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Behavioural intentions of using virtual reality in learning: perspectives of acceptance of information technology and learning style

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Abstract

The use of virtual reality (VR) has become a viable alternative to conventional learning methods in various knowledge domains. Wearable head-mounted displays (HMDs) are devices that provide users with an immersive VR experience. To investigate the direct determinants affecting students' reasons for HMD use in learning, hypotheses relating to information technology acceptance and Kolb's learning styles were proposed and tested in this study. Participants were recruited through stratified random sampling according to the population ratio of colleges at a university in Taiwan. Students were shown a video on VR applications in learning, after which an online survey was completed. In total, 387 questionnaires were collected of which 376 were valid. An inference analysis of the samples was performed by structural equation modelling with eight exogenous latent variables, namely the four constructs of the unified theory of acceptance and use of technology (UTAUT) and the four modes of Kolb's learning styles. All eight variables pointed to one endogenous latent variable: behavioural intention. The results showed all four constructs of the UTAUT to have a positive and significant effect on students' behavioural intention to use HMDs in learning and only the concrete experience mode of Kolb's learning styles to have a positive and significant effect. Based on these findings, this study provides suggestions on how to encourage HMDs use in learning to VR developers and educational institutions.

Keywords Virtual reality · UTAUT · Learning styles · Behavioural intentions

1 Introduction

The term virtual reality (VR) refers to a simulated interactive environment created by a three-dimensional (3D) computer-generated graphics system in combination with various interference devices. Such an environment offers an immersive experience, which users can explore and interact with. Having the ability to transform abstract concepts into concrete visualisations, 3D simulation environments can enhance users' sensory understanding of otherwise unobservable objects (Jonassen 2000) and circumstances (Shaw 2012). Breakthrough technologies and innovations have shaped the development of VR in different applications (Ali and Nasser 2017). Wearable head-mounted displays (HMDs), which provide an immediate and vivid user experience, are one of the major trends in VR and are expected to achieve a five-year compound annual growth rate (CAGR) of 48.7% from 2016 to 2021 (IDC 2017). In education applications, trainers can use the simulated content provided by VR to enable students to engage in learning processes (Hanson and Shelton 2008). Because of the ability of VR to captivate users and fully engage them in the virtual environment, educators are often eager to utilise VR technology in teaching and learning activities (Hanson and Shelton 2008). Indeed, studies have shown that the use of 3D VR systems in education is the most suitable alternative to conventional text- and web-based systems (Hauptman and Cohen 2011; Shih and Yang 2008). For example, in one study second-year design students utilised a full HMD-based VR environment to introduce modification during the process of design and the conclusion was that the real-time feedback of VR immersive environments may enhance students' comprehension of architectural spatial design (Antonieta 2014).

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Moreover, the utilisation of VR in education provides a safe training environment because it obviates the physical dangers of real-life training situations while widening the range of learning and increasing students' engagement and motivation. Pelargos et al. (2017) consider VR technology to be an extremely valuable tool in neurosurgical rehearsal and resident education, because of the complex and sophisticated nature of operations. The intrinsic properties of VR and the representation system enables it to play a critical role in the training and learning process, creatively conveying information, engaging the senses and inspiring innovative ideas (Salvadori et al. 2016). VR technology has presented a viable and robust alternative to traditional monolithic solution to learning and demonstrated a wide range of applications in education (Lytras et al. 2016). Therefore, understanding students' intentions in using HMDs may improve the development of VR and enhance the user experience.

To understand people's underlying behaviour towards new technology, different theories have been proposed. The information technology (IT) acceptance and use approach has been an important theory for observing how an individual perceives and accepts IT products based on the intentionality framework. Several studies have approached IT acceptance and use from the organisational behaviour perspective (Leonard-Barton and Deschamps 1988) or the task–fitness perspective (Goodhue 1995; Goodhue and Thompson 1995), while others have focused on direct determinants such as behavioural intention and usage behaviour (Compeau and Higgins 1995; Davis 1989). Personality differences have also been proven to affect individuals' IT acceptance and use (Maruping et al. 2017; Thatcher and Perrewe 2002). However, the approach considering the relationship between individual learning styles and technology use provides a different perspective from which to investigate underlying behavioural intentions towards new technology. Kolb's study (1976) concludes that differences in individual learning styles can explain variations between individuals in an instructional process, and other studies have comprehensively investigated the relationships between learning styles and virtual learning environments (Hauptman and Cohen 2011; Jordanov 2001). To the best of our knowledge, no study has investigated the behavioural intentions of using a new technology from the perspectives of both IT acceptance and learning styles. Therefore, in this study, research hypotheses were proposed to investigate the effect of IT acceptance on students' behavioural intentions to use VR HMDs on the basis of the unified theory of acceptance and use of technology (UTAUT) proposed by Venkatesh et al. (2003) to explain intentions to use an information system. We also applied Kolb's experiential learning theory (ELT) to examine research hypotheses regarding the effect of four modes of learning styles on students' behavioural intentions to use VR HMDs. Based on the results of the hypotheses tests, this study provides suggestions on how to motivate HMDs use in learning to VR developers and educational institutions.

The following sections of this paper are organised as follows. Section 2 briefly reviews the literature in regard to existing approaches on IT acceptance and learning styles. Section 3 describes our proposed hypotheses from the perspectives of IT acceptance and Kolb's learning styles to examine their relationship to students' behavioural intentions to use VR HMDs. Section 4 describes the measurement of variables and the research method used in this study. Section 5 provides the results of hypotheses tests from the sample of students attending a university in Taiwan. Section 6 concludes the paper and offers ideas for future research.

2 Literature review

Recently, IT products have become much more affordable to organisations. This enables the adoption of computers and IT systems that can substantially increase the productivity of firms, provided that such products are accepted and used by employees. Over the past two decades, IT acceptance and use has been extensively evaluated in information system research (Hu et al. 1999). Numerous models have been proposed from the perspectives of information systems, psychology and sociology (Taylor and Todd 1995; Venkatesh 2000). To develop a unified model to evaluate the likelihood of successful IT introduction, Venkatesh et al. (2003) integrated eight key competing theoretical models from the research, comprising 32 constructs showing some similarity across the models. Four new prominent constructs (performance expectancy, effort expectancy, social influence and facilitating conditions) were generalised based on these 32 constructs and validated by an empirical study. Based on these constructs, the proposed UTAUT clarifies the dynamics and motivation which facilitate users' engagement with new technology, inspiring a new approach for exploring IT acceptance. Subsequently, Wu et al. (2007) examined the effect of user experiences of 3G mobile telecommunication services based on the determinants of UTAUT; they reported that performance expectancy, social influence and facilitating conditions significantly influenced behavioural intentions. Carlsson et al. (2006) employed the same model to explain users' acceptance of mobile devices and services. Marchewka and Kostiwa (2007) included two more constructs in the UTAUT, self-efficacy and anxiety, to explore a web-based course management software programme commonly applied in higher education. Chiu and Wang (2008) also extended the UTAUT by introducing the task value component to examine students' continuing intention to engage in web-based learning. From the interactional psychology perspective and by using the components of the

Five-Factor model of personality within the conceptual framework of the UTAUT, Barnett et al. (2015) argued that conscientiousness and neuroticism are linked to the perceived and actual use of technology. Teo and Noyes (2014) stated that the UTAUT can be used to interpret trainee teachers' intentions to use IT and their IT acceptance, and suggested that the applicability of the UTAUT is limited by different technologies, user population and culture.

Experiential learning refers to styles and approaches adopted to improve learning effectiveness. Bandura (1986) indicated that individuals tend to adopt a learning strategy that helps them achieve their goals within the constraints of their abilities. Experiential education, which emphasises direct feedback and active interaction, is one such strategy reputed to enhance a learning experience (Haller et al. 1999). Kolb's ELT integrates three crucial experiential learning models, namely Dewey's model of learning, Lewinian's model of action research and laboratory training, and Piaget's model of learning and cognitive development (Kolb 1984). Kolb's ELT is an alternative to behavioural and cognitive learning theories, positing that learning is best conceived of as a holistic process of adaptation to the world and a continuous process grounded in experience. The ELT provides a research framework that combines experience, perception, cognition and behaviour. In the ELT, knowledge is the result of grasping an experience and transforming it. Kolb describes the process of learning with four adaptive learning modes in two distinct dimensions of prehension and transformation. In the former, concrete experience and abstract conceptualisation represent two opposing processes of grasping experience, and in the latter active experimentation and reflective observation are two opposite means of transforming experience. The combination of two grasping modes and two transforming modes results in four distinct learning styles: diverging, assimilating, converging and accommodating. Kolb's ELT, being different to the Big Five personality traits perspective that is so commonly used in research, was incorporated in this study of behavioural intention to use HMDs in learning. Terrell (2002) observed that doctoral students in the field of computing technology who had the learning styles of accommodator and diverger dropped out of web-based courses in high numbers. Kolb and Kolb (2005) introduced the concept of applying learning space as a framework to investigate the interaction between students' learning styles and the institutional learning environment and suggested how to develop an educational environment that facilitates improvement in students' meta-thinking ability and self-directed learning. Using Kolb's learning style inventory (LSI), Wang et al. (2006) investigated the influence of formative assessment and learning style on students' learning accomplishments in a web-based learning environment and found that students characterised as divergers were the highest achievers, followed by assimilators, accommodators and convergers. Sun et al. (2008) reported that primary-school-age students classified as accommodator learners were the highest achievers and that those engaging in an online virtual laboratory obtained higher grades than those learning in a conventional class setting; they also found that students preferred the online virtual learning experience to textbook learning.

3 Hypotheses

Understanding the adoption and use of IT is crucial in the field of information systems. Since Ajzen and Fishbein (1975) proposed the theory of reasoned action, different IT acceptance models have been developed. These conceptual models are important contributions to research on IT acceptance and use. Among them, the UTAUT synergises various constructs from the eight key models of intention and use of IT and posits that four main constructs—performance expectancy, effort expectancy, social influence and facilitating conditions—play critical roles as the direct determinants of user acceptance and usage behaviour (Venkatesh et al. 2003).

The UTAUT was employed in this study because it is considered the most prominent and unified model in IT acceptance research; it has been rigorously empirically validated by within-subject longitudinal data from different organisations (Li and Kishore 2006). We consider the four constructs of the UTAUT to be the direct determinants of the behavioural intention to use VR HMDs in learning. Performance expectancy has been defined as the degree to which an individual believes that using a system may help him or her improve job performance (Venkatesh et al. 2003); this is likely to be affected by gender and age. Many studies have shown that performance expectancy significantly affects individuals' behavioural intentions (Al-Qeisi et al. 2014; Barnett et al. 2015; Carlsson et al. 2006; Chiu and Wang 2008; Marchewka and Kostiwa 2007; Teo and Noyes 2014), while van Schaik (2009) studied students' use of learning websites in higher education in terms of UTAUT and concluded that performance expectancy, effort expectancy and social influence were antecedents of behavioural intention. VR HMDs will be considered useful if they help students to learn quickly and/or improve their performance. Accordingly, we formulated our first hypothesis:

H_1 Performance expectancy has a significant effect on the behavioural intention to learn when VR HMDs are used.

Effort expectancy has been defined as the degree to which an individual believes that a system will be easy to use (Venkatesh et al. 2003). Many studies have shown that effort expectancy significantly affects individuals' behavioural intentions (Al-Qeisi et al. 2014; Anderson and Gerbing 1988; Barnett et al. 2015; Carlsson et al. 2006; Chiu and Wang 2008; Marchewka and Kostiwa 2007; Teo and Noyes 2014; Venkatesh et al. 2012). In particular, this has a strong effect on women and older workers (Venkatesh 2000; Venkatesh et al. 2003). This study expected that students would have a greater behavioural intention to use VR HMDs if they believed that they would not have to expend much effort in learning how these worked. Therefore, we proposed our second hypothesis:

H_2 Effort expectancy has a significant effect on the behavioural intention to learn when VR HMDs are used.

Social influence has been defined as the degree to which an individual perceives that people they regard as important believe they should use a new system (Venkatesh et al. 2003). Social influence has been shown to have a significant effect on individuals' behavioural intentions (Al-Qeisi et al. 2014; Anderson and Gerbing 1988; Barnett et al. 2015; Carlsson et al. 2006; Chiu and Wang 2008; Marchewka and Kostiwa 2007; Teo and Noyes 2014; Venkatesh et al. 2012). Women have been found to have a tendency to be affected by others' opinions; therefore, they are likely to be affected by social influence when developing an intention to use IT products (Venkatesh 2000). As indicated by the study of performance and effort expectancies, socially constructed gender roles, which may be shaped by psychological phenomena, generate the gender effect (Venkatesh et al. 2003). In our study, we expected that students would increase their intention to use VR HMDs in learning when they were encouraged by faculty members. Accordingly, we posited the third hypothesis:

H_3 Social influence has a significant effect on the behavioural intention to learn when VR HMDs are used.

Facilitating conditions have been defined as the degree to which an individual believes that organisational and technical infrastructure exists to support the use of a system (Venkatesh et al. 2003). The major concern here is the concept of supportive infrastructure, which reflects how easy it is to use a piece of technology (Venkatesh 2000). In UTAUT, facilitating conditions do not predict behavioural intention to use new technology; however, other research has shown that facilitating conditions significantly affect individuals' behavioural intentions (Cheong et al. 2004; Wu et al. 2007). In our study, we expected students' intentions to be influenced by the belief that they could have sufficient VR HMD resources and be able to get help with these quickly if they needed it. Thus, we proposed our fourth hypothesis:

H_4 Facilitating conditions have a significant effect on the behavioural intention to learn when VR HMDs are used.

In addition, understanding the adoption and use of technology from the perspective of personality traits is crucial in the field of information systems (Barnett et al. 2015). Recently, studies have focused on this subject in regard to the Big Five personality factors (AbuShanab et al. 2010; Aldás-Manzano et al. 2009; Devaraj et al. 2008; Svendsen et al. 2013). Kolb's learning styles have gained widespread acceptance and provide a foundation for understanding experiential learning (Kayes 2005; Manolis et al. 2013). They have been utilised as a framework in which to understand learning performance in different contexts. For example, Komarraju et al. (2011) examined the relationship between Big Five personality traits, learning styles and academic achievement, and Kim (2013) studied the effects of these personality traits and Kolb's learning styles on academic achievements in a blended learning environment. According to Kolb's ELT, learning is best conceived of as a process of creating knowledge and the process of experiential learning can be considered as a nonlinear cycle involving four learning modes. In this study, we wished to explore the relationship between Kolb's learning modes and the behavioural intention to use VR HMDs in learning. Therefore, we posited four hypotheses related to concrete experience, reflective observation, abstract conceptualisation and active experimentation which correspond to the four modes of Kolb's learning styles:

H_5 Concrete experience has a significant effect on behavioural intention to learn when VR HMDs are used;

H_6 Reflective observation has a significant effect on behavioural intention to learn when VR HMDs are used;

H_7 Abstract conceptualisation has a significant effect on behavioural intention to learn when VR HMDs are used;

H_8 Active experimentation has a significant effect on behavioural intention to learn when VR HMDs are used.

4 Methodology

The UTAUT and Kolb's learning styles were adopted in this study to examine the different effects on the behavioural intention to use VR HMDs to learn. Eight hypotheses were proposed, and an online questionnaire was designed to disseminate to university students. To verify our hypotheses, the results were analysed using structural equation modelling (SEM).

4.1 Measurement of variables

The definition of the four UTAUT constructs was taken from the research of Venkatesh et al. (2003). In the present study, the definition of performance expectancy was modified to the degree to which a student believed that using a VR HMD would help them to improve their academic performance. Four items regarding usefulness, productivity, effectiveness and academic performance were designed. Effort expectancy was modified to the degree to which a student believed that VR HMDs would be easy to use in learning. Four items regarding use, interaction and operations were designed. The definition of social influence was modified to the degree to which a student perceived that people they regarded as important or influential believed they should use VR HMDs in learning. Four items regarding the influence of tutors, educational authorities and other meaningful people were designed for this construct. Finally, the definition of facilitating conditions was modified to the degree to which a student believed that their college supported the use of VR HMDs. For this construct, four items regarding resources, knowledge, compatibility and assistance were designed. Behavioural intention has been defined as an individual's positive or negative feelings about performing a target behaviour (Ajzen and Fishbein 1975; Davis 1989; Fishbein and Ajzen 1975). In this study, this definition was modified to the degree to which a student would be willing to use VR HMDs in their learning in the near future. Three items were designed for behavioural intention. Four construct items pertaining to UTAUT and behavioural intention are shown in Table 1.

In addition, this study used Kolb's LSI, one of the most influential and widely applied instruments for measuring individual e-learning preference (Shaw 2012; Terrell 2002). Manolis et al. (2013) suggested that Kobe's LSI should be transformed from a categorical to a continuous measure. Accordingly, 48 items from Kolb's LSI version 3.1, incorporated with the aforementioned scoring scale, were employed in this study. Thus, a 67-item questionnaire was designed and all items in it evaluated on a 5-point Likert scale: 1, strongly disagree; 2, disagree; 3, neither agree nor disagree; 4, agree; and 5, strongly agree.

4.2 Research method

Data analysis and model validation through statistical description, reliability analysis, validity analysis and SEM were performed using SPSS and AMOS 22. The reliability of the survey results was evaluated using the Cronbach α, as is typical for responses evaluated on a Likert scale. A higher α score indicates higher internal consistency. Nunnally et al. (1967) suggested that α should be at least 0.5; $\alpha > 0.8$ is preferred in empirical studies.

To assess the validity of the measurement model, confirmatory factor analysis (CFA) was performed to test how well the items in each construct related to one another by evaluating evidence on the validity of individual item measures based on the model's overall fit and other evidence of construct validity. Moreover, both convergent validity (CV) and discriminant validity (DV) were examined to assess construct validity. The CV and DV of the constructs were evaluated by calculating the average variance extracted (AVE), composite reliability

Table 1 UTAUT and behavioural intention items

Variable	Item
Performance expectancy	PE1: I would find the VRH useful in my learning PE2: Using the VRH in my learning would increase my productivity PE3: Using the VRH in my learning would enhance my effectiveness PE4: Using the VRH in my learning would improve my academic performance
Effort expectancy	EE1: My interaction with the VRH would be clear and understandable EE2: It would be easy for me to become skilful at using the VRH EE3: I would find the VRH easy to use EE4: Learning to operate the VRH would be easy for me
Social influences	SI1: People who influences my behaviour think that I should use the VRH for learning SI2: People who are important to me think that I should use the VRH for learning SI3: In general, the college authorities have supported the use of the VRH for learning SI4: In general, my teacher is very supportive of the use of the VRH for learning
Facilitating conditions	FC1: I have the resources necessary to use the VRH FC2: I have the knowledge necessary to use the VRH FC3: The VRH is not compatible with other learning systems I use FC4: A special person (or group) is available for assistance with VRH difficulties
Behavioural intention	BI1: I intend to use the VRH for learning in the near future BI2: I predict I would use the VRH in the near future BI3: I plan to use the system in the near future

(CR) and standardised path coefficients (SPCs). To assess structural model validity, which was estimated using CFA based on the calculated SPCs and the structural relationship between the constructs, the fit of the SEM model was firstly evaluated; subsequently, whether the structural relationships were consistent with the research expectation was determined.

As shown in Fig. 1, eight exogenous latent variables ξ and one endogenous variable η were included in our SEM model. Concrete experience (CE), reflective observation

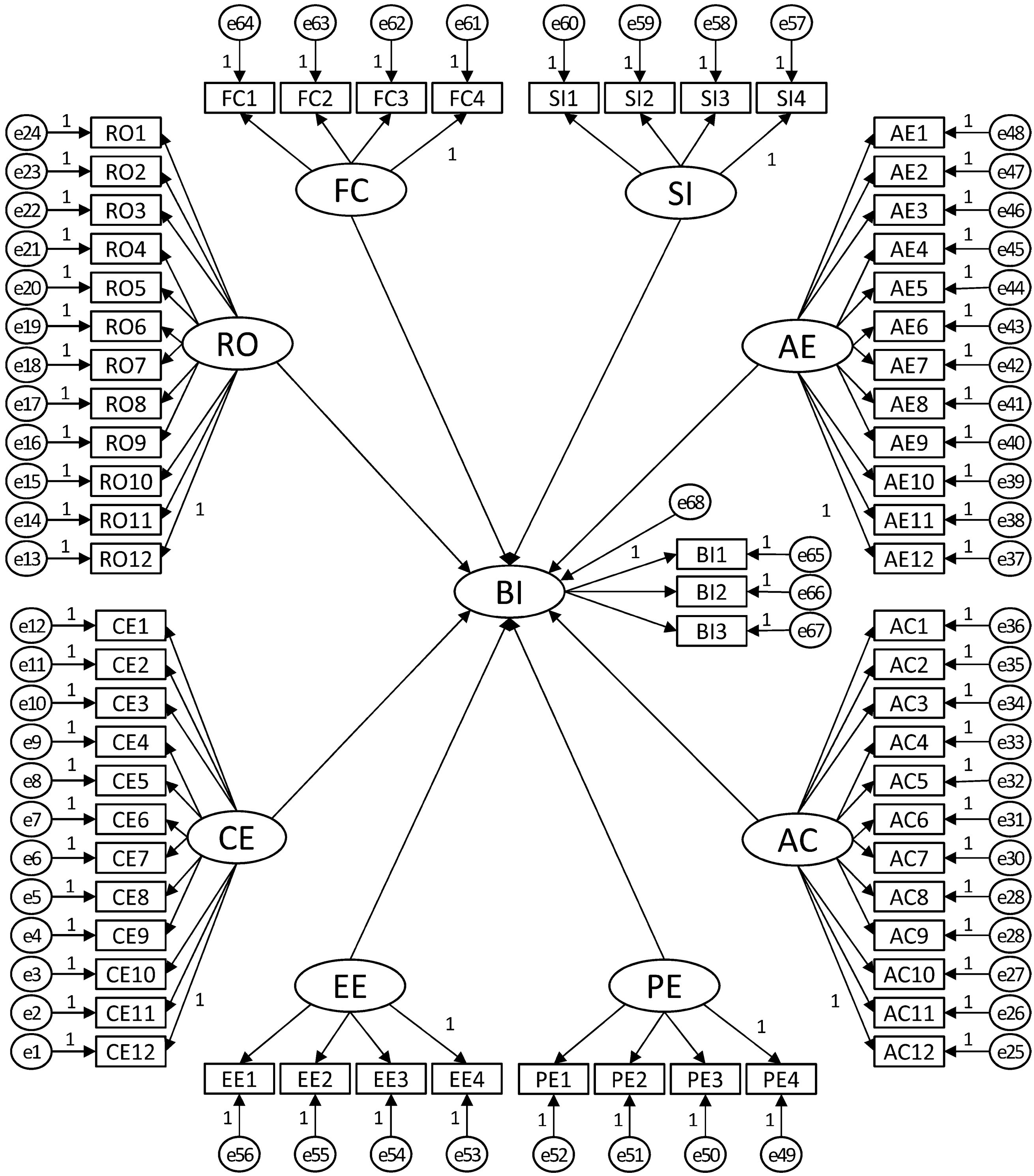

Fig. 1 Proposed structural equation model

(RO), abstract conceptualisation (AC) and active experimentation (AE), each with 12 survey items, were Kolb's learning styles constructs used. Performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC), each with four items, were the constructs used from the UTAUT. All of the exogenous latent variables (CE, RO, AC, AE, PE, EE, SI and FC) pointed to one endogenous latent variable, behavioural intention (BI), which had three items.

4.3 Data collection

The population of the study was students at National Central University in Taiwan. The participants were recruited through stratified random sampling according to the population ratio of the different colleges at the university. A descriptive statistics of the sample are shown in Table 2. Students from the College of Management and the College of Engineering accounted for over 50% of the participants. Female students accounted for 62.2%. The mean age was 22.23 with standard deviation 2.61. Most participants belonged to the 21–23 age group (40.2%), followed by the 18–20 age group (29.8%) and the ≥ 24 age group (30.0%). Regarding educational background, 54.8% were undergraduate students and 45.2% were graduate students. In total, 387 questionnaires were collected, of which 376 were valid. Before taking an online survey, the participants were asked to watch a two-minute video. The online video showed the devices needed to enable a VR environment, as well as students in a classroom setting using HMDs to learn about the human skeleton and organs. The participants, who watched the video, were able to watch the VR contents through computer screens in the video.

Table 2 Descriptive statistics of the sample

Variable	Value	Frequency	%
Gender	Male	142	37.8
	Female	234	62.2
Age	18–20	112	29.8
	21–23	151	40.2
	≥ 24	113	30.0
Education	Undergraduate students	206	54.8
	Graduate students	170	45.2
College	Management	111	29.5
	Engineering	83	22.1
	Electrical engineering and computer science	68	18.1
	Science	55	14.6
	Liberal arts and Hakka studies	35	9.3
	Biotechnology and earth sciences	24	6.4

5 Results

5.1 SEM analysis

Firstly, the importance of the items in the questionnaire was evaluated by calculating the factor loadings using CFA. As suggested by Hair et al. (Hair et al. 2006), items with a factor loading of > 0.5 were considered important, and the unimportant items were removed from the data set used for the subsequent reliability analysis. Table 3 summarises the improved measurement model calculated based on the remaining items for each construct. The α values of most of the constructs were higher than the suggested threshold of 0.7, except for the variables of CE and FC (Nunnally 1978). The α values of these two constructs were much higher than 0.35 and were thus considered acceptable (Roberts and Wortzel 1979). The overall α value was 0.901. The results demonstrated the reliability of the improved measurement model.

In this study, CV and DV were used to verify construct validity. After removing the unimportant items with a factor loading of < 0.5, CR and AVE were used to evaluate the CV and DV, respectively. The calculated CRs and AVEs for each construct are summarised in Table 4. Most of the

Table 3 Reliability analysis results

Construct	Removed Items	Remaining no.	α
CE	CE1, CE2, CE3, CE4, CE5, CE6, CE6, CE9, CE10	3	0.605
RO	RO1, RO2, RO3, RO5, RO8, RO10, RO12	5	0.812
AC	AC5, AC7, AC8, AC9, AC10, AC11	6	0.756
AE	AE2, AE3, AE11, AE12	8	0.884
PE	None	4	0.764
EE	None	4	0.812
SI	SI1	3	0.728
FC	FC3	3	0.645
BI	None	3	0.777
Whole		39	0.901

Table 4 Results of the CV analysis

Construct	CR	AVE
CE	0.753	0.506
RO	0.904	0.652
AC	0.876	0.541
AE	0.921	0.594
PE	0.850	0.591
EE	0.878	0.648
SI	0.802	0.586
FC	0.692	0.430
BI	0.831	0.623

calculated CRs were higher than 0.7, except for FC, of which the CR was nevertheless nearly 0.7 (0.692). Thus, the results revealed that the questionnaire had a high CV. Similarly, most AVEs were higher than the suggested threshold of 0.50, except for FC (0.430); nevertheless, FC was retained in the analysis, because its AVE was sufficiently close to the threshold.

The results of the DV analysis are summarised in Table 5. The entries along the diagonal line show the calculated AVEs, and those below the diagonal line are the squares of the correlation coefficients of the two intersecting constructs. The discrimination between any two constructs is significant if the square of the correlation coefficient is smaller than the AVE of both constructs. For example, the discrimination between CE and RO is significant because the AVE of CE (0.506) is greater than the square of the correlation coefficients of CE and RO (0.281). As shown in Table 5, each construct was valid.

Based on the items selected during the reliability analysis, the structural equation model was modified by fixing free parameters. Figure 2 shows the modified structural equation model, where BI was the only endogenous latent variable with three items. In the first step, the structural model validity was assessed by calculating the overall model fit. The ratio of χ^2 to the degree of freedom was 2.6 ($\chi^2 = 1800.85$, $DF = 693$), which is within the acceptable range. However, the GFI (0.78) and AGFI (0.75) were lower than 0.8 and were thus considered unacceptable, and the RMESA (0.07) was higher than the recommended criterion. Moreover, the CFI (0.79) was lower than the recommended criterion. The proposed research model did not seem to satisfy the requirement of the goodness of fit. We know that $\chi^2 = (N-1)\ F_{\min}$, where N is the sample size and $F_{\min}$ is the minimum value of the fitting function. The equation shows that χ^2 is highly sensitive to sample size. Therefore, the reason for a poor fit is either the structural model itself or an overly large research sample. To determine the reason, a modified Bollen–Stine bootstrap method was used to assess the research model (Bollen and Stine 1992). A null hypothesis was proposed, there being no difference between the Bollen–Stine-corrected χ^2 and the original χ^2. After a 1000 bootstrap resampling, the results indicated that the model was a better fit in all the bootstrapping samples. The corrected p value calculated using this method was 0.001; this implies the null hypothesis to be rejected and that a difference existed in χ^2 between the bootstrapping and original samples. Thus, the overly large research sample was the cause of the poor fit of the modified structural equation model. The χ^2 mean of 1000 bootstrap samples was 833.60, and this was used to recalculate the model fit.

The amended results of the overall model fit obtained using Bollen–Stine bootstrapping are shown in Table 6. The ratio of χ^2 to the degree of freedom was 1.203, which is below the maximum threshold. Moreover, the GFI and AGFI were higher than 0.8 and were thus considered acceptable, and the RMESA met the recommended criteria. In addition, both the CFI and IFI were higher than the recommended criteria. Hence, the modified structural equation model shown in Fig. 2 satisfied the requirements of the overall model fit for the SEM approach.

5.2 Discussion

Finally, the inferences from all of the exogenous variables to behavioural intention were reviewed. SPCs and p values were calculated to verify our hypotheses (Table 7). The results revealed support for the initial hypotheses, H_1 to

Table 5 Results of the DV analysis

	CE	RO	AC	AE	PE	EE	SI	FC	BI
CE	0.506								
RO	0.281	0.652							
AC	0.336	0.176	0.541						
AE	0.250	0.185	0.123	0.594					
PE	0.185	0.063	0.040	0.096	0.591				
EE	0.026	0.053	0.078	0.048	0.160	0.648			
SI	0.109	0.084	0.029	0.053	0.336	0.084	0.586		
FC	0.096	0.068	0.053	0.073	0.137	0.260	0.240	0.430	
BI	0.194	0.078	0.063	0.073	0.436	0.168	0.449	0.250	0.623

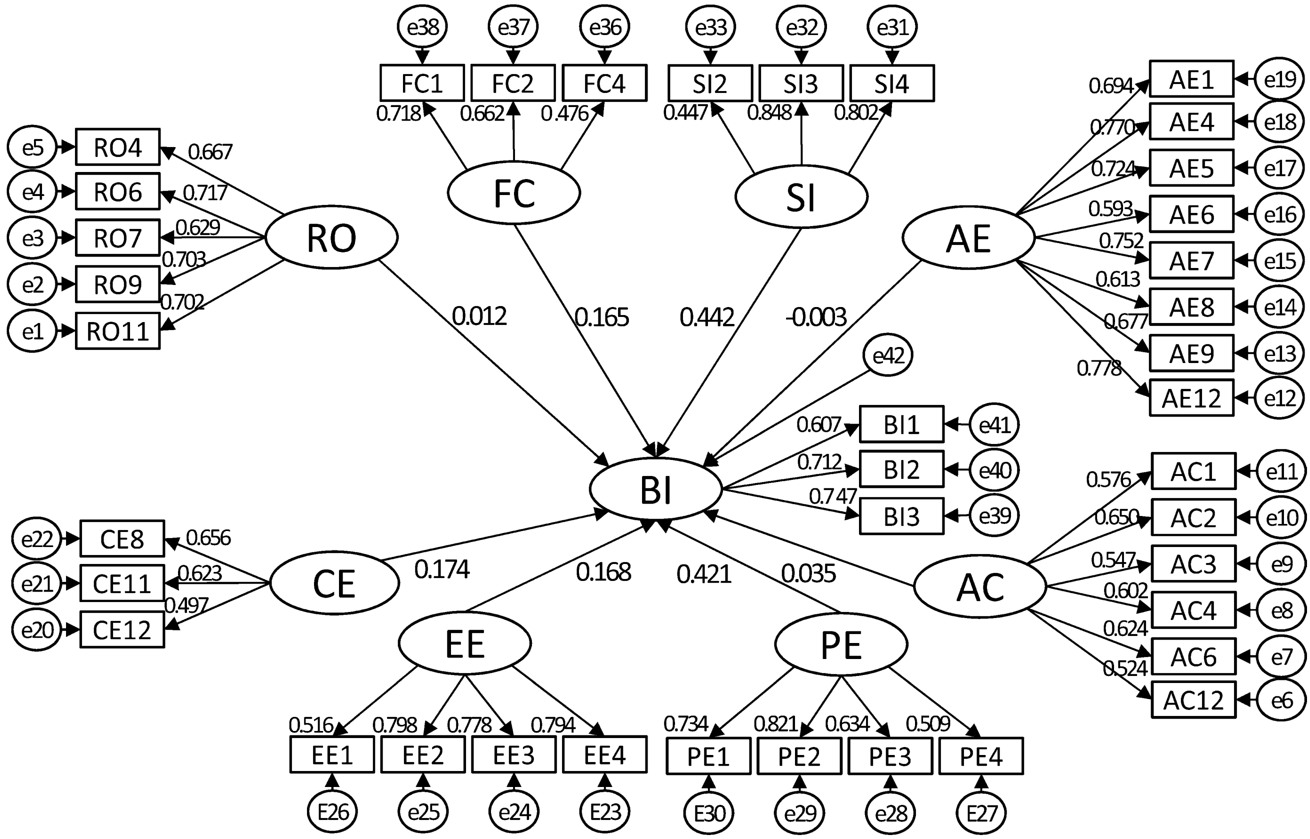

Fig. 2 Modified structural equation model

Table 6 Overall model fit after modification

Fit index	Recommended criteria	Result
Bollen–Stine χ^2	the less the better	833.601
χ^2/DF	$1 < \chi^2/DF < 3$	1.203
GFI	> 0.9	0.863
AGFI	> 0.9	0.844
RMSEA	≤ 0.05	0.023
CFI	> 0.9	0.974
IFI	> 0.9	0.974

Table 7 Hypothesis validation

Hypothesis	Path	SPC	*p* value	Significant
H_1	PE → BI	0.421	< 0.001	Yes
H_2	EE → BI	0.168	0.003	Yes
H_3	SI → BI	0.442	< 0.001	Yes
H_4	FC → BI	0.165	0.012	Yes
H_5	CE → BI	0.174	0.011	Yes
H_6	RO → BI	0.012	0.833	No
H_7	AC → BI	0.035	0.554	No
H_8	AE → BI	− 0.003	0.953	No

H_4, which related to the four constructs of the UTAUT and BI. Social influence was found to have the most significant effect on behavioural intention, followed by performance expectation, effort expectation and facilitating conditions. The results suggest that the students in this study believed that using VR HMDs would improve their learning efficacy and academic performance, thus increasing their behavioural intention to use them. Their intention to use VR HMDs to learn increased when they felt that VR HMDs were easy to use and when adequate resources and convenient facilities and infrastructure were available. Support from authority figures, such as tutors, and other people important to the students also affected their intentions. H_5 to H_8 concerned the relationships between the four constructs of Kolb's learning modes and behavioural intention. Our results suggest that only concrete experience has a significant effect on behavioural intention, whereas reflective observation, abstract conceptualisation and active experimentation have no significant correlations to behavioural intention. According to Kolb's learning structure, concrete experience and abstract conceptualisation represent two opposing processes of acquiring experience. In contrast, reflective observation and active experimentation represent two opposing methods of transforming the acquired experience. Thus, learning results from the resolution of conflict in four adaptive modes; the four modes must be confronted and synergised into an innovative combination. VR provides learners with a virtual experience; it is not designed to, and is incapable of providing a symbolic representation of the experience. Through watching the video on VR HMD application in learning, the students recognised that it is capable of providing a type of solid experience but not conceptual knowledge. Therefore, H_5, which is related to concrete experience, is supported, but H_7, which related to abstract conceptualisation, was not supported. In addition, reflective observation and active experimentation alone cannot provide a complete learning experience in terms of transformation. Because of this limitation, we were unable to implement a real VR HMD learning experience for the students; thus, H_6 and H_8 were not supported.

6 Conclusion

The benefits of using VR in learning have been demonstrated in various subject domains. Our study combined the four constructs of the UTAUT and the four modes of Kolb's learning styles to examine behavioural intentions to use VR HMDs in learning, which notably differs from common approaches combining the UTAUT and the Big Five personality traits. We proposed eight hypotheses regarding the relationships of variables with behavioural intentions and tested them using SME analysis. Five of the eight constructs, namely performance expectancy, effort expectancy, social influence, facilitating conditions and concrete experience, were concluded to be the direct determinants of students' behavioural intentions to use VR HMDs in their learning. Fundamentally, students using them expected their academic performance to improve and they were more likely to use them if they perceived them to be simple to use. Support from university authorities and tutors, adequate VR HMD resources, and convenient facilities and infrastructure were considered important for increasing the intention to use VR HMDs, and the interactive experience provided by VR also enhanced behavioural intention.

For training institutions, our findings contribute valuable information on how to promote the use of VR in student learning. For the VR industry, this study provides an insight into user needs to enable the development of next-generation products. For example, as social influence determines students' behavioural intentions, encouragement from educational authorities and trainers is likely to be a strong driver in increased VR HMD use in learning. Performance expectancy increases students' behavioural intentions; thus, promptly updating academic performance records effectively motivates students to use VR HMDs in learning. From the perspective of effort expectancy, easy operation and the ability to become proficient are important factors in students' intentions to use VR HMDs. Thus, regarding the direction of development, VR manufacturers should focus on the optimisation of user experience. Facilitating conditions implies that having sufficient resources to support student learning through VR is an important consideration impacting their intentions. In addition, the only determinate variable from the learning modes, CE, reflects that students learn best when they are open-minded and also feel personally involved in learning activities. These findings regarding learning through VR technology reflect that students are inspired by the personal experiences and intuitive engagement provided by 3D VR. Hence, content providers of VR training applications should investigate how to use VR HMDs to strengthen students' visual impressions and responses and how to ensure an immersive and engaging experience for students. Developers of VR learning materials should carefully consider all of the items related to the concrete experience mode in Kolb's learning styles.

Our study sample was students from one university in one country, which may lead to a conclusion of homogeneity. Therefore, future studies should recruit students from different educational institutions and countries. In addition, as our research mainly targeted students' behavioural intentions, the participants had no opportunity for real VR immersion. Thus, future studies should evaluate real VR HMD experiences to yield comprehensive findings.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest regarding the publication of this paper.

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