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Attributes of virtual and augmented reality tourism mobile applications predicting tourist behavioral engagement

Abstract

The study aims to explore the attributes of VR/AR tourism mobile applications (apps) and their impact on Tourist Behavioral Engagement (TBE), mediated by app satisfaction. The authors employed a text mining and Partial Least Squares-Structural Equation Modelling (PLS-SEM) approach to analyze 6,998 Google Play VR/AR tourism mobile apps online reviews. A word frequency matrix (WFM) was generated and used as an input for PLS-SEM to test the raised hypotheses. The findings revealed that utilitarian gratification, perceived usefulness, ease-of-use, and VR/AR immersion features (context awareness, presence, and telepresence) are key predictors of TBE, with app satisfaction playing a critical mediating role between these VR/AR attributions and TBE, emphasizing the vital role of Technology Acceptance Model (TAM) in driving sustained app engagement. The proposed framework advances theoretical literature on the TBE predictors and provides a guide for VR/AR tourism apps developers/designers to enable adoption, engagement, and proliferation among tourists.

Keywords: Tourism Behavioral Engagement, Virtual Reality, Augmented Reality, Tourism Mobile Applications.

1. Introduction

With the advent of Mobile Applications (apps), Virtual Reality (VR) and Augmented Reality (AR) apps transformed the tourism industry, redefining how tourists interact with destinations and setting new paradigms for engaging (Creed et al., 2023). VR and AR tourism apps are virtual technologies that allow tourists to interact with technologies within a simulated environment, revealing the destination in a unique and immersive way (Chung et al., 2024). They bridge virtual and physical environments, connecting tourists emotionally to destinations (Kefi et al., 2024). Additionally, they facilitate tourists' decision-making process, diminishing the risk/uncertainty and attracting more visitors by enabling them to experience tourist destinations before visitation (Trunfio et al., 2022). The interest of the tourism industry is revealed by the 24$ billion expected market growth by 2027 (Statista, 2022). Although the rapid integration and potential of these technologies to revolutionize the tourism industry, there remains a lack of understanding of how virtual technologies influence tourism behavioral engagement (TBE).

Technology engagement refers to an individual's level of involvement, interaction, and connection with a technology (e.g., smartphones and tablets) (Kim et al., 2013). Accordingly, tourism managers can leverage VR/AR apps to enhance engagement and improve tourists' experiences (Fenu & Pittarello, 2018; Omran et al., 2024), creating a highly interactive environment (Katkuri et al., 2019). TBE, with technology, captures value-adding social interactions sustained after the initial adoption of apps (Fang et al., 2017), creating sustained beneficial interactions through referrals or with other users (Tian et al., 2021). The extant literature on the usage of travel apps suggests that quality factors impact user engagement (Ali et al., 2021), while others indicate that gratification aspects enhance user engagement (Fang et al., 2017). In turn, usability app elements influence user engagement (Tian et al., 2021).

Several studies have investigated factors influencing the adoption of VR/AR tourism apps, focusing on usability, technological features, and tourist expectations (Anand et al., 2023; Ustun et al., 2024; Wen et al., 2023; Yu et al., 2024), they fail to identify the drivers contributing to sustained engagement and long-term usage. Others examined app satisfaction as both an antecedent and a consequence of app engagement (Lee et al., 2023; Su et al., 2023), leading to conflicting perspectives on its role in driving TBE. Although immersive, social, and interactive features of VR/AR apps are widely emphasized (Fan et al., 2022; Jiang et al., 2023; Wen et al., 2023; Yılmaz, 2022), the app's utilitarian value has received little recognition, which could be vital in encouraging sustained engagement. Others prioritize VR/AR app technological novelty like vividness and embodiment (Balakrishnan et al., 2024; Sharma et al., 2024; Zhang et al., 2023; Zhu et al., 2024), while they ignore meaningful and user-centric design considerations that align with user needs, creating a mismatch between app capabilities and user expectations and contributing to disengagement. This study aims to investigate the attributes of VR/AR tourism apps that drive TBE. To achieve this aim, 6,998 Google Play VR/AR tourism apps online reviews were collected and analyzed through a multi-method approach, using text mining techniques and Partial Least Squares-Structural Equation Modelling (PLS-SEM) to explore the relationship between variables. The results expect to extend the theoretical knowledge of TBE through VR/AR tourism apps and offer practical contributions for VR/AR tourism apps designers and service providers to foster TBE intentions.

The paper is structured as follows: The introduction outlines the research topic, gaps, and aims. The literature review examines VR/AR tourism apps and develops hypotheses. Methods, results, and discussion follow this. Finally, implications, limitations, future directions, and conclusions are presented.

2. Literature Review

2.1 VR/AR tourism mobile apps

The proliferation diffusion of VR/AR tourism apps and the swift advancement of related technologies have given destination managers/tourism service providers more flexibility in promoting destinations and enriching tourist experiences (Olsson et al., 2013; Yu et al., 2024).

VR tourism is an immersive 3D simulated environment that allows tourists to feel like they are in a real-world environment (Beck et al., 2019), while AR is defined as enhancing a real-world environment using layers of computer-generated images through a device (Dirin & Laine, 2018). While both technologies represent differences, they are increasingly conceptualized under a broader umbrella of immersive and extended reality (Omran et al., 2024). Many tourism apps incorporate AR and VR elements (e.g., 360-degree virtual tourism supplemented by location-based AR features) to enrich user experiences. Accordingly, investigating them jointly provides a comprehensive understanding of app features that contribute to app engagement and offer complementary strengths and synergies that enrich destination perception (AlGerafi et al., 2023; Liebers et al., 2024; Yu et al., 2024).

The literature has suggested VR/AR apps' ability to enhance social lives (Sigala, 2018), create emotional connections with destinations (Olsson et al., 2013), and interact constructively with tourists each other. AR tourism apps offer many advantages, such as environmental awareness, multimodal alerts, flexibility, mobility, and wearability (Baker et al., 2020).

This study integrated the Technological Acceptance Model (TAM) model with the Uses and Gratifications Theory (UGT), emphasizing ease-of-use, perceived usefulness, and utilitarian gratification to construct the conceptual model and applied in VR/AR tourism literature to understand tourists' attitudes, acceptance, and gratifications for adopting such technology (Geng et al., 2024; Marto et al., 2023).

Stemming from the bulk of previous research on the usage of VR/AR apps in the tourism contexts (Table 1), this study asserts the prominence of integrating more than one theory to attain a broad viewpoint of TBE intentions and heighten app satisfaction, by analyzing post-experience real opinions of the tourist (reviews).

Table 1. Prior literature on VR/AR tourism apps

N	Applied Theory/Model	Type of App	Summary of findings	Context	Reference
1	TAM	AR	Perceived usefulness, perceived enjoyment, ease-of-use had a direct effect on the intention to use AR apps. Perceived usefulness, perceived enjoyment were mediators between ease-of-use and intention to use AR apps	Cultural Heritage	Haugstvedt and Krogstie (2012)
2	Stimulus–Organism–Response model (S–O–R)	AR	Operational properties of AR systems trigger feelings of enjoyment and arousal, leading to higher intentions to adopt the AR apps	Destination	Kourouthanassis et al.(2015)
3	-	VR	Presenting the graphical information about the virtual destinations contribute to enhancing VR app usage	Destination	Castro et al.(2017)
4	TAM, and Diffusion of Innovation	AR	The quality of information/system, endorsements, personal innovativeness, and facilitating conditions positively influence tourist perceptions (ease-of-use and perceived usefulness), leading to a favorable attitude to embrace/download AR apps, unlike cost and risks aspects which lead to unfavorable attitude to adopt these apps	Urban Heritage	tom Dieck and Jung (2018)
5	Hofstede's cultural dimensions	AR	Perceived usefulness, perceived ease-of-use , perceived enjoyment, and social influence have a positive influence on behavioral intention to use AR apps, moderated by country context. AR aesthetics influence behavioral intention to use AR apps, mediated by perceived usefulness, perceived ease-of-use , and perceived enjoyment	Cultural Heritage	Jung et al.(2018)
6	UTAUT2 and Task Technology Fit (TTF)	AR	Performance expectancy, facilitating conditions, hedonic motivations, habit, and effort expectancy have a positive effect on behavioral intention to use AR app. Effort expectancy, price value and social influence are not significant	Destination	Paulo et al.(2018)
7	Information system success theory (ISS)/ (S–O–R)	AR	The quality dimensions (information, system, and service) positively influence on tourist satisfaction, leading to intention to reuse AR apps	Destination	Anand et al.(2023)

2.2 Hypotheses formulation

This section reviews relevant literature on the attributes of VR/AR tourism apps in fostering TBE intentions and the mediating effect of app satisfaction.

2.2.1 Utilitarian gratification impact on app satisfaction

Utilitarian gratification enhances practical aspects of the travel experience, leading to favorable tourist behaviors (Cheng et al., 2022). It provides tourists with entertaining/memorable experiences, improving navigation and accessibility to different locations (Akdim et al., 2022).

In the VR/AR context, it represents the tourist's perceptions of VR/AR's ability to deliver an efficient, helpful, and practical/realistic experience in the tourism context (Cheng et al., 2022).

The UGT has been applied in previous VR/AR research to investigate users' behaviors and motivations for smartphone adoption (Kim et al., 2020; Moon & An, 2022). Considering VR as a marketing tool, the gratification content (informativeness) increases app satisfaction to visit the destinations (Geng et al., 2024). Gratification VR/AR elements such as accessing information and learning about cultural heritage sites through storytelling and navigation assistance positively influence tourists' attitudes to these apps and increase app satisfaction levels (Rather et al., 2023). Former studies mainly focused on the utilitarian aspects of general usage of travel apps (Mendes-Filho et al., 2015). Accordingly, limited research focuses on VR/AR tourism apps. Given the swift adoption of VR/AR apps for tourism purposes, identifying the utilitarian aspects of these technologies can create enjoyable and beneficial experiences, allowing designers to develop VR/AR apps to meet tourists' expectations. Hence, the following hypothesis is proposed:

H1: *The VR/AR utilitarian gratification positively impacts app satisfaction.*

2.2.2 Perceived usefulness impact on app satisfaction

VR/AR's perceived usefulness provides tourists with valuable journeys and facilitates the decision to adopt the technology (Archi & Benbba, 2023). It helps to assess the VR/AR effectiveness to enhance the overall experience, including accessibility and information delivery (Yu et al., 2024). The perceived usefulness is the extent to which an individual believes that employing a particular technology will enhance their ability to complete a task (Davis, 1989). VR/AR tourism apps represent tourists' perceptions of how effectively these apps will improve their planning, navigation, acquiring information, and destination interaction (Chung et al., 2015).

VR/AR tourism literature widely employed TAM to understand various aspects of users' technology acceptance (Li & Jiang, 2023; Teng et al., 2024). The perceived usefulness of a travel app, such as improving destination knowledge and providing real-time updates, makes travelers feel fulfilled and satisfied with apps (Gao et al., 2024). AR apps in E-shopping allow customers to try products virtually, choose suitable shades, obtain realistic photos, improve the overall shopping experience, enhancing app satisfaction (Voicu et al., 2023). The perceived benefit attributes of VR/AR (i.e., functionalities, information sharing, and other valuable co-creations) increase tourists' interactions with these technologies, fostering app satisfaction (McLean, 2018; Tian et al., 2021).

Others integrated the attention-interest-desire-action (AIDA) model with TAM, showing that perceived usefulness, driven by personal innovativeness and interest, influences attitude, desire, and VR tourism intentions, ultimately enhancing VR satisfaction (Teng et al., 2024).

Various studies confirmed the positive relationship between VR/AR's perceived usefulness and app satisfaction (Foroughi et al., 2024; McLean & Wilson, 2019). However, the effect of VR/AR perceived usefulness on app satisfaction in the context of tourism apps is understudied. Acknowledging how VR/AR perceived unusefulness helps enhance and optimize VR/AR apps to

meet the tourists' expectations is essential. Accordingly, tourists with positive perceptions of virtual technologies due to their valuable attributes will likely develop a satisfactory app feeling (El Archi & Benbba, 2023). So, we propose the following hypothesis:

H2: *The perceived usefulness of VR/AR positively impacts app satisfaction.*

2.2.3 Ease-of-use impact on app satisfaction

Technology ease-of-use improves efficiency, allowing users to complete tasks more quickly and effortlessly (Camilleri et al., 2023). The user-friendliness and simplicity of VR/AR apps are imperative as they promote their acceptance and ensure a larger demographic of tourists across different age groups embrace them (De Canio et al., 2022). Ease-of-use is when an individual believes using a particular technology will require little effort (Davis, 1989). VR/AR represents tourists' belief that the effortless use of virtual technology contributes to more interaction (Fan et al., 2022).

Several studies employed ease-of-use within TAM to understand the adoption of tourism apps and comprehend tourist perceptions and behavior (Asif & Fazel, 2024; Xiong & Zhang, 2024). Ease-of-use enhances enjoyment/pleasure, impacting the overall experience and increasing tourist VR app satisfaction (De Canio et al., 2022). User-friendly VR/AR apps allow tourists to perceive the destinations in a favorable virtual experience, making it smooth and enjoyable, promoting their app satisfaction, and facilitating high app system quality (Van NGUYEN et al., 2024). The extended TAM model showed that educational quality, social influence, and perceived enjoyment positively affect ease-of-use, enhancing student satisfaction with e-learning technologies (Nazari-Shirkouhi et al., 2023). In hotel booking, VR/AR perceived ease-of-use, such as intuitive navigation and simple booking, significantly enhance app tourists' satisfaction and propensity to utilize VR/AR (Lim et al., 2024). Integrating the expectation confirmation model with TAM

discloses that knowledge-sharing motivation and information system quality enhance perceived ease-of-use, which improves the courier's satisfaction with the online logistics platform (Nazari-Shirkouhi et al., 2023).

Past literature verified a positive relation between AR/VR ease-of-use and app satisfaction. However, it is limited to hospitality (Lim et al., 2024). This relation enhances impulse buying behaviors in tourism services (Do et al., 2020).

Innovative technology can paradoxically lead to app dissatisfaction and negative engagement if this technology proves challenging to operate/run (Batat, 2021). Thus, it is essential to measure how VR/AR app ease-of-use contributes to app satisfaction experiences: the VR/AR user-friendliness attributes enhance its wide adoption and continuance usage (Gharaibeh et al., 2021; Yersüren & Özel, 2023) These features improve apps navigation experiences leading to sustained interactions with these technologies, which in turn creates a positive app satisfaction experience (Fan et al., 2022).

The following hypothesis is postulated:

H3: *The ease-of-use of VR/AR tourism apps positively impacts app satisfaction.*

2.2.4 VR/AR apps immersive features impact app satisfaction

VR/AR immersive features allow tourists to preview destinations before the actual visit, influencing travel decision-making (Trunfio et al., 2022). Besides, it provides tourists with interactive information and cultural interpretations, enriching their experience about destinations (Cho, 2012; Omran et al., 2024).

VR/AR Immersion features are the feeling of being physically present and deeply engaged in a virtual environment resulting from a collection of sensory inputs and presence (Fan et al., 2022).

Various studies validated the role of VR/AR immersion features in enhancing the tourist experience (Bec et al., 2019; Ying et al., 2022). Immersive features increase tourists' social interaction, creating an emotional connection with destinations, which augmented tourist satisfaction with this technology (Verma et al., 2022). Similarly, a higher level of VR/AR immersive features can enhance the novelty and enjoyment of this experience by incorporating factors such as interactivity and sensor stimulation into the environment, leading to more satisfied tourists with these technologies (Lee & Kim, 2021).

Prior literature has only proven the indirect positive influence of a sense of presence on app satisfaction by mediating the role of TAM factors (Fan et al., 2022). Accordingly, no study examines the direct relation between immersive features (presence, telepresence, and context awareness) and tourist app satisfaction with adopting VR/AR apps. It is relevant to examine the connection between VR/AR immersive features and app satisfaction in the context of VR/AR apps to understand the effectiveness of these technologies in tourism engagement and guiding technical improvements for a more immersive, satisfied experience (Voicu et al., 2023). Tourists are expected to be highly satisfied with these apps during their experience in this immersive environment (Luo et al., 2022). Therefore, we formulate the following hypothesis:

H4: *The VR/AR tourism app immersion positively impacts app satisfaction.*

2.2.5 The mediating role of app satisfaction

In the evolving tourism industry, prioritizing tourist satisfaction through technology is paramount for businesses seeking a competitive edge and sustained success (Goo et al., 2022). App satisfaction is an excellent predictor of tourist behavior when adopting travel apps (Ali et al., 2021). App satisfaction describes expectations and performance after consumption the technology (Oliver, 1980).

In adopting VR/AR apps, satisfaction refers to consistency between tourists' initial expectations about VR/AR apps and their actual experiences (Foroughi et al., 2024). In this study, app tourism satisfaction has two dimensions: app emotional satisfaction is a pleasurable feeling using this app when the virtual tour experience surpasses expectations, while cognitive satisfaction is a rewarding experience using these apps within the virtual tour setting (Ladhari, 2009; Martin & O'Neill, 2010).

Tourist satisfaction has been widely discussed in the literature on VR/AR (Anand et al., 2023; Trunfio et al., 2022). Literature explored the mediator role of app satisfaction between the quality aspects of AR apps and reuse intention/intention to recommend (Anand et al., 2023; Jung et al., 2015). Previous research indicated that when tourists perceive elevated levels of VR/AR as beneficial and entertaining experiences, it will enhance technology satisfaction and increase engagement with these apps (Godovykh et al., 2022). The gratification features (i.e., educational aspects) of AR/VR generate an app-satisfactory and enriching experience, fostering engagement with this technology (Trunfio et al., 2022).

To our knowledge, no study examined the mediation role of app satisfaction between VR/AR app attributions and TBE. Understanding the mediating role of app satisfaction in reinforcing the mechanism through which VR/AR app attributes contribute to TBE can encourage app developers to implement an effective design and improvements that satisfy tourists toward these apps and further TBE. App satisfaction is a key antecedent of continuance usage and collaborative (interactive) behavior, attributed to the valuable functionality features of tourism apps such as ease-of-use and immersion (Genç, 2018; Tian et al., 2021). Hence, the following hypothesis is proposed:

H5: *App satisfaction mediates the relationship between the VR/AR app features (i.e., utilitarian gratification, perceived usefulness, ease-of-use, and immersive) and TBE.*

Considering the hypotheses, we propose the following conceptual model (Figure 1).

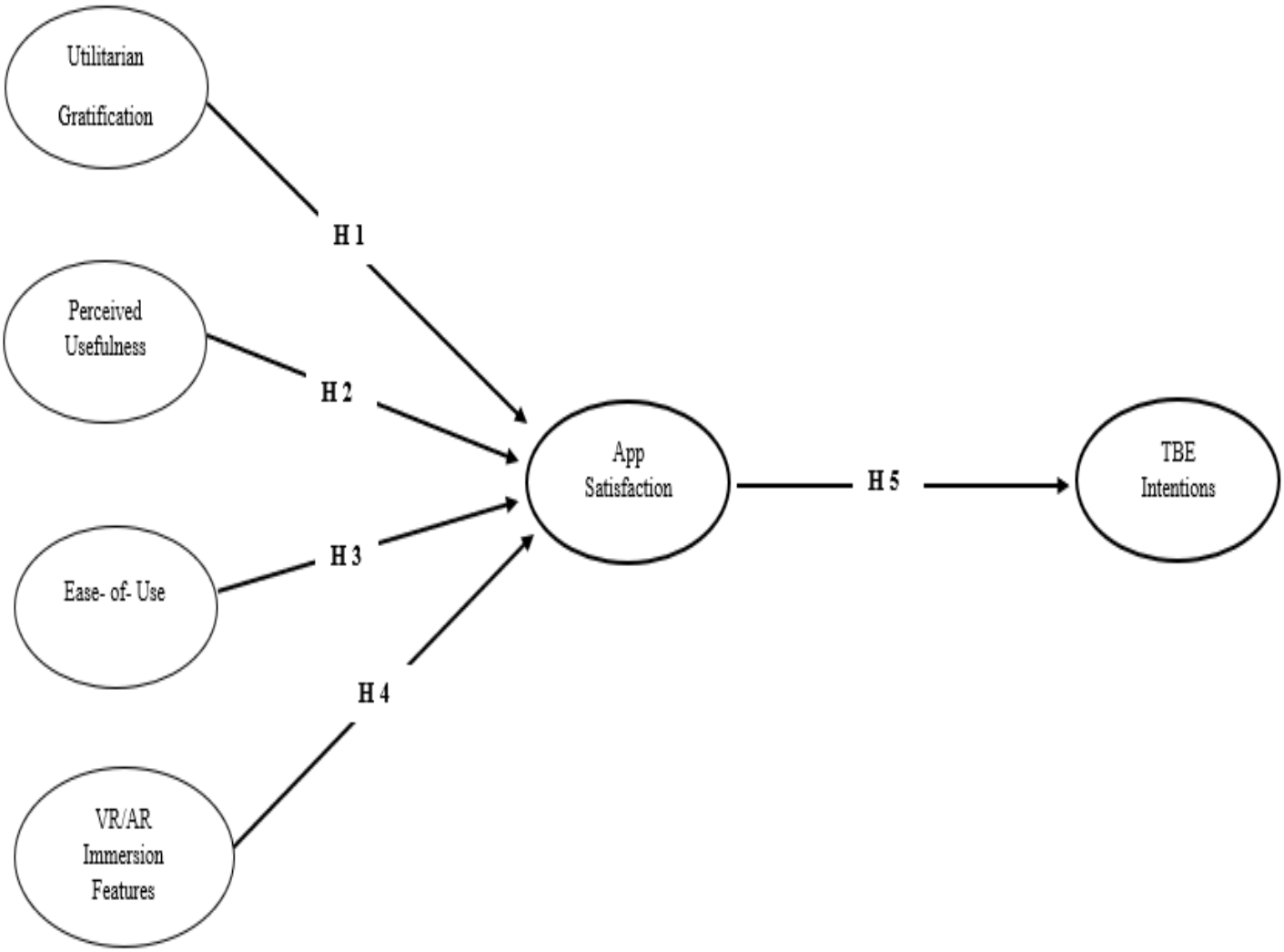


Figure 1. Conceptual Model

This framework provides a structured approach in understanding how VR/AR tourism apps attributes interact with app satisfaction as a mediator to influence TBE, offering valuable insights for tourism management and app designers in optimizing tourist experience and enhancing long-term app engagement.

3. Method

This study employed a multi-method quantitative approach using text mining techniques and PLS-SEM (Ramos et al., 2023; Ribeiro et al., 2024). Data included online reviews from users who experienced tourism VR/AR apps. Online reviews are valuable as they are convenient and offer access to freely contributed opinions with minimal availability issues. The reviews convey the true essence of tourists'/visitors' perceptions (Ribeiro et al., 2024).

3.1 Data collection and preparation

We gathered 6.998 online reviews from ten VR/AR tourism apps to understand TBE intentions with reality technologies. The reviews were collected from the ten highest-ranked VR/AR tourism apps on Google Play, selected based on use-attributed rankings to ensure the inclusion of widely used and highly rated applications, thus reflecting broad user experiences (Table 2). Google Play Store is an app distribution outlet run by Google that provides a wide variety of products where users can download and evaluate apps (Bigabid, 2023). Further, there are 3.5 million apps accessible on Google's Play Store, compared with 2.2 million apps available on Apple's App Store (App Radar, 2022).

Table 2. Dictionary for the TBE intentions model variables

Construct Variable	Items	Example/Terms
Utilitarian gratification	Adventure activities	Discovery, Adventure
	Seeking for exploration	Navigation, Exploration
Perceived usefulness	Expected benefit	Benefit, Usefulness
	Learning and Educational Benefits	Learn, Train, Education
Ease-of-use	User-friendliness	Usable, Use, Simple
VR/AR immersion	Presence	Realistic, Real
	Telepresence	Virtual, Augmented
	Context awareness	Location, Recognize, Sensor
App satisfaction	Emotional satisfaction	Appreciation, Glad
	Cognitive satisfaction	Gratitude, Satisfaction
Tourist engagement	Behavioral	Interact, Involvement, Engage

The reviews that reflect tourists'/visitors' thoughts and perspectives (Quintal et al., 2024) were collected using a web scraping script in R statistical program relying on the 'rvest' package (Galhoz et al., 2024). Prior to data analysis, the data were subject to pre-processing using the 'tm' package. This procedure included the deletion of stopwords, articles, and adverbs and converting the dataset into lowercase (Piccinelli et al., 2021). Stopwords are commonly applied words that lack semantic value, such as "the" and "of" (Ribeiro et al., 2024). Additionally, stemming was applied, which entailed merging identical/similar words into standard terms (e.g., 'loved' or 'loving' = 'love'). Finally, the dataset was broken into single words. Following the approach of Ramos et al. (2023) and Quintal et al. (2024), the individual words that were repeated at least ten times were retained and grouped into relevant theoretical constructs, creating a dictionary (Table 3).

Table 3. Selected VR-AR tourism apps from google play

VR/AR Apps	Rating
1. Gala 360 VR	4.5
2. Relax River VR	4.3
3. Egypt VR 360	4.3
4. Sites in VR	4.3
5. Caribbean VR Google Cardboard	4.2
6. World Virtual Reality Tour	4.0
7. Horizon Explorer AR	4.0
8. Veer VR	3.8
9. Brink Traveler	3.5
10. View Ranger AR	3.5

Two procedures were employed to validate the dictionary and minimize the inherent subjectivity of creating one. Initially, a random assessment was conducted on 5% of the reviews to verify if the terms were contextualized to the items (Piccinelli et al., 2021). Next, following the approach of Ribeiro et al. (2024), the dictionary was revised by an independent panel of three Tourism Marketing experts to evaluate the representativeness of each word in each item. The experts were briefed about the study's aim and the methodology used in this study. When doubts existed after the experts' validation, the authors confirmed the context where the terms were mentioned in the dataset to support the final decision.

3.2 Data Analysis

A word frequency matrix (WFM) was created by crossing individual reviews with the dictionary. Each row corresponds to an individual review, while each column represents the number of times an item was mentioned in a review. For instance, the review "Just dive into it! smooth navigation, endless exploration. Seriously, this app is a game changer for adventurers like me" captured two terms related to "seeking for exploration" (navigation, exploration) and one term related to "adventure activities" (adventurers). The WFM mimicked individual responses to survey

questions linked to theoretical concepts on a case-by-case basis (Ramos et al., 2023). Finally, the WFM was used as an input for PLS-SEM to analyze predictors of TBE.

An overview of the method we employed is presented in Figure 2.

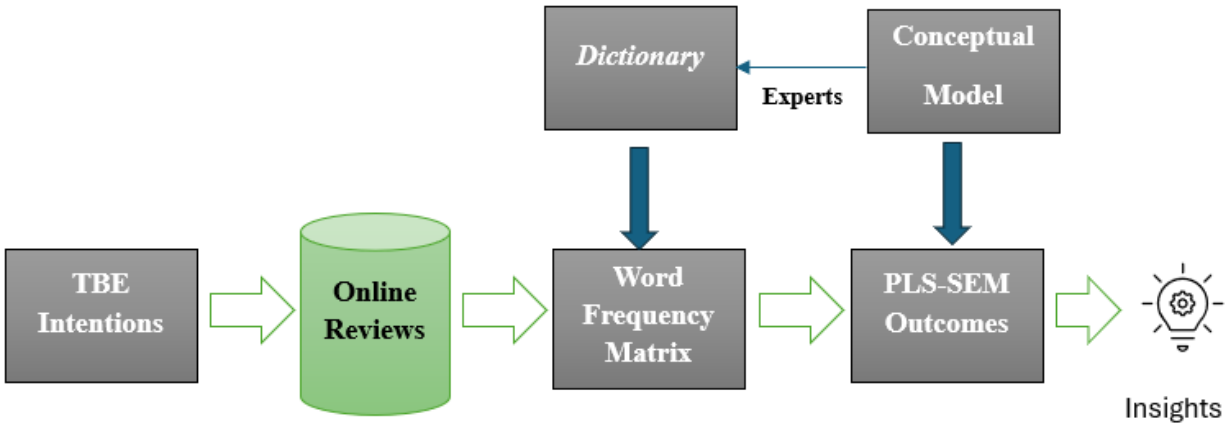


Figure 2. Summary of the data collection and analysis scheme

The proposed relationships were estimated using PLS-SEM in Smart PLS 4 software. PLS-SEM permits the estimation of models with many constructs, indicators, and structural relationships without relying on specific distributional assumptions for the data (Hair et al., 2019). Aligned with the present study, PLS-SEM is regarded as an appropriate approach for theory development studies, mainly when the analysis involves secondary data, metric or quasi-metric, and facilitates the unrestricted use of single-item and formative measures (Hair et al., 2020; Richter et al., 2020). The estimation used a formative assessment instead of the reflective approach, as it allows distinct TBE relationships and does not introduce co-variation issues (Ramos et al., 2023), the six after nonparametric bootstrapping of 5,000 samples following Hair et al. (2019).

4. Results

4.1 Assessing formative measurement model

By checking the items for validity, Table 4 showed that the outer loading of all items was above 0.7 (Hair et al., 2022). The outer weights analysis revealed that all items are positive and significant ($p < .001$, $p < .01$) (Hair et al., 2020).

The values of the inner variance inflation factor (VIF) for the (items and constructs) were calculated and found to be < 3.3, indicating no problem with multicollinearity (Diamantopoulos & Siguaw, 2006). Besides, the F square for all constructs is > 0.02 (Hair et al., 2019).

Table 4. Descriptive statistics, Outer Loading, Outer Weight, T-values

Variables	Item	Min-Max	M/SD	Outer Loading	Outer Weight	T-values
Utilitarian gratification	Adventure activities	0-4	0.193 (0.508)	.898	.505	9.36***
	Seeking for exploration	0-2	0.072 (0.322)	.926	.590	10.82**
Perceived usefulness	Expected benefit	0-2	0.137 (0.43)	.896	.408	5.89***
	Learning and Educational Benefits	0-3	0.118 (0.436)	.962	.660	10.48***
Ease-of-use	User-friendliness	0-6	0.195 (0.54)	1.000	1.000	NA
VR/AR immersion	Presence	0-8	0.193 (0.502)	.714	.478	6.316***
	Telepresence	0-6	0.159 (0.65)	.889	.377	3.031**
	Context awareness	0-3	0.165 (0.555)	.904	.336	4.44***
App satisfaction	Emotional satisfaction	0-9	0.613 (0.508)	.791	.618	25.70***
	Cognitive satisfaction	0-5	0.483 (0.947)	.718	.703	4.44***
TBE	Behavioral	0-4	0.157 (0.675)	1.000	1.000	NA

***Notes**: Min = Minimum; Max = Maximum; M = mean score; SD = standard deviation; β = beta weight; t = t-value; *** = significant at .001 level; ** = significant at .01 level*

4.2 Summary of the model

The estimated TBE hypothesized model has a moderate explanatory power given its high coefficient of multiple determinations (i.e., adjusted R^2), as shown in Figure 4. The four VR/AR attributes explained 25% of the variance in app satisfaction (adjusted $R^2 = 0.254$). Further, app satisfaction explained 45% of the variance in TBE intentions (adjusted $R^2 = 0.454$). The explained variance is acceptable as it exceeds the acceptable threshold ($R^2 > 0.25$) for studies focusing on consumer (tourist) behaviors (Hair et al., 2019) and calculating Q2, with all values > 0, showing the predictive accuracy of our model (Figure 3).

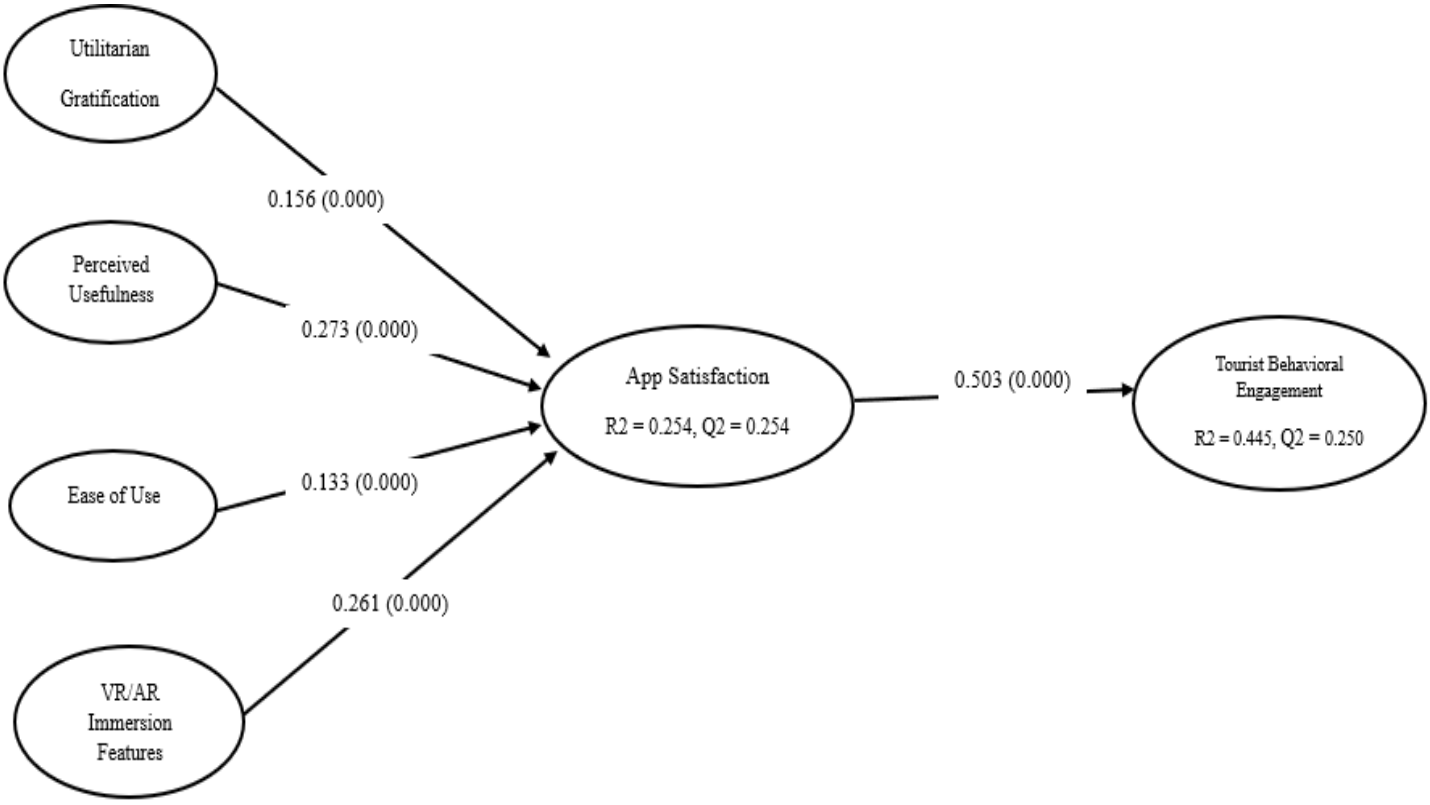


Figure 3. PLS results

All the hypotheses are valid (Table 4). The findings illustrated that utilitarian gratification of VR/AR significantly positively affects app satisfaction, confirming H1($\beta = 0.156$, $\rho < .001$). The perceived usefulness of VR/AR apps has a significant positive impact on app satisfaction, proving H2 ($\beta = 0.273$, $\rho < .001$). The ease-of-use attributes of VR/AR apps significantly impact app satisfaction, validating H3 ($\beta = 0.133$, $\rho < .001$). VR/AR immersion features significantly influence app satisfaction, evoking H4 ($\beta = 0.261$, $\rho < .001$). App satisfaction was a key mediator factor in strengthening the relationship between the VR/AR attributes and TBE intentions, confirming H5 ($\beta = 0.503$, $\rho < .001$).

Table 5**.** Hypotheses testing

Hypothesis	Path	Coefficient (β)	t	P-value	Decision
H1	Utilitarian Gratification → Satisfaction	.156***	5.121	0.000	Supported
H2	Perceived Usefulness → Satisfaction	.273***	7.737	0.000	Supported
H3	Ease-of-use → Satisfaction	.133***	3.787	0.000	Supported
H4	VR/AR Immersion → Satisfaction	.261***	9.094	0.000	Supported
H5	App satisfaction → TE	.503***	13.352	0.000	Supported

Variable	**Explained Variance**	**Predictive Capacity**
Satisfaction	$R^2 = 0.254$	$Q^2 = 0.254$
TBE	$R^2 = 0.445$	$Q^2 = 0.250$

Notes: *β = beta weight; t = t-value; *** = significant at .001 level*

5. Discussion

This study aims to inspect the attributes of VR/AR tourism apps that drive TBE and examine the mediation role of app satisfaction in strengthening this relation. SEM and text mining approaches are combined. This investigation's secondary database included 6,998 VR/AR tourism apps reviews to test the proposed model.

H1 result suggests that adventure activities and seeking exploration via VR/AR apps were predictors of app satisfaction. Prior studies demonstrated equivalent results. Utilitarian benefits (performing bookings and trip planning) via travel apps are increasing app satisfaction (Zhou et al., 2022). In the context of smart tourism technology, which provides gratification benefits like informative content and seamless transaction capabilities, optimizing technology satisfaction (Buonincontri & Marasco, 2017; Ng et al., 2023). In a marketing context, AR apps' utilitarian benefits, such as (learning and skill acquisition and efficiency in shopping) trigger app satisfaction (Nikhashemi et al., 2021). Opposing some prior studies that stated customer satisfaction in AR-enabled shopping environments is powerfully shaped by perceived enjoyment, not utilitarianism, as it permits clients to have a more engaging experience (Pantano & Servidio, 2012). Recognizing utilitarian benefits aids developers in enhancing VR/AR tourism apps' functionality, helping marketers design apps that meet practical tourist needs and increase app satisfaction and adoption. The outcome of H2 indicated that perceived and educational benefits provided by VR/AR impacted app satisfaction, which aligns with the foundational premise of perceived usefulness in TAM as a fundamental determinant of user acceptance, indicating that more users perceive value from technologies, satisfying user experience (Wixom & Todd, 2005). For example, perceived usefulness was a positive antecedent of customer satisfaction with app commerce by Millennial consumers in South Africa (Ngubelanga & Duffett, 2021). Enhance AR satisfaction, demonstrating the value customers derive from these technologies (Do et al., 2020). VR/AR perceived usefulness enhances guest satisfaction with VR/AR in the hospitality context (Lim et al., 2024). Contrary to other studies, perceived usefulness did not significantly impact satisfaction due to mobile shopping in China (Shang & Wu, 2017). This insight underscores that developing

content with learning opportunities and practical benefits in VR/AR app design and marketing boosts app tourists' satisfaction and retention.

Findings from H3 revealed that ease-of-use contributes to VR/AR tourist satisfaction. This finding aligns with the user satisfaction literature (Wixom & Todd, 2005) and the technology acceptance literature TAM (Venkatesh et al., 2012). For instance, positively perceived ease-of-use and customer satisfaction associations owing to e-commerce-related and mobile-based assessments among Millennials (Trivedi & Yadav, 2018). In the hospitality context, ease-of-use without any mental effort via VR/AR to hotels enhances app satisfaction (Lim et al., 2024). The perceived usability of VR apps to be unsophisticated, the headset comfortable, the audio clear, and the visual more interactive, resulting in a seamless ease-of-use and giving users control, improving VR app satisfaction (Jung et al., 2017). In contrast, some works uncovered that perceived ease-of-use was not a significant factor in satisfaction owing to computing device app usage in Asia (Do et al., 2020; Son et al., 2012). This insight helps VR/AR app designers craft intuitive interfaces and guides marketing managers in promoting user-friendly features to enhance customer engagement and retention.

H4 confirmed that context awareness, presence, and telepresence features of VR/AR apps functioned as key drivers of app satisfaction. Our research validates previous studies in the shopping context. The immersive features of AR (vividness) enhance the app satisfaction experience of the customers by providing information utility and enjoyment (Barhorst et al., 2021). AR retail apps' aesthetic/visual appeal makes customers more satisfied with their shopping experience (David et al., 2021). AR aesthetics features such as visual appeal allow tourists to experience more authentic, entertaining, and enjoyable destinations, increasing their AR satisfaction (Han et al., 2021). The presence dimensions (spatial, social, Self-Location, and

departure) of the VR app, yield consistently positive evaluation and attitude, which foster greater VR app satisfaction among tourists (Nam et al., 2023). Understanding this relation can guide the development and promotion of more interactive/engaging aspects of VR/AR, leading to improved tourist retention and competitive advantage.

H5 verified that satisfaction with VR/AR apps is a key mediator between VR/AR attributions and TBE. Similar outcomes to previous studies that satisfaction mediates the relationship between utilitarian benefits and behavior intention (Basaran & Buyukyilmaz, 2015; Ha & Jang, 2010; Hsiao et al., 2016; Livingstone & Helsper, 2010). The functional features of AR games evoke pleasurable feelings and delight players, which ultimately influences behavioral intentions to use AR app games (Faqih, 2022). Besides, this result aligns with prior studies employing the TAM model, such as customer satisfaction with online, digital, and mobile banking platforms, mediating between TAM dimensions and customer engagement with banking services (Kumar et al., 2024). Satisfaction with health apps mediates the relationship between TAM dimensions and the continued use of these apps (Cho, 2016). Satisfaction with self-service kiosks in quick-service restaurants mediated the impact of the extended TAM model on customer behavior intentions (Rastegar, 2018).

Contrary to other studies, long-term technology adoption is determined by repeat use and attitude (Liao et al., 2009). Also, TBE plays a mediator role between TAM dimensions, immersion in immersive technologies, and app satisfaction (Abou-Shouk et al., 2024). From this perspective, improving VR/AR app satisfaction by optimizing app attributions is a bridge to stronger TBE. This insight guides app designers to focus on satisfying tourists and engaging them with these apps.

6. Conclusions

Our study represents a significant advancement in the dynamic realm of TBE with VR/AR by shifting the focus toward the impacting features of VR/AR tourism apps. Our study identified VR/AR immersive features (context awareness, presence, and telepresence), utilitarian gratification (adventure activities and seeking exploration), ease-of-use (User-friendliness), and perceived usefulness (perceived and education benefits) as significant contributors to app satisfaction. In addition, we highlighted tourist satisfaction with VR/AR apps as a critical mediator between these attributes and TBE, as we anticipate that utilizing VR/AR apps will grow swiftly. The findings highlight the importance of enhancing satisfaction with VR/AR apps to boost TBE by optimizing app features. Developers should prioritize seamless usability, immersive/interactive experiences, and perceived utility. Tourism marketers can leverage VR/AR satisfaction to foster deeper long-term engagement. Overall, investing in satisfaction-driven design can amplify the impact of VR/AR on TBE. The research offers a theoretical contribution to the literature by combining TAM and UGT theories to comprehend the TBE with AR/VR tourism apps.

6.1 Theoretical implications

This study presents several considerable theoretical implications for the literature on VR/AR tourism apps covering different tourism contexts. *Firstly*, the study developed and validated a theoretical framework to understand TBE intentions by grasping the attributions of VR/AR tourism apps for impacting tourists' behavior and intention to continue to use/engage with this technology in the future. *Secondly*, this study expands the applicability of UGT and TAM in the context of VR/AR tourism apps in various tourism settings, indicating the diversity and relevance of these theories to vigorously elucidate the technology adoption and behavioral engagement across multiple contexts (Carlisle et al., 2023). This supports the notion that employing multiple

theories can fulfill a valued theoretical framework for exploring nascent technologies to further behavioral engagement (Chung et al., 2015; Lim, 2018). *Thirdly*, the study highlights the central role/mediation of app satisfaction in sparking the relationship between VR/AR tourism app features and TBE intentions, responding to the call of previous scholars for further investigation in this regard (Tussyadiah et al., 2018). *Fourthly*, the study emphasizes the importance of boosting utilitarian gratification of VR/AR apps, which can make trips more trustworthy/beneficial for tourists, elicit emotional/cognitive app satisfaction, and enhance TBE. *Finally*, this study extends the current knowledge of the vital role of VR/AR immersive features to examine their impact on tourists' emotional and cognitive app satisfaction in the context of VR/AR tourism apps. It emphasizes its significance to provide realistic, engaged, enjoyable, and empowering experiences.

6.2 Practical implications

This study's findings offer valuable practical implications for app developers/designers and service providers who pursue leverage from adopting VR/AR tourism apps to bolster app satisfaction and TBE. *Firstly*, developers/designers should enhance utilitarian gratification by providing practical benefits, such as language translation to facilitate communications/interaction with content, live navigation, and dynamic maps. As many tourists mentioned, there is an unavailability of complete information. They should also integrate features that facilitate trip planning, such as virtual avatar tour guides, which offer information about local services, directions, weather, transportation, and essential contacts and answer multiple questions. ***Secondly*****,** developers/designers should improve ease-of-use and create a user-friendly interface that would improve usability, like simple navigation, search features, ease of installation, and clear guidelines—additionally, focusing on implementing tutorials/immersive learning to educate tourists well and make them comprehend the app's functionality. Moreover, frequently update the apps derived from tourist feedback to

tackle usability issues and meet tourists' preferences/needs. *Third***,** regarding boosting perceived usefulness, most tourists who experienced these apps conveyed their role in relaxation/tranquility/well-being, from this viewpoint, the developers should incorporate elements that augment this feeling by adding music, sleep aids, stress-reliever facets that make their immersive journey calming and unwind from the mess in their daily routine.

Additionally, offering virtual collaboration/social interaction opportunities so tourists can share their experiences, exchange information, and participate in virtual group tours will improve their app satisfaction. *Fourth,* enrich the immersive experience by offering high-quality graphics/imagery/3D models, realistic simulations, integrating street view, give users more control, for example, open doors, manipulating objects, dynamic weather, and sunrise light, which make the tour more realistic and interactive. Further, activate context-aware features that adapt content based on tourist location, preferences, and historical interactions with the app. *Fifth,* developers should integrate features/settings to meet disabled users' needs and preferences to facilitate their accessibility and interaction, such as keystroke navigation for those who have mobility incapacities, an understandable guide for those who have cognitive difficulties, and visual contrast/color pallets/varying font size which has challenges in sight. These implementations will allow disabled users to participate /engage with these apps to experience tourism activities. *Lastly,* destination managers/service providers should collaborate with app developers to ensure that VR/AR apps are compatible with destinations/attractions' unique attributes and provide them with updated information about these destinations.

6.3 Limitations and future research

The study has several limitations, and they can be viewed as a basis for future research in elevating TBE. *First*, the study only used reviews from Google Play, which may lead to platform-specific bias and exclude insights from iOS users and those on other platforms. Future research should include reviews from multiple platforms (e.g., Apple App Store, social media, forums) to capture a more diverse range of tourist experiences and opinions. This will better comprehend new features and might provide insights into these apps' continuing adoption and engagement. Second, our study concentrated on the utilitarian aspect of VR/AR tourism apps. Future research should also investigate this technology's hedonic/social factors and their impact on app satisfaction and TBE. *Third*, Future research should incorporate elements related to the content elements of VR/AR apps (i.e., innovation, diversity, and richness) and reality congruence/ realistic feel as mediators in the conceptual model. Understanding these features might provide insights into the continuing adoption of this technology in the future. *Fourth*, the collected reviews do not explicitly distinguish the specific contexts in which apps were used (e.g., for trip planning, during the trip, or post-trip reflection), so verifying their specific app usage behavior is challenging. Further studies could explore the contexts in which travel stage these apps are applied by collecting primary data from users directly or using app analytics that track user behavior. *Fifth*, the study focused solely on the TAM model. It did not integrate the Unified Theory of Acceptance and Use of Technology (UTAUT), which may limit exploring broader factors influencing tourist acceptance and engagement. Future research could explore the integration of TAM and UTAUT to understand better the combined impact of both models on the TBE of VR/AR apps.

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