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A SYSTEMATIC LITERATURE REVIEW OF FACTORS INFLUENCING ACCEPTANCE ON MIXED REALITY TECHNOLOGY

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ABSTRACT

Mixed Reality (MR) is amongst the potential technologies that have attracted attention recently. The MR environment is unique since it combines real and virtual objects, interactive in real time and registered in 3-dimension. Even though proponents of MR put forward many advantages of MR, but there are still lack of studies on the users' acceptance of the MR technology. Understanding the factors influencing users' acceptance on the MR technology especially in education helps the developers to produce useful MR applications. The aim of this study is to identify the factors that determine users' acceptance of MR application. A Systematic Literature Review (SLR) was carried since it uses a more rigorous and well-defined approach to reviewing the research evidence relevant to the study. Initially, 336 papers were retrieved by a manual search in six databases and 26 primary studies were finally included. Consequently, 27 factors were identified and analyzed. The findings have revealed that there are four types of factors that can be used to examine the acceptance of MR: productivity-oriented; entertainment dimensions; users personal background and overall system evaluation.

Keywords: mixed reality, technology acceptance, systematic literature review.

INTRODUCTION

In today's society, technology has become a crucial part of our lives. It has changed how people think and apply knowledge. One of the newest developing technologies is mixed reality (MR), which can be applied to computers, tablets and smartphones. MR affords the ability to overlay images, text, video, and audio components onto existing images or space. The MR environment is unique since it combines real and virtual objects, interactive in real time and registered in 3-dimension. It can support the seamless interaction between the real and virtual environments. MR technology has gained a following in the educational market for its ability to bridge gaps and bring a more tangible approach to learning where student–centered activities are enhanced by the incorporation of virtual and real–world experience. Because of these characteristics, the experiences offered by MR are realistic, authentic, engaging, and fun [1,2,3]. The implementation of this new technology in teaching and learning can increase students' motivation [4].

MR technology was invented almost 50 years ago, however the use of MR applications tend to be related to laboratory research. Although many research systems have been developed, only several have matured beyond laboratory-based prototypes and social acceptance issues should be addressed before they can be widely accepted [5]. The research on MR has so far mostly focused on the development of enabling technologies, for example, various types of displays and other output devices[7,8] and algorithms for identifying and tracking real-world objects [9,10] to integrate the real and the virtual. User research has been conducted mainly to evaluate the technical demonstrators, focusing on perception and cognition studies, user task performance or other usability-related aspects [11] or to provide usability-oriented guidelines for design [12,13,14]. Even though proponents of MR put forward many advantages, further implementation of MR would require understanding of users' perceptions towards this technology. The feedback on end-users' views of MR system can guide developers of MR system and administrators who are considering implementing MR technology in the future. A long term goal of MR research is for MR systems to become fully usable and user-friendly, however there are problems addressing human factors in MR systems [6]. Overall, the research regarding user expectations, user experiences and acceptance issues of MR are still underutilized in MR applications [7,15,16]. It is important to properly designed virtual environment using MR interface so it can foster neomillenial learning style through physical and sensory immersion [17].

Acceptance of new information technology (IT) is one area of studies that many researchers and practitioners have investigated since 1990s. Users' acceptance can be defined as the demonstrable willingness within a user group to employ IT for the tasks it is designed to support [18]. Previous research claimed that lack of users' acceptance has been an impediment to the success of new implemented IT system [19,20]. It is important to understand the reasons people accept MR applications as it can help in improving the design, evaluation, and prediction of how users will respond to the new technology such as MR [48]. So, the purpose of this study is to obtain relevant research articles that identify the factors that influence users to accept MR system. The next section provides further background on MR technology, technology acceptance, acceptance of MR technology and hype cycle for emerging technologies. Our research method is presented in the following section that discusses the SLR that has been performed followed by the results section. The discussion section closes the paper with a brief discussion of the researchable issues on this topic.

STUDY BACKGROUND

Mixed reality technology

Milgram and Kishino described a reality-virtuality continuum that spans from the real environment to a pure virtual environment as shown in Figure-1 [44]. Augmented reality (AR) lies near the real world end of the line with the predominate perception being the real world augmented by computer generated data. Augmented Virtuality (AV) refers to systems which are mostly synthetic with some real world imagery added such as texture mapping video onto virtual objects. Mixed Reality (MR) consists of AR and AV. Azuma described the three characteristics of AR environment: combined real and virtual objects, interactive in real-time, and registered in 3-dimension [40]. This definition of an AR system was extended by definition of MR system as an interactive system with inputs from the real world that combined digital and physical entities [41]. MR applications can potentially be applied in various practical day-to-day use cases such as education, entertainment and gaming, as well as in tourism and marketing.

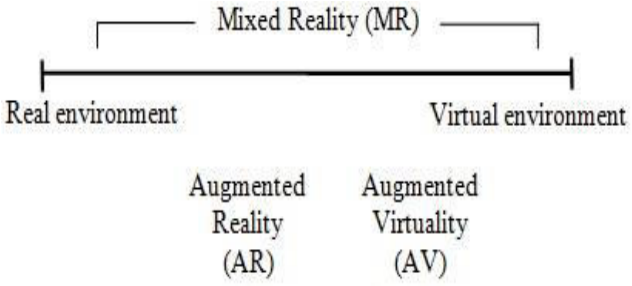

Figure-1. Reality-virtuality continuum [44].

Technology acceptance

Technology acceptance can be defined as the way people perceive, accept, and adopt new technology [42]. A new technology is considered to have been successfully integrated into an organisation or workplace when it is used by the people for the tasks it is intended for. There are many instances where technology has been introduced in organisations and then not been used for a number of reasons. One major contributor to the lack of usage is the usability of the product or system itself. Another issue is how well the system operates in tandem with the users in a social context. Sometimes, the users are not interested to use the system because they do not see the same potential in the system as the management who decide to introduce it in the organisation.

Technology acceptance models are used to explain how users come to use or accept a specific technology. These models have their origins in the disciplines of Psychology, Information Systems and Sociology. Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB) have been widely used to predict and understand behaviour and attitudes [43]. Many models to measure end-users' acceptance of a new technology have been suggested such as Technology Acceptance Model (TAM) [20], Innovation Diffusion Theory (IDT) [21]), and Unified Theory of Acceptance and Use of Technology (UTAUT) [18]. Technology Acceptance Model (TAM) has become one of the most widely used and empirically validated models within the information system research [22]. TAM has been applied to different technologies and has been tested in different contexts. Drawing on the belief-attitude-behaviour models as exemplified by the TRA, suggested that the major factors influencing the intention to use of any technology are predicted by perceived usefulness and perceived ease of use [23].

Acceptance of mixed reality technology

MR is a relatively new technology, considering the limited commercially and publicly available applications. However, as a research field, it has existed for almost five decades with applications in diverse domains, such as military applications, entertainment, technical support and industry applications [6]. Furthermore, MR systems are expensive to design and develop. History has shown the need to carry out users' studies to understand their perceptions of usability and usefulness of new technologies before a technology-based system matures and succeed in being accepted in our daily lives. The acceptance level of and the perceptions toward new technologies is important because by knowing them, it means avoiding having to do expensive remedial [24]. Since users' acceptance research involves different technologies, to determine the acceptance of a specific technology, researchers usually merge the basic TAM model with other constructs that are deemed appropriate for the technology system being tested [25]. Determining the constructs associated with user acceptance of new systems is an important research area in the field of information systems [26].

Hype cycle for emerging technologies

Figure-2 shows the current development stage of several emerging technologies in Gartner Hype Cycle for 2015. According to the cycle, MR technology has already passed the Technology Trigger stage where technology is conceptualized and many prototypes have been developed but there are often no functional products or market studies on them. The potential of MR technology spurs media interest and sometimes proof-of-concept demonstrations. In the Peak of Inflated Expectations stage, the technology is implemented, especially by early adopters. There is a lot of publicity about both successful and unsuccessful implementations of this technology. Currently, AR or MR technology is in the Trough of Disillusionment stage. This stage is very important because if the technology inevitably fails to meet the expectations of its launch phase, failures lead to some disappointment and the technology will be abandoned. If the developers are able to develop reliable and useful applications it will gradually recover from the Slope of Enlightenment and ultimately leads to a situation in which the technology becomes stable or mature, its benefits

become broadly accepted and it is adopted by mainstream users, known as Plateau of Productivity stage.

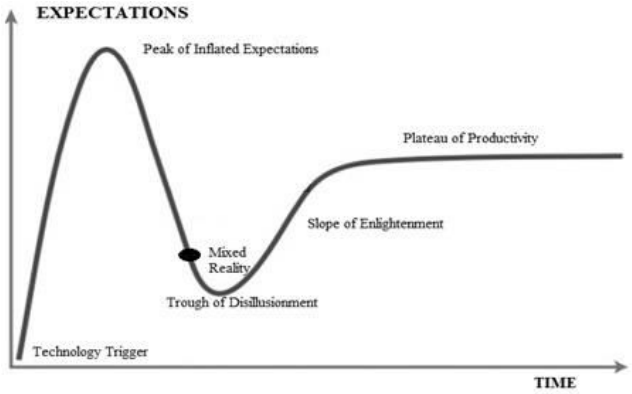

Figure-2. The current development stage of MR technology in Gartner Hype Cycle as July 2015 (http://www.gartner.com/newsroom/id/3114217)

METHODOLOGY

In order to find previous researches on the factors influencing users to accept application using MR technology, this study was chosen to undertake a systematic literature review (SLR) approach. SLR is a secondary study that uses a more rigorous and has a well-defined methodological steps or protocol to review the research evidence relevant to the study. The SLR methodology is a means of identifying, evaluating and interpreting all available researches relevant to a particular research questions, or topic areas, or phenomenon of interests. The methodological steps, search strategies and research questions are explicitly defined so that other researchers can reproduce the same protocol. SLR is likely to produce unbiased and comprehensive accounts of the literature. SLR activities can be grouped into three phases : planning the review; conducting the review; and reporting the review. This study adopted a systematic or evidence-informed approach based on the five-step approach outlined by Denyer and Tranfield [27]. Figure-3 shows the five steps used for this study.

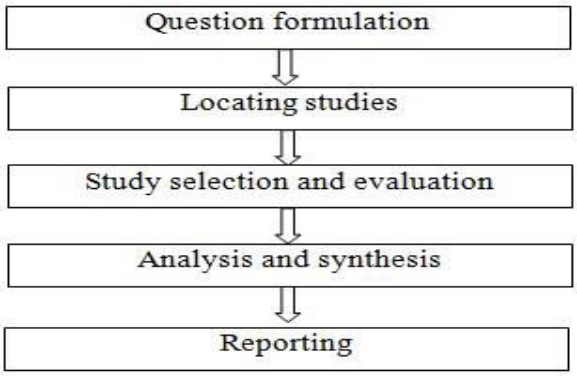

Figure-3. Five steps to conducting a systematic literature review (SLR) [27]

These steps are briefly described as follows:

Question formulation – This is a vital step where a review question is formulated. A clear review question is critical to provide the focus and direction for the study. The question must be dissected into smaller and more specific questions that individual studies can address.

Locating studies – In this step, resources to be searched will be identified. The most common way to find information for a systematic review is to search electronic literature databases.

Study selection and evaluation - Study selection criteria are used to determine which studies are included in, or excluded from the review. Common inclusion criteria include timeframe or publication date range, language or national context and main focus of the paper. Selected studies are to be subjected to a more refined quality assessment normally using quality assessment criteria.

Analysis and synthesis – After the initial screening, the relevant studies will be identified. The aim of the analysis is to break down individual studies into each constituent parts and describe how each relates to one another. On the other hand, the aim of synthesis is to make associations between the parts identified in individual studies.

Reporting : The results will be revealed.

RESULT AND DISCUSSION

This section will present the results established for each steps in SLR.

i. Question formulation

The primary question that this study seeks to address is 'What are the factors that affect acceptance on augmented or mixed reality technology?'. Our literature search was performed in electronic databases with "acceptance OR adoption" AND "augmented reality OR mixed reality" AND "application OR technology OR system" as the search key. The literature search strategy used in this review was intentionally broad and covered many types of MR systems. A wide net allows us to assess whether the factors that predict acceptance of MR systems will be the same as others.

ii. Locating studies

This SLR concentrates on searching in scientific databases rather than in specific books or technical reports, as it assumes that the major research results in books and reports are also usually described or referenced in scientific papers. This research identified six electronic databases as the data sources. They are ACM Digital Library, Taylor & Francis Online, ScienceDirect, SpringerLink, IEEEXplore Digital Library, ProQuest and Emerald which was subscribed by researchers' library.

- ACM Digital Library (http://portal.acm.org).
- IEEE Xplore Digital Library (http://www.ieee.org/web/publications/xplore/).

- Science Direct – Elsevier (http://www.elsevier.com).
- Springer Link (http://www.springerlink.com).
- Taylor and Francis (www.tandfonline.com).
- Google Scholar (www.scholar.google.com).

iii. Study selection and evaluation

Given the breadth and fragmentation of the field, a decision was taken not to try and reduce the number of articles further by refining the search strings. The selection criteria used were: (a) the study was empirical with a substantive focus on quantitatively determining variables associated with acceptance of any type of AR or MR systems; (b) the article was written in the English language; and (c) the article was published in a peer-reviewed journal or conference proceedings. Because this review study examined empirical findings about predictors of MR users' acceptance, we excluded review papers, theoretical and conceptual articles, editorials, and letters. The reviews include articles that were published between January 2005 and 2015. The skimming process has been done by focusing on two different parts of article based on the following sequence: title and abstract, and main body of article.

Initially, the search returned 334 articles for possible inclusion where the titles and abstracts were read. After excluding the duplicate papers and papers that did not meet the inclusion criteria, 47 articles were retained for more detailed review. Finally, 26 articles met the criteria and were included in this review study. Figure-4 shows the selection process for including articles in the review.

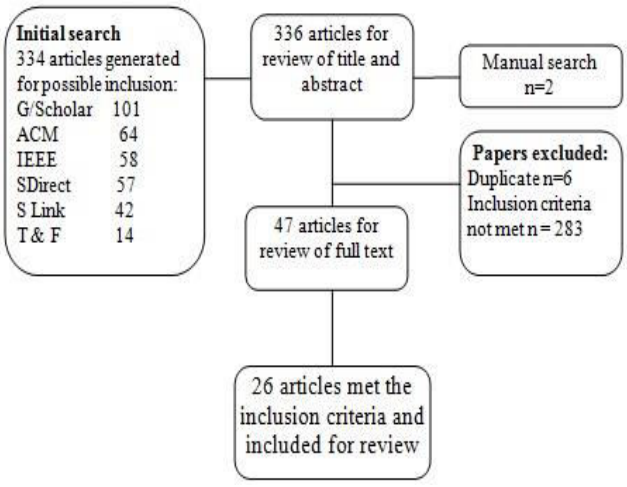

Figure-4. The selection process for including articles in review.

Table-1 shows the number of articles found based on the keywords search in six selected databases.

Table-1. Number of related articles and their source.

Source	Papers found	After excluded	Selected
Google Scholar	101	25	12
ACM Digital Library	64	7	3
IEEE Xplore	58	6	3
Science Direct – Elsevier	57	3	3
Springer Link	42	5	4
Taylor and Francis	14	1	1
Total	336	47	26

iv. Analysis and synthesis

Of the 26 studies reviewed, the main area that has used MR application is education (11 studies). Previous research found that the use of technology in education enabled learning process to be more active, attractive, motivating, simulating, and meaningful to the students [45]. MR is an advanced technology that enables users to interact with virtual and real world in real time application. MR provides a more natural experience, raises attention and motivation to students with a high potential to enhance the learning experience. Previous researches have showed that MR systems have educational values because students enjoy the interaction with virtual objects which is also effective to improve students' learning performance [30,46,47]. The reviewed articles also have showed that MR applications were used to promote marketing (eight studies). Today's new and cutting-edge IT has generally encouraged consumers' experience and hence, has increased the demand for the goods and service [7,37] due to immersive advertising and marketing which are supported by IT. Besides marketing, seven reviewed articles used MR applications in tourism. MR applications have been developed by numerous tourism institutions or organizations around the world in order to provide tourists with unique and memorable experiences. Tourists can be physically and virtually immersed in tourism sites with aesthetic experience provided by MR application that provides tourists with information and enjoyment, and ultimately enhances their experience [28,29]. Basically, the effects of 27 different factors on users' acceptance of MR systems were tested in the 26 studies reviewed. Table-2 shows the number of studies for each factor.

Table-2. Identified acceptance factors of for reviewed papers.

Factors	No of articles
Perceived usefulness	16
Perceived ease of use	15
Intention to use	17
Enjoyment	9
Information quality	5
System quality	3
Personal innovativeness	3
Engagement	3
Self-efficacy	2
Playfulness	2
Aesthetics	2
Service excellent	2

One study has been conducted on each of the following factors: facilitating condition, visual appeal, media richness, perceived value, drawback, social influence, friendliness, presentation, curiosity, cognitive anxiety, environment quality, presence and service quality. Perceived usefulness can be defined as the extent of which the person thinks using the system will enhance his or her job performance [20]. Perceived ease of use is the extent to which the person perceives using the MR system will be free of effort [20]. Intention to use can be defined as the degree to which a person has formulated conscious plans to perform or not perform some specified future behaviour [20]. Enjoyment is the extent to which the activity of using MR system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use [30]. Information quality can be defined as the success of the information in conveying the intended meaning [31]. Personal innovativeness is the willingness of an individual to try out any new information technology [32]. Engagement can be defined as the psychological immersion which occurs when users encounter and become involved, absorbed in mediated experiences [33]. Self-efficacy is defined as one's belief in one's ability to succeed in specific situations [34]. Playfulness is fun or escapism, allowing users to temporarily escape from reality and feel enjoyment [35]. Aesthetics is the visual appeal and entertainment value of the application [36]. Service excellent is the user's appraisal and evaluation of MR application being used [37].

v. Reporting and using the results

Each paper was analyzed for both its descriptive and thematic content. The descriptive analysis was more deductive in nature, and focused on the categorization of papers by year, factors and field of study. The thematic analysis identifies and categorizes the factors according to related conceptual framework. Mixed reality application, games, blogs and social network sites, can be considered as dual-purpose information system that are not completely productivity-oriented but have a substantial entertainment dimension. These entertainment-oriented IS are termed Hedonic IS (HIS) [38]. So, the technology acceptance model TAM provide the conceptual framework for this study [20,38,39]. The TAM suggests that users' decisions to accept a new technology is based on perceived ease of use and perceived usefulness. Since original TAM variables may not adequately capture key beliefs that influence users attitudes on the acceptance of dual-purpose information system such as MR technology, the constructs for entertainment-oriented IS should be added to the classical TAM model in order to examine more thorough on how users accept applications using MR technology. Constructs that examine the emotional, aesthetic and social elements when interacting with MR application is worthwhile to measure in order to gain more understanding on users acceptance of application using MR technology. User experience (UX) takes a broad perspective on the user's interaction with a product or system. UX moves beyond usability (i.e. effective, efficient and satisfactory) interaction with the product towards more emotionally appealing relationships between the user and the system [7].

In the 26 reviewed articles, factors tested on the MR acceptance were related to productivity-oriented, entertainment dimensions, users personal background and overall system evaluation. This review showed that acceptance on productivity-oriented factors such as perceived usefulness and perceived ease of use were still dominant factors in the research on the acceptance of MR technology (40.8%). Entertainment dimensions related with emotions such as enjoyment, engagement, playfulness, curiosity, cognitive anxiety and presence also were tested (22.4%). Evaluation on the aesthetic values of the MR applications such as visual appeal, media richness, friendliness, presentation, perceived value and aesthetics were gradually integrated on the MR systems (10.5%). Some researchers also investigated the effects of personal background such as self-efficacy and personal innovativeness (6.6%) on users' intention to use MR applications. Overall system evaluation such as information quality, system quality, service excellent, service quality and environment quality (15.8%) were also considered as the factors that influence on MR acceptance. Other external factors such as facilitating condition, the drawback of the MR system and the social influence (3.9%) were also examined to predict acceptance in at least one study.

CONCLUSIONS

Based on a SLR, this paper has identified the constructs to examine the acceptance of MR applications. MR technology that combines real and virtual world, interactive in real time and registered in 3-dimension . The main contribution of this literature review is that it brings together the theoretical arguments and findings from six

databases where 27 different factors in the 26 studies were reviewed and synthesised into four types of constructs that can be used to examine the acceptance of MR : productivity-oriented; entertainment dimensions; users personal background and overall system evaluation. Most studies still use the productivity-oriented factors such as perceived usefulness and perceived ease of use to assess the acceptance of MR technology. Entertainment factors such as enjoyment, engagement, playfulness, curiosity, cognitive anxiety and presence have also been studied to understand users' emotion while experiencing applications using MR technology. The aesthetic values of the MR applications such as visual appeal, media richness, friendliness, presentation and perceived value have also been investigated. Overall system evaluation such as information quality, system quality, service excellent, service quality and environment quality have also been studied on MR acceptance. These empirical findings will give direction to our future work which includes proposing an acceptance model of mixed reality technology in education.

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