used in three publications in combination with the technology used. We eliminated the papers that did not specify a technology or use multiple technologies in comparison for simplification reasons because they are not relevant here. Mobile AR is used in all the theories, which underlines the importance and diffusion of mobile AR technologies. Publications regarding AR glasses apply acceptance theories such as TAM or UTAUT, in addition to S-O-R Theory and UGT. Desktop AR is combined with the UTAUT2 and the Cue Utilization Theory. Projection-based AR is not used in combination with one of the most common theories.

We did the same analysis regarding AR technologies, but in combination with topics that are at least used in two publications (see Table 10). Shopping and retail are prevalent topics, used in combination with all technology types. Because Pokémon Go is a mobile application, publications only consider mobile AR in publications. Tourism, training, and gaming are likewise only used in combination with mobile AR. Education settings use mobile AR and desktop AR, which might be explainable by hardware accessibility. Privacy and health care are both relevant for mobile AR and AR glasses.

Table 10. Applied theories and topics itemized by technology.

		Mobile AR	AR glasses	Desktop AR	Projection-based AR
Theory	TAM	x	x	-	-
	S-O-R Theory	x	x	-	-
	UGT	x	x	-	-
	Flow Theory	x	-	-	-
	UTAUT	x	x	-	-
	UTAUT2	x	-	x	-
	Experience Economy Theory	x	-	-	-
	Cue Utilization Theory	x	-	x	-
Topic	Shopping/ Retail	x	x	x	x
	Pokémon Go	x	-	-	-
	Tourism	x	-	-	-
	Education	x	-	x	-
	Training	x	-	-	-
	Gaming	x	-	-	-
	Privacy	x	x	-	-
	AR content	-	-	-	-
	Health care	x	x	-	-

4.7. AR glasses-specific analysis

The results indicate that the use of AR glasses in publications containing SEMs or causal models is sparse, although they are one of the first associated technologies when considering AR. This fact justifies a closer look into publications concerning AR glasses. Overall, we found eight publications. Figure 4 visualizes all publications, elements, theories, and topics related to AR glasses technology. In sum, 50 elements are used regarding AR glasses (see pink nodes in Figure 4). In the center of the graph is a dense cluster of elements having many relationships and interdependencies. Nonetheless, only the element Perceived Usefulness is used in two publications, and all the other elements are used once.

Eight theories are applied to publications (see dark green nodes in Figure 4). Table 11 lists the theories in combination with the publication in which they are used. As described in the last section, acceptance theories, S-O-R, and UGT are applied. The theories Big Five Theory of Human Personality, TOE Framework, ESP, and Media Richness Theory are each used by one publication. Topics are visualized as red nodes in Figure 4. In sum, six different topics are addressed in the publications (see Table 12). The topics, except for the popular ones described above, Assembly, Hardware, and Industry, are each subject to one publication.

Table 11. Theories used in publications using AR glasses as technology.

Theory	Publication
TAM	(Dehghani et al., 2020; Holdack et al., 2020; Schuster et al., 2021)
UTAUT	(Dehghani et al., 2020; Schuster et al., 2021)
UGT	(Dehghani et al., 2020; Rauschnabel et al., 2018)
Big Five Theory of Human Personality	(Rauschnabel et al., 2015)
TOE Framework	(Masood & Egger, 2019)
ESP	(Dehghani et al., 2020)
Media Richness Theory	(Amorim et al., 2022)
S-O-R Theory	(Amorim et al., 2022)

5. Discussion

Our analysis shows that the most used elements and the elements with the highest outgoing centrality come from TAM, i.e., it is the most influential theory with the most influential element nodes. This is consistent because TAM is the most used theory in our database. Consequently, TAM is overrepresented in causal AR models. However, papers applying TAM mainly refer to the acceptance of a specific use case or AR application, and there is no overarching model explaining the acceptance of AR. The results show that there is a large number of once-used elements. This could be due to the inconsistent naming of elements between different publications. Although we normalized naming to a certain degree, it was not everywhere possible. Some very specified publications with niche use cases may propose customized naming of the elements, which could be one explanation for many unique elements. Surprisingly, the *Gender* element is in the top ten of betweenness centrality. One explanation could be that gender often functions as a moderator in causal models, and – as suggested by Song et al. (2021b) – we coded moderators as a triangular relationship between two elements.

Table 12. Topics used in publications using AR glasses as technology.

Topic	Publication
Shopping/ Retail	(Amorim et al., 2022; Dehghani et al., 2020; Holdack et al., 2020)
Assembly	(Schuster et al., 2021)
Hardware	(Rauschnabel et al., 2015)
Health Care	(Klinker et al., 2020)
Industry	(Masood & Egger, 2019)
Privacy	(Rauschnabel et al., 2018)

Mobile AR is the leading technology in our graph database. One explanation could be that it is the easiest to assess because the hardware is available and reasonably priced. Because the main topics, shopping, retail, and Pokémon Go, are mostly consumer applications, it underlines the argument regarding available and affordable hardware. The analysis shows that the constructs applied are not AR-specific but rather general. Additionally, the conceptual models mainly utilized, namely TAM and UTAUT, have been developed in an era prior to the recent possibilities of IS, especially AR. Thus, a thorough assessment of the timeliness of these constructs, as suggested by (Compeau et al., 2022), could help develop a common set of constructs that can be applied to AR in general and not specific representations such as mobile AR.

The breadth of authors and corresponding backgrounds can be seen as a cause for the diverse use of theories. Different experiences and prior training could be the origin of such heterogeneity.

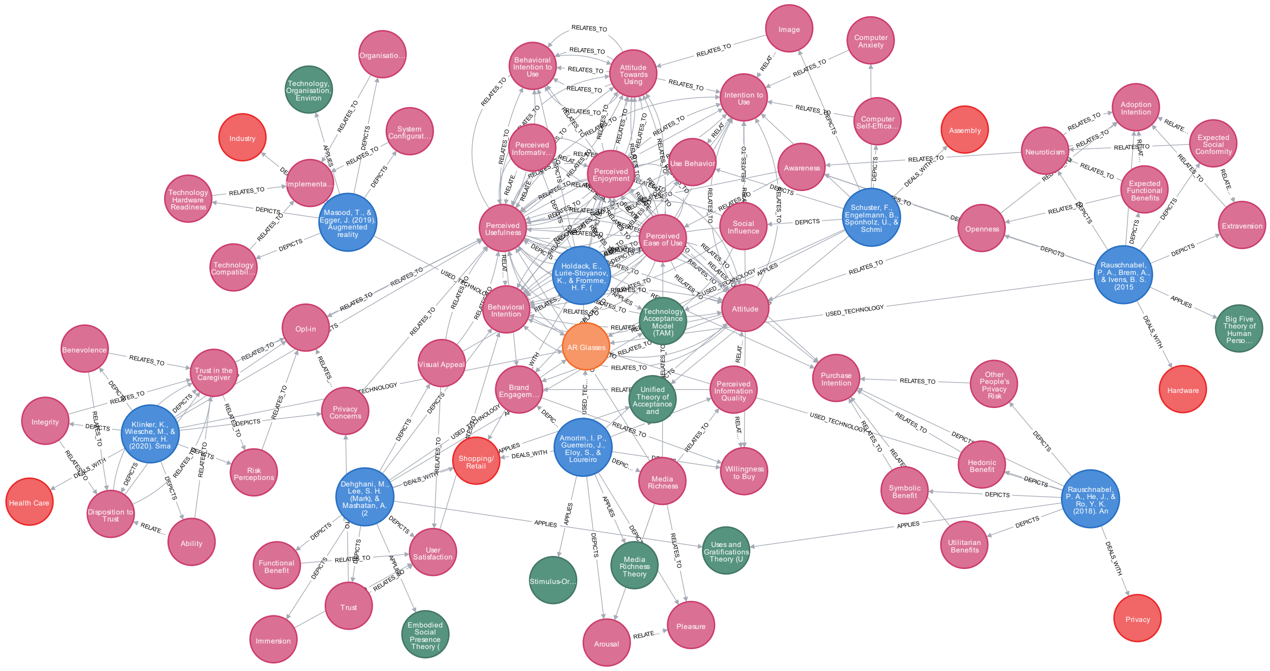

Figure 4. Overview of all nodes related to AR glasses.

Although Pokémon Go is the second most popular topic, the analysis shows that there definitely is more than Pokémon Go. The topic varies immensely from shopping and consumer studies to the health care and manufacturing industry. However, most publications deal with shopping, retail, or the AR game Pokémon Go. This could be explained by the use of AR technologies because mobile AR is the most used technology, and most retail papers use mobile AR, and Pokémon Go obviously is restricted to mobile AR. The fact that privacy is the topic of papers dealing with mobile AR and AR glasses is particularly interesting because AR glasses suddenly need new privacy requirements (Rauschnabel et al., 2018). Healthcare-related publications also use mobile AR and AR glasses, which can be explained by the fact that AR glasses bear great potential for hands-free working (Klinker et al., 2020).

By doing the analysis, it becomes apparent that the field of research on AR is relatively immature and explorative in its nature. There are no established measures and underlying theories that build the core foundation of SEM or causal modeling regarding AR. This could be the case as there is a lack of specific theories on AR and its adoption, or the rather generally established theories are deemed appropriate and interchangeable. Thus, following Compeau et al. (2022), assessing the elements regarding their appropriateness to represent recent information system use could be beneficial for further research on AR.

From a methodical perspective, the approach to analyzing SEMs or causal models using a graph database is highly supportive. It provides better structuring and easier information extraction and synthesis by querying. The Codasaurus tool (Song et al., 2021b) aims to simplify the coding process to make the approach accessible without learning Cypher coding. Our research has shown that the core idea of Codasaurus is beneficial, but customization is still needed depending on the context. In this regard, a more flexible approach would be valuable.

6. Conclusion and outlook

The rise of AR as a technology that impacts professional and consumer electronics while changing human interaction with information systems is mirrored in research. We analyzed the body of knowledge on conceptual modeling as an avenue to understand the application of AR. Within this corpus, we identified 103 relevant papers that cover a wide range of disciplines, topics, and theoretical approaches. In answering the first research question, we provided a comprehensive overview of which constructs are used to explain causalities related to AR. The results show that most research is done in the domain of mobile AR. As this representation of AR is the most common and widely available, rather pragmatic reasons could lead to this emphasis. Likewise, the topics addressed are driven mainly by consumer electronics, like retail, gaming, and tourism. This could be interpreted as lacking business applications and use cases. Following the second research question, we also explored the theoretical perspectives guiding AR research. The results show that it is worthwhile to further deep dive into the heterogeneity of underlying theories. Based on these findings, future research has manifold avenues to contribute to understanding AR's application and utility. Especially professional, business-oriented research is missing. Nevertheless, with improving HMDs, changes in application and acceptance are interesting. Furthermore, a thorough comparison and synthesis of conceptual models could help strengthen the results and identify potential extensions that would help understand AR in practice. The methodological approach also bears potential for future research. This might include integrating articles that do not use dedicated causal models or include virtual and mixed reality to analyze commonalities and differences.

7. Acknowledgments

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8. References

Amorim, I. P., Guerreiro, J., Eloy, S., & Loureiro, S. M. C. (2022). How augmented reality media richness influences consumer behaviour. *International Journal of Consumer Studies*. https://doi.org/10.1111/ijcs.12790

Azuma, R. T. (1997). A Survey of Augmented Reality. *Presence: Teleoperators & Virtual Environments*, *6*(4), 355–385.

Bimber, O., & Raskar, R. (2006). *Modern Approaches to Augmented Reality*. ACM SIGGRAPH 2006 Courses.

Bitner, M. J. (1992). Servicescapes: The Impact of Physical Surroundings on Customers and Employees. *Journal of Marketing*, *56*(2), 57–71. https://doi.org/10.1177/002224299205600205

Bräker, J., Hertel, J., & Semmann, M. (2022). Conceptualizing Interactions of Augmented Reality Solutions. *Proceedings of the 55th HICSS.*

Brocke, J. vom, Simons, A., Niehaves, B., Niehaves, B., Reimer, K., Plattfaut, R., & Cleven, A. (2009). Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. *ECIS 2009 Proceedings*.

Burton-Jones, A., & Lee, A. S. (2017). Thinking about measures and measurement in positivist research: A proposal for refocusing on fundamentals. *Information Systems Research*, *28*(3), 451–467. https://doi.org/10.1287/isre.2017.0704

Chapple, C. (2022). *Pokémon GO Catches $6 Billion in Lifetime Player Spending*. SensorTower. https://sensortower.com/blog/pokemon-go-6-billion-revenue

Compeau, D., Correia, J., & Bennett Thatcher, J. (2022). When Constructs Become Obsolete: A Systematic Approach to Evaluating and Updating Constructs for Information Systems Research. *MIS Quarterly*, *46*(2), 679–711. https://doi.org/10.25300/MISQ/2022/15516

Csikszentmihalyi, M., & LeFevre, J. (1989). Optimal experience in work and leisure. *Journal of Personality and Social Psychology*, *56*(5), 815–822. https://doi.org/10.1037/0022-3514.56.5.815

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340. https://doi.org/Doi 10.2307/249008

Dehghani, M., Lee, S. H. (Mark), & Mashatan, A. (2020). Touching holograms with windows mixed reality: Renovating the consumer retailing services. *Technology in Society*, *63*. https://doi.org/10.1016/j.techsoc.2020.101394

Ernst, C.-P. H., & Ernst, A. W. (2015). Why People Play Pokémon: The Role of Perceived Belonging. *AMCIS 2015 Proceedings*.

Habibi, P., & Chattopadhyay, D. (2021). The impact of handedness on user performance in touchless input. *International Journal of Human-Computer Studies*, *149*. https://doi.org/10.1016/j.ijhcs.2021.102600

Harborth, D., & Pape, S. (2017). Exploring the Hype: Investigating Technology Acceptance Factors of Pokémon Go. *Proceedings of the 2017 IEEE ISMAR*, 155–168.

Harborth, D., & Pape, S. (2019). Investigating privacy concerns related to mobile augmented reality applications. *ICIS 2019 Proceedings*.

Harborth, D., & Pape, S. (2020). How nostalgic feelings impact Pokémon Go players – integrating childhood brand nostalgia into the technology acceptance theory. *Behaviour & Information Technology*, *39*(12), 1276–1296. https://doi.org/10.1080/0144929X.2019.1662486

Harborth, D., & Pape, S. (2021). Investigating privacy concerns related to mobile augmented reality Apps – A vignette based online experiment. *Computers in Human Behavior*, *122*, 106833. https://doi.org/10.1016/j.chb.2021.106833

Hertel, J., Karaosmanoglu, S., Schmidt, S., Bräker, J., Semmann, M., & Steinicke, F. (2021). A Taxonomy of Interaction Techniques for Immersive Augmented Reality based on an Iterative Literature Review. *Proceedings of the 2021 IEEE ISMAR*, 431–440.

Hinsch, C., Felix, R., & Rauschnabel, P. A. (2020). Nostalgia beats the wow-effect: Inspiration, awe and meaningful associations in augmented reality marketing. *Journal of Retailing and Consumer Services*, *53*. https://doi.org/10.1016/j.jretconser.2019.101987

Holdack, E., Lurie-Stoyanov, K., & Fromme, H. F. (2020). The role of perceived enjoyment and perceived informativeness in assessing the acceptance of AR wearables. *Journal of Retailing and Consumer Services*. https://doi.org/10.1016/j.jretconser.2020.102259

Huang, T.-L. (2019). Psychological mechanisms of brand love and information technology identity in virtual retail environments. *Journal of Retailing and Consumer Services*, *47*, 251–264. https://doi.org/10.1016/j.jretconser.2018.11.016

Huang, T.-L. (2021). Restorative experiences and online tourists' willingness to pay a price premium in an augmented reality environment. *Journal of Retailing and Consumer Services*, *58*. https://doi.org/10.1016/j.jretconser.2020.102256

Huang, T.-L., & Liu, B. S. C. (2021). Augmented reality is human-like: How the humanizing experience inspires destination brand love. *Technological Forecasting and Social Change*, *170*. https://doi.org/10.1016/j.techfore.2021.120853

Jacoby, J. (2002). Stimulus-organism-response reconsidered: An evolutionary step in modeling (consumer) behavior. *Journal of Consumer Psychology*, *12*(1), 51–57.

Klinker, K., Wiesche, M., & Krcmar, H. (2019). Digital transformation in health care: Augmented reality for hands-free service innovation. *Information Systems Frontiers*, 1–13.

Klinker, K., Wiesche, M., & Krcmar, H. (2020). Smart glasses in health care: A patient trust perspective. *Proceedings of the 53rd HICSS*, 3548–3557.

Laato, S., Hyrynsalmi, S. M., Rauti, S., & Sutinen, E. (2020). The Effects Playing Pokémon GO has on Physical Activity -A Systematic Literature Review. *Proceedings of the 53rd HICSS*, 3407–3416.

Masood, T., & Egger, J. (2019). Augmented reality in support of Industry 4.0—Implementation challenges and success factors. *Robotics and Computer-Integrated Manufacturing*, *58*, 181–195. https://doi.org/10.1016/j.rcim.2019.02.003

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, *77*(12), 1321–1329.

Montgomery, H., Sharafi, P., & Hedman, L. R. (2004). Engaging in activities involving information technology: Dimensions, modes, and flow. *Human Factors*, *46*(2), 334–348.

Niemöller, C., Niemöller, D., Berkemeier, L., Zobel, B., & Thomas, O. (2019). *Mobile Service Support based on Smart Glasses*. *20*(1), 32.

Olson, J. C., & Jacoby, J. (1972). Cue utilization in the quality perception process. *In SV - Proceedings of the Third Annual Conference of the Association for Consumer Research*, 167–179.

Osterbrink, A., Bräker, J., Semmann, M., & Wiesche, M. (2021). Requirements for Augmented Reality Solutions for Safety-Critical Services – The Case of Water Depth Management in a Maritime Logistics Hub. *16th International Conference on Wirtschaftsinformatik*.

Pine, B. J., & Gilmore, J. H. (2013). The experience economy: Past, present and future. In *Handbook on the experience economy* (pp. 21–44). Edward Elgar Publishing.

Rauschnabel, P. A., Brem, A., & 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*, *49*, 635–647. https://doi.org/10.1016/j.chb.2015.03.003

Rauschnabel, P. A., Felix, R., & Hinsch, C. (2019). Augmented reality marketing: How mobile AR-apps can improve brands through inspiration. *Journal of Retailing and Consumer Services*, *49*, 43–53. https://doi.org/10.1016/j.jretconser.2019.03.004

Rauschnabel, P. A., He, J., & Ro, Y. K. (2018). Antecedents to the adoption of augmented reality smart glasses: A closer look at privacy risks. *Journal of Business Research*, *92*, 374–384. https://doi.org/10.1016/j.jbusres.2018.08.008

Rauschnabel, P. A., & Ro, Y. K. (2016). Augmented reality smart glasses: An investigation of technology acceptance drivers. *International Journal of Technology Marketing*, *11*(2), 123–148. https://doi.org/10.1504/IJTMKT.2016.075690

Rauschnabel, P. A., Rossmann, A., & tom Dieck, M. C. (2017). An adoption framework for mobile augmented reality games: The case of Pokémon Go. *Computers in Human Behavior*, *76*, 276–286. https://doi.org/10.1016/j.chb.2017.07.030

Richardson, P. S., Dick, A. S., & Jain, A. K. (1994). Extrinsic and intrinsic cue effects on perceptions of store brand quality. *Journal of Marketing*, *58*(4), 28–36.

Schuster, F., Engelmann, B., Sponholz, U., & Schmitt, J. (2021). Human acceptance evaluation of AR-assisted assembly scenarios. *Journal of Manufacturing Systems*. https://doi.org/10.1016/j.jmsy.2020.12.012

Sheldon, P. (2008). Student favorite: Facebook and motives for its use. *Southwestern Mass Communication Journal*, *23*(2).

Song, Y., Watson, R. T., & Zhao, X. (2021a). Literature Reviewing: Addressing the Jingle and Jangle Fallacies and Jungle Conundrum Using Graph Theory and NLP. *ICIS 2021 Proceedings*.

Song, Y., Watson, R. T., Zhao, X., & Kelley, N. (2021b). A Causal Model Analysis Approach to Literature Reviewing: A Tutorial on the Application of Graph Theory. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3870782

Sutherland, I. E. (1968). A head-mounted three dimensional display. *Proceedings of the December 9-11, 1968, Fall Joint Computer Conference, Part I*, 757–764. https://doi.org/10.1145/1476589.1476686

tom Dieck, M. C., Jung, T. H., & Rauschnabel, P. A. (2018). Determining visitor engagement through augmented reality at science festivals: An experience economy perspective. *Computers in Human Behavior*, *82*, 44–53. https://doi.org/10.1016/j.chb.2017.12.043

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27*(3), 425–478. https://doi.org/10.2307/30036540

Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Quarterly*, 157–178.

Weber, R. (2021). Constructs and Indicator: An Ontological Analysis. *MIS Quarterly, 45*(4), 1644–1678.

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, xiii–xxiii.