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Analysis of the Technology Acceptance Theoretical Model in Examining Users' Behavioural Intention to Use an Augmented Reality App (IMAP-Campus)

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ABSTRACT

As technology penetrates into our lives, the vital need for institutions to provide rapid access to information has grown. Recently, Augmented Reality (AR) has emerged as a technology for educational institutions to enhance users' experience by overlaying computational information into their reality. iMAP_CampUS is a mobile AR application showing campus-related information superimposed on a map of Macquarie University. Using iMAP_CampUS app, our goal is to investigate the factors influencing the acceptance of a typical mobile AR system. The thesis proposes a theoretical framework with 14 research hypotheses based on UTAUT, IS success factors and Motivation theory. This framework is empirically examined using web-based survey data from a sample of 86 users. We use Structural Equation Modeling (SEM) and Partial Least Squares (PLS) to evaluate the acceptance and behavioural intention to use iMAP-CampUS app. The results indicate that ten research hypotheses have been significantly supported, while four have been rejected. The findings state that perceived enjoyment and user's satisfaction are important determinants for the use of iMap-CampUS. However, performance expectancy has not demonstrated any significant impacts on behavioural intention to use the app.

Keywords-- Human Computer Interaction, Augmented Reality, Acceptance model, UTAUT

I. INTRODUCTION

Advantages of using AR in educational institutions, particularly universities, has been widely acknowledged. A considerable number of universities have started perceiving the potentials and benefits of AR [1]. In spite of the popularity of widespread AR applications and user acceptance of geo-based AR technology, there is limited academic research conducted to study users' acceptance of AR applications, and none of those focus on the retention of university campus-related information. The aim of this paper is to propose an AR Technology (ART) Acceptance framework by developing a mobile AR application. The mobile AR application shows campus-related information superimposed on a map of Macquarie University, Sydney. We use this app to review the factors influencing the acceptance of AR technology. The ART Acceptance Framework integrates the Unified Theory of Acceptance and Use of Technology (UTAUT) with the IS success factors and Motivation theory.

In the remaining sections of this paper, we will first, review AR and mobile AR systems. Then, we will explain the system architecture of the AR system to be used for validating the ART framework. We will discuss the Unified Theory of Acceptance, IS success model, and Motivation Theory. Finally, integrating these theories and models, we will propose a framework for measuring the acceptance of AR technology.

The focus of the study is users' behavioural intention to use iMAP-CampUS. Specific objectives are to:

(i) identify the factors that influence students' and visitors' intention to use iMAP-CampUS; and determine the underlying relationships among the factors.

1.1 Augmented Reality

Augmented Reality (AR) is different from Virtual Reality (VR), as they appear at the opposite ends of the Reality-Virtuality Continuum (see Fig.1). VR technology totally immerses users within an artificial environment where users cannot see the real world around, whereas AR permits the user to see the real world, with virtual objects superimposed upon or composited with the reality. Thus, AR supplements reality, instead of entirely replacing it [2].

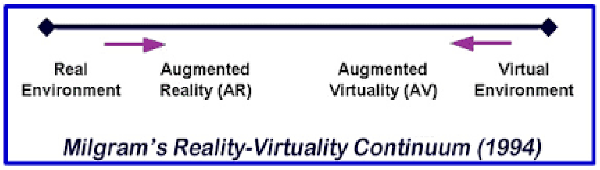

Figure 1 : Virtual and Augmented Reality

Recent developments in mobile computing, wireless sensors, and computer graphics technologies have stimulated the rapid development of AR applications on smartphones [2]. AR applications are currently seen in various fields such as education [1], medical science, and architecture. However, mobile AR applications developed for self-guided tours, such as campus navigation systems [1]are relatively less explored. The use of AR in self-guided tours has practical advantages sinceAR provides a natural mapping between information and real locations. Therefore, it can enhance students and visitors understanding of the current environment.

1.2 Mobile Augmented Reality

Mobile AR is defined as ‘‘AR created and accessed with mobile devices in cellular contexts of use" [3]. Mobile AR systems give similar services to traditional AR systems without forcing the users to choose a particular location [4]. According to [2], mobile AR is one of the fastest growing research areas in the AR zone, as a result of the prevalence of smartphones that provide powerful platforms for supporting AR on a mobile platform. Current smartphones and tablets combine a fast processor with graphics hardware, a touch screen, and relevant embedded sensors such as cameras, GPS, and Wifi for indoor and outdoor positioning [5].

Mobile AR is classified into two categories: marker-less and marker-based. Marker-less AR uses location data (GPS) from the mobile device or image recognition to determine the user's location and superimpose virtual information. Marker-based AR applications need a camera to catch a specific code to access the desired information through a code recognition process. Mobile AR applications take the technology a step further and let the institutions provide information to the user, where the user is located. As an example, FJU Mobile campus touring system developed in 2012, uses AR technology with smartphones [1]. It allows all visitors to familiarise themselves with Fu-Jen campus using a self-guided device.

1.3 The Development of iMAP-CampUS Mobile Application

1.3.1 System overview and Functionality

iMAP-CampUS was developed using the Layar platform [6]. It is available for both Android and iOS devices. iMAP-CampUS gives users information regarding various buildings, while navigating the campus. The GPS coordinates of specific locations on campus were gathered and stored in a database. The iMAP-CampUS application shows the points of interest (POI’s) within a particular range, along with information regarding these points on the user’s smartphone. The supplementary information regarding each POI was provided by the Macquarie University staff. Geo-location information for each POI, was acquired by using Google Maps.

The iMAP-CampUS application contains approximately 25 POIs including various buildings around the campus such as Macquarie Library, Macquarie Theatre and Macquarie Hospital; however, it visualises POIs in distinct styles, through colours and size, representing buildings by their proximity. The size of each POI’s icon is dynamically modified according to the distance of users from that POI. The bigger the icon, the closer the user is to the POI (Fig. 2). All POIs are represented by circular silver icons; and the activated POIsby black disks for simplicity, to reduce cognitive load.

The main window of the iMAP-CampUS supports three different types of functionality (Fig. 2). After launching iMAP-CampUS system, GPS information is accessed instantly, and then POI information is loaded according to the user’s location. Then, the user can activate one of these POIs to get detailed information about a specific POI. Finally, users may ask for navigation directions to a specific location/POI by clicking ‘‘Take me there’’ button. Directions for navigation are displayed on Google Maps.

1.3.2 Demonstration

The iMAP-CampUS Reality Browser runs on an iPhone or Android. As a 2D application, it consists of various features such as the reality view, map view, POI pop-up window in addition to “about” and “take me there” buttons that give more information about the POI as well as directions on how to get to the POI using the smartphones’ map. Other features in the iMAP-CampUS include a horizontal grid to display distance on the app’s screen as well as a filter that adjusts the search range. Further, share option is also provided to share iMAP-CampUS with friends through various channels such as Facebook, WhatsApp and Twitter. Finally, a facility for taking photos of what you see on the browser is also available (Fig.3).

1.3.2.1 Reality View

The reality view is the default view that is going to be the most commonly used view. The students hold their smartphone vertically to the ground and view reality through the camera lens. Superimposed over reality in a 2D layer are the POI icons. Each POI icon points to a point of interest. In the Macquarie Campus map, the POI icons mark various buildings around the campus (Fig.4.)

Fig 2:POI Size &colour Fig 3:App options Fig 4: Reality View

1.3.2.2 Map View

The map view as shown in Fig 5, is helpful for navigation.

1.3.2.3 BWI Pop-up Window

Choosing a POI launches its BIW (Brief Information Widget) which shows brief information about the POI. The Macquarie Campus Map BIW's contain several buttons such as a title for the POI, a description of what the POI is marking, an image of the POI, a "take me there" option (Fig.7), an "About" button that brings up a brief web site about the building and a "play video" button, "play audio" button as well as others. (Fig.6).

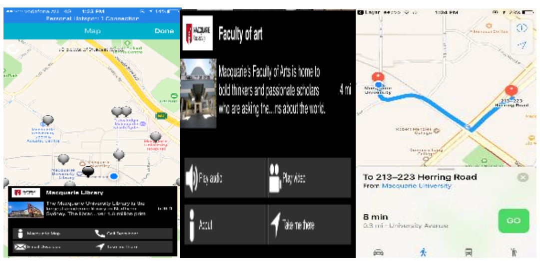

Fig 5: Map View **Fig 6:** BIW pop-up **Fig 7**: Take me there

II. USER ACCEPTANCE

An important part of implementing a new technological innovation in educational institutions especially universities is to assess and understand the adoption of a new technology among students. Numerous studies evaluate the determinants of IT adoption to understand the factors that influence acceptance and use [7], [8]. However, in contrast to expectations, AR is not widely utilised, and, as a new phenomenon, it appears more slowly than expected [9]. Also, academic research on AR has primarily focused on the importance of utilisation of AR, its features, technology, and development phases [1]. In this paper, our goal is to develop a model for a unified theory of user acceptance specifically for AR applications. We will examine these constructs and their usability in AR.

The acceptance of the use of AR technology can be experienced from various perspectives based on information technology (IT) acceptance [10], [11]. Users may develop a positive behavioral intention toward AR, based on whether the use of AR is easy, attractive, available, informative, and fast [12], [13]. Thus, this paper introduces a theoretical model that assists in understanding users' behavioural intention to use mobile AR systems in a higher-education setting. The comprehensive model combines the Unified Theory of Acceptance and Use of Technology (UTAUT), Information System (IS) Success Model and Motivation Theory. This integration results in three success measures and two acceptance constructs. The success criteria include the following: information quality, system quality, and user satisfaction; while the following are the acceptance measures: effort expectancy and facilitating condition. Further, this study introduces Motivation Theory as perceived enjoyment that is believed to influence students' behavioural intention. Based on previous studies, perceived enjoyment has been affected by visual quality. Therefore, visual quality is one of the external factors in our model.

2.1 Technology Acceptance Model

The Technology Acceptance Model (TAM) has been applied in various areas to demonstrate the intentions of individual behaviours[14] in information systems (IS). TAM contains two important factors; perceived usefulness and perceived ease of use, as the key determinants of behavioural intention (see Fig.8). Davis [14] initially proposed that perceived ease of use indirectly affects behavioural intentions and attitude in the original model. However, the attitude factor was later dismissed by Davis in the model owing to the weak mediation effect of attitude. His following study also revealed that the two behavioural beliefs, perceived usefulness and perceived ease of use, are directly associated with the behavioural intention [15].

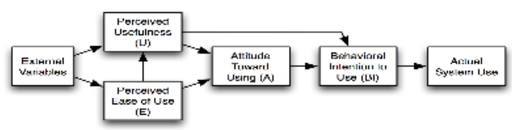

Figure 8: Technology Acceptance Model

Although a significant number of theories tried to explain AR adoption or behavioural intention, these theories did not ultimately support utilitarian and hedonic significance concurrently. Van der Heijden explained that hedonic value is also a key determinant of the intention of individual behaviour [15]. As a result, TAM has been extended byadding a hedonic factor, which is perceived enjoyment. Utilising TAM, the field of AR has consistently expanded the the model with the new technology concepts (e.g.,[15]).

However, TAM does not illustrate post-adoption behaviour or the continuation of behavioural intention to use AR. As a consequence, Bhattacherjee designed an expectation-confirmation model (ECM) to explain the continuation of intention of AR adoption [16]. The ECM revealed that user satisfaction is a crucial factor affecting the continuation of intention of AR adoption. User satisfaction can be defined after an overall evaluation of AR apps[16]. In the research study [14] conducted by Davis, the extended TAM, was called as the Unified Theory of Acceptance and

Use of Technology (UTAUT). UTAUT constructs are derived from the eight models aforementioned [17]. For measuring IS success, Wang and Shee, in their research [18]stated that the D&M model on IS success [18, 19] appears continually in several system-success studies. In this study instead of employing only TAM, we utilize UTAUT as the theoretical framework integrating it with the motivation theory and IS success factors.

The UTAUT aimed at unifying previous theories, as there was an argument about similarities in factors that predicted AR acceptance in the relevant models [20]. UTAUT, as shown in Fig.9, proposes that four core constructs, namely performance expectancy, effort expectancy, social influence, and facilitating conditions affect users' behavioural intention and use behaviour. It also integrates four other factors: gender, age, experience, and voluntariness of use that employ to moderate users' adoption of an IS.

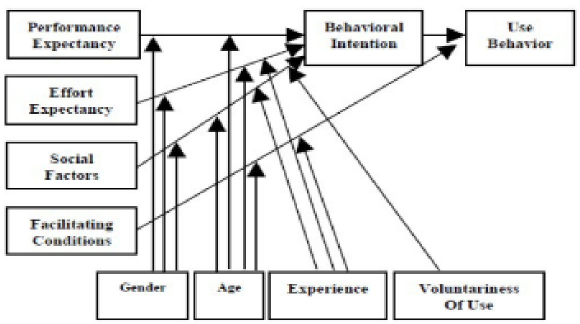

Figure 9: Unified Theory of Acceptance and Use of Technology Model

In terms of UTAUT, the two dominant beliefs in TAM are similar to performance expectancy(PE) and effort expectancy(EE). The other constructs are social influence, which directly affect behavioural intention, and facilitating conditions, which changes use behaviour.

In the ART Acceptance Framework we propose, social influence was omitted, as it is not an immediate determinant of behavioural intention to use AR technology. Age and gender are also eliminated for simplicity, as we expect most of the participants to be students at the university. The other two variables, experience and voluntariness of use, suggested by UTAUT are also removed because we only examine the use of AR only in voluntary conditions and no one has prior experience that will moderate user behaviour. Since the goal of this study is to measure users' behavioural intention to use mobile AR, the use behaviour in UTAUT and use in the D&M model are also deleted. According to TAM, effort expectancy, a significant construct in UTAUT, is convenient for illustrating use behaviour at the first stage, whereas it is not functional when used to explain behavioural intention at the last stage [17]. Since the concentration of this study is to examine behavioural intention to use AR system, effort expectancy was not considered in the model.

2.2 IS Success Model

D&M model suggested a model for measuring IS success [18], [19]. After an overall survey of the pertinent literature regarding IS success measures, D&M reported that IS success can be measured using a multidimensional model that embraces six different success groups: system quality, information quality, use, user satisfaction, individual impact, and organisational impact (see Fig.10).

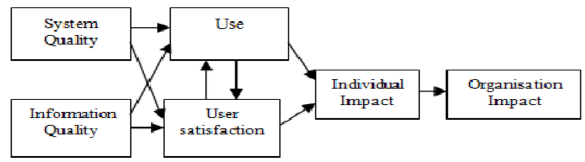

Figure 10: IS Success Factors

Success measures differ from one IS to another [21]. Stockdale and Borovicka report that success measures are affected by the type of system being examined. Thus, it is critical to link the context of the IS to the appropriate success measures[21]. In this study, information quality, system quality and user satisfaction are adopted from DeLone and McLean [18]. Ahn reviewed users who used online retailing systems to examine the extended TAM model and showed empirically that system quality and information quality were positively associated with Performance Expectancy (PE)[22].

2.3 Motivation Theory

This study focuses on both hedonic and utilitarian features of AR using the Motivation Theory proposed by Deci in [23], which supposes that user acceptance of an AR app can be explained by extrinsic and intrinsic motivations. In term of AR usage, the extrinsic motivation is concerned with utilitarian goal of AR usage such as expecting rewards or benefits [23], [24], whereas the intrinsic motivation is concerned with the hedonic goal of AR usage such as expecting pleasure or satisfaction from the interaction with the system itself [16]. Performance Expectancy(PE) is associated with extrinsic motivation, while Perceived Enjoyment (PENJ) associated with intrinsic motivation [25]. These two beliefs are principal constructs in UTAUT to predict behavioural intention [14], [17]. Thus, in this study, we investigate both extrinsic and intrinsic motivation influencing the behavioural intention to use AR technology.

III. RESEARCH MODEL AND HYPOTHESIS

This study proposes a research model in Fig. 11 (The ART Acceptance Framework) that originates from the combination of IS success factors, motivation theory, and the UTAUT model. The ART Acceptance Framework suggests system quality(SQ), information quality(IQ), visual quality(VQ) and facilitating condition(FC) as predictors of performance expectancy(PE) and perceived enjoyment(PENJ). The ART Acceptance Framework also suggests that performance expectancy and perceived enjoyment are predictors of satisfaction(SAT) towards AR. Finally, users' satisfaction is a predictor of behavioural intention (BI) to use AR apps. System quality, information quality, visual quality and facilitating condition are independent variables whereas performance expectancy, perceived enjoyment, satisfaction and the behavioural intention to reuse AR are dependent variables.

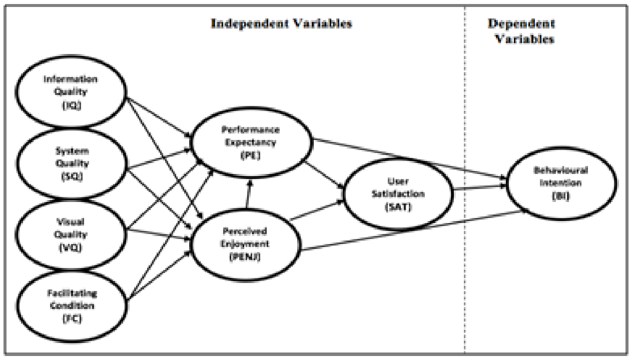

Figure 11: The ART Acceptance Framework

3.1 The relationship between External variables and UTAUT constructs

3.1.1 Success Measures and AR

According to DeLone and McLean, information quality is the quality of the output of an IS [18]. It considers whether the IS provides all relevant information. Information quality is gauged by the style and information presentation. Another success measure in the D&M model, system quality, gauges the functionality and performance of the IS. There are many studies which state that information quality influences performance expectancy. It has been found in the literature that the D&M model validates that information quality and system quality independently influence performance expectancy. Saeed and Abdinnour-Helm proposed that information quality and system quality influences perceived usefulness in IS and that eventually affects the post-adoption usage of IS [26]. From this standpoint, virtual objects demand accurate tracking in an AR mobile application, and with a high level of information quality, either student or visitor will realize that it is helpful. Therefore, it is expected that the information quality and system quality of an AR mobile app are correlated with performance expectancy [27]. For AR mobile apps, providing adequate information is important. The apps process various types of information (e.g., location, time, view, and direction). Consequently, users expect AR mobile apps to provide precise, timely, and trustworthy information [28].If users are provided with the high-quality comprehensive information, user may feel that the AR app experience is enjoyable. Thus, information quality and system quality have significant positive effects on perceived enjoyment. Based on prior literature, various hypotheses are formulated:

H1: IQ would positively affect PE about AR systems.
H2: SQ would positively affect PE about AR systems.
H3. IQ would positively affect PENJ.
H4. SQ would positively affect PENJ.

3.1.2 Visual Quality and AR

Perceived visual quality is an external factor defined in prior research as the degree to which a user considers that the app is aesthetically attractive to the eye. Because the AR is a visualisation technique that combines multimedia information with the real view, visual quality is likely to influence the use of AR. Initial effect originated from the visual quality can encourage users to judge the usefulness or enjoyment of the app [29]. Previous research stated that AR systems enhance the user's view of the real world and users' familiarity with AR apps influence performance expectancy and effort expectancy in AR apps [1].Aesthetics of AR has an effect on motivating positive beliefs such as PE and PENJ [30]. Therefore, we postulated that visual quality of AR affects students' and visitors' beliefs on AR apps. Thus, the following hypotheses are proposed:

H5. VQ would positively affect AR PE.
H6. VQ would positively affect AR PENJ.

3.1.3 The Facilitating conditions and AR

Facilitating conditions have been taken into consideration as crucial factors in using new technology in various studies [31]. This study defines facilitating conditions as the degree to which a person believes that the use of AR is supported by an organisational and technical infrastructure. Particularly, because AR is a cutting-edge technology [32], facilitating conditions are required, such as whether students and visitors have devices to use the AR apps, whether students and visitors have knowledge about the availability of AR apps, and whether an assistant is available to help them with using the AR apps. When these environmental conditions are satisfied, students and visitors more readily use AR at the universities. Some prior studies also have found that facilitating conditions are positively related to PE and PENJ [33]. Hence, this study proposes the following hypotheses:

H7. FC would positively affect AR PE.
H8. FC would positively affect AR PENJ.

3.2 The relationship between main mediators and behavioural intention

3.2.1 Performance expectancy

Since system quality can be interpreted as effort expectancy, effort expectancy is removed from the proposed model in[34]. In contrast, performance expectancy, defined as the extent to which a person believes that using the system will either improve his or her job performance [15] or help users earn future advantages from performing the task. Performance expectancy could be the main determinant factor in both the IS success model and the revised UTAUT model because performance expectancy is considered to be appropriate to both models [24]. In this study, performance expectancy is a direct determinant of a user's behavioural intention to use an IS, thus it can be validated. Therefore, performance expectancy is a mediating variable within proposed framework. A large number of researchers concluded that there is also a direct relationship between performance expectancy and the behavioural intention to use AR [30].Therefore, the following hypotheses are constructed:

H9: PE would positively affect BI about AR systems.

H10: PE would positively affect users' SAT with AR App.

3.2.2 Perceived Enjoyment

As identified above, only a small number of studies have focused on AR acceptance and those did incorporate perceived enjoyment as a strong variable in their AR acceptance models[35]. However, some researchers indicate that perceived enjoyment influences performance expectancy (PE). In [36], the authors suggested that if the users of an education system feel that the system is enjoyable, that feeling is connected to the feeling that the system is useful. Therefore, their study concluded that the perceived enjoyment of an education system has a significant influence on the PE of the education system. This study focuses on the student and visitor perspective to predict that a users' intrinsic motivation toward their AR smartphone app can influence extrinsic motivation and visitors' and students' satisfaction. It follows that:

H11. PENJ would positively affect PE.

H12. PENJ would positively affect users' SAT.

H13. PENJ would positively affect BI to use AR.

3.2.3 Satisfaction

User satisfaction are connected to students' and visitors' perception, and a Student's and visitor's pleasure is linked to their post-usage intention [37]. In prior research, McDougall and Levesque in [37] suggested that perceived value of a system is the most significant factor affecting user satisfaction in the service industry. Applying these findings to an AR mobile app, we conclude that:

H14. Users' SAT would positively affect BI to use AR.

3.3 Influencing Factors of Behavioural Intention to Use AR

The behavioural intention is a behaviour that has been considered in various AR studies (e.g.,[15], [33]). Based on previous studies, it was empirically shown that PE and user satisfaction are powerful predictors of a user's behavioural intention [38]. Perceived enjoyment is also an antecedent of behavioural intention. Based on motivation theory, Thong et al. found that PE, PENJ, and satisfaction are the key determinants of a user's behavioural intention to use AR [38].

IV. METHOD

4.1 Participants and data collection procedure

In this study, the population of interest comprised all students at MQ and all visitors to the campus. Clearly, it was not possible to determine the total number of such individuals. Hence, a web-based survey was used to reach as many participants as possible. The advantages of web-based surveys include their low cost, fast collection times, wide invitational scope, ease of follow up and ease of analysis [39].

Students and visitors at MQ were randomly approached during orientation week and in the following week in the first term of 2017 and especially first year students were invited to participate in the survey, due to direct benefit. Those who agreed (N-196) provided their email contact details. An invitation letter was sent via email describing the purpose of the research and explaining the use of the iMAP-CampUS app. The email also asked recipients to forward the invitation letter to friends who were studying, or planning to study, at MQ (a technique known as snowball sampling). The invitation letter contained a link and QR code for completing the survey. It also contained a YouTube video link to familiarise participants with the app before completing the survey. The online questionnaire was accessible from 22 March to 5 April 2017. One reminder email was sent on 28 March 2017.

4.2 Instrument and measures

Our questionnaire contained 40 questions designed to evaluate the eight constructs of the proposed model (information quality, system quality, visual quality, facilitating condition, performance expectancy, perceived enjoyment, satisfaction and behavioural intention). These items were derived from previously published measures and were adapted to our research setting. The introductory section has 6 questions that collected demographic data. The second section collected data on the eight constructs of our technology acceptance model (34 measurements in total).

The online questionnaire was built and managed in Qualtrics (www.qualtrics.com). The data were collected through the online platform of Qualtrics.

The items in the online questionnaire were kept simple and easy to follow to encourage completion. The responses were constructed on a 7-point Likert scale from "strongly disagree" (1) to "strongly agree" (7). All of the questionnaire items were close-ended to facilitate analysis.

The proposed model constructs were operationalised using validated items from previous related research. Some changes in wording were made to reflect the purpose of the study.

Information quality (IQ)

IQ1: Using iMAP-CampUS application is beneficial.

IQ2: The iMAP-CampUS application provides precise information that the user needs.

IQ3: Information that is provided by the iMAP-CampUS application is clear and understandable.

System quality (SQ)

SQ1: The iMAP-CampUS application is easy to use.

SQ2: The interaction with the iMAP-CampUS application does not require much effort.

SQ3: I find it easy to access the desired information through the iMAP-CampUS application.

SQ4: The iMAP-CampUS application for AR is fast.
SQ5: The iMAP-CampUS application for AR is easy to navigate.

Visual Quality (VQ)

VQ1: The iMAP-CampUS application is in harmony with the environment at Macquarie University.
VQ2: The iMAP-CampUS application is quite attractive.
VQ3: The iMAP-CampUS application is visually quite appealing.
VQ4: The iMAP-CampUS application provided a way for users to easily experience it.

Facilitating Conditions (FC)

FC1: I have the necessary resources to use iMAP-CampUS application.
FC2: I have the necessary knowledge to use iMAP-CampUS application.
FC3: I can use the iMAP-CampUS application with my current smartphone.
FC4: An assistant is available for help with using the iMAP-CampUS application.

Performance Expectancy (PE)

PE1: The iMAP-CampUS application makes the tour at the Macquarie University useful.
PE2: Using iMAP-CampUSapplication helps me to know the surrounding places.
PE3: Using iMAP-CampUSapplication guides me in case of getting lost.
PE4: Using the iMAP-CampUS application enables me to get desired building quickly.
PE5: Using the iMAP-CampUS application makes it easier for me to choose which building I will visit.

Perceived Enjoyment (PENJ)

PENJ1: Using iMAP-CampUSapplication is interesting.
PENJ2: Using iMAP-CampUSapplication makes me feel enjoyable.
PENJ3: Using iMAP-CampUS application is a good way to spend my leisure time.
PENJ4: Using iMAP-CampUSapplication involves me in the enjoyable process.

Satisfaction (SAT)

SAT1: I am satisfied with using the iMAP-CampUSapp.
SAT2: I am satisfied with using the iMAP-CampUSappfunctions.
SAT3: I am satisfied with the contents of the iMAP-CampUSapp.
SAT4: The iMAP-CampUSapplication fulfills my demand.

Behavioural intention to use iMAP-CampUS app (BI)

BI1: I use (intend to use) the iMAP-CampUSapplicationfrequently.
BI2: I use (intend to use) the iMAP-CampUSapplicationwhenever appropriate.
BI3: I would recommend the iMAP-CampUSapplicationto others .
BI4: I would say positive things about the iMAP-CampUSapp.
BI5: I will visit the Macquarie University again after experiencing the iMAP-CampUSapp.

V. RESULTS: DATA ANALYSIS

Two software tools were employed in data analysis. First, the survey data were recorded by Qualtrics and imported to SPSS. SPSS software is readily available and can be used to generate descriptive statistics and support the process of data analysis. Various analyses were performed using SPSS. Descriptive statistics were used to analyse each variable separately and to summarise the demographic characteristics of participants. Second, partial least squares (PLS) regression was used for structural equation modeling (SEM).

Before any analyses were conducted, data normality for each measured item was tested for skewness. The skewness values for the eight constructs were between -3 and +3. This indicated that that the eight items were almost normally distributed, so further calculations were performed, as elaborated below.

5.1 Characteristics of Participants

We received far fewer responses than we had expected. Although the questionnaire link was sent to 196 respondents to the invitation letter, and they were asked to pass it on to their friends, only 125 questionnaires were received. After filtering, 39 of these were found to be incomplete. The actual completion (response) rate could not be calculated since we did not know how many people received the invitation letter.

Gender. There was a fairly equal distribution of males (57%) and females (43%).

Age. The largest group of respondents (34%) was aged 26-30, followed by those aged 22--25 (24%), 31- 35 (17%), 18-21 (12%) and 36- 40 (8%). Only 5% of participants belonged to the 41+ category.

Nationality. Only two options for nationality were available - Australian and non-Australian. The majority (70%) reported that they were non-Australian.

Education. Most respondents were highly educated; 62% were undergraduate university students; 17% were postgraduate students; 16% were enrolled in a 2-year college degree; and 5% were high school students.

Occupation. Four options were available: Student, Employed, Unemployed and Retired. The largest category of respondents was students (86%); 12% of participants were employed, and only 1% was unemployed or retired.

Experience with AR app. More than two-thirds (81%) of respondents had previously used an AR app; 19% were first time users.

5.2 Model validation

This section describes the assessment and testing of the proposed model using SEM. Because PLS does not provide goodness-of-fit criteria, the procedure for testing PLS was performed in two stages: assessing the reliability and validity of the measurement model; and testing the hypotheses in the structural model.

5.2.1 Measurement Model

5.2.1.1 Reliability analysis

The measurement model is evaluated by estimating the internal consistency reliability. The internal consistency reliability is assessed using the values for Cronbach's alpha, composite reliability and average variance extracted (AVE) [40].

Cronbach's alpha is a measure of internal consistency that measures the correlation between items in a scale. The Cronbach's alpha for each construct had to be greater than 0.7 [41] .

Composite reliability is similar to Cronbach's alpha. It measures the actual factor loadings rather than assuming that each item is equally weighted. The standardised path loading of each item should be statistically significant. In addition, the loadings should, ideally, be at least greater than 0.7.

AVE indicates the amount of variance in a measure that is due to the hypothesised underlying latent variable. The average variance extracted (AVE) for each construct has to exceed 0.5. Values greater than 0.50 are considered satisfactory. They indicate that at least 50% of the variance in the answers to the items is due to the hypothesised underlying latent variable.

All eight scales reached a composite reliability value of at least 0.71(ranging from 0.711 to 0.897). Thus, they exceeded the 0.70 threshold for composite reliability. In addition, the scales exhibited high internal consistency; the lowest Cronbach's alpha was 0.81, which is well above the 0.70 threshold for confirmatory research. The AVE for each construct was greater than 0.5 (ranging from 0.628 to 0.758) as shown in Tables 1 .Therefore, the internal consistency reliability for the constructs was confirmed [42].

Table1: Construct Reliability and Validity

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
BI	0.881	0.913	0.678
FC	0.817	0.879	0.646
IQ	0.840	0.904	0.758
PE	0.850	0.894	0.628
PENJ	0.821	0.882	0.652
SAT	0.863	0.907	0.710
SQ	0.861	0.900	0.645
VQ	0.865	0.908	0.711

5.2.1.2 Validity analysis

Construct validity consists of convergent validity and discriminate validity.

Convergent validity is achieved when each measurement item correlates strongly with its proposed theoretical construct. It is checked by testing the factor loadings of the outer model. The outer model loadings for all items are all above 0.50. Therefore, convergent validity was established [43].

Discriminant *validity* is achieved when each measurement item correlates weakly with all other proposed constructs than the one to which it is theoretically associated. The discriminant validity of the measurement model is tested using two criteria suggested by Gefen and Straub [44]: (1) item loading to construct correlations is larger than its loading on any other constructs ; and (2) the square root of the AVE for each latent construct should be greater than the correlations between that construct and other constructs in the model . The lowest acceptable value is 0.50. As shown in Tables 2 and 3, all items showed substantially higher loading than other factors, and the square root of the AVE for each construct exceeded the correlations between that construct and the other constructs. Therefore, discriminant validity was established [43].

Table 2: Discriminant Validity

	BI	FC	IQ	PE	PENJ	SAT	SQ	VQ
BI	**0.823**							
FC	0.720	**0.803**						
IQ	0.695	0.686	**0.870**					
PE	0.754	0.776	0.745	**0.793**				
PENJ	0.754	0.797	0.664	0.792	**0.808**			
SAT	0.791	0.720	0.691	0.784	0.795	**0.843**		
SQ	0.741	0.730	0.781	0.751	0.738	0.704	**0.803**	
VQ	0.733	0.700	0.698	0.614	0.684	0.668	0.739	**0.843**

Table 3: Cross Loading

	BI	FC	IQ	PE	PENJ	SAT	SQ	VQ
BI_1	0.863	0.643	0.604	0.693	0.746	0.730	0.638	0.665
BI_2	0.745	0.526	0.462	0.464	0.437	0.494	0.532	0.584
BI_3	0.816	0.585	0.571	0.578	0.616	0.660	0.580	0.576
BI_4	0.829	0.660	0.629	0.707	0.645	0.689	0.673	0.615
BI_5	0.859	0.534	0.572	0.622	0.608	0.645	0.614	0.577
FC_1	0.406	0.740	0.455	0.483	0.556	0.383	0.453	0.464
FC_2	0.6	0.7	0.5	0.5	0.53	0.5	0.5	0.5

	50	76	23	71	3	79	86	88
FC_3	0.630	0.858	0.607	0.727	0.725	0.618	0.644	0.605
FC_4	0.610	0.835	0.600	0.677	0.713	0.697	0.642	0.584
IQ_1	0.572	0.604	0.864	0.633	0.571	0.614	0.630	0.540
IQ_2	0.623	0.589	0.855	0.640	0.576	0.603	0.715	0.655
IQ_3	0.618	0.599	0.892	0.671	0.587	0.587	0.693	0.626
PENJ_1	0.588	0.603	0.602	0.664	0.825	0.621	0.597	0.541
PENJ_2	0.543	0.691	0.556	0.632	0.763	0.589	0.607	0.543
PENJ_3	0.658	0.663	0.484	0.668	0.860	0.737	0.600	0.555
PENJ_4	0.642	0.617	0.510	0.592	0.779	0.612	0.580	0.570
PE_1	0.694	0.754	0.664	0.896	0.718	0.714	0.656	0.556
PE_2	0.506	0.538	0.478	0.726	0.527	0.551	0.464	0.313
PE_3	0.536	0.481	0.536	0.713	0.520	0.528	0.625	0.433
PE_4	0.581	0.536	0.599	0.773	0.594	0.609	0.586	0.475
PE_5	0.650	0.723	0.655	0.840	0.745	0.682	0.636	0.619
SAT_1	0.674	0.574	0.570	0.668	0.648	0.840	0.566	0.573
SAT_2	0.679	0.612	0.568	0.636	0.704	0.897	0.627	0.547
SAT_3	0.621	0.568	0.493	0.639	0.641	0.801	0.547	0.557
SAT_4	0.689	0.667	0.689	0.696	0.682	0.831	0.629	0.573
SQ_1	0.523	0.516	0.659	0.576	0.486	0.463	0.711	0.550
SQ_2	0.557	0.577	0.699	0.654	0.582	0.623	0.808	0.558
SQ_3	0.598	0.647	0.599	0.623	0.593	0.571	0.838	0.520
SQ_4	0.634	0.574	0.578	0.567	0.661	0.585	0.816	0.646
SQ_5	0.658	0.613	0.606	0.593	0.629	0.574	0.835	0.690
VQ_1	0.607	0.588	0.619	0.525	0.592	0.507	0.727	0.839
VQ_2	0.597	0.519	0.554	0.473	0.539	0.511	0.624	0.862
VQ_3	0.583	0.571	0.532	0.494	0.524	0.532	0.558	0.830
VQ_4	0.6	0.6	0.6	0.5	0.63	0.6	0.5	0.8
	75	68	37	70	7	84	81	42

5.2.2 Structural Model

This study presents 14 hypotheses that were used to examine the relationships between the latent variables. The structural model was assessed by evaluating the following criteria:

Path coefficients. Path coefficients are explained with the t-statistics computed using bootstrapping 200 samples. The tests point to positive or negative relationships between exogenous constructs and endogenous variables and the strength of these relationships. Path coefficients should be directionally consistent with the hypothesis.

Coefficient of determination as R^2 values. R^2 provides the amount of variance of dependent variables explained by the independent variables. In our analysis, the R^2 coefficient of determination indicates the predictive power of the model for each dependent construct. According to [45], an R^2 value of 0.67 in the PLS path model is considered substantial. Therefore, our model has the ability to explain the endogenous constructs.

Our research model in Fig. 12 is able to explain 74.8% of the variance in PE towards using iMAP_CampUS, 69.3% of the variance in PENJ, 69.5% of the variance in SAT and around 68.7% of the variance in BI.

According to the path coefficients and t-test values presented in Figure 12, we found adequate evidence for each hypothesis. The path coefficient (t statistics) values for n = 200 (sub-samples from bootstrapping), p<0.05, p<0.01, and p<0.1.

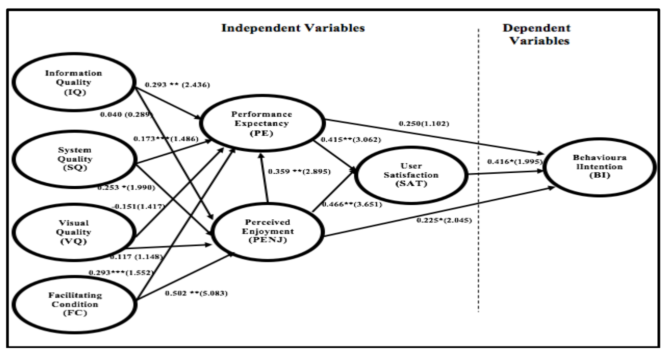

Figure 12: PLS results for the proposed model

The SEM results revealed that most of the proposed external variables (exogenous variables), except visual quality (SQ, SQ and FC), have significant effect on endogenous variables (PE and PENJ, SAT and BI) regarding the user intention to use iMAP-CampUS. Out of the proposed 14 hypotheses, 10 were supported. Thus, four paths were not statistically significant as shown in Tables 4.

Table 4 shows a summary of the hypothesis testing results. Assessment of the structural model estimates results suggested that 10 out of 14 hypothesised paths were significant. As discussed above, the t values for both H2, H5, H6 and H9 did not exceed the cut-off point required for statistical significance. Thus, these paths were not statistically significant.

Table 4: hypotheses testing including T-statistics and P values

Hypothesis	**Relationship**	**T Statistics**	**P Values**	**Support**
H1	**IQ -> PE**	2.436	0.015	**Yes**
H2	**IQ -> PENJ**	0.289	0.773	**No**
H3	**SQ -> PE**	1.486	0.138	**Yes**
H4	**SQ -> PENJ**	1.990	0.047	**Yes**
H5	**VQ -> PE**	1.417	0.157	**No**
H6	**VQ -> PENJ**	1.148	0.251	**No**
H7	**FC -> PE**	1.552	0.121	**Yes**
H8	**FC -> PENJ**	5.083	0.000	**Yes**
H9	**PE -> BI**	1.102	0.271	**No**
H10	**PE -> SAT**	3.062	0.002	**Yes**
H11	**PENJ -> PE**	2.895	0.004	**Yes**
H12	**PENJ -> SAT**	3.651	0.000	**Yes**
H13	**PENJ -> BI**	2.045	0.041	**Yes**
H14	**SAT -> BI**	1.995	0.047	**Yes**

5.3 Modifying the structural model by removing non-significant paths

The results suggested that after removing four non-significant paths of hypotheses H2, H5, H6 and H9, the best parsimonious model can be achieved. The model was revised in order to achieve a prudent model that fits the data well; not only this, but the revised model is now consistent with the observed data. The revised structural model is shown in Fig. 13.

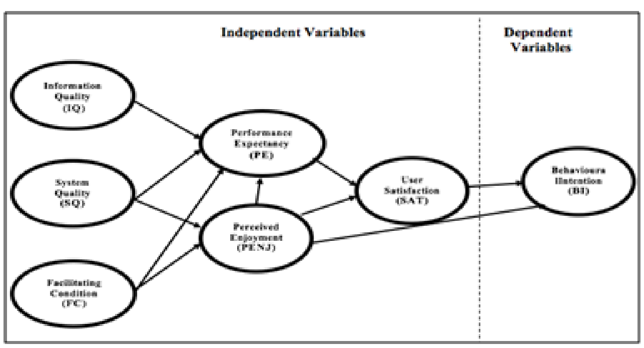

Figure 13: The revised mobile AR user acceptance model

VI. DISCUSSION

The current research combined well-known theories that have been employed in similar studies. The research framework used constructs from UTAUT, IS Success Factors, Modified IS Success Factors, Motivation Theory and other relevant literature. The overall results were consistent with findings from similar studies and showed strong and positive relationships between the various study constructs and students' behavioural intention to use iMAP-CampUS app.

The findings suggest that most of the previously mentioned variables can positively influence students' and visitors' behavioural intention to use iMap-CampUS app. Students' and visitors' behavioural intention to use iMAP-CampUS app is highly impacted by the perception of its performance expectancy, perceived enjoyment and students' and visitors' satisfaction either directly or indirectly. Information quality, system quality and facilitating conditions are also important external factors that enhance students' and visitors' behavioural intention by increasing performance expectancy, perceived enjoyment and satisfaction in relation to iMap-CampUS app. In contrast, the results showed that visual quality is less likely to influence students and visitors toward a positive behavioural intention.

The structural model shows that ten out of the 14 hypotheses were supported. The t-statistics for the paths shown in Figure 12 showed strong support for H1. This study supports the finding that information quality has a relatively strong influence on performance expectancy. This is consistent with the findings of previous research [7, 26]. According to Saeed and Abdinnour-Helm, the level of information quality directly affects the performance expectancy of an IS and is a significant antecedent of performance expectancy.

As shown in Figure 12, the results showed that system quality (SQ) had a significant positive effect on performance expectancy (PE) of iMAP-CampUS app. This indicates that students and visitors place emphasis on quality issues including functions, content, navigation speed and interaction capability of the app. Also, H 4 is supported since system quality positively influenced perceived enjoyment of iMAP-CampUS app. The findings support previous research by confirming the effects of system quality on perceived enjoyment and the behavioural intention to use the app [27]. System quality was found to be the second major determinant of perceived enjoyment in our proposed model.

This study revealed a positive effect of facilitating conditions (FC) on performance expectancy toward using iMAP-CampUS (H7). These include adequate guidance on the use of the app and availability of immediate assistance. However, our current finding contradicts the results of Panda and Mishra , which indicated that inadequate FC was one of the most important barriers to new technology usage by users [46]. Facilitating conditions were a significant determinant of the performance expectancy of iMAP-CampUS app. Additionally, the path coefficient and t-statistics for FC to PENJ showed that this was a major determinant of the perceived enjoyment of iMAP-CampUS app. Thus, the results showed strong support for H8. Our findings partially support Teo and Timothy in [47] stating that facilitating conditions had positive effects on hedonic factors.

As shown in Figure 12, performance expectancy was a strong predictor (p = 0.4 and t = 3.1) of students' satisfaction with AR systems (H10). This result is consistent with the findings of earlier studies which reported that performance expectancy is a strong predictor of user satisfaction [48].

The study results also showed strong support for H11, H12 and H13 which was suggested in the framework explained in section V. The results indicate that perceived enjoyment influences students' and visitors' performance expectancy, satisfaction and behavioural intention to use the iMAp-CampUS app. In previous research, perceived enjoyment was shown to be a strong predictor of PE and BI, which is consistent with our results [48].

More importantly, the relationship between perceived enjoyment and behavioural intention to use the app is stronger than the relationship between students' and visitors' satisfaction and behavioural intention. In other words, a focus on perceived enjoyment is required to improve the behavioural intention to use AR systems.

This study supports the finding that students' and visitors' satisfaction has a relatively strong influence on behavioural intention to use AR systems (H14). This is consistent with the findings of previous research. According to [48], students' and visitors' satisfaction directly affects the behavioural intention of an IS. students' and visitors' satisfaction was found to be a significant determinant of the behavioural intention to use iMAP-CampUS app.

Finally, H2, H5, H6 and H9 were rejected due to:

- Information quality had no significant effect on perceived enjoyment of iMAP-CampUS app.
- Visual quality had only a weak effect on performance expectancy and Perceived enjoyment than information quality and system quality.
- Performance expectancy did not have a strong positive influence on students' and visitors' behavioural intention to use the app.

VII. LIMITATIONS

Several limitations of this research should be noted. First, the study employed a cross-sectional research design. Longitudinal data will enhance our understanding of what constructs affect individuals' behavioural intention to use the iMAP-CampUS app. Only quantitative data were collected. Qualitative data generated from interviews or focus groups could yield insight into other factors that affect users' satisfaction and behavioural intentions.

Second, interpretation of the results was limited by the small sample size (86) and low completion rate. A larger sample would have improved the ability to generalise the findings to a wider population. It should be noted, however, that the use of SmartPLS as a data analysis tool overcomes this limitation since it can generalise results with a very small sample size. Third, the study was conducted in one university (MQ) so the results may not be applicable to all Australian universities, even if the education system and culture are the same.

Fourth, this study examined a marker-less AR application in a controlled outdoor environment (MQ) based on GPS-enabled technology. Similar research should be conducted in an indoor environment to confirm the result. Fifth, the study participants were students and visitors aged 18 years and over. Future research should include children. Finally, not all factors related to the higher education institution were taken into consideration. AR usage in such institutions will be better understood if other factors, such as cultural motivation and visitor knowledge, are taken into account.

VIII. CONCLUSION

In this paper, we presented a mobile AR app named iMAP-CampUS, developed using the AR platform, Layar. It requests data about surrounding buildings using a database provided by Macquarie University Property Office as well as Google maps. The application aims at facilitating the free-flow navigation of surrounding buildings to help students determine nearby POIs. The paper proposes an ART Acceptance framework to gauge user's behavioural intention to use mobile AR apps and to review the factors influencing the acceptance of AR technology. This framework integrates the Unified Theory of Acceptance and Use of Technology(UTAUT), IS-Success model (D&M) and Motivation Theory. The constructs adapted from UTAUT are performance expectancy and facilitating condition. The constructs adapted from D&M model are information quality, system quality, and user satisfaction. The construct adapted from motivation theory is perceived enjoyment. An additional construct, visual quality,is also added to the constructs. The results indicate that ten research hypotheses have been significantly supported, while four have been rejected. The findings state that perceived enjoyment and user's satisfaction are important determinants for the use of iMap-CampUS. However, performance expectancy has not demonstrated any significant impacts on behavioural intention to use the app.

Future research should examine the validity of the proposed model in different cultural settings. Second, as mentioned above, the desirability of collecting both longitudinal and qualitative data is indicated. Third, actual usage of the iMAP-CampUS app could be added as another dependent variable to measure user acceptance. It would also be useful to explore the role of other constructs, such as users' characteristics, experience, complexity of and familiarity with the app, and to add to the original constructs found in the models that informed this research. Finally, other statistical tests such as multiple regressions could be conducted to affirm the constructs' validity.

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