

¹ Nur Asyiah Suwadi² Meng Chun Lam³ Nur Fazidah Elias⁴ Nazatul Aini Abd Majid

Collaborative Augmented Reality: A Proposed Technology Acceptance Model



Abstract: - A collaborative augmented reality (CAR) system allows multiple users to communicate with each other in a shared 3D environment. Technology Acceptance Model (TAM) is a well-known method for predicting user acceptance of new technology, it also has the two strongest dimensions of acceptance: perceived usefulness and perceived ease of use. However, it can be further developed with external dimensions to investigate acceptance more comprehensively for the CAR system, with its 3D characteristics and collaborative ability, requires additional dimensions for measurement. This study aims to analyze and identify a suitable external dimension to be incorporated in TAM for CAR. We acquired the previous using the Web of Science database, which included keywords such as 'augmented reality,' 'virtual reality,' and 'technology acceptance model.' We analyzed eighteen high quality papers from a pool of ninety-seven papers, including journals and conferences. Resultantly, thirty-two external dimensions have been identified from previous TAM studies. After thorough analysis, a foundation TAM for the CAR system is proposed, along with suggestions for external dimensions for different CAR domain applications. The developed TAM includes perceived enjoyment, aesthetic quality, system quality, social presence, satisfaction, information quality, interactivity, collaboration quality and embodiment quality in the CAR context. Other factors, such as social norms, mobility, and others, are applicable to different CAR domain applications. The identified acceptance factors will assist researchers in enhancing their collaborative experience and conducting further analysis in the field of CAR.

Keywords: Technology acceptance model, augmented reality, collaborative.

I. INTRODUCTION

Augmented Reality (AR) enables users to interrelate with virtual objects in a real environment seamlessly [1]. AR technology enables information that once seemed impossible. The commonly accepted definition of AR as a technology which has three principal features: the combination of the virtual world and the real world, interaction in real-time, and 3D registration [2]. The AR technology has greatly benefited in practical implementation and learning [3, 4], improved communication and interaction, expanded user experience [5] and addressed several complex aspects related to with communication, network and consistency problems [6]. This technology has the potential to overcome some of today's technological deficiencies and allow multi-user communication naturally, resulting in a new term, collaborative augmented reality (CAR). CAR is a collaborative space that allows multi-users to communicate with displayed AR content [7] and collaborate to achieve a common goal [8]. CAR not just connect the physical object in physical world with 3D digital content, it also improves user understanding and communication with each other to efficiently coordinate their actions [6].

The CAR applications also contribute to valuable learning and experiences for users that can help them explore knowledge by leveraging this technology. The AR, VR and CAR applications are available in platform either for face-to-face or remote collaboration. However, without identifying user acceptance and behavior, it is difficult to assess the potential of these existing technologies. The Technology Acceptance Model (TAM) is normally applied because of its ability to utilize the two strongest dimensions of acceptance, namely perceived usefulness (PU) and perceived ease of use (PEOU) and can be developed with external dimensions to further investigate the acceptance of new technology.

Previous studies have assessed the user acceptance in the use of AR and VR, however, research on the acceptance of CAR is still limited. Past researches such as Papakostas, Troussas, Krouska and Sgouropoulou [9], Pantano, Rese and Baier [10], Álvarez-Marín, Velázquez-Iturbide and Castillo-Vergara [11], and Ibili, Resnyansky and Billinghurst [12] studied user acceptance in AR, while Castiblanco Jimenez, Cepeda García, Violante, Marcolin and Vezzetti [13], and [14] studied technology acceptance in VR. In AR related TAM, the factor involve includes perceived interactivity, perceived personalization [9], aesthetic quality, interactivity, response time and information quality [10]. At the same time, [11] listed technology innovativeness and technology optimize while

^{1,2,4} Mixed Reality and Pervasive Computing Lab, Center for Artificial Intelligence Technology, Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia

³ Center for Software Technology and Management, Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia

Email: ¹ sylah94@gmail.com, ² lammc@ukm.edu.my, ³ fazidah@ukm.edu.my, ⁴ nazatulaini@ukm.edu.my

Copyright © JES 2024 on-line: journal.esrgroups.org

[12] suggested social norm and anxiety. On the other hands, the factor of TAM related to VR are computer self-efficacy, individual innovativeness, computer anxiety, perceived enjoyment, experience, subjective norm, content quality, and facilitating conditions [13]. Besides, [14] listed perceived visual design and perceived task technology fitted. The TAM relationship has been confirmed for AR/VR-based systems through studies, but it remains unclear for the CAR case. It is evident that additional factors need to be incorporated into the TAM to enhance its comprehensiveness and predict the user acceptance level in the context of CAR. Therefore, this study aims to create a model that can measure the acceptance of CAR applications by utilizing related dimensions from previous study.

II. LITERATURE REVIEW

The advancement of CAR applications provides users with valuable insights and experiences, facilitating learning exploration through the utilization of current technology. Moreover, AR, VR, and CAR can engage with the public through smartphones, as well as head-mounted devices, whether wired or wireless, providing users with a fully immersive experience in the virtual world. Nevertheless, without identifying user acceptance and behavior, assessing the potential of these existing technologies becomes difficult. The section below discussed the early study of TAM and the TAM for the AR and CAR cases.

A. *Technology Acceptance Model (Tam)*

TAM of Davis (1989) has been used in several research projects and the results show that some literature shows that TAM is significant enough for technology acceptance [15]. Furthermore, a recent systematic evaluation showed that the use of TAM in the adoption of technology has shown its effectiveness when compared to other theoretical models [16]. According to the theory, the external dimension of a specific system influences two personal beliefs; "perceived usefulness" (PU) and "perceived ease of use" (PEOU) to determine a person's attitude towards the use of technology. The attitude itself has an effect on the behavioral intention (BI) to use a certain technology [17].

PU is defined as "the degree to which an individual believes that using a particular system will increase his productivity" [18]. PEOU is defined as "the degree to which an individual believes that using a particular system will be free of effort" [18]. Individuals' intention to use technology is determined by PU and PEOU which are influenced by external dimensions and specific systems to predict attitudes towards the use of a technology. Attitudes then influence users' behavioral intentions to use certain technologies [18, 19]. Although technology is not fun to use, an individual will use technology if it is practical, easy, and socially desirable [20]. TAM claims that individual behavioral intentions are the result of decisions made by cognitive processes [21] and has been used in some past research to see the aspects that influence how users accept adopt new technologies [22]. Previous studies show that the importance of these factors varies depending on the type of user and technology system [23]. TAM has been used in several scenarios, where researchers have sought to reveal factors that influence individual attitudes as well as behavioral intentions to use mobile technology and AR.

Nevertheless, Venkatesh, Thong and Xu [24] stated that the TAM is too simplistic and considered insufficient to explain user behavior in a real-life environment. Tan and Ooi [25] agree with that argument and that emphasize that the original TAM does not have external variables. Nguyen and Bednarz [26] confirmed that AR elements in applications may influence users' PU. The original TAM can only explain about 40% of the variation in the model [27] and for that reason, the TAM should be combined with other external variables to better predict user behavior nowadays [13]. Although there are weaknesses in the original TAM, TAM serves as a great foundation tool to analyze the user intention to use the technology by adding new constructs to their context of study [28, 29].

B. *Technology Acceptance Model for Augmented Reality and Collaborative Augmented Reality*

Previous studies have examined on AR with the TAM with various domain such as engineering [11], education [26] history [30] training [9] and retail [10]. Augmented Reality Online Decision Maker Acceptance Model (Figure 1) is one of the studies that adapt the TAM with external dimension to investigate the impact of AR technology on user behavior in an online business environment [10]. In previous days, there were limited possibilities for users to virtually try a product before making an effective purchasing decision online. Therefore, AR systems were introduced to fulfil users' needs and enable them to virtually see the items they wish to purchase. Based on their conceptual model, new constructs related to technological features such as aesthetic quality, interactivity, response time and information quality have been taken into consideration. The aesthetic quality includes graphic effects in terms of clarity, realism of 3D images, visual appeal of graphic appearance in the AR environment which are developed from the construct of website quality for e-commerce [31]. Besides, interactivity construct is conceptualized as "the extent to which users can participate in modifying the form and content of a mediated

environment in real time" [32] which allow user to interact and customized the information on the virtual platform. At the same time, in information quality, users expect to easily find information using the virtual platform, which, in turn, should be useful for supporting the purchase decision. The AR system needs to provide high-quality information in terms of availability, accessibility, completeness, accuracy, and adequacy, which might determine the overall usefulness of the system.

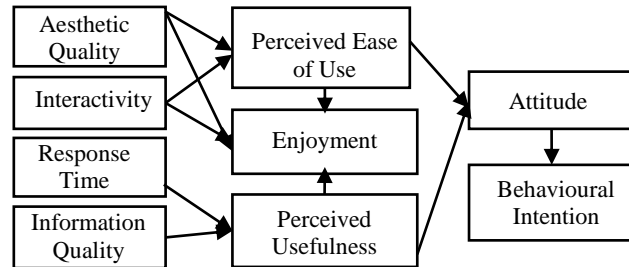


Figure 1. Online Decision Maker Acceptance Model with Augmented Reality
Source: Pantano, Rese and Baier [10]

Furthermore, Mobile Reality Augmented Training System Acceptance Model (Figure 2) is a model that also adapts TAM as the main model [9]. The TAM was modified and matched with system requirements to evaluate AR user experience in firefighter training. This research identified the external construct which are perceived interactivity and the perceived personalization to study the system and individual acceptance. Past AR research provides empirical evidence supporting the perceived interactivity as a prerequisite factor to develop the core model of TAM to understand usage behavior [33]. McMillan and Hwang [34] measured interactivity based on three elements, namely, communication direction, user control, and time. The communication direction focuses on how computers facilitate human interaction that emphasizes two-way communication. User control studies how humans control computers and time assesses the user's ability to navigate within the application quickly and easily. Furthermore, personalization is found to be one of the main components of various information technology-based systems [35]. Personalized training within an AR environment can tailor learning to individual needs, enhancing the quality of training by allowing them to repeat the training stages as many times as they need, learning at their own pace. The results demonstrate that both external variables, perceived interactivity, and perceived personalization, are essential prerequisites for the development of the TAM and influence the PEOU. These identified acceptance factors have facilitated the development of AR technologies, subsequently improving the training experience for firefighters.

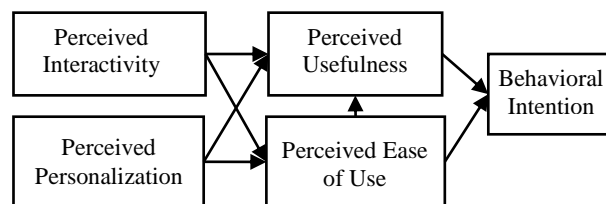


Figure 2. Mobile Augmented Reality Training System Acceptance Model
Source: Papakostas, Troussas, Krouska and Sgouropoulou [9]

There is a study on a model explaining primary school students' learning outcomes when using multi-user virtual environments (MUVE) [36]. Eight variables were used to build this research model: PEOU, realism, collaboration, presence, enjoyment, motivation, perceived usefulness, and learning. However, these studies did not fully adopt the entire TAM framework but rather adapted dimensions to create their own model (see Figure 3). Realism is determined by the level of detail in virtual objects and how closely their behavior resembles reality and plays an important role when individuals use MUVES/VR [37]. Additionally, collaboration is a fundamental feature of MUVES, enabling users to collaborate with each other, including engaging in social interactions and providing peer feedback. Previous study has demonstrated that collaboration is a crucial element in the learning processes within MUVES [38]. Therefore, collaboration factors in MUVE have been adapted to the current research as the collaboration includes social interaction and teammate feedback which match with the CAR environment itself.

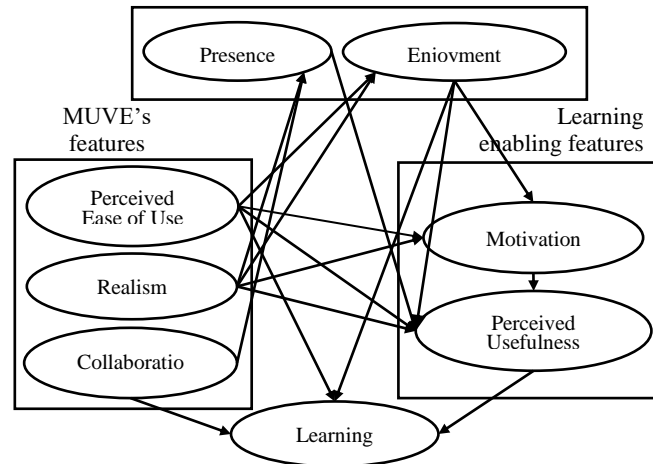


Figure 3. Multi-User Virtual Environments proposed model.

Source: Fokides [36]

In the 'state of mind' section, Fokides [36] lists two factors: enjoyment and presence. Enjoyment refers to the fun and pleasure experienced in a MUVE and can be defined as the degree to which a user finds their experience enjoyable [39]. AR offers playful and entertaining momentary experiences to which users found the application enjoyable. These positive feelings also contribute to learning outcome [40] and knowledge acquisition [41]. At the same time, the presence is to measure the multi-user existence while interacting with AR application.

Besides, motivation is not static attributes which are inherently volatile and sensitive to the way content is presented [42]. Research has indicated that the 3D presentation of the MUVE, interaction with its objects, and increased control over what the user selects to view can influence motivation and, consequently, the learning outcomes [43].

A study was conducted on CAR related to TAM back in 2014, specifically focusing on mobile collaborative augmented reality (MCAR) within field service networks [44]. The investigation focuses on how collaboration among field technicians and remote experts could be improved by means of AR and mobile technologies. Therefore, a questionnaire was designed in accordance with the theory of the TAM [18]. The questionnaire was designed to reflect the items that are generally used to measure the perceptions of respondents about their attitude to, and affection towards, a technology. Participants agree that the device was found to be easy to use, simple, and user-friendly. However, the study only adopted the TAM framework and did not introduce any new external dimensions, especially related to collaborative quality. From our literature review finding, including aforementioned research, there is not much study proposed the TAM for the CAR setting. Therefore, our study has been looking forward to investigating aspects related to collaborative quality.

III. ANALYSIS OF PREVIOUS MODEL

This section presents the research model in this research and explains the constructs that make up the research model with relevant hypotheses. The findings of the preliminary study conducted are discussed based on the study of TAM found in previous studies. As a result of these findings, external dimensions and other constructs of the model were mapped based on the identified themes. A research model was developed based on discussion of the findings of the analysis and literature review. Finally, the theoretical and practical implications of the developed model are discussed in this chapter.

Various specific user acceptance factors involving AR and collaboration have been identified by previous researchers. This study has done an iterative literate review by acquiring sources in the Web of Science database, due to the good quality of the publication, with the keywords includes "augmented reality", "virtual reality" and "technology acceptance model". Initially, 97 articles and proceeding papers were yielded from the search and analyzed. Subsequently, a mass of studies that do not involve collaboration and a review study were excluded from the analysis. The research that studied technology acceptance model on AR/VR setting is included. The dimensions obtained have been narrowed down to the study as shown in Table 1, and rearranged and summarized according to frequency.

Preliminary analysis found that 32 dimensions were obtained from the content analysis of 18 selected articles. The frequency of the dimension is one of the reasons why the dimension was chosen in addition to its suitability

of evaluating against the CAR application. In order to ensure the selection of the suitable dimension for this study, the definition of each selected dimension is explained and listed in Table 1. A total of six external dimensions and two perceptions are selected from Table 1, which is based on previous studies with a frequency of at least 3 times and relevant relation with CAR. However, it is crucial to include other specific dimensions too such as interactivity and collaborative quality in collaborative works. Meanwhile, one dimension, which is the embodiment quality dimension is included from a specific study in the past [45, 46] which made it total seven external dimensions. Embodiment quality is defined as the replacement of a person's real body with a virtual body representation, enabling them to feel as though they are immersed in a virtual environment [47]. This sense of presence fosters an improved collaboration quality among users within the environment.

Table 1. Frequency of Dimension

No	Dimension	Definition	Fr.	Source
1	Perceived usefulness*	The degree to which individuals believe that a new technology will help them perform their tasks better. Related factor: <ul style="list-style-type: none"> • Perceived advantage • Perceived learning effectiveness 	16	[48],[9], [11]
2	Perceived ease of use *	The degree to which individuals perceive that using a particular technology will not be complicated.	15	[48],[9], [11]
3	Behavioral intention *	A person's subjective probability that he will perform a certain behavior.	15	[48],[9], [11]
4	Attitude*	The degree to which a person has positive or negative feelings towards a system.	12	[48],[11], [49]
5	Perceived enjoyment*	The extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated.	7	[17],[50], [51]
6	Aesthetic quality *	The hedonic dimension of the system creating pleasure and enjoyment in the electronic system.	4	[30],[26], [52]
7	System quality*	A system wherein the desired characteristics of devices are believed to be available to users" and explains reliability, convenience of access, response time, and system flexibility.	4	[9],[49], [53]
8	Social presence *	The level of awareness of the presence with other individuals, the level of importance of others in the interaction, and the feeling that one has access or insight into other individuals' intentions, cognitive or affective.	3	[54],[55], [56]
9	Satisfaction*	The perceived degree of contentment with regard to a user's prior experience in using software for learning purposes.	3	[52], [50]
10	Information Quality*	The use of technology to find information that may be important for learning and that is updated, so that it is easier for user to understand it or receives complete, accurate and fast information through the electronic service interface. Related factor: <ul style="list-style-type: none"> • Perceived informativeness • Content quality 	3	[17], [51] [10]
11	Interactivity *	The degree to which communication technology allows the design of an environment where participants have the chance to interchange messages as well as to communicate synchronously and asynchronously with one or more people at the same time.	2	[9], [10]
12	Collaboration quality *	Allows collaboration between users (including social interaction and teammate feedback)	2	[53], [36]
13	Response time	The time to complete the task or effective access to information can reduce potential errors Related factor—Reduction of Time and Errors	2	[57], [10]
14	Mobility	The ability of using cloud applications via mobile devices freely without any time or place limitation	2	[53], [54]
15	Motivation	Support from peers	2	[48], [36]
16	Perceived technology - task fit	The degree to which a technology assists an individual in performing his or her portfolio of tasks. The technology must be utilized and fitted with the tasks it supports in order to achieve good impacts on individual performance	2	[30], [26]

17	Social norm	The subjective belief that the individual should use or not use the new system and has an important influence on intention in the early stage of technology adoption.	2	[48], [12]
18	Subjective norms	The belief that an important person or group of people will approve and support a particular behavior.	2	[11], [17]
19	Spatial representation	Being able to mentally represent and manipulate visual - spatial information	1	[57]
20	Perceived Adaptivity	The perceived ability of the system to be adaptive to the changing needs of the user.	1	[55]
21	Vividness	The representational richness of a mediated environment as defined by its formal features; that is, the way in which an environment presents information to the senses.	1	[49]
22	Sense of belonging	The feeling of virtual community members that they are integral parts of the virtual community.	1	[54]
23	Perceived Sociability	Users' learning ability in a robot-supported collaborative context.	1	[55]
24	Technology innovativeness	A person's inclination to try new information technologies. People's tendency to be pioneering users of technology and be leaders in its use.	1	[11]
25	Technology optimism	Having a positive view of technology, including control, flexibility, convenience, and efficiency.	1	[11]
26	Anxiety	The tendency of an individual to be restless, anxious or frightened about the current or future use of technology in general.	1	[12]
27	Self - presentation	The creative expression that requires both target audiences and contexts of social interaction to determine which information to present and which to eliminate	1	[50]
28	Information sharing	Providing information to people who require it	1	[50]
29	Perceived realism	How detailed the virtual objects are and, in general, how close to reality their behavior is	1	[36]
30	Computer self-efficacy	The individuals' confidence in their own capacity to take steps needed to deal with future situations	1	[17]
31	Perceived accessibility	The degree of ease of how a user can access and use the information and extracted from the system.	1	[17]
32	Perceived Playfulness	The degree of cognitive spontaneity in microcomputer interaction.	1	[17]

* The dimensions chosen to form the acceptance model in this study

IV. RESULT AND DISCUSSION

TAM has been adapted with the selected external dimension, which is perceived enjoyment, aesthetic quality, system quality, information quality, interactivity, collaboration quality and embodiment quality. Meanwhile the additional perception of TAM is the satisfaction and social presence. The model has been discussed with experts to produce the current output model for CAR (Figure 4).

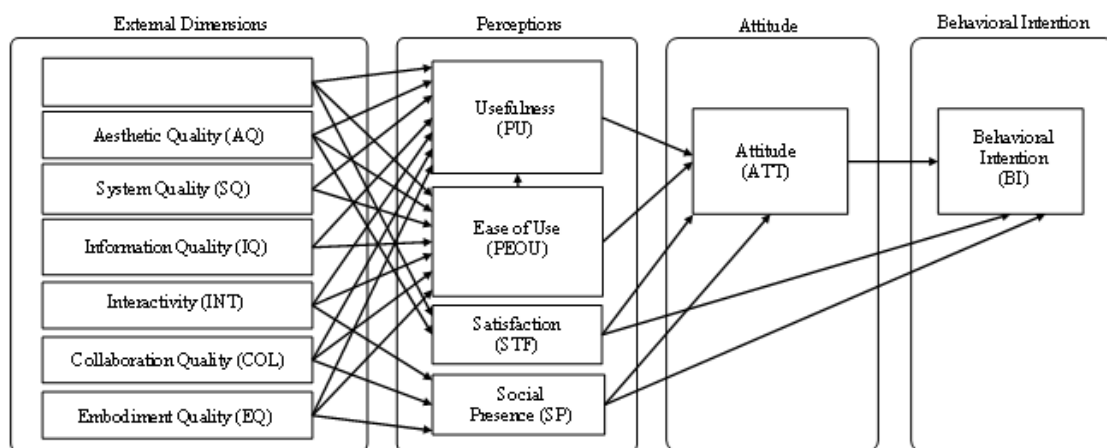


Figure 4. Collaborative augmented reality proposed model

Perceived enjoyment (PE) explored as a vital attribute for CAR. It signifies the extent to which using the system is perceived as pleasant, independent of expected performance, and has the potential to influence users' usage of a particular system [10, 22]. Therefore, it is linked to the enjoyment derived from the system usage [58]. Both theoretical and empirical research have validated the notion that PE is a crucial factor for successful application usage [22] and may even surpass PU as a determinant of hedonic application use [58].

Moreover, aesthetic quality (AQ) acts as an external dimension that can enrich the environment with virtual representation to the real environment allowing it to become a variable that can influence users in the decision-making process. For example, Wixom and Todd [59] outline the importance of the AQ of the system to influence user acceptance, including the system's ability to adapt to user demand, accessibility and response time to user demand. In fact, virtual feedback with the product is also involved, through 3D animation, which provides an additional experience that can compensate for the lack of real product touch. Thus, the clarity, understanding and AQ of the virtual image stimulate the user's sense of perception on the formation of a digital image through the experience they have when using the AR system [10].

Moreover, system quality (SQ) encompasses factors such as reliability, convenience of access, response time, and system flexibility [61]. It captured the technical level of communication [61] and previous research has consistently emphasized the significance of SQ across various technological applications including AR [62].

Next, the integrated dimension to consider is information quality (IQ), which includes content accuracy, completeness, and content presentation format [63]. Users, in fact, expect to find information, including selecting and filtering, which should be useful easily and quickly in supporting their decision-making process. It is essential to provide high-quality information in terms of availability, accessibility, completeness, accuracy, and adequacy, as these factors collectively determine the overall usefulness of the system [59].

The next integrated dimension is the interactivity (INT) dimension. Interactivity enable user to engage in modifying the form and content of the mediated environment in real time [32]. An empirical evidence on interactivity presented as a prerequisite factor for developing the basic model of TAM to better understand user behaviors [33]. The focus on the communication element in interactivity is how systems in technology can enhance human-computer interaction, with a strong emphasis on two-way communication. Through interactivity, the way humans control systems can be studied [64]. In the context of AR research, interactivity results in users' positive beliefs about ease of use of AR applications, which in turn influences their behavioral intentions in using the application for learning [9].

Furthermore, collaboration quality (COL) refers to the degree of coordination and activation of mutual interaction among collaboration partners [65]. Collaboration has been stated as a significant feature of the learning environment in existing literature studies [66]. AR technology is able to provide a collaborative tool that allows users to produce and share knowledge in a shared environment and is proven to increase user engagement and train user's critical thinking [53, 67]. Thus, collaboration proven as one of the components that has a positive impact on PU and PEOU in his study on the use of online collaborative technology [53].

The embodiment quality is getting popular and usually discussed in related papers for CAR [45, 46] in the usability studies. However, it is being overlooked especially in relation to the TAM model. On that account, we are adding the embodiment quality as a factor in the TAM model. Embodiment, in this context, refers to a virtual representation that enhances awareness of collaborators' activities by simulating physical conditions, including factors like location, style, movement, and hand gestures [68]. Prior research has consistently demonstrated that incorporating embodiment elements such as the user's body or gestures can significantly enhance collaboration within shared AR and VR environments. The inclusion of embodiment elements also serves to increase social presence, allowing users to naturally employ non-verbal communication signals and facilitating shared interactions with virtual content within shared virtual spaces [45] and thereby improve the overall quality of collaboration [47].

On the other hand, according to the expectation confirmation theory, users' intention to continue using a particular information technology mainly depends on their previous satisfaction with the use of that technology [69]. Satisfaction denotes psychological feelings or affect that originate from the cognitive inconsistency between expectations for and the actual use of an object [50, 52]; therefore, satisfaction is crucial in the process of usage behavior. When using an application, the user reflects on the time spent using that application and the form of media content [50]. Users continue to use the application if they are satisfied with the media behavior and cease use when they are no longer satisfied.

Last but not least, social presence has been added to the developed CAR TAM. Social presence is defined as the concept of being with others which they are able to share the level of awareness of the presence with other individuals, importance of others in the interaction and the feeling that one has access or insight into other individuals' intentions, cognitive or affective [54, 55]. In the literature, social presence is defined as the extent to which a medium allows users to feel that others are also psychologically present [56]. Therefore, users feel the presence of teammates when performing tasks together using the CAR application.

In summary, nine factors have been identified: perceived enjoyment, aesthetic quality, system quality, information quality, interactivity, collaboration quality and embodiment quality as external dimensions, while

satisfaction and social presence is an additional perception dimension added to the current TAM. These factors were selected after a review of previous research related to TAM and CAR studies, along with discussions and considerations from expert views. It could serve as a base model for the CAR application.

This study also done some analysis for different CAR’s domains or context such as education, engineering, training and retail. Researchers can consider the related external dimension as listed in Table 2 to incorporate it in the foundation TAM for CAR (Figure 4) to evaluate the CAR system for those domains.

Table 2. External dimensions on different domains.

Domain	Suggested External Factor	Example	Source
Education	-Perceived technology-task fit -Aesthetic quality -Social norm -Anxiety -Mobility -Sense of belonging -Social presence -Motivation -Collaboration -Personalization -Perceived realism	-Mayo Language Learning -Historical remains of U.S. Civil War -Augmented Reality Geometry Tutorial System (ARGTS) -Mobile social learning platform -Digital textbook	[48],[30],[26],[12],[53],[36], [70]
Engineering	-Technology innovativeness -Technology optimism	-AR app on electrical circuits to visualize the electricity works.	[11]
Training	-Perceived interactivity -Perceived personalization	-Training of ship crews in firefighting operations.	[9]
Retail	-Aesthetic quality -Interactivity -Response Time -Information Quality -Social presence -Perceived enjoyment	-Virtual try-on (a smart mirror for virtual glasses -Screens from IKEA's mobile catalogue app	[10],[51], [56]

V. CONCLUSION

This study enhances the existing body of research utilizing the TAM approach, introducing new tests of external variables on factors identified within the TAM framework. The proposed model holds the potential to make several significant contributions. Firstly, it aims to examine the factors influencing the acceptance of CAR in studies, thereby enriching the scientific literature within the realm of CAR adoption. To achieve this, the TAM has been extended to encompass technology-driven strategies, particularly those involving collaborative augmented reality. The extended TAM provides insights for future planning and the design of various forms of presence in CAR. It's important to note that this study is still in its preliminary stage. While an extensive literature review has been conducted in alignment with related studies, it has not yet been validated through empirical measurements. It will be validated in the next stage of the study.

VI. ACKNOWLEDGMENTS

This research was supported and sponsored by Universiti Kebangsaan Malaysia (GUP-2022-059).

REFERENCES

- [1] I. E. Sutherland, "The ultimate display." pp. 506-508.
- [2] R. T. Azuma, "A survey of augmented reality," Presence: teleoperators & virtual environments, vol. 6, no. 4, pp. 355-385, 1997.
- [3] S.-C. Chang, and G.-J. Hwang, "Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions," Computers & Education, vol. 125, pp. 226-239, 2018.
- [4] R.-C. Chang, and L.-Y. Chung, "Integrating augmented reality technology into subject teaching: The implementation of an elementary science curriculum." pp. 187-195.
- [5] M. C. Lam, H. K. Tee, S. S. M. Nizam et al., "Interactive Augmented Reality with Natural Action for Chemistry Experiment Learning," Tem Journal, vol. 9, no. 1, 2020.
- [6] S. Touel, M. Mekkadem, M. Kenoui et al., "Collocated learning experience within collaborative augmented environment (anatomy course)." pp. 1-5.
- [7] A. Irlitti, R. T. Smith, S. Von Itzstein et al., "Challenges for asynchronous collaboration in augmented reality." pp. 31-35.

- [8] F. Bork, A. Lehner, D. Kugelmann et al., "Vesarius: An augmented reality system for large-group co-located anatomy learning." pp. 122-123.
- [9] C. Papakostas, C. Troussas, A. Krouska et al., "Measuring user experience, usability and interactivity of a personalized mobile augmented reality training system," *Sensors*, vol. 21, no. 11, pp. 3888, 2021.
- [10] E. Pantano, A. Rese, and D. Baier, "Enhancing the online decision-making process by using augmented reality: A two country comparison of youth markets," *Journal of Retailing and Consumer Services*, vol. 38, pp. 81-95, 2017.
- [11] A. Álvarez-Marín, J. Á. Velázquez-Iturbide, and M. Castillo-Vergara, "Technology acceptance of an interactive augmented reality app on resistive circuits for engineering students," *Electronics*, vol. 10, no. 11, pp. 1286, 2021.
- [12] E. Ibili, D. Resnyansky, and M. Billingham, "Applying the technology acceptance model to understand maths teachers' perceptions towards an augmented reality tutoring system," *Education and Information Technologies*, vol. 24, pp. 2653-2675, 2019.
- [13] I. A. Castiblanco Jimenez, L. C. Cepeda García, M. G. Violante et al., "Commonly used external TAM variables in e-learning, agriculture and virtual reality applications," *Future Internet*, vol. 13, no. 1, pp. 7, 2020.
- [14] K. Jung, V. T. Nguyen, D. Piscarac et al., "Meet the virtual jeju dol harubang—The mixed VR/Ar application for cultural immersion in Korea's main heritage," *ISPRS International Journal of Geo-Information*, vol. 9, no. 6, pp. 367, 2020.
- [15] C.-T. Chang, J. Hajiyev, and C.-R. Su, "Examining the students' behavioral intention to use e-learning in Azerbaijan? The general extended technology acceptance model for e-learning approach," *Computers & Education*, vol. 111, pp. 128-143, 2017.
- [16] N. Al-Qaysi, N. Mohamad-Nordin, and M. Al-Emran, "A systematic review of social media acceptance from the perspective of educational and information systems theories and models," *Journal of Educational Computing Research*, vol. 57, no. 8, pp. 2085-2109, 2020.
- [17] S. A. Salloum, A. Q. M. Alhamad, M. Al-Emran et al., "Exploring students' acceptance of e-learning through the development of a comprehensive technology acceptance model," *IEEE access*, vol. 7, pp. 128445-128462, 2019.
- [18] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS quarterly*, pp. 319-340, 1989.
- [19] J. S. C. Hsieh, Y.-M. Huang, and W.-C. V. Wu, "Technological acceptance of LINE in flipped EFL oral training," *Computers in Human Behavior*, vol. 70, pp. 178-190, 2017.
- [20] V. L. Saga, and R. W. Zmud, "The nature and determinants of IT acceptance, routinization, and infusion." pp. 67-86.
- [21] M. Drucker, "Commentary: Crossing the digital divide: How race, class, and culture matter," *Contemporary Issues in Technology and Teacher Education*, vol. 6, no. 1, pp. 43-45, 2006.
- [22] V. Venkatesh, and F. D. Davis, "A theoretical extension of the technology acceptance model: Four longitudinal field studies," *Management science*, vol. 46, no. 2, pp. 186-204, 2000.
- [23] R. H. Shroff, C. C. Deneen, and E. M. Ng, "Analysis of the technology acceptance model in examining students' behavioural intention to use an e-portfolio system," *Australasian Journal of Educational Technology*, vol. 27, no. 4, 2011.
- [24] V. Venkatesh, J. Y. Thong, and X. Xu, "Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology," *MIS quarterly*, pp. 157-178, 2012.
- [25] G. W.-H. Tan, and K.-B. Ooi, "Gender and age: Do they really moderate mobile tourism shopping behavior?," *Telematics and Informatics*, vol. 35, no. 6, pp. 1617-1642, 2018.
- [26] H. Nguyen, and T. Bednarz, "User experience in collaborative extended reality: overview study." pp. 41-70.
- [27] Y.-F. Kuo, and S.-N. Yen, "Towards an understanding of the behavioral intention to use 3G mobile value-added services," *Computers in Human Behavior*, vol. 25, no. 1, pp. 103-110, 2009.
- [28] D. Magni, V. Scuotto, A. Pezzi et al., "Employees' acceptance of wearable devices: Towards a predictive model," *Technological Forecasting and Social Change*, vol. 172, pp. 121022, 2021.
- [29] G. Wang, G. W.-H. Tan, Y. Yuan et al., "Revisiting TAM2 in behavioral targeting advertising: a deep learning-based dual-stage SEM-ANN analysis," *Technological Forecasting and Social Change*, vol. 175, pp. 121345, 2022.
- [30] K. Jung, V. T. Nguyen, S.-C. Yoo et al., "Palmitoar: The last battle of the US Civil war reenacted using augmented reality," *ISPRS International Journal of Geo-Information*, vol. 9, no. 2, pp. 75, 2020.
- [31] D. Cyr, and C. Bonanni, "Gender and website design in e-business," *International Journal of Electronic Business*, vol. 3, no. 6, pp. 565-582, 2005.
- [32] J. Steuer, "Defining Virtual Reality: Dimensions Determining Telepresence. *Journal of Communication*, 42 (4), 73-93," *Future Generation Computer Systems*, vol. 94, pp. 302-316, 1992.
- [33] J.-H. Lee, and C.-F. Lee, "Extension of TAM by perceived interactivity to understand usage behaviors on ACG social media sites," *Sustainability*, vol. 11, no. 20, pp. 5723, 2019.
- [34] S. J. McMillan, and J.-S. Hwang, "Measures of perceived interactivity: An exploration of the role of direction of communication, user control, and time in shaping perceptions of interactivity," *Journal of advertising*, vol. 31, no. 3, pp. 29-42, 2002.
- [35] T.-P. Liang, H.-Y. Chen, and E. Turban, "Effect of personalization on the perceived usefulness of online customer services: A dual-core theory." pp. 279-288.
- [36] E. Fokides, "A model for explaining primary school students' learning outcomes when they use multi-user virtual environments," *Journal of Computers in Education*, vol. 4, no. 3, pp. 225-250, 2017.
- [37] B. Dalgarno, and M. J. Lee, "What are the learning affordances of 3 - D virtual environments?," *British journal of educational technology*, vol. 41, no. 1, pp. 10-32, 2010.
- [38] D. Zheng, and K. Newgarden, "Rethinking language learning: Virtual worlds as a catalyst for change," *International Journal of Learning and Media*, vol. 3, no. 2, 2012.
- [39] R. H. Ducoffe, "Advertising value and advertising on the web," *Journal of advertising research*, vol. 36, no. 5, pp. 21-21, 1996.
- [40] E. A.-L. Lee, K. W. Wong, and C. C. Fung, "How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach," *Computers & Education*, vol. 55, no. 4, pp. 1424-1442, 2010.
- [41] A. Faiola, C. Newlon, M. Pfaff et al., "Correlating the effects of flow and telepresence in virtual worlds: Enhancing our understanding of user behavior in game-based learning," *Computers in Human Behavior*, vol. 29, no. 3, pp. 1113-1121, 2013.

- [42] E. A. Linnenbrink, and P. R. Pintrich, "Motivation as an enabler for academic success," *School psychology review*, vol. 31, no. 3, pp. 313-327, 2002.
- [43] R. Benbunan-Fich, and S. R. Hiltz, "Mediators of the effectiveness of online courses," *IEEE Transactions on Professional communication*, vol. 46, no. 4, pp. 298-312, 2003.
- [44] M. Rapaccini, I. Porcelli, D. B. Espindola et al., "Evaluating the use of mobile collaborative augmented reality within field service networks: the case of Océ Italia–Canon Group," *Production & Manufacturing Research*, vol. 2, no. 1, pp. 738-755, 2014.
- [45] T. Piumsomboon, A. Dey, B. Ens et al., "The effects of sharing awareness cues in collaborative mixed reality," *Frontiers in Robotics and AI*, vol. 6, pp. 5, 2019.
- [46] Z. Zhao, F. Han, and X. Ma, "Live emoji: A live storytelling vr system with programmable cartoon-style emotion embodiment." pp. 251-2511.
- [47] M. Matamala-Gomez, T. Donegan, S. Bottiroli et al., "Immersive virtual reality and virtual embodiment for pain relief," *Frontiers in human neuroscience*, vol. 13, pp. 279, 2019.
- [48] J. Jang, Y. Ko, W. S. Shin et al., "Augmented reality and virtual reality for learning: An examination using an extended technology acceptance model," *IEEE access*, vol. 9, pp. 6798-6809, 2021.
- [49] M. Lee, S. A. Lee, M. Jeong et al., "Quality of virtual reality and its impacts on behavioral intention," *International Journal of Hospitality Management*, vol. 90, pp. 102595, 2020.
- [50] H.-F. Lin, and C.-H. Chen, "Combining the technology acceptance model and uses and gratifications theory to examine the usage behavior of an augmented reality tour-sharing application," *Symmetry*, vol. 9, no. 7, pp. 113, 2017.
- [51] A. Rese, D. Baier, A. Geyer-Schulz et al., "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, 2017.
- [52] N. Chung, H. Lee, J.-Y. Kim et al., "The role of augmented reality for experience-influenced environments: The case of cultural heritage tourism in Korea," *Journal of Travel Research*, vol. 57, no. 5, pp. 627-643, 2018.
- [53] E. Yadegaridehkordi, N. F. B. M. Noor, M. N. B. Ayub et al., "Affective computing in education: A systematic review and future research," *Computers & Education*, vol. 142, pp. 103649, 2019.
- [54] K.-B. Ooi, J.-J. Hew, and V.-H. Lee, "Could the mobile and social perspectives of mobile social learning platforms motivate learners to learn continuously?," *Computers & Education*, vol. 120, pp. 127-145, 2018.
- [55] D.-H. Shin, and H. Choo, "Modeling the acceptance of socially interactive robotics: Social presence in human–robot interaction," *Interaction Studies*, vol. 12, no. 3, pp. 430-460, 2011.
- [56] K. Hassanein, and M. Head, "The impact of infusing social presence in the web interface: An investigation across product types," *International Journal of Electronic Commerce*, vol. 10, no. 2, pp. 31-55, 2005.
- [57] J. Jetter, J. Eimecke, and A. Rese, "Augmented reality tools for industrial applications: What are potential key performance indicators and who benefits?," *Computers in Human Behavior*, vol. 87, pp. 18-33, 2018.
- [58] H. Van der Heijden, "Factors influencing the usage of websites: the case of a generic portal in The Netherlands," *Information & management*, vol. 40, no. 6, pp. 541-549, 2003.
- [59] B. H. Wixom, and P. A. Todd, "A theoretical integration of user satisfaction and technology acceptance," *Information systems research*, vol. 16, no. 1, pp. 85-102, 2005.
- [60] L. Y. Chen, "The quality of mobile shopping system and its impact on purchase intention and performance," *International Journal of Managing Information Technology (IJMIT) Vol*, vol. 5, 2013.
- [61] W. H. DeLone, and E. R. McLean, "The DeLone and McLean model of information systems success: a ten-year update," *Journal of management information systems*, vol. 19, no. 4, pp. 9-30, 2003.
- [62] H.-J. Jung, "Fostering an English teaching environment: Factors influencing English as a foreign language teachers' adoption of mobile learning," *Informatics in Education-An International Journal*, vol. 14, no. 2, pp. 219-241, 2015.
- [63] R. R. Nelson, P. A. Todd, and B. H. Wixom, "Antecedents of information and system quality: an empirical examination within the context of data warehousing," *Journal of management information systems*, vol. 21, no. 4, pp. 199-235, 2005.
- [64] B. Reeves, and C. Nass, "The media equation: How people treat computers, television, and new media like real people," *Cambridge, UK*, vol. 10, no. 10, 1996.
- [65] Y. Lee, I. Cho, and H. Park, "The effect of collaboration quality on collaboration performance: Empirical evidence from manufacturing SMEs in the Republic of Korea," *Total Quality Management & Business Excellence*, vol. 26, no. 9-10, pp. 986-1001, 2015.
- [66] Q. Conley, R. K. Atkinson, F. Nguyen et al., "MantarayAR: Leveraging augmented reality to teach probability and sampling," *Computers & Education*, vol. 153, pp. 103895, 2020.
- [67] Y. Zhang, L. Tao, Y. Lu et al., "Design of paper book oriented augmented reality collaborative annotation system for science education." pp. 417-421.
- [68] C. Gutwin, S. Greenberg, and M. Roseman, "Workspace awareness in real-time distributed groupware: Framework, widgets, and evaluation." pp. 281-298.
- [69] D.-H. Shin, "Understanding e-book users: Uses and gratification expectancy model," *New Media & Society*, vol. 13, no. 2, pp. 260-278, 2011.
- [70] K.-B. Ooi, and G. W.-H. Tan, "Mobile technology acceptance model: An investigation using mobile users to explore smartphone credit card," *Expert Systems with Applications*, vol. 59, pp. 33-46, 2016.