Virtual Reality
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ORIGINAL ARTICLE

Elucidating the impact of critical determinants on purchase decision in virtual reality products by Analytic Hierarchy Process approach

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Abstract

Virtual Reality (VR) is a technology that uses a specialized user interface to connect people to the virtual world, where they can enjoy a multitude of visual, auditory, olfactory, and tactile experiences. In this study, the analytic hierarchy process method is used to analyze the following four factors that affect consumers' purchase decisions with respect to VR products: VR system requirements, purchase-oriented marketing of VR products, VR application types, and user-friendliness of VR products. Additionally, this study also examines consumer preferences for various VR products. Despite the interviewees' concerns regarding computing power, product pricing, after-sales services, knowledge learning, and user-friendliness, the results of this study reveal that what they need most are VR products that can be used on the go. Therefore, portable VR is expected to be the trend as people are hoping to use VR applications whenever and wherever they wish to use them. This research provides the theoretical and managerial implications for understanding the potential trends for VR products and thus develops the appropriate marketing strategies for them.

Keywords Virtual reality (VR) · VR device · Purchase intention · Analytic hierarchy process (AHP)

1 Introduction

As the name implies, virtual reality (VR) is the simulation of real-world environments using computer graphics to model real scenarios. It integrates computer-related software and hardware devices to create three-dimensional (3D) virtual environments that appear real to users. In recent years, VR has gained popularity and attracted investments from large as well as small businesses. Advances in display technology and improvements in resolution and reaction speed have facilitated the development of interactive devices such as smartphones, head-mounted displays, and VR glasses. The potential applications of VR have been widely discussed in science and technology. In recent years, continuous investments have been directed toward the development and improvement of novel VR hardware products and applications. A special feature of VR is its provision of an experience that is not limited by time and space. It gives participants a strong sense of coexistence, and thus increases their mutual understanding and generates interactions between them. When applied to the field of education, VR could assist students to identify, understand and improve the learning situations (Huang et al. 2016). Furthermore, VR users can achieve realistic visual and auditory stimulations through the use of various induction systems (e.g., 3D glasses and stereo systems). Thus, it can be said that using VR products help learners to immerse in the learning environment and detect learning issues (Huang et al. 2010). Additionally, VR users can interact in a virtual scenario via the appropriate human–computer interface. VR allows the execution of repetitive operations, thus enabling learners to learn important functions through trial and error. This aids them in problem solving.

VR products differ in their price, equipment, and operational specifications. VR products with various

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specifications provide users with varying video/audio experiences and involvements. Given the flourishing VR market, many large multinational companies have invested in the research and development of VR-related products, some of which are HoloLens by Microsoft, Daydream by Google, Vive by HTC, Oculus Rift by Facebook, and Gear VR by Samsung. Google has launched a low-cost VR device called Cardboard to provide beginners with a device that is easy to use (Cochrane 2016).

As software and hardware complement each other, so is application content a crucial factor to VR products. Hence, the development of software application content can be considered a core value of a VR product. Content design and development affect the creation of contents (e.g., scripts, scenarios, modules and music). One of the application areas of VR is in education and learning, where it provides students with experiences that allow them to go beyond traditional textbook-based teaching and learning. VR is not limited by time and space, thus, it offers learning perspectives, experiences, and interactions that are available at any time (Sun et al. 2018). For example, zSpace uses VR so that students can learn directly from the screen by wearing glasses and thus move away from heavy textbooks, and it also uses attractive VR technology to attract students' interest (Brown and Green 2016; Jones et al. 2016). Simulated 3D scenarios in VR produce impressive visual and auditory effects on users. They can also stimulate learning throughout the entire brain. VR establishes 3D spatial concepts, thus reducing the difficulties related to the conversion of 2D images into 3D objects (Kober et al. 2012). An example of the ideal integration of science and technology into education is the ability of the users to control 2D images in a VR environment. Moreover, participants can receive proper guidance in unfamiliar environments by using simulation-based navigators for outdoor traveling, natural environment education, museums, exhibitions, and other learning spaces. For instance, museums in the United States have increased the flow of visitors through the extensive incorporation of iPad- and phone-mediated VR. Hence, VR was successfully implemented in the Van Gogh Museum, helping participants experience their favorite works of art and increasing the number of visitors due to the convenience of mobile devices and VR facilities (Abry et al. 2013).

Due to the intense competition between businesses, the search for innovative new marketing methods is promoted. Thus, many companies have joined the battle in the field of virtual platforms (Shobeiri et al. 2012). Despite the large number of research studies on VR-related factors (Barnes 2011; Goel et al. 2011; Jung 2011; Mäntymäki and Islam 2014; Cheng et al. 2014; Verhulst et al. 2017), few studies have focused on the vital cognitive and decisive factors that affect the consumers' choice of VR. Currently, there are only a few empirical studies and discussions related to consumers' choice of VR equipment. These studies focused their analyses on the selection and preference of VR products by consumers faced with numerous choices. This study aims to understand and evaluate users' willingness and needs in terms of the various aspects of VR use such as VR system level, VR marketing, application content type, and ease of VR use to provide a reference for the development of application content and the related software and hardware.

The remainder of this study is organized as follows. Section 2 introduces the current VR equipment types and applications. Section 3 presents the research methodology, and Sect. 4 demonstrates the analysis results. Finally, Sect. 5 presents findings, practical implications and theoretical contributions of this research.

2 VR equipment types

The concept of VR, as opposed to the simple display of images used in the past, originated from the "Ultimate Display" proposed by Professor Ivan E. Sutherland in the 1960 s. The main concept involved is the use of a 3D space to create an immersive and interactive visual interface that involved sensory interaction. VR products use computer-related software and hardware technologies (e.g., computer graphics and imaging tools) to simulate real-world environments, sounds, and images. This enables users to interact with people and other objects in a VR environment. VR products generate feedback through visual, auditory, and tactile stimulation. They also give users the feeling of being immersed in the virtual environment. As a result, VR is a novel interface for user–information interaction. In general, VR can be categorized into the following types:

- Immersion VR (or immersive VR): this type of VR requires special equipment (e.g., a head-mounted display, 3D mouse, tracker, and data gloves) and it encases the audio and visual perception of its user in the VR environment and cuts out all outside information so that the experience is fully immersive (e.g., Freeman et al. 2014; Slater and Sanchez-Vives 2016).
- Desktop VR: this type of VR only requires a regular multimedia computer and VR software, and it can be operated using a keyboard and mouse. Multiple screens can be used to affect the sense of space and direction. The advantage of a desktop VR is the widespread use of desktop computers and laptops while its disadvantage is the inability of its users to immerse in and perceive a 3D environment due to the 2D display (Santos et al. 2009, 2011; Merchant et al. 2012; Lee and Wong 2014).
- Simulator VR: this type of VR helps to simulate a real environment and special operational interfaces, allowing users to simulate the feeling of actual operations and

control in a specific environment. Simulator VR was the earliest VR system developed. Such a VR system is often used to train pilots or drivers (e.g., Kenney et al. 2009; Cox et al. 2010; Kober et al. 2012; Grabowski and Jankowski 2015).

- Projection VR: this type of VR uses a projector to project a simulated image on a 3D display or wall so that the user is surrounded by the simulated environment. Users can wear 3D glasses to experience VR. The effect of projection VR is similar to that of a 3D motion picture. One of the advantages of projection VR is that it can be used simultaneously by multiple people within a single space and one of its disadvantages is the inability to generate high-level interaction and feedback in such a VR environment (e.g., Huang et al. 2016).

3 Research methodology

To enhance the precision of this study, some existing studies and related reports on global market sales of VR products were used to explore the critical determinants affecting user's willingness to change from early adopters to early followers of VR products.

In this study, some questionnaires were distributed to some participants after which the validity of the questionnaire's contents was verified by five experts. The questionnaire items' correlation and formulation were evaluated according to the research objectives and factors of VR purchase and selection. Questionnaire items with a low degree of discrimination were removed while ambiguous items were revised. The revised questionnaire was used in the formal sample collection, which involved 30 participants including senior information technology users and new technology-adoption pioneers. Based on the scope and types of decision-making problems examined in this study, as well as the number of experts (i.e., 5–15) involved, as recommended in Saaty (2008), the experts and decision-makers were recruited to fill in the analytic hierarchy process (AHP) expert questionnaires, and the factor weights for each level were calculated based on the survey results.

This study also examined consumer orientation toward the use of workstation VR (a computer server connected with a wired head-mounted device, such as HTC Vive) and mobile VR (a phone or mobile device connected with a wireless head-mounted device, such as a smartphone with the Samsung Gear VR). The constructs and criteria for evaluating the key factors for VR product purchase decisions are formulated based on a robust literature review and the AHP theoretical framework proposed by Saaty (1990). The first level included four constructs: VR system level, VR marketing, application content types and ease of VR use. Each construct involved 4–5 evaluation criteria. The final evaluation framework is demonstrated in Fig. 1.

4 Data analysis

Decision-making is a process that involves the evaluation of whether a project should be accepted or rejected. Consumers make decisions by analyzing their experience and information obtained. The AHP is a multiple-attribute decision-making analysis method (Kuo et al. 2008; Velasquez and Hester 2013; Wu et al. 2015). Under the premise that the decision options have already been established, AHP can be applied to determine the optimal choice and it can also be used to provide objective and comprehensive information for decision-making by using a hierarchical framework to decompose complex problems, hence, reducing the risk of erroneous decisions (Saaty 2008).

The main concept of AHP proposed by Saaty (1990) was solving decision-making problems in uncertain situations by applying multiple evaluation criteria. AHP has wide applications in problems related to resource allocation, risk assessment, system design, solution choice, priority establishment, conflict management, planning, and performance measurement (Huang et al. 2011). The first requirement of this method is the establishment of a general objective relevant to the problem, based on which the sub-objectives, that is, lower-level elements, were developed. The procedure was repeated until the final layer of elements was established. Thus, a complex problem could be systematically evaluated by clearly indicated levels. A problem was decomposed into several hierarchical levels, forming a hierarchical structure. The variables of each level were mutually independent. This method facilitated the understanding and analysis of the problem. A ratio scale was used to perform a paired comparison of factors and each pair of evaluation criteria was compared using a 1–9 ratio scale, based on which a comparison matrix was established. The matrix reflected the priority order of factors belonging to each level. Furthermore, factor weights were analyzed based on experts' opinions.

In this study, the Expert Choice software was used to analyze the hierarchical data. After the questionnaire data of individual respondents were input in the software, the questionnaire's consistency index (CI) ($CI < 0.1$) and consistency ratio (CR) ($CR < 0.1$) were calculated to test the reliability of the characteristic vector to avoid bias due to contradictory assessments. The results indicated that the data in this study met the consistency requirement. Thus, the weights for the evaluation criteria calculated in this study were rational and meaningful. The calculation data and results are described below.

The evaluation constructs used in this study are provided in Fig. 2. The analysis results showed that the ratio of ease

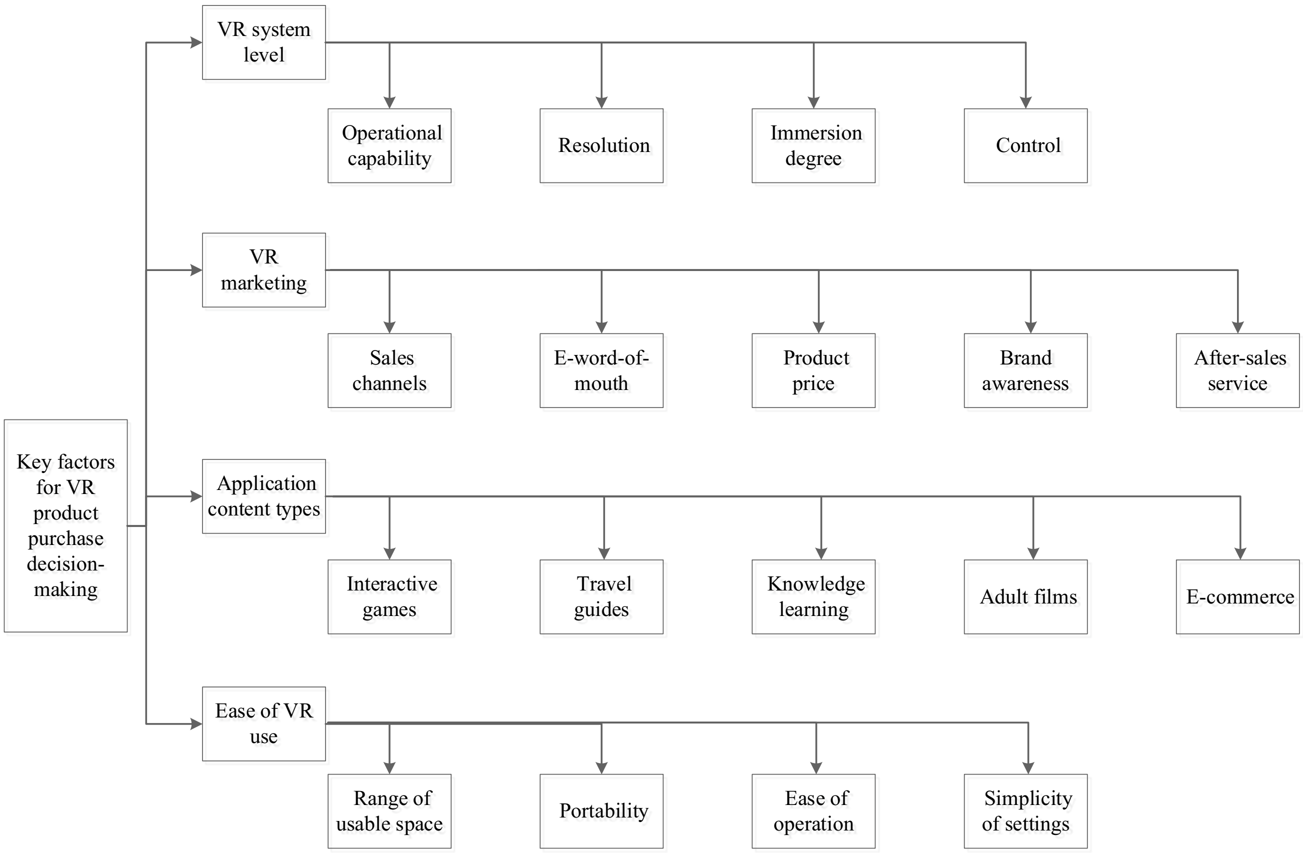

Fig. 1 Research framework

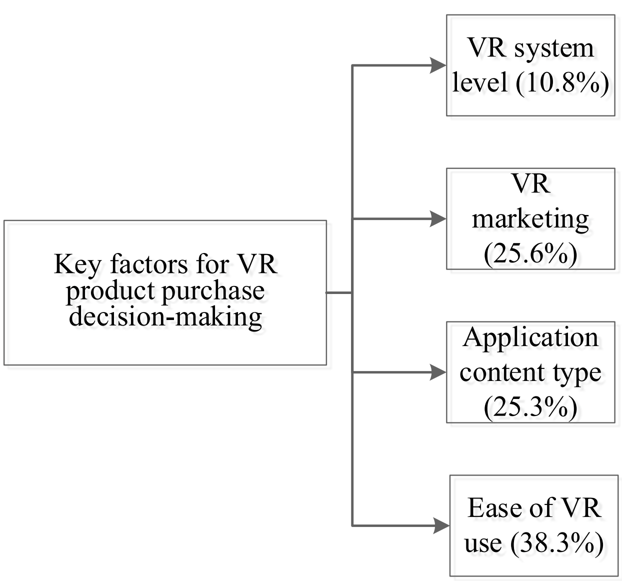

Fig. 2 Evaluation criteria of the key factors for VR purchase decision-making

of VR use was 38.3% among the key factors for VR product purchase decision-making. Hence, this construct had a major influence on key factors for VR product purchase decision-making, followed by VR marketing (25.6%), application content types (25.3%), and VR system level (10.8%).

Apart from SONY products, which have a certain level of market share, the sales growth of VR head-mounted devices has been slow as a whole. HTC Vive and Facebook Oculus have announced price reductions, aiming to transit from the high-end market to the mainstream market in order to expand their consumer base (Tromp et al. 2018). The year 2016 is considered the beginning of the VR era. In terms of the number of products sold on the market in 2016, both HTC Vive and Facebook Oculus did not reach a million units, forming a gap with SONY. Price reduction was a market share strategy used to enter the mainstream market and attract more consumers. The data above show that price is among the factors influencing consumers' experience. With regard to the value of application content, equipment level, and ease of use, this study aimed to explore whether the market would decline in the case of an improved hardware system level but a lack of attractive content, and in the case of attractive content but low ease of use. These issues were addressed by experts. Thus, the ratios of the four construct factors in this study were used to explain the effects of VR head-mounted devices on consumers' experience and willingness to make a purchase.

The results of the VR system level construct analysis indicated that, as suggested by VR experiencers and buyers, operational capability had the largest influence (26.2%) among the evaluation criteria for this construct. However, the ratio of this factor was close to that of control (26.1%), which is only 0.1% higher than the latter. The performance of chips used in modern smartphones has been gradually approaching that of chips used in tablets, laptops, and even desktop computers. Moreover, many users have become increasingly reliant on mobile modes to handle various affairs. In the future, mobile and fixed devices will be similar in their operational capability. Therefore, consumers will pay attention to control items, user-friendliness, and the simplicity of the interface, which explains the proximity values of the two key factors. These factors were followed by resolution (25.3%) and immersion degree (22.3%) (as shown in Fig. 3).

The analysis of the VR marketing construct indicated that, as suggested by VR experiencers and buyers, after-sales service had the largest influence (31.7%) among the evaluation criteria for this construct, followed by product price (25.4%), electronic word-of-mouth (19.1%), brand awareness (16.8%), and sales channels (7.1%) (as shown in Fig. 4).

The results of the application content construct analysis are presented in Fig. 5. The results indicated that, as suggested by VR experiencers and buyers, knowledge learning had the largest influence (24.0%) among the evaluation criteria for this construct, followed by interactive games

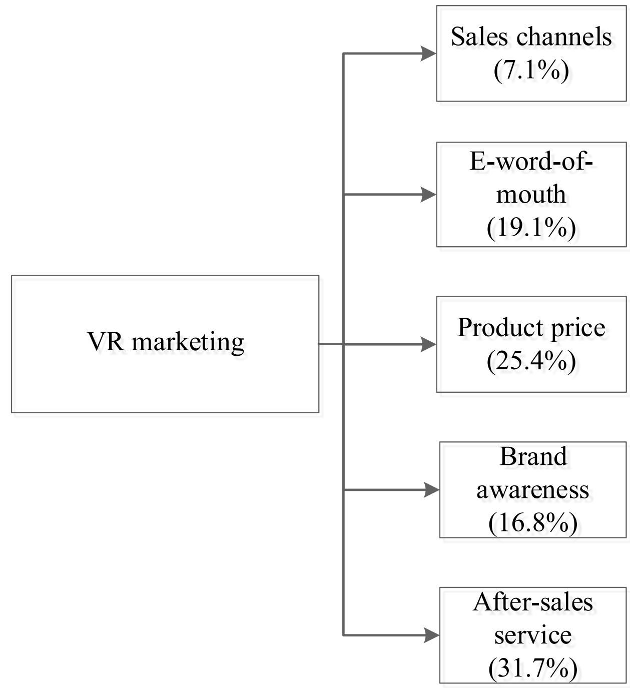

Fig. 4 Results of evaluation criteria in the construct of VR marketing

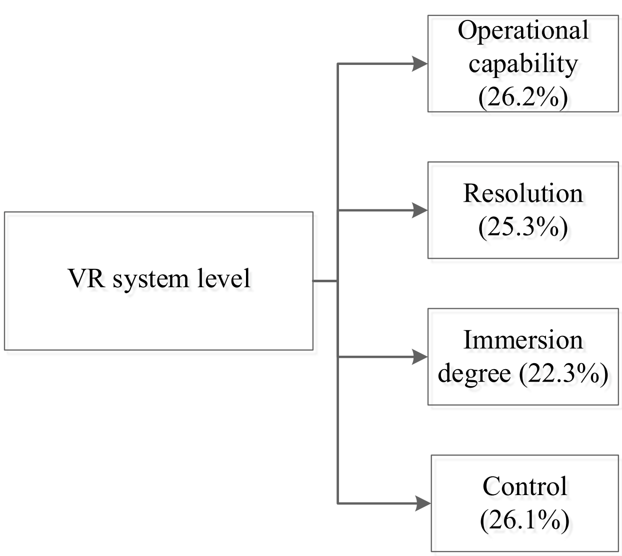

Fig. 3 Results of evaluation criteria in the construct of VR system level

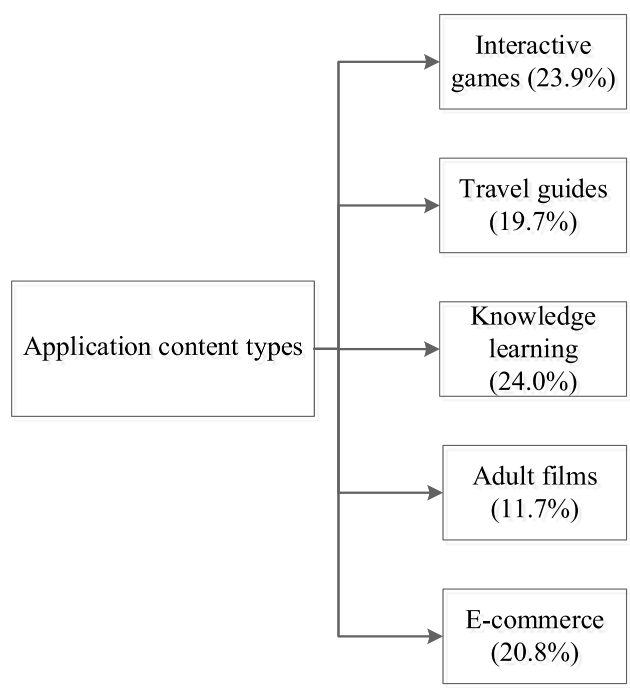

Fig. 5 Results of evaluation criteria in the construct of application content types

(23.9%), e-commerce (20.8%), travel guides (19.7%), and adult films (11.7%). However, according to the questionnaire's results, the ratios of knowledge learning and interactive games differed by only 0.1% and have received the most attention from VR experiencers and buyers. Nevertheless, knowledge learning and interactive games are not the only content pursued by consumers willing to experience or purchase VR but they are also attracted to other types of application content. In the future, VR-related industries can use this information to promote VR sales growth or use related application software to increase the number of consumers willing to experience or purchase a VR product. For instance, Alibaba Group applied VR in e-commerce and Japan adopted VR in adult films (e.g., Lombard and Jones 2013).

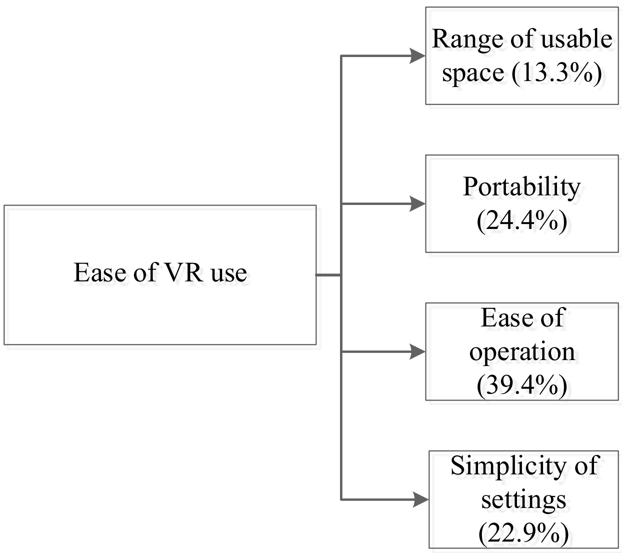

Fig. 6 Results of evaluation criteria in the construct of ease of VR use

The analysis results related to the ease of VR use are presented in Fig. 6. The results indicated that, as suggested by VR experiencers and buyers, ease of operation had the largest influence (39.4%) among the evaluation criteria for this construct, followed by portability (24.4%), the simplicity of settings (22.9%), and range of usable space (13.3%).

Weights were calculated for the evaluation criteria for each construct, and the weights of the constructs were multiplied by the weights of their respective evaluation criteria. Thus, the proportions of each evaluation criterion in the entire evaluation model were obtained. The results were summarized into an evaluation criteria weights table (see Table 1). The descending order of the constructs was as follows: ease of VR use (37.0%), VR marketing (27.0%), application content type (25.4%), and VR system level (10.6%). With regard to the weights of the sub-factors, ease of operation had the proportion of 14.52%; simplicity of settings, 8.99%; and portability, 8.59%. With regard to the sub-factors

Table 1 Weights of constructs and evaluation criteria

Key factor	Key sub-factor	Sub-factor loading (%)	The proportion of total weight (%)	Total weight ranking	Device		
					Workstation VR (%)	Mobile VR (%)	Relative weight
VR system level	Operational capability	26.2	2.83	14	2.83	1.41	0.5
10.8%	Resolution	25.3	2.73	16	2.73	1.37	0.5
	Immersion degree	22.3	2.41	17	2.41	1.20	0.5
	Control	26.1	2.82	15	2.82	2.82	1
VR marketing	Sales channel	7.1	1.82	18	1.82	1.82	1
25.6%	E-word-of-mouth	19.1	4.89	11	4.89	4.89	1
	Product price	25.4	6.50	5	6.50	6.50	1
	Brand awareness	16.8	4.30	12	4.30	4.30	1
	After-sales service	31.7	8.12	4	8.12	8.12	1
Application content type	Interactive games	23.9	6.05	7	6.05	6.05	1
25.3%	Travel guides	19.7	4.98	10	4.98	4.98	1
	Knowledge learning	24.0	6.07	6	6.07	6.07	1
	Adult films	11.7	2.96	13	2.96	2.96	1
	E-commerce	20.8	5.26	8	5.26	5.26	1
Ease of VR use	Range of usable space	13.3	5.09	9	5.09	10.19	2
38.3%	Portability	24.4	9.35	2	9.35	18.69	2
	Ease of operation	39.4	15.09	1	15.09	30.18	2
	Simplicity of settings	22.9	8.77	3	8.77	8.77	1

of the VR system level construct, control had the proportion of 2.81%; operational capability, 2.79%; resolution, 2.55%; and immersion degree, 2.46%. There were no sub-factors with a higher proportion than the factors of VR marketing, application content type, or ease of VR use. Thus, respondents suggested that ease of VR use had a considerable effect on decision-making related to product purchase. Table 1 presents the relative weight multipliers, which were determined with reference to the computer and phone evaluation settings of Computer Hope (2017), including the level of power, screen dimensions, storage capacity, operational system, mobility, and convenience.

5 Discussion and conclusion

In recent years, VR has been one of the fastest-growing smart machine technologies; it can simulate multiple visual and auditory environments and gather multiple sensory feedback features (Lytras et al. 2017). Although some relevant empirical researches have been carried out in the field of VR (e.g., Mäntymäki and Islam 2014; Cheng et al. 2014; Huang et al. 2016; Verhulst et al. 2017), they only focused on the understanding and assessment of the relevant factors relating to VR usage intentions from different viewpoints. The main objective of this study is to propose and verify the critical determinants of purchase and selection of VR products. VR has potential applications in education as it provides a visual and auditory stimulation of the real-world environment. This helps to reduce the number of cognitive layers needed as well as the risk of possible erroneous concepts that could be generated in the process of converting printed data into a proper mental model. Many factors influence consumers' decisions on VR products to be purchased. These factors include the following: considerations of usable space, ease of operation, portability (similar to that of a phone), the appeal of the application content, attractiveness, after-sales service, and price.

In this study, we formulated the key criteria for the evaluation of VR product purchase decision-making following the sampling and analysis procedure. The analysis results with respect to the relative weights and the priority order of the evaluation criteria are discussed as follows. Firstly, with regard to the four main constructs, the construct of ease of VR use was found to have the greatest effect on consumers' willingness to experience or purchase VR products. These findings show that consumers' considerations of mobility and convenience must be given attention to in future research and development of VR products.

Secondly, with regard to the evaluation criteria relating to application content types, the concerned industries can consider and develop knowledge learning, interactive games, e-commerce, travel guides, and adult films. The related companies can establish future VR development goals by taking into consideration the software users and the five factors.

Thirdly, with regard to the evaluation criteria for each construct, the weight analysis ensured that the criteria with relatively higher importance were associated with a higher importance in the entire construct. Moreover, the analysis results confirmed that the leading factors affecting consumers' willingness to experience or purchase VR products included ease of operation, portability, the simplicity of settings, after-sales service, and product price.

Fourthly, with regard to the evaluation of solutions, weight analysis indicated that "Phone VR" was the optimal solution that affected consumers' willingness to experience or purchase VR products. Moreover, the results showed the tendencies and variations among consumers' willingness to experience or purchase VR products based on the ease of VR use, application content type, VR marketing, and VR system level.

The gradual integration of VR products into the mainstream market requires dialogue and planning. Although VR products are currently not as popular as smartphones and video games, the frequency of VR utilization as well as its acceptance among consumers, has been growing slowly. Moreover, due to the introduction of the price reduction strategy, VR sales increased in 2017. The official global sales of VR devices in the third quarter of 2017 exceeded 1 million units, marking the first time that this figure has surpassed the 1 million mark within a single quarter (Alto 2017). Concerning VR use in the future, the founder of Facebook, Mark Zuckerberg, hopes that VR products will not be limited to a single location or fixed space, become portable and easy to use and operate, and hence become part of social interaction—forming the so-called social VR (Tromp et al. 2018). Although price reductions are widely implemented to promote the growth of the VR market, with respect to product specifications, HTC's Vive outperforms Facebook's Oculus in terms of system level. However, Facebook's Oculus is easier to use than HTC's Vive. Moreover, Mark Zuckerberg announced that VR devices that are easy to use, portable, and more affordable will be developed in the future; the estimated price of such a product is below $200. At the same time, another tech giant, Google, has launched a simplified VR product called Cardboard, which can be easily used by consumers interested in VR and willing to understand or experience it. Users can experience VR by using Cardboard with their phone. A slightly more advanced product is Google Daydream, which provides a fast mobile experience via phone and portable remote control. The ideas and products of the tech giants validate the conclusions of this study. Respondents willing to experience or purchase VR products expected it to be portable, easy to operate, and have simple settings. The analysis results and conclusions provide a reference and basis for the development of products and market decisions by related industries. They also help the industries to complete plans and achieve goals related to VR products.

The analysis performed in this study focused on the key factors affecting consumers' willingness to purchase or experience VR products. This study also aimed to evaluate the trends in consumers' choice of VR products. However, due to limited research resources and the incompleteness of the evaluation criteria, the following suggestions are proposed as a reference for future studies. Firstly, the hierarchical structure and evaluation criteria established in this study did not consider the effect of culture, technological development, gender, age, and other characteristics on consumers' willingness to experience and purchase VR products; in this case, different evaluation criteria may be applied. Future studies should also consider various details about the participants so that the developed evaluation model matches the market demand. Secondly, the hierarchical structure and evaluation criteria in this study were established based on related literature and experts' suggestions only. However, national culture, technological development, ethnic group, region, and community culture may also affect consumers' willingness to experience or buy VR products, in which case another set of different evaluation criteria may be applied. Therefore, future research should consider various details about the participants so that the developed evaluation model matches the market demand.

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