



Cross-cultural factors influencing the adoption of virtual reality for practical learning

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Abstract

Education is one area that was significantly affected by the COVID-19 pandemic with much of the education being transferred online. Many subjects that require hands-on experimental experience suffer when taught online. Education is also one area that many believe can benefit from the advances in virtual reality (VR) technology, particularly for remote, online learning. Furthermore, because the technology shows overall good results with hands-on experiential learning education, one possible way to overcome online education barriers is with the use of VR applications. Given that VR has yet to make significant inroads in education, it is essential to understand what factors will influence this technology's adoption and acceptance. In this work, we explore factors influencing the adoption of VR for hands-on practical learning around the world based on the Unified Theory of Acceptance and Use of Technology and three additional constructs. We also performed a cross-cultural analysis to examine the model fit for developed and developing countries and regions. Moreover, through open-ended questions, we gauge the overall feeling people in these countries have regarding VR for practical learning and how it compares with regular online learning.

Keywords Technology acceptance · Virtual reality · Cross-cultural · Survey · Practical learning · Training · COVID-19

1 Introduction

Education is one area that many believe can benefit from the advances of virtual reality (VR) technology [1, 2], particularly for remote, online learning. VR can be used for various training applications, such as in science and mathematical

education [3, 4], heavy machinery manipulation [5], safety training, and public speaking scenarios [6, 7]. Research has shown positive results from using VR. In the future, results are likely to keep improving with investigations towards the best methodologies and content to teach in VR [5] and to support students with different learning styles.

Currently, the world of education is going through a shift caused by the need for social distancing due to the spread of the COVID-19 virus [8, 9]. Many educational institutions have been forced to adopt online education as the primary means of delivering content and for students to access it [10] while gaining practical learning in isolation and away from the physical campus. Online learning can work well with some non-hands-on courses. However, many subjects that require hands-on experimental experience suffer [8]. Because of its overall positive results for hands-on experiential learning, one possible way to overcome these barriers is through the use of VR applications and technologies [11, 12].

VR can encompass a wide range of systems including 3D immersive desktops, CAVE (or cave automatic virtual environment), and VR head-mounted displays (HMDs). The focus of this research is on the latter (i.e. VR HMDs). This is

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because, while growing rapidly and no longer an emerging technology, VR HMDs (hereafter simply VR) are still evolving and is yet to be widely adopted, particularly in education. Due to its low cost and unique affordances, VR has the potential to transform how people can engage with virtual content, especially in remote scenarios. As such, it is crucial to understand the factors that would affect its adoption in a global, cross-cultural context. This is because education is no longer limited to national and cultural boundaries. In an age of global interconnectedness, it is important to understand if some factors are more prevalent in some cultures to design and use VR technology that can bypass these barriers or make it more tailored.

User acceptance can be defined as the willingness within a group to employ information technology to accomplish objectives within the scope of that technology [13]. Since the mid-70 s, researchers have been interested in understanding what influences users to adopt different technologies and ways to predict their adoption and/or acceptance [14]. Previous research claimed that lack of user acceptance has impeded the success of newly implemented devices and systems [13, 15]. Therefore, it is essential to understand why some technologies are well accepted, especially VR, which can be a disruptive technology in the context of education. This can help improve the design, evaluation, and prediction of the response to new, not-yet-widely-adopted technologies [13]. To understand users' behaviour, the Technology Acceptance Model (TAM) was proposed [14, 16].

Even though several studies have used TAM [17, 18], it is not the only one in the literature attempting to answer these technology adoption questions. Several different models and adaptations of the TAM regarding the acceptance and use of technology have been proposed and tested. We can cite, for example, the Theory of Reasoned Action, the Innovation Diffusion Theory, and the Unified Theory of Acceptance and Use of Technology [16, 19–22]. As one of the oldest models, initially developed in 1980 as the Theory of Reasoned Action (TRA), it has been revised several times, eventually becoming its current and most comprehensive version as the Unified Theory of Acceptance and Use of Technology (UTAUT) [16] and the UTAUT 2 [23].

While these theories and models have been applied and tested in many different countries, cross-cultural comparative studies are still rare [24]. In this study, we aim to fill this gap and analyse how the intention to adopt is modelled in different cultures. In this research, we utilise the UTAUT to demonstrate the acceptance and use of VR-based learning environments for practical, experimental learning. We collected data from respondents worldwide in both developed and developing countries and analyse them using the UTAUT framework.

The main contributions of this research are three-fold: (1) a list of factors that affect behavioural intention across

different cultures; (2) the verification that different countries and regions need their own model(s); and (3) the detection of barriers in the adoption of VR.

The results of this research lead to the following lessons for the adoption of VR in different cultures: (1) Users' self-efficacy in using VR is crucial for them to adopt it. It is important to make the hardware and applications easy to learn, self-explanatory and provide necessary tutorials. This will positively influence their expectancy, which in turn will lead to positive attitudes and behavioural intentions. (2) For developed countries and regions, it is important to manage users' performance expectancy and mitigate the anxiety factor. Anxiety can be reduced if the experience of VR symptoms can be improved. (3) For developing countries and regions, effort expectancy and social influence play more important roles. Finally, (4) efforts are needed to explore ways to reach women to improve their impressions and motivate their adoption of VR.

This paper first presents a literature review and presents our research model by providing the rationale behind our hypotheses. After providing information regarding the study sample and scales, the study hypotheses are tested, and the results are discussed later.

2 Related work

2.1 Technology acceptance

As digital technologies become more pervasive worldwide and ubiquitous across domains, interest in how technology is perceived, accepted, and used by individuals has also grown [19, 25–29]. Whether different societies will equally accept technologies and what factors will lead to their acceptance are pertinent questions subject to considerable debate. Various studies in the literature have attempted to answer these questions [19, 21, 24].

Venkatesh et al. [16] integrated competing theoretical models, comprising 32 constructs presenting the similarities across the models to develop a unified model to predict the chances of successfully implementing new technologies that will be adopted by their intended users. Four prominent constructs (*Performance Expectancy*, *Effort Expectancy*, *Social Influence* and *Facilitating Conditions*) were generalised and experimentally validated from the previous ones. Based on these constructs, the proposed UTAUT clarifies the dynamics and motivation that facilitate users' engagement [26]. The model was used in the early days to examine the effect of user experiences of 3 G mobile telecommunication services [30] and employed to explain users' acceptance of mobile devices and services [31]. However, the four constructs were not enough for all analyses and systems [32]. To explore a web-based course management software applied

in higher education, the inclusion of two other constructs in the UTAUT (*Self-Efficacy* and *Anxiety*) was necessary [33].

UTAUT has been further extended into UTAUT 2 [23] by including three other constructs (*Hedonic Motivation*, *Price Value*, and *Habit*). While TAM is simplistic and UTAUT 2 is somewhat more complete, in this research, we employed UTAUT because of how well-regarded it is for this kind of study [34] and has already been employed in other cross-cultural comparisons regarding the use of virtual reality for education [24], which would offer a basis for comparison. In addition, while we primarily focused on UTAUT, we have included *Attitude* as a construct in our model, which is not part of either UTAUT or UTAUT 2. This construct shows implications for hedonism (e.g. *Studying with VR would be fun*) and habit (e.g. *I would like working with VR*). The price value and habit are also captured to some degree in user demographics.

We consider the four constructs of the UTAUT to be the direct determinants of the *Behavioural Intention* to use VR HMDs in learning. However, because VR is not entirely new and has been often portrayed in the media as an entertainment system, we believe *Attitude* might also be a determinant factor. Similarly, because in scenarios involving online teaching, we believe *Self-Efficacy* and *Anxiety* to be relevant for the analysis [33].

2.2 Virtual reality learning environments

Many studies have shown that online teaching can yield positive results and that using computers and games can be advantageous to teach mathematics [35], and language [36, 37], for example. Recently, with the advent of commercial VR head-mounted displays (HMDs), newer studies have

shown the potential VR has to be used to teach many different subjects [3, 5, 6, 38, 39].

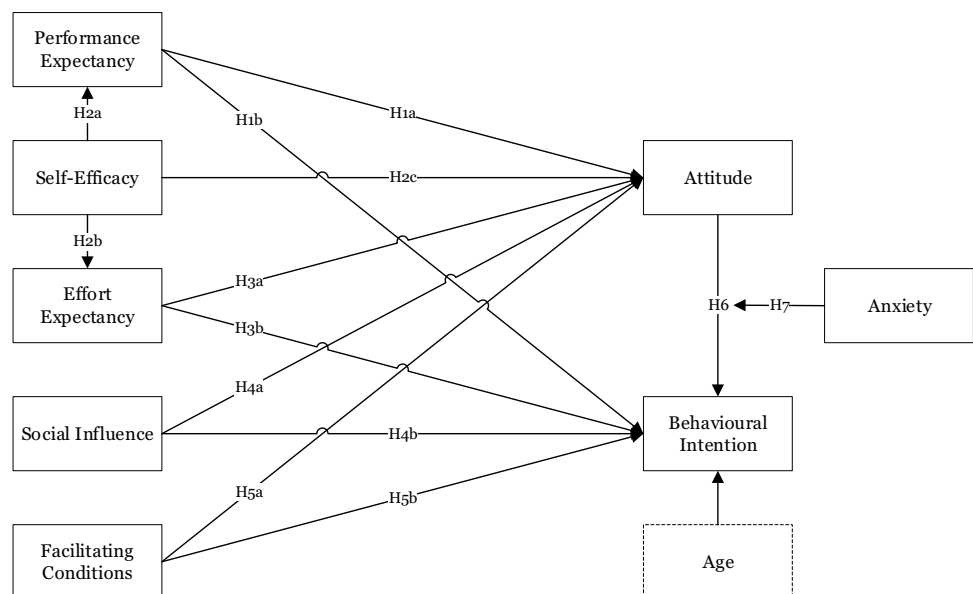
VR has been proven to be useful to train surgeons [40] and geographers [41], and assist in architecture endeavours [42]. In recent years, between 2016 and 2018, at least 38 articles were published about VR for higher education [43]. 34% (the highest percentage) were aimed at teaching procedural and practical knowledge, with a constant number between 2017 and 2018. Because their results are still experimental, it is not clear how their adoption will be received, especially in the COVID-19 times and within a cross-cultural context. Thus, it is vital that we learn what factors influence the adoption of this technology in different places to help tailor their development to success from an early stage.

3 Research model and hypotheses

Various studies in the literature emphasise that there are differences between countries with regards to the acceptance and use of different technologies [17, 21, 24, 29]. We aim to investigate cross-cultural differences in user acceptance of VR for practical learning based on the UTAUT model. We expect a model spanning across different cultures to have additional influencing factors than a model relating to specific countries or sub-regions. Thus, we intend to create a General Model (GM) and evaluate if the same hypotheses are compatible with the models of developed (ED) and developing (NG) countries and regions. We propose the GM in Fig. 1.

The UTAUT indicates the effects of Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI) and Facilitating Conditions (FC) on Behavioural

Fig. 1 The proposed adapted UTAUT model that takes into account the respondents from all countries and regions and includes three additional constructs: *attitude*, *self-efficacy* and *anxiety*. *Age* is a control variable



Intention [16, 23]. Dwivedi et al. [44] reexamined the UTAUT and proposed a revised model that includes Attitude (ATT) as a main construct. They found that the original four main constructs in UTAUT also have positive influences on Attitude. As discussed in the related work, Self-Efficacy (SE) and Anxiety (ANX) are important factors in the context of teaching and learning. We detailed our hypotheses in the following paragraphs.

Performance expectancy Van Schaik [45] studied students' use of learning websites in higher education and determined that performance expectancy, effort expectancy and social influence would lead to behavioural intention. Performance expectancy can be defined as how much someone thinks using the system will improve their performance at work or school [16]. It is expected that users who believe using VR can improve their performance in learning will have a more positive attitude (H1a) and a greater behavioural intention (H1b).

Effort expectancy Effort expectancy has been defined as how complex the user expects the system or device to be [16]. Two decades ago, this component seemed to strongly affect the general population about adopting new systems [31–33]. We expect that students will have a greater behavioural intention to use VR HMDs if they believe that the devices will be virtually plug-and-play (H3b). In addition, the demand for efforts will have an influence on their attitude towards VR use (H3a).

Self-efficacy Self-efficacy was shown to influence attitudes towards the use of mobile payment [46]. We believe that people who think they can use a system without external help will be more likely to trust VR as a sound learning system (H2c) that improves their performance (H2a) and requires little effort to use (H2b).

Social influence Social influence is how much someone believes others think the system should be adopted. Research has shown that social influence is an influencing factor on attitude [44] (H4a) and behavioural intention [16] (H4b). Students may be particularly sensitive to what their classmates or teachers think about them.

Facilitating conditions As defined initially, the facilitating conditions construct is the belief that an organisation would provide adequate materials to support a new system. Studies in the literature emphasise that this definition of facilitating conditions affects user behaviour rather than behavioural intention [16, 32]. However, in the current remote working context, it is necessary to evaluate if the individual has the necessary structure to support introducing a new system or device to be part of their learning ecosystem. Thus, we hypothesise that the facilitating conditions will affect the attitude (H5a) and behavioural intention of adopting the VR system (H5b). These are drawn from the related work [16, 44].

Attitude In the original UTAUT paper, the authors mention that the attitude seems relevant in some models and not in others and define it as the affective response to the system [16]. However, as their original model was focused on working environments, the affective models did not include other forms of affective adoption and consumption [47]. The revised model proposed by Dwivedi et al. [44] included attitude as a main construct that contributes to behavioural intention. Thus, we propose the hypothesis that people who believe VR is positive will be more likely to intend to acquire it (H6).

Anxiety Being afraid of using computers for essential tasks has been reported as a hindrance in computer adoption in the late-80 s [48]. At the time, personal computers were a novelty; computer anxiety related to negative perceptions about computers, problems in playing with them, and avoidance of the technology [49]. VR headsets, while not entirely new, are still a novelty to many and as such they might carry similar fears and stigmas about their use in education. Thus, we propose that anxiety negatively moderates the relationship between attitude and behaviour intention (H7). We summarise and formalise all our hypotheses in Table 1.

Age Apart from these hypotheses, we also include age in the proposed model, as some prior studies have shown that different age groups have distinct reactions towards and levels of acceptance of VR applications (e.g. see [50] for VR games).

4 Methodology

4.1 Data collection

To test our hypotheses, we collected data using a questionnaire-based method. We prepared our questions based on our literature review and the adaptations needed to fit the context of this research. When preparing the questionnaire, the constructs and questions were primarily based on the study of Venkatesh et al. [16], the developers of the UTAUT model. The specific questions used in our questionnaire are seen in Table 2. Respondents answered the questions on a 7-point Likert scale.

The questions were offered in English, Chinese, and Portuguese using the Microsoft Forms website's regionalize function. The questions were translated from English by native academics of the other languages and verified by a second native speaker of the respective languages. Before taking the technology acceptance part of the questionnaire, participants were presented with a 65-second video that shows possible training features and capabilities of VR for practical, hands-on learning. The video could be watched as often as the participants desired and at a speed preferred by them, as the link would allow the video to be watched up

Table 1 Summary of the hypotheses tested in this research

Hypothesis	Description
H1a	PE positively influences ATT to use VR for practical learning
H1b	PE positively influences BI to use VR for practical learning
H2a	SE positively influences PE to use VR for practical learning
H2b	SE positively influences EE to use VR for practical learning
H2c	SE positively influences ATT to use VR for practical learning
H3a	EE positively influences ATT to use VR for practical learning
H3b	EE positively influences BI to use VR for practical learning
H4a	SI positively influences ATT to use VR for practical learning
H4b	SI positively influences BI to use VR for practical learning
H5a	FC positively influences ATT to use VR for practical learning
H5b	FC positively influences BI to use VR for practical learning
H6	ATT positively influences BI to use VR for practical learning
H7	ANX negatively moderates the relationship between ATT and BI

Table 2 Measurement items and factor loadings of the constructs

Construct	Item	Loadings
Performance expectancy	I would find VR useful for practical learning.	0.869
	Using VR could enable me to learn more quickly.	0.896
	Using VR could increase my productivity.	0.898
	If I used VR, it would increase my chances of getting better grades.	0.826
Self-efficacy	<i>I could complete a job or task using VR...</i>	
	Even if there was no one around to tell me what to do as I go.	0.735
	If I could call someone for help if I got stuck.	0.770
	If I had a lot of time to complete the job for which the Head-Mounted Display was provided.	0.718
Effort expectancy	Even if I had just the built-in help facility for assistance.	0.842
	My interactions with VR would be clear and understandable.	0.824
	It would be easy for me to become skilful at using VR.	0.862
	I would find VR easy to use.	0.892
Social influence	Learning to interact with virtual objects would be easy for me.	0.898
	People who influence my behaviour think that I should use VR.	0.892
	People who are important to me think that I should use VR.	0.900
	The instructors of the courses would be helpful in the use of VR.	0.880
Facilitating conditions	In general, the university would support the use of VR.	0.878
	I have the resources necessary to use VR.	0.956
	I have the knowledge necessary to use VR.	0.969
	I have a specific person (or group) available for assistance with VR difficulties.	0.948
Attitude	Using VR is a good idea.	0.903
	VR would make studying more interesting.	0.924
	Studying with VR would be fun.	0.924
	I would like to work with VR.	0.847
Anxiety	I feel apprehensive about using VR.	0.830
	I hesitate to use VR for fear of “learning wrong”.	0.877
	VR is somewhat intimidating to me.	0.896
Behavioural intention	I intend to start using VR <n-months> after available.	0.952
	I predict I would use VR in the next <n-months>.	0.964
	I already plan to use VR in the next <n-months>.	0.949

to a quarter of the regular speed. This is a similar approach used in previous work [26]. Participants were then asked to answer some demographic questions. At the end, they could answer two open-ended questions: their opinions about VR in education and online education.

Participants were recruited through social media and Amazon Mechanical Turk. The participants from Amazon MTurk received a symbolic US\$0.01 for their participation. Participants recruited through social media did not receive any monetary compensation to preserve their anonymity. Participants were informed about the nature of the survey upon recruitment and were informed that they could stop it at any moment and request that any data they gave would not be used.

At the time of writing, we received 293 responses. From these, 48 responses did not present satisfactory answers: questionnaires were incomplete or had a single value selected for all answers. We removed the unsatisfactory questionnaires and started the analysis of the remaining 245 complete responses.

4.2 Sample characteristics

The 245 respondents are from 28 countries and regions worldwide. Specifically, we had 149 respondents from 11 developed countries and regions: United States of America ($N = 120$), Italy ($N = 10$), Canada ($N = 8$), France ($N = 2$), South Korea ($N = 2$), Australia ($N = 2$), Netherlands, United Kingdom, Hong Kong, Israel, and Spain. The rest 96 responses are from 17 developing countries and regions, including Brazil ($N = 24$), India ($N = 22$), China ($N = 20$), Indonesia ($N = 14$), Iran ($N = 2$), Philippines ($N = 2$), Thailand ($N = 2$), Argentina, Bangladesh, Estonia, Greece, Madagascar, Mauritius, Nigeria, Poland, South Africa, and Tanzania. The characteristics of our sample are summarised in Table 3. In our research, we characterised VR experience to mean someone who had used VR for more than 5 min which was not experienced as part of a demonstration, including but not exclusively fun fairs and store displays. In addition, symptoms related to VR use (e.g. nausea, dizziness, and headache) were presented as non-exclusive examples of VR sickness. 26.53% of the respondents ($N = 65$) have a VR device. This ratio for developed countries and regions is 34.22% ($N = 51$) and 14.58% for developing countries and regions ($N = 14$).

5 Data analysis

5.1 Measurement validity and reliability

To examine the robustness of the questionnaire items, the measurement model was assessed by examining the

Table 3 Demographic information of the respondents

		General model (GM)	Developed (ED)	Developing (NG)
Age	18–24	69	26	43
	25–31	62	40	22
	32 and up	110	83	27
	Undeclared	4	0	4
Gender	Male	126	72	54
	Female	116	76	40
	Undeclared	3	1	2
VR experience	None	54	28	26
	Demo	57	30	27
	Used VR	134	91	43
VR sickness	No experience	111	58	53
	No	63	46	17
	A little	60	38	22
	Yes	11	7	4
Total		245	149	96

Table 4 Results of the construct reliability and validity test, showing the values of Cronbach's Alpha (CA), Composite Reliability (CR), and Average Variance Extracted (AVE)

Construct	CA	CR	AVE
Performance expectancy	0.896	0.927	0.761
Self-efficacy	0.767	0.851	0.589
Effort expectancy	0.892	0.925	0.756
Social influence	0.91	0.937	0.788
Facilitating conditions	0.955	0.971	0.917
Attitude	0.921	0.945	0.810
Anxiety	0.837	0.902	0.754
Behavioural intention	0.952	0.969	0.913

construct reliability, convergent validity, and discriminant validity. Specifically, the Cronbach's alpha (CA) and composite reliability (CR) values are examined for all constructs to ensure the internal reliability of items. The convergent validity was then assessed by measuring the average variance extracted (AVE) of factors. Accordingly, the evaluation of related indicators was conducted following the previous studies [51, 52]. The CA, AVE, and CR results are presented in Table 4.

For construct reliability, which indicates how well a construct is measured by its items, the values of CA and CR were first examined. As shown in Table 4, for all factors, the CA values ranged from 0.767 to 0.955, and the CR values ranged from 0.851 to 0.971. For both measures, all constructs exceeded the recommended threshold of 0.7 [51, 52], thereby suggesting a high level of construct reliability

for the measurement model. In addition, the AVE ranged from 0.589 to 0.917, which was greater than the suggested threshold value of 0.5 [51], thereby indicating a high level of convergent validity.

To evaluate the discriminant validity, the square root of the AVE of each latent construct was compared with its inter-construct correlation. The square root of the AVE of a construct should be greater than its correlations with other constructs to achieve satisfactory discriminant validity [51, 52]. Additionally, the diagonal values should be higher than the off-diagonal values in the corresponding columns and rows [53]. As shown in Table 5, our results show that for each construct, the square root of the AVE exceeds the inter-construct correlations, thereby indicating an appropriate level of discriminant validity.

5.2 Structural equation modelling analysis and hypotheses testing

Partial least squares (PLS) regression is one of the most commonly adopted structural equation modelling (SEM) techniques used to validate structured data. PLS regression is especially effective for data analysis during the early stages of theory development when the theoretical model and its measures are not yet complete [54]. In this study, PLS regression was used to perform bootstrapping for our research model and to test and validate the proposed model, as well as the relationships among the hypothesised constructs.

To assess the overall quality of the research model, the SEM procedure based on PLS regression was applied to analyse the goodness of fit (GoF), path coefficients, and coefficient of determination (R^2). The GoF ($0 < \text{GoF} < 1$) is considered the geometric mean of the average commonality and average coefficient of determination, which can be calculated using the formula:

$$\text{GoF} = \sqrt{\text{AVE} * R^2}$$

[55]. The general model has a GoF value of 0.705, which exceeds the 0.36 benchmark value suggested by [56]. Thus, the proposed model has a good overall fit.

The relationships proposed by the hypotheses are examined by using the path coefficient (β) and t statistics. To illustrate the distinction of adoption factors between different cultural backgrounds, this study further tested the research model on two sub-samples divided by the countries and regions the respondents come from: *developed* and *developing*. The results of path significance of each hypothesis test using the PLS-SEM analysis are presented in Table 6.

For the general model, most of the proposed hypotheses are supported, except for the H1b, H2c, and H3b. With the

Table 6 Summary of the PLS-SEM analysis results showing standardised coefficients (β) and goodness of fit (GoF) for the *general model* (GM), and models for *developed* (ED) and *developing* (NG) countries and regions

Path	GM	ED	NG
H1a: PE → ATT	0.082*	0.208***	0.038
H1b: PE → BI	-0.072	-0.056	-0.083
H2a: SE → PE	0.615***	0.596***	0.622***
H2b: SE → EE	0.586***	0.647***	0.497***
H2c: SE → ATT	-0.014	-0.047	0.006
H3a: EE → ATT	0.112**	0.112	0.111*
H3b: EE → BI	-0.043	0.046	-0.081
H4a: SI → ATT	0.632***	0.522***	0.662***
H4b: SI → BI	0.160*	0.047	0.283*
H5a: FC → ATT	0.221***	0.229***	0.237***
H5b: FC → BI	0.472***	0.574***	0.323
H6: ATT → BI	0.346***	0.269***	0.414*
H7: ATT * ANX → BI	-0.051*	-0.064**	-0.036
GoF	0.705	0.727	0.715

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 5 Results for the discriminant validity test

	ANX	ATT	BI	EE	FC	PE	SE	SI
ANX	0.868							
ATT	-0.297	0.900						
BI	-0.614	0.815	0.955					
EE	-0.210	0.818	0.643	0.87				
FC	-0.644	0.784	0.910	0.638	0.958			
PE	-0.132	0.809	0.621	0.804	0.632	0.873		
SE	-0.177	0.576	0.521	0.586	0.518	0.615	0.768	
SI	-0.188	0.836	0.747	0.804	0.708	0.801	0.570	0.888

The square root of the AVE of each latent construct is shown diagonally in bold. ANX—Anxiety, ATT—Attitude, BI—Behavioural intention, EE—Effort expectancy, FC—Facilitating conditions, PE—Performance expectancy, SE—Self-efficacy, SI—Social influence

confirmation of the significance of both H1a ($\beta = 0.082$, $p < 0.05$) and H3a ($\beta = 0.112$, $p < 0.01$), it can be inferred that the effects of both performance expectancy and effort expectancy on behavioural intention are fully mediated through the attitude towards VR technology. Similarly, since both H2a ($\beta = 0.615$, $p < 0.001$) and H2b ($\beta = 0.586$, $p < 0.001$) are supported and H2c ($\beta = -0.014$, *n.s.*) is rejected in the result, the effect of self-efficacy on attitude is also fully mediated by both the performance and effort expectancy. Besides, for the other two factors in the UTAUT model, the effects of social influence and facilitating conditions are significant for both the attitude and the behaviour in adopting VR technologies (H4a: $\beta = 0.632$, $p < 0.001$; H4b: $\beta = 0.160$, $p < 0.05$; H5a: $\beta = 0.221$, $p < 0.001$; H5b: $\beta = 0.472$, $p < 0.001$). The significant relationship between attitude and behavioural intention is also confirmed (H6: $\beta = 0.346$, $p < 0.001$), with a negative moderation effect of anxiety identified (H7: $\beta = -0.051$, $p < 0.05$). Finally, age, as a control variable in the general model, is shown to have a significant negative impact ($\beta = -0.050$, $p < 0.01$) on behavioural intention, indicating that the greater the age is, the less likely a user is to adopt VR for learning.

5.3 Cross-cultural comparison

To compare the effects of adoption factors under the cross-cultural context, we conduct the PLS-SEM analysis on two separated sub-samples: developED (ED) and developiNG (NG) countries and regions. The results for the analysis of both models are presented in Table 6 and Fig. 2. The values of GoF for both models (i.e. $GoF_{ED} = 0.727$ and $GoF_{NG} = 0.715$) also exceed the recommended threshold, which indicates a good model fit.

For the antecedents of attitude, it can be concluded from the results that social influence ($H4a_{ED}$: $\beta = 0.522$, $p < 0.001$; $H4a_{NG}$: $\beta = 0.662$, $p < 0.001$) and facilitating conditions ($H5a_{ED}$: $\beta = 0.229$, $p < 0.001$; $H5a_{NG}$: $\beta = 0.237$,

$p < 0.001$) maintain consistent relationships in both models. The effects of performance expectancy and effort expectancy on attitude vary in the two models. Performance expectancy has significant influence on attitude in ED but not NG ($H1a_{ED}$: $\beta = 0.208$, $p < 0.001$; $H1a_{NG}$: $\beta = 0.038$, *n.s.*), whereas effort expectancy has significant influence on attitude in NG but not ED ($H3a_{ED}$: $\beta = 0.112$, *n.s.*; $H3a_{NG}$: $\beta = 0.111$, $p < 0.05$). In terms of the effect of self-efficacy, the same pattern appears in both models, which is also congruent with findings in the general model.

For the factors that lead to the behavioural intention of VR adoption for practical learning, the effects of performance expectancy and effort expectancy show similar results in the general model: both are rejected. Social influence is only found to be a significant antecedent for behavioural intention in NG, but not ED ($H4b_{ED}$: $\beta = 0.047$, *n.s.*; $H4b_{NG}$: $\beta = 0.283$, $p < 0.05$). Contrarily, facilitating conditions only significantly increase the behavioural intention in ED ($H5b_{ED}$: $\beta = 0.574$, $p < 0.001$), but not NG ($H5b_{NG}$: $\beta = 0.323$, *n.s.*). Finally, the moderation effect of anxiety on the relationship between attitude and behavioural intention are only found significant in ED ($H7_{ED}$: $\beta = -0.064$, $p < 0.01$; $H7_{NG}$: $\beta = -0.036$, *n.s.*), which indicates that the anxiety only affects the strength of attitude in developed countries, but not in developing countries. Age as a control variable does not have a significant effect on behavioural intention in the two models.

We performed independent samples *t* test to understand better how the different constructs and behavioural intention compared between ED and NG. Performance expectancy, self-efficacy, effort expectancy and social influence were significantly higher in ED compared to NG. The result is the same for attitude. The differences in facilitating conditions, anxiety and behavioural intention between ED and NG were insignificant. These results are summarised in Fig. 3.

Fig. 2 Models of *developed* (left, ED) and *developing* (right, NG) countries and regions. Values on path are coefficients (β). * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. A dashed line indicates an insignificant path

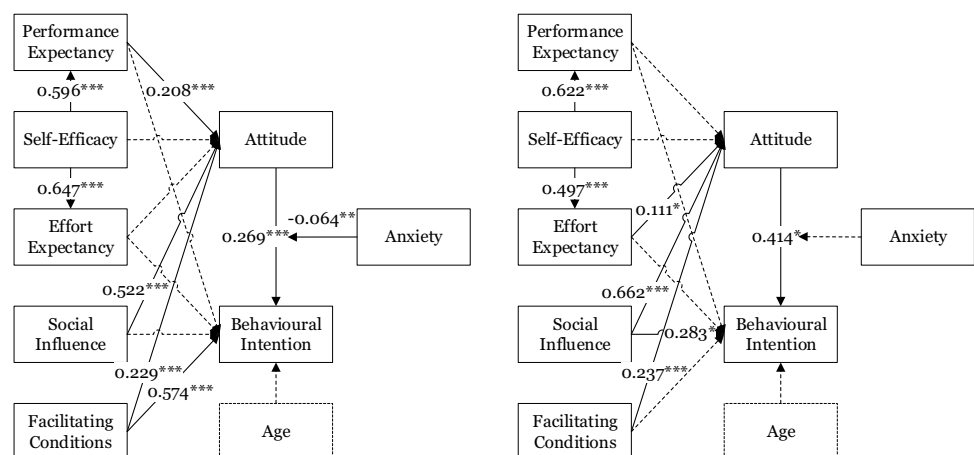
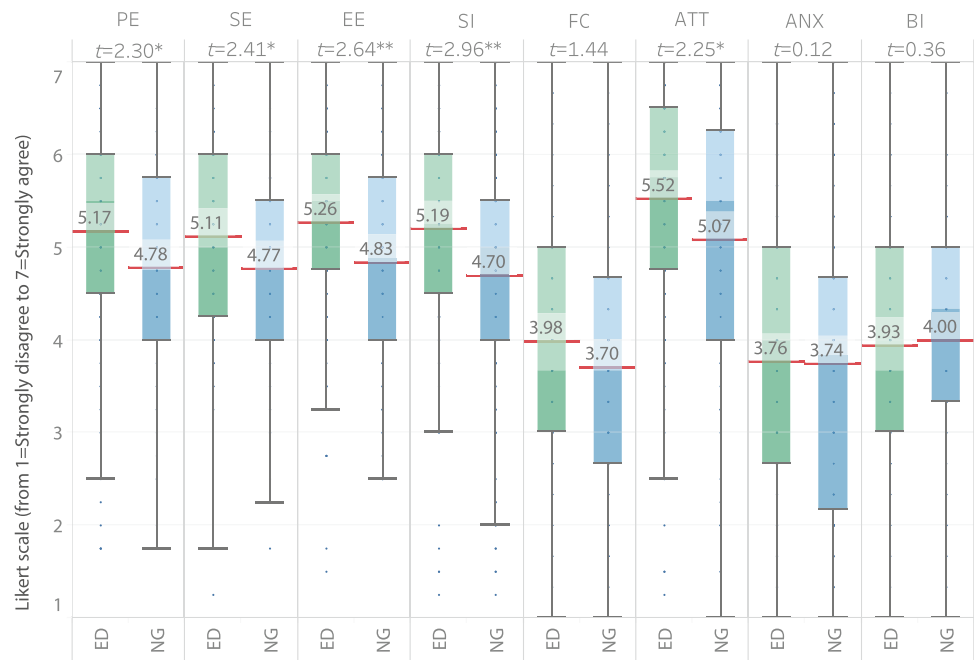


Fig. 3 Box plots and means of the construct measurements, and the t test results for the comparison of developED (ED) and developiNG (NG) countries and regions. * $p < 0.05$; ** $p < 0.01$



5.4 Qualitative analysis

Besides the quantitative investigation of adoption factors for VR technology, this study further explored participants' comments and subjective feelings about online education and VR education. These are provided by participants in the two open-ended questions in the survey: "What's your opinion about online education?" and "What's your opinion about VR in education?".

Online education From the participants who provided their opinions about online education, 57 declared a positive view of studying online, 21 viewed online education negatively, and 41 believed the technology to be neutral. This shows an overall positive view of learning online. Those who declared negative feelings towards online education presented ten types of concerns. The three most common concerns were regarding effectiveness ($N = 7$), socialisation ($N = 3$) and boredom ($N = 3$). 4 participants just declared their dislike without any particular reason. The participants who felt somewhat neutral emphasised the need for the choice and that it is not well-suited for everyone. However, they admitted some people might benefit from it, examples are "I think it's a good option for some" and "it is very good for adults, but I think for young children would not be the best way to learn". Other common occurrences in the neutral answers' overarching theme were: (1) the focus on the current social isolation directives; and (2) concerns about the teacher's current preparation and ability level for online teaching. Finally, most people who viewed online education favourably did not offer much insight. Favourable declarations were often written "good", "nice" or "I like it"

($N = 30$). Others focused on convenience, including being able to use it everywhere and being able to watch classes many times ($N = 11$). A few answers ($N = 5$) focused on how VR could improve online education, e.g. "It's helpful (online education) but using VR would make it better for some subjects".

VR education Compared to online education, a considerably lower percentage of the 162 respondents who gave their opinions declared negative feelings about VR in education ($N = 7$). The negative comments were given by 3 participants from the USA, 2 from China, and 2 from Brazil and Indonesia. The most common negative comments were about its comfort level ($N = 3$) and concerns with people who wear glasses ("Wearing glasses makes VR headsets uncomfortable and impractical"). Other concerns within the negative group were the price ($N = 2$), and the ability of some people to focus ($N = 1$): "I don't know if it would be useful, since the children can easily get distracted with anything, and I also don't know if they would know how to handle it properly". Of the respondents who presented neutral feelings ($N = 23$), most presented similar concerns as the participants who answer neutrally about online education, emphasising the need for choice, to be used in specific situations, and a greater preparation from educators to deal with the technology, and a need for a lower cost ($N = 1$). Further, some ($N = 3$) commented on the need to reduce VR sickness: "It's a great idea, but we have to solve the problem of motion sickness experienced by some people". Still, the somewhat neutral comments are optimistic about the future of VR: "Maybe 200 years from now school will be done at home with VR". The overwhelming majority of participants

answered favourably about the use of VR for education. From the ones with a positive view, 21 suggested use cases in which VR would be especially welcome. The other positive comments mentioned how fun and immersive VR can be. One theme that appeared somewhat frequently ($N = 3$) is the use of VR for people with special needs in education: “I’ve never really thought about it before, but it could be a wonderful way to help a student. I have ADHD and it would have helped me a lot to stay focused”. Other recurring themes were: (1) using VR to teach children ($N = 4$); (2) using VR to visualise models and demonstrate abstract and complex concepts ($N = 5$); and (3) using VR to replace labs for practical classes, artistic and scientific settings ($N = 9$).

Country-specific results on attitude We looked into the data for country-specific results for four countries: USA, Brazil, India, and China. These have relatively large subsample sizes. In total, 80.46% ($N = 70$) of the comments from the USA sample were positive, 11.09% were neutral, and 3.45% were negative. 85.71% ($N = 10$) of the Brazil comments were positive, 7.14% were neutral and 7.14% were negative ($N = 1$). 100% ($N = 11$) of the respondents from India were positive. The China sample had the lowest positive percentage of comments about VR in education (66.67%, $N = 11$), and the highest negative percentage (11.11%). The GM sample is similar to the USA sample, where 82.47% ($N = 127$) had a positive view of VR, 13.64% were neutral and 3.90% were negative.

Gender, VR experience, and VR sickness Overall, 55.12% of the positive comments were from women, nearly equivalent to their percentage in the total number of comments (56.49%). However, women disproportionately represented the negative (61.90%) and neutral (66.67%) comments. The negative comments in the USA, Brazil, India, and China samples were all associated with female participants. From the 112 who had experienced VR and answered the questions, 81.25% ($N = 91$) had a positive outlook on the technology, and 5.36% had a negative outlook. From the 51 who had not tried VR before and answered the questions, 78.43% ($N = 40$) had a positive view of VR and 1.96% ($N = 1$) viewed VR negatively. Around 52.99% of the population that has tried VR presented some level of simulator sickness. The ratio was higher in NG (60.47%) than in ED (49.45%). Our analysis also showed a significant positive correlation between VR sickness and anxiety ($r = 0.17, p < 0.05$).

6 Discussion

We examined the technology acceptance of the use of VR for practical learning using a combined quantitative and qualitative analysis approach. The qualitative answers suggest that overall VR is seen in a positive light. It received more positive comments than online education and is believed to be

the next step (or part of it) in the evolution of teaching and learning. The number of participants who had and had not tried it and thought it was positive was similar. Such results suggest that performance expectations and attitudes towards VR are positively linked to social expectations rather than positive experiences.

The quantitative investigation of VR adoption through PLS-SEM analysis confirmed most of the proposed hypotheses for the general model. Some interesting findings could be identified from the results. First, the positive relationship between attitude and behavioural intention indicates that in the context of using VR for practical learning, a positive attitude towards VR will significantly encourage users to use the technology. Oppositely, failing to maintain a good reputation or impression for the use VR in practical learning will seriously damage the possibility for potential users in trying the technology. Hence, this finding explicitly indicates the importance of users’ individual opinions on their adoption plans of VR in practical learning. In addition, this effect is confirmed in the analysis results of the ED and NG models, which show the reliability of this finding is free from differences among countries and regions.

6.1 Effect of self-efficacy on attitude towards VR

Performance expectancy and effort expectancy are both significant sources for the positive attitude towards VR, and self-efficacy is found to be a salient antecedent for these two constructs. This finding is in line with previous studies [57], which proposed that self-efficacy could increase the perceived usefulness of technology, and lower the anticipated difficulties with inductive transfer learning. Moreover, although self-efficacy shows no direct effect on the attitude towards VR, its influence is fully mediated by performance expectancy and effort expectancy.

Based on this finding, practitioners in education could stimulate potential users’ interests and awareness by focusing on the two performance-related aspects, such as the increased learning outcome from immersive and practical learning, and effort-related aspects, such as ready-to-use bundle or software and hardware support, in both the development and promotion of VR for practical learning. Moreover, besides these endeavours, future use of VR for practical learning should also consider providing tutorials and training for potential users to increase the self-efficacy of their VR abilities, which will further contribute to the positive expectation of technology.

6.2 Moderation effect of anxiety

Anxiety demonstrates a significant moderation effect on the relationship between attitude and behavioural intention in GM and ED. This indicates that for users who have positive

attitudes, their behavioural intention will not be activated if they have a high level of anxiety about using VR for practical learning. The anxiety in using VR includes the fear of “learning wrong” and the feeling of apprehension and intimidation. These concerns about the potentially negative experience or outcome will discard VR as an option that they will eventually choose. Future applications of VR in education should consider mitigating the negative effect of anxiety by providing guidance, new interaction methods, and emotional support to comfort and ease these worries. Otherwise, their efforts in promoting VR towards a positive attitude will not be that fruitful as it will impair behavioural intention. Interestingly, this moderation effect of anxiety is insignificant in NG. One possible reason is that participants in developing countries tend to consider VR in education as an institutional decision instead of for individual uses, as indicated in our qualitative findings. This may have weakened the moderation effect of anxiety for the adoption of VR for practical learning in developing countries.

6.3 Cross-cultural adoption of VR

Attitude Our cross-cultural examination of technology acceptance illustrates that developed countries and regions depend more on performance expectancy, while developing countries rely more on effort expectancy in forming the attitude. The reason for this difference may be rooted in the difference in technological foundations. In developed countries, users normally have a higher level of knowledge of new technologies. Meanwhile, they are able to afford the cost of adopting them so the effort expectancy for them plays a less important role in forming the attitude. On the other hand, in developing countries, due to the limited resources available to these users in purchasing and trying alternative technologies, the cost-effectiveness of adopting and learning from VR is their first concern in evaluating this technology.

Along with the two expectation-related factors, social influence and facilitating conditions are found to be the other two significant sources of positive attitudes. This finding is identical to previous research [44], and supported in both ED and NG in our research. For social influence, it is natural that users form their attitude partly based on other users’ opinions. In the context of practical learning, since learning is essentially a social experience, users tend to be influenced by others’ comments to obtain a diverse and holistic view. Therefore, to increase the attitude of users towards VR for practical learning, it is important to put efforts into advertising and maintaining a positive social environment for VR use, and encouraging users to recommend VR to their friends. Additionally, facilitating conditions, as a practical basis for the potential usage of VR technology, has a positive influence on attitude. This finding suggests that to use VR for practical learning, one should try hard to cut down the

threshold for the use of VR, by either reducing the hardware requirements or increasing the compatibility of VR to work with other software. The finding is applicable to both developed and developing countries and regions.

Behavioural intention For the direct influences of the UTAUT factors on behavioural intention, the effects of social influence and facilitating conditions remain significant in the general model, while the effects of performance expectancy and effort expectancy are fully mediated through attitude. This finding, clearly, recognises the importance of social influence and facilitating conditions, and implies that these two factors could consistently encourage users to use VR for practical learning, regardless of their personal attitude. This finding is also confirmed by the qualitative data, where participants indicated that they would benefit from the use of VR for learning if universities or learning institutions provide equipment and technical support. A ready-to-use environment and positive social influence could lessen or even erase the concern about adopting VR before its actual use. While the facilitating conditions were supported in both ED and NG, the effect of social influence was only found significant in NG. Developing countries should consider more on social influence, as it will make users think twice about whether or not to use VR for practical learning.

Negative effects Our results indicated a high ratio (53%) of VR sickness reported by the participants, and it was higher in NG than in ED. This represents a challenge to the adoption of VR, since our results associated it with higher levels of anxiety about the use of VR for learning. In addition, it is important to investigate ways to reach women to incentivise the adoption of the technology, as we found a disproportional number of women’s comments that are critical about the use of VR in education.

The NG sample, especially the Chinese respondents seem to be more sceptical about VR. They expect it to be harder and less useful to use than the other populations. Moreover, they presented the highest anxiety about using VR as a tool for learning. This was reflected in their comments about VR: they had the lowest percentage of positive comments and the greatest percentage of negative comments. Perhaps this is associated with their higher rates of VR sickness. They had the highest percentage of participants who declared having felt some discomfort.

6.4 Lessons learned from the study

Our results show that a general model cannot be used for individual countries. In other words, culture shows a big influence on the factors associated with the intention to use VR as a learning tool. Even though the factors that lead people to intend to use VR are different across cultures, the behavioural intention is consistent across the countries we

analysed, and this suggests that VR has the potential to be well-received across cultures, albeit for different reasons.

From the results, we summarise the following main lessons for the adoption of VR in different cultures. (1) Users' self-efficacy in using VR is crucial for them to adopt it. As such, it is important to make the hardware and applications easy to learn and self-explanatory and provide necessary easy-to-follow tutorials. This will positively influence their expectancy, which in turn will lead to positive attitudes and behavioural intentions. (2) For developed countries and regions, it is helpful to manage users' performance expectancy and mitigate the anxiety factor. Users' anxiety can be reduced if their experience of VR symptoms can be improved and minimised or eliminated altogether. (3) For developing countries and regions, users' effort expectancy and social influence play more important roles. Finally, (4) efforts are needed to explore ways to reach women to improve their impressions and motivate their adoption and use of VR.

6.5 Limitations and future work

The focus of this work is on procedural training, which is more fitting for young adults and late teenagers. These results might have been different had we presented the demonstration content focused on children or the elderly. Besides using only age as a control variable, understanding factors that can impact the adoption of VR for learning and training across age groups is interesting and worth exploring in the future studies. In addition to cross-generational aspects, understanding cross-cultural factors across several age groups could be also a potential and fruitful line of work.

We asked if the participants had the resources to use VR (Facilitating Conditions) but we did not explore in detail the socio-economic background of our participants, nor had we analysed the typical income and accessibility of different technological items in the different analysed regions. Socio-economic issues are important and, as our participants come from several places, can be a topic of research by itself. As such, they were beyond the scope of this research, which sought primarily to understand the acceptance and perceived barriers of VR and not its current feasibility. Future work can involve investigating social and economic aspects in more detail.

The number of respondents was not the same across the different countries and regions. While our sample was not perfectly balanced in countries and regions, it is unlikely that it could have a significant impact on our findings. The comparisons between developed and developing countries and regions were balanced pairwise and revealed interesting results. Further research could attempt to collect data from balanced population samples across countries and regions of interest to see if additional insights could be found.

Finally, there are other models that can be used (e.g. UTAUT 2) and other factors that can be included more explicitly (e.g. risk aversion, price sensitivity, enjoyment, collaborative learning, and imaginative thinking). Our adaption of UTAUT and analyses of the collected data have presented some interesting findings and observations, which can serve as foundational blocks on top of which further research can build and extend.

7 Conclusion

Given that in the present-day world teaching in many places had to be moved online, this research investigated a model based on UTAUT to identify factors associated with the intention to adopt virtual reality (VR) for practical learning. In addition to the original constructs, we introduce self-efficacy, anxiety, and attitude as three new constructs that emerged to be relevant to the VR education context, but were not examined in the previous work. We presented the results of a survey with 245 participants. In addition to a general model, we divided the data into two balanced sub-samples, analysed the results from the developed and developing countries and regions separately, and presented some country-specific findings. We observed that the general model could not be easily translated to a specific country or region. Some interesting differences were observed in the cross-cultural comparison. For example, performance expectancy significantly affects attitude in developed countries but not in developing countries, whereas the effect for effort expectancy shows opposite results. Moreover, we observed the challenges imposed by simulator sickness that affects more than half of the participants who had tried VR before and could potentially increase anxiety about using this technology.

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Availability of data and materials Data can be made available upon reasonable request.

Declarations

Conflict of interest The study was categorised as Low-Risk Research (LRR) research, conducted according to the guidelines regulating LRR projects, and approved by the University Ethics Committee at Xi'an Jiaotong-Liverpool University. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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