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ORIGINAL ARTICLE

Understanding user behavior of virtual personal assistant devices

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Abstract

With the development of artificial intelligence technology, the market for virtual personal assistant (VPA) devices is emerging as a new battleground for global information technology companies. This study develops a comprehensive research model, based on perceived value theory, to explain potential customers' intentions to adopt and use VPA devices. It investigates the relationship between perceived usefulness, perceived enjoyment, and product-related characteristics (i.e., portability, automation, and visual attractiveness). The research model and hypotheses are evaluated through Partial least squares analysis, using 313 survey samples. The results show that perceived usefulness and enjoyment have a significant impact on usage intention. Among the three constructs reflecting software- and hardware-based utilitarian value, content quality has the strongest impact on perceived usefulness. From the perspective of hedonic value, content quality, which is also a utilitarian attribute of VPA devices, and visual attractiveness positively affect perceived enjoyment. This study concludes by discussing implications and offering useful suggestions for academia and practice.

Keywords Virtual personal assistant (VPA) device · Perceived value · Portability · Automation · Content quality · Visual attractiveness

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1 Introduction

In the late 2010s, virtual personal assistant (VPA) devices emerged as the next mainstream artificial intelligence service platform. Large global ICT (information and communication technology) companies are starting to compete fiercely in this new market. The products include Google's Google Home, Amazon's Amazon Echo, Apple's HomePod, and Microsoft's Invoke, all of which are voice-enabled devices for answering users' questions, making a phone call, sending a text message, and searching for specific information that users want to obtain (Saad et al. 2016). VoiceLabs (Marchick 2017) reported that 24.5 million VPA devices will ship in 2017. This figure will represent a significant increase from 1.7 million in 2015 and 6.5 million in 2016. Gartner (2016) anticipate that by 2020, global spending on VPA devices will exceed US $2 billion and 3.3% of households worldwide will have adopted VPA devices.

The advantage of VPA devices lies in their flexibility, and their potential to be used in various ways. For example, VPAs can evolve into hub devices for smart homes. Through VPA devices, residents can control home appliances such as televisions, refrigerators, washing machines, and lights. Further, if VPA devices learn individuals' life patterns, schedules, and tastes by using artificial intelligence (AI) algorithms such as deep learning, proactive smart home services will be realized that do not need people's intervention (Augusto and Nugent 2006). VPA devices can also be used in the workplace. In March 2017, Amazon announced the integration of Amazon Echo with Microsoft's Office 365 calendar. Through this connection, people can command their Office 365 calendars with voice control; for example, they can seek information about future appointments and add or cancel meetings. Moreover, a B2B company, Teem, recently built an application that enables users to book or extend a meeting while in-room, as well as for online booking, with Amazon Echo.

Despite the positive prospects and usability of VPA devices, there is a major concern about VPA diffusion: VPA applications struggle to retain users. According to a report from VoiceLabs (Marchick 2017), only 3% of users are active in the second week. This means that users are not attracted to current VPA devices. However, the reasons are not clear. It may be a hardware or software problem, or both. For instance, recent VPA devices are similar in appearance, which can affect their visual attractiveness to users. In addition, contents delivered by VPA tend to be playful in order to attract attention. As a result, users may not be aware of its practical value yet. In academia, a limited number of studies have been undertaken on user adoption and behaviors concerning VPAs, because the devices have only been commercially available in recent years. In addition, the literature focuses only on software-type VPAs. Jiang et al. (2015) suggested that an automatic method should be used to assess user satisfaction with VPAs. Further, Saad et al. (2016) assessed the usability of VPAs with various levels of multimedia immersion.

This study integrates several strands of the literature to investigate the perceptions and adoption behaviors of users regarding VPA devices. It discusses

whether hardware or software factors play a more important role in the diffusion of VPA. It also examines the effects of VPA's convenience, functional, content, and esthetic aspects on user acceptance. Perceived value (utilitarian value and hedonic value) theory, which is widely used in the IT field, is applied as the main theory. This study then develops a new comprehensive model that views utilitarian value and hedonic value as multidimensional constructs that reflect the characteristics of VPA devices.

2 Related literature

2.1 VPA devices

A VPA device is any type of device that is equipped with a software agent that provides professional, technical, or social assistance by automating and simplifying many daily tasks (Saad et al. 2016; Santos et al. 2016). The origins of these devices are software-type VPAs such as Siri, Google Assistant, and Cortana. Indeed, all VPA devices are based on these software-type VPA and AI technologies. Current commercial VPA devices can understand users' voice commands and provide appropriate information or services. Some VPA devices even react to people's gestures through embedded cameras and sensors. Table 1 compares a range of VPA devices.

Jiang et al. (2015) summarized the major functionalities of VPA devices as (1) dialog, (2) web search, and (3) chat. A dialog function enables users to interact with devices for specific commands such as calling somebody. Through a web search function, users can search and identify specific information in the same way as using the traditional Internet. A chat is a form of informal communication with VPAs (e.g., who is your father?). Technically, VPA devices are driven by AI functions such as voice recognition and natural language processing algorithms. First, embedded multiple microphones listen and record users' voices and send the recoded files

Table 1 VPA devices comparison

	Apple	Google	Amazon	
	Apple Homepod	Google Home	Amazon Echo	Echo Look
				
Price	$349	$129	$179	$200
Dimensions	6.8×5.6″	5.6×3.8″	9.3×3.3″	6.3×2.4″
Wake-up word	Hey Siri	OK google	Alexa	Alexa
# of microphones	6	2	7	4
# of speakers	8	3	2	1
# of cameras	N/A	N/A	N/A	1

to a natural language processing cloud server via the Internet. Then, servers interpret users' commands and provide the best answers or select the most appropriate services (e.g., confirm an appointment's time, play music, call somebody). Lastly, VPA devices reply to users based on text-to-speech (TTS) technology. Figure 1 illustrates the service flow of the Amazon Echo VPA device.

The performance of VPA devices depends on the number of equipped interactive voice applications (e.g., Amazon Skill and Google Action). Consequently, VPA manufacturers have released a software development kit (SDK) to external third-party developers, thereby enabling the latter to enhance the interactive voice application development ecosystem. According to Kinsella (2017), Alexa skills that are available to U.S. users officially surpassed ten thousand in the first quarter of 2017, while Google Home has only 165 actions.

Even though VPA-enabled wireless speakers are currently popular, they will evolve into various forms and will be used in many industries. For example, the personal service robot, JIBO, which is currently under development, can recognize users' faces and voices and interact with users like a friend. It can also play games

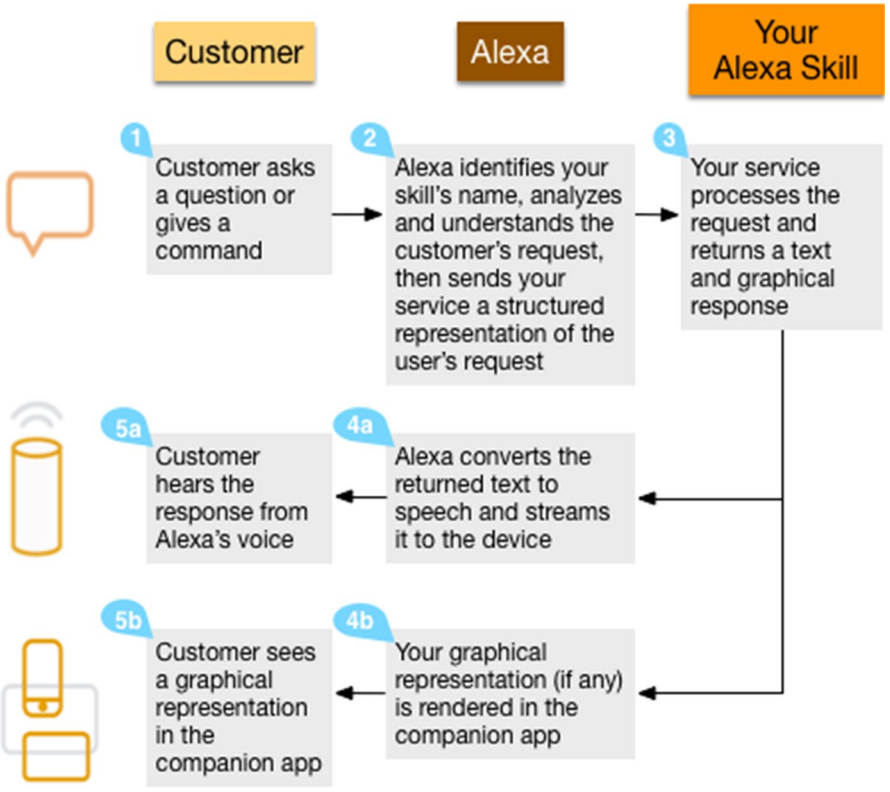

Fig. 1 Service Flow of Amazon Echo (https://developer.amazon.com/public/solutions/alexa/alexa-skills-kit/overviews/understanding-custom-skills)

and read books to children. Further, LG Electronics has introduced commercial robots, which come with their own voice recognition system, to Incheon International Airport. The robots can understand not only Korean but also English, Chinese, and Japanese. In addition, they can provide information such as the locations of boarding gates and escort services for visitors.

2.2 Technology adoption in AI based services, including VPA devices

In the ICT service business value literature, AI has received considerable attention in terms of technology adoption. For example, Liker and Sindi (1997) developed and tested a user acceptance model for expert systems, which emulate the decision-making ability of human experts, based on theory of reasoned action, and identified that the intentions to use these systems were affected by attitude, perceived usefulness, perceived impact on career, and perceived impact on job security. Jen-Hwa Hu et al. (2005) examined user acceptance of ISI (Intelligence and Security Informatics) in a law enforcement context, and found that technological usefulness and efficiency gain positively affected the intention to accept. Augusto and Nugent (2006) insisted that AI could improve smart-home functionalities by proactively and intelligently helping residents. Zhang and Curley (2018) explored the effect of explanations within an online recommender agent (RA) to consumers' trust in the RA and their willingness to adopt its recommendations. Fan et al. (2018) investigated the factors that impact healthcare professionals to adopt the AIMDSS (Artificial Intelligence-based Medical Diagnosis Support System) by introducing a new model, based on original UTAUT (Unified Theory of Acceptance and Use of Technology). Fountoukidou et al. (2018) concluded that the use of artificial agents as a behavioral model leads to an increase in computer self-efficacy and perceived ease of use of an eye-tracking software.

In addition, as the popularity of VPA devices increases, so does research in the field. Moorthy and Vu (2014) attempted to understand the perceived acceptability of using VPAs in smartphones, and showed that smartphone users prefer to use VPAs in a private location rather than in a public space. Reis et al. (2017) analyzed the features of the commercialized VPA devices and preliminary proposed the best product to strengthen the elderlies' social bonds. Wallace and Morris (2018) tested the usability of Amazon Echo and Google Home for patients with mTBI (mild Traumatic Brain Injury) by comparing the ease of their set-up process, perceived design, and perceived functionalities, and conducting an overall assessment of the two devices (Table 2).

2.3 Utilitarian value and hedonic value

Perceived value is significant to understanding users' adoption behaviors. Many researchers in the marketing and information systems (IS) fields have tried to define perceived value in various ways. Ultimately, perceived value is "the consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given" (Zeithaml 1988). Following this conceptualization, some studies

Table 2 Previous research on AI services

Researcher	Topic	Key components
Liker and Sindi (1997)	Willingness to use Expert system	Perceived usefulness, perceived ease of use, perceived impact on valued skills, subjective norms
Jen-Hwa Hu et al. (2005)	Willingness to use ISI (Intelligence and Security Informatics)	Perceived usefulness, perceived ease of use, efficiency gain
Augusto and Nugent (2006)	Enhancement of smart home functionalities with AI	Artificial intelligence
Zhang and Curley (2018)	Willingness to use RA (Recommender Agents)	Integrity, competence, perceived personalization
Fan et al. (2018)	Willingness to use AIMDSS (Artificial Intelligence-based Medical Diagnosis Support System)	Initial trust, social influence, performance expectancy, effort expectancy, propensity to trust, task complexity, personal innovation, technology characteristics
Fountoukidou et al. (2018)	The impact of artificial agent on computer self-efficacy and perceived ease of use of an assistive technology	Agent social modeling versus agent lectures, Agent likeability
Moorthy and Vu (2014)	Willingness to use VPA on smartphone	Location, private information, perceived social acceptability
Reis et al. (2017)	Analysis of the functionalities of commercialized VPA devices for the elderlies' social bonds	Create a shopping list, check calendar, set alarms, play music, control home temperature and light, etc.
Wallace and Morris (2018)	Usability test of VPA devices by military combat veterans with mild traumatic brain injury	Set-up process, design, functionalities, overall assessment

have suggested a multidimensional perceived value construct. For example, Holbrook (1999) categorized customer value as excellence (quality), play, aesthetics, esteem, status, ethics, and spirituality. Sheth et al. (1991) proposed multiple perceived value dimensions consisting of social, emotional, functional, epistemic, and conditional dimensions. Sweeney and Soutar (2001) suggested emotional, social, quality/performance, and price/value for money factors as a consumer-value scale. Teke et al. (2012) classified perceived value into four dimensions: functional, economic, emotional, and social. Current studies tend to define three perspectives of perceived value, namely, utilitarian, hedonic, and social views (Hsiao et al. 2016).

The most common way to analyze perceived value as a multidimensional construct is to examine utilitarian and hedonic values. These are key values to comprehend consumers' assessments of consumption experiences (Babin et al. 1994). Utilitarian value is defined as "an overall assessment of functional benefits and sacrifices" (Overby and Lee 2006). Utilitarian value is economic value, and incorporates the assessment of convenience and saving of time (Teo 2001; Zeithaml 1988). However, hedonic value is "more subjective and personal than its utilitarian counterpart and resulting more from fun and playfulness than from task completion" (Babin et al. 1994). A recent IS study added social value to existing utilitarian and hedonic value as a new component of perceived value. According to Yu et al. (2013) study, hedonic value has a strong positive impact on user satisfaction for location-based social networks (LBSNs).

In this current study, we adopt the pervasive two-dimension (utilitarian value and hedonic value) view, and additionally deconstruct these two values, taking into account the inherent attributes of VPA devices and usage patterns.

3 Research model and hypotheses development

The research model of this study is shown in Fig. 2. The model extends the perceived value theory with the sub-factors of customers' utilitarian value (i.e., perceived usefulness, automation, and content quality) and hedonic value (i.e., perceived enjoyment, visual attractiveness, and content quality, the last of which is also a sub-factor of utilitarian value). Thus, the model reflects not only the high-tech hardware characteristics of VPA devices, but also their AI-based software characteristics. Note that this study does not consider perceived ease of use because it is only meaningful for non-experienced users (Wu and Wang 2005); further, most VPAs have similar user interfaces and usability.

3.1 Perceived usefulness

Perceived usefulness refers to "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis 1989, p. 320). With regard to this definition, it can be said that perceived usefulness is conceptually similar to utilitarian value in that it emphasizes task-oriented customer value. Indeed, in prior studies, perceived usefulness has been considered one of the most

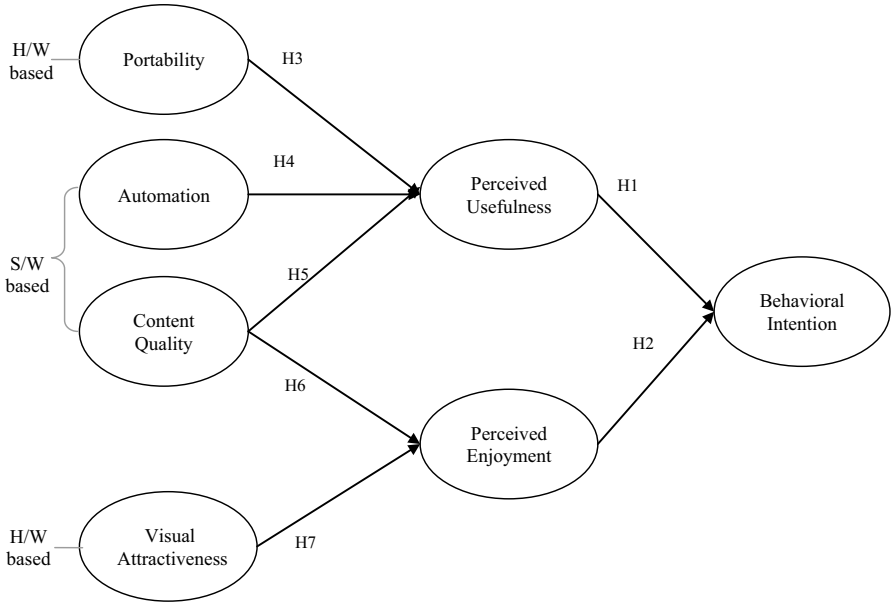

Fig. 2 Research model

important utilitarian and extrinsic values (Hsu et al. 2014; Kalinic and Marinkovic 2016). Kim et al. (2007) categorized perceived usefulness as a utilitarian benefit component of the adoption of the mobile Internet. Many studies have also verified the causal relationship between perceived usefulness and the adoption of ICT products and services (Saeed and Abdinnour-Helm 2008; Seol et al. 2016). Yang and Lee (2017) showed that the perceived usefulness of streaming media devices positively affect the intention to use the devices. Park and Chen (2007) proved that usage intention regarding smartphones is strongly influenced by perceived usefulness. In Suki and Suki (2017) study, perceived usefulness represents the most significant influence on individuals in respect of their intentions to use mobile ticket-booking applications.

H1 Perceived usefulness positively affects the behavioral intention to use VPA devices.

3.2 Perceived enjoyment

Perceived enjoyment has been considered as a critical hedonic and intrinsic motivation for adopting information technology products and services (Venkatesh 2000; Yang et al. 2016). It is defined as "the extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated" (Davis et al. 1992). Childers et al. (2002) argued that perceived enjoyment embodies the hedonic aspect of interactive media-based

services, while perceived usefulness reflects the more instrumental aspect. Many studies have investigated the impact of perceived enjoyment on behavioral intention (Hung et al. 2016; Wang et al. 2013). Kim et al. (2007) treated perceived enjoyment as the representative component of hedonic benefit, and found that it is the most important factor that affects the intention to adopt the mobile Internet. Chen et al. (2014) focused on perceived enjoyment as the representative intrinsic motivation of blog service usage and showed that the novelty, understandability, and interest of blogs' content positively affect behavioral intention through perceived enjoyment.

H2 Perceived enjoyment positively affects the behavioral intention to use VPA devices.

3.3 Portability

Portability refers to users' feelings about the perceived mobility of specific devices (Park et al. 2015). It is directly related to the functionality of mobile devices because it can enhance the service access points of users (Yang et al. 2017). In 2016, Amazon unveiled Amazon Echo Dot and Amazon Tap, both of which are smaller and cheaper than Amazon Echo, their forerunner, but with almost the same features. This development means that customers can use VPAs more easily than before by deploying smaller devices in each room at home or by carrying them outside. Thus, portability can be a core component of utilitarian value, because it allows customers to use VPA devices without space constraints in order to complete their tasks. Such portable devices also offer an economic benefit because they sell for a lower price than their larger equivalents. Teo et al. (1999) found that product portability is positively related to satisfaction and attitude. In the case of a long-term evolution (LTE) service, the mobility affects system/service quality and perceived usefulness (Park and Joon Kim 2013).

H3 Portability positively affects the perceived usefulness of VPA devices.

3.4 Automation

Parasuraman and Riley (1997) defined automation as "the execution by a machine agent of a function that was previously carried out by a human." Luor et al. (2015) argued that automation has been widely adopted because it can improve affordability and simplicity in a smart home. Fully proactive automation, which is the long-standing dream of a smart home, can be realized by AI (Augusto and Nugent 2006). The current study defines automation as the execution of tasks by VPA devices without human intervention, thereby significantly improving users' job performance and lives by such means as automatically receiving missed calls/e-mails, informing users of their personal work schedules, and noticing breakdowns of linked home appliances. Moreover, Croxatto et al. (2016) verified that laboratory automation positively affects the turnaround time for microbial detection and

identification. Further, Luor et al. (2015) showed that the automation function is positively related to residents' attitudes about using smart homes.

H4 Automation positively affects the perceived usefulness of VPA devices.

3.5 Content quality

VPA devices can provide users with all types of content such as voice, text, image, and video content through embedded speakers or displays. Thus, high-quality content is the most important criterion for the performance of VPA devices. Content quality reflects users' perceptions of immediacy, richness, and personalization of the provision of all types of content via VPA devices (Jung et al. 2009). Existing studies have proved that high-quality content influence positive user behavior (Koo et al. 2015). Yang and Lee (2017) showed that the content quality of a streaming media device such as Google Chromecast is positively associated with perceived usefulness and flow. Jung et al. (2009) also revealed that the content quality of hedonic IT has a positive influence on flow and perceived usefulness. Yu et al. (2017) verified that the media content of tablets positively affects perceived usefulness and perceived enjoyment. Thus, content quality has utilitarian and hedonic attributes. Indeed, informative and task-related content can increase perceived usefulness for users. Content such as music, movies, and photographs that is tailored to a user's taste is closely related to perceived enjoyment.

H5 Content quality positively affects the perceived usefulness of VPA devices.

H6 Content quality positively affects the perceived enjoyment of VPA devices.

3.6 Visual attractiveness

Visual attractiveness has been regarded as one of the most important attributes of hardware products. Bloch (1995) insisted that product design may elicit an aesthetic response relating to customers' hedonic experiences. Many studies about user adoption of IT products and services have argued that a product's visual attractiveness has an effect on the emotional attachment of users (Hsiao 2013). Yang et al. (2016) showed that the visual attractiveness of wearable devices is a significant antecedent that positively affects perceived enjoyment and social image. Van der Heijden (2003) showed that new perceived visual attractiveness of web sites significantly affects perceived enjoyment. In accordance with the literature, visual attractiveness implies an aesthetic product design (e.g., shapes, colors, and size) and user interfaces (e.g., menus and applications) of VPA devices in the current study.

H7 Visual attractiveness positively affects the perceived enjoyment of VPA devices.

4 Research method

4.1 Data

The proposed research model was validated with an online survey that was undertaken over 2 weeks in June 2017. Because most VPA devices have now been commercialized in the U.S., recruited survey participants who had experience using VPA services were recruited. The survey was conducted in the U.S. using Amazon Mechanical Turk (MTurk), which is a popular tool of behavioral research (Mason and Suri 2012; Yang et al. 2017). The respondents who successfully completed our survey received $1 as a reward. We gathered 330 samples and finally obtained 313 valid samples after excluding those with missing or erroneous data. Table 3 lists the demographic characteristics of research samples.

Table 3 Characteristics of the respondents

Characteristics	Respondents (n = 313)	
	Number	Percentage
Gender		
Male	173	55.3
Female	140	44.7
Age		
15–19	10	3.2
20–29	141	45.0
30–39	118	37.7
40–49	33	10.5
50+	11	3.5
Education		
Less than high school	72	23.0
College or university	168	53.7
Advanced degree	73	23.3
Monthly income ($)		
Less than 2000	114	36.4
2000–3500	60	19.2
3500–5000	79	25.2
5000+	60	19.2
Occupation		
Official worker	90	28.8
Service worker	33	10.5
Professional/researcher	56	17.9
Self-employer	53	16.9
Public service worker	13	4.2
Student	29	9.3
Housewife	12	3.8
Other	27	8.6

4.2 Instrumental development

All measurement items of constructs were adapted from previous studies. The total of 23 items describe seven latent constructs: perceived usefulness, perceived enjoyment, portability, automation, content quality, visual attractiveness, and behavioral intention. All items were measured on a seven-point Likert scale that ranged from "strongly disagree" to "strongly agree." Table 4 summarizes the measurement items used in the study and their sources.

5 Data analysis and results

5.1 Measurement model

PLS-SEM (Partial least squares based structural equation model) analysis was used to verify the research model and hypotheses with Smart PLS 2.0 software. PLS-SEM focuses on path coefficients and explained variance, and it is widely adopted to test complex relationships between constructs (Chin et al. 2003); it is particularly appropriate when examining certain target relationships among constructs (Ringle and Sarstedt 2016). In addition, PLS-SEM is applicable to small and medium samples in estimation, and it is possible to calculate both formative and reflective relationships (Bhuasiri et al. 2016). One of the advantages of PLS-SEM is that user-friendly software is available (Hair et al. 2017). As this study examines the complex relationships with various latent variables, PLS-SEM is a relevant statistical approach to verify the measurement and research model of this study.

Convergent validity was assessed by conducting CFA (confirmatory factor analysis), which examines the factor loading score of each item, the significance level of the loading, the reliability, and the average variance extracted (AVE) of the construct. Table 5 shows the cross-loadings, which are high enough within their respective constructs. Table 6 summarizes the convergent validity of the constructs. Factor loadings show that all items meet the minimum requirement (0.60) to assure convergent validity (Anderson and Gerbing 1988). All Cronbach's alpha values exceed the cut-off value (0.70). The AVE value of all constructs is greater than 0.5. As a result, convergent validity is confirmed.

With regard to discriminant validity, the square root of the AVE for each construct should be higher than the corresponding inter-construct correlations. As shown in Table 7, all diagonal values are higher than the other correlation coefficients, demonstrating discriminant validity. The heterotrait-monotrait (HTMT) ratio is an alternative way to check discriminant validity. It is recommended that the HTMT ratio is lower than 0.85 (Henseler et al. 2016). As the maximum HTMT value is 0.773, it is confirmed that this study's measurement model satisfies the HTMT criteria.

Common method variance (CMV), which may occur when a study uses self-reported data from a survey, should also be considered. Harman's single factor technique was applied to check CMV. The test found seven factors. The variance of the first emerged factor is under 50%. Thus, the CMV problem is not a concern for this study's data (Podsakoff et al. 2003). The goodness of fit (GoF), in accordance

Table 4 Survey items used in this study

Construct	Item No.	Measurement items	References
Perceived usefulness	PU1	VPA devices are very useful to my life in general	Davis (1989), Shin (2007)
	PU2	VPA devices provide very useful service and information to me	
	PU3	Using VPA devices improve the quality of the work I do	
	PU4	Using VPA devices increase my productivity	
	PU5	Using VPA devices enhances my effectiveness on the job	
Perceived enjoyment	PE1	Using VPA devices is truly fun	Sweeney and Soutar (2001), Venkatesh (2000)
	PE2	I know using VPA devices to be enjoyable	
	PE3	The use of VPA devices gives me pleasure	
	PE4	The use of VPA devices makes me feel good	
Portability	PO1	The compact design of VPA devices allow users to carry them easily anywhere	Xu et al. (2009), Yang and Lee (2017)
	PO2	Portability is an outstanding advantage of VPA devices	
Automation	AT1	It is convenient that VPA devices help the users proactively without human intervention	Augusto and Nugent (2006), Luor et al. (2015)
	AT2	It is convenient that VPA devices provide auto-adjusted control	
Content quality	CQ1	VPA devices provide up-to-date contents or information	Jung et al. (2009)
	CQ2	VPA devices provide sufficient contents or information	
	CQ3	VPA devices provide content or information pertaining to my concerns	
Visual attractiveness	VA1	The user interface of VPA devices is attractive	Cyr et al. (2006), Yang et al. (2016)
	VA2	VPA devices look professionally designed	
	VA3	The overall look and feel of VPA devices is visually appealing	
	VA4	Overall, VPA devices look attractive	
Behavioral intention	BI1	I intend to use VPA devices in the future	Davis (1989), Yang et al. (2016)
	BI2	I predict I would use VPA devices in the future	
	BI3	I recommend others to use VPA devices	

Table 5 Construct cross-loadings

	PU	PE	PO	AT	CQ	VA	BI
PU1	**0.872**	0.656	0.404	0.508	0.533	0.484	0.686
PU2	**0.859**	0.616	0.389	0.498	0.565	0.508	0.635
PU3	**0.897**	0.587	0.316	0.413	0.469	0.394	0.566
PU4	**0.895**	0.622	0.325	0.463	0.511	0.449	0.592
PU5	**0.904**	0.599	0.294	0.415	0.463	0.430	0.572
PE1	0.482	**0.890**	0.482	0.575	0.491	0.557	0.658
PE2	0.430	**0.897**	0.430	0.525	0.457	0.501	0.622
PE3	0.400	**0.883**	0.400	0.520	0.496	0.480	0.618
PE4	0.462	**0.886**	0.462	0.549	0.498	0.479	0.616
PO1	0.338	0.456	**0.922**	0.500	0.546	0.586	0.509
PO2	0.394	0.475	**0.943**	0.531	0.503	0.563	0.537
AT1	0.476	0.545	0.480	**0.919**	0.566	0.502	0.584
AT2	0.487	0.579	0.540	**0.923**	0.569	0.547	0.636
CQ1	0.488	0.513	0.544	0.608	**0.910**	0.668	0.588
CQ2	0.564	0.486	0.472	0.518	**0.903**	0.598	0.579
CQ3	0.509	0.479	0.503	0.545	**0.894**	0.607	0.549
VA1	0.496	0.516	0.520	0.472	0.614	**0.887**	0.538
VA2	0.421	0.489	0.592	0.546	0.585	**0.858**	0.560
VA3	0.469	0.512	0.567	0.516	0.643	**0.903**	0.563
VA4	0.439	0.497	0.502	0.489	0.608	**0.896**	0.525
BI1	0.618	0.649	0.522	0.602	0.587	0.577	**0.935**
BI2	0.595	0.638	0.523	0.632	0.598	0.584	**0.923**
BI3	0.703	0.674	0.513	0.605	0.576	0.551	**0.916**

Bold values indicate item loadings on the assigned constructs

with Tenenhaus et al. (2005), was checked to determine the overall fitness of the research model. The baseline values for GoF are small = 0.1, medium = 0.25, and large = 0.36 (Wetzels et al. 2009). This study's GoF value is 0.602, which exceeds the cut-off value for large effect sizes. Thus, this research model's GoF is considered sufficiently high.

5.2 Hypotheses' testing

Figure 3 summarizes the results of the structural equation model through the employment of a bootstrapping technique to calculate the corresponding t-statistics for each hypothesized relationship. Of the seven proposed hypotheses, six are supported. Perceived usefulness and perceived enjoyment significantly affect the behavioral intention to use VPA devices, thereby supporting H1 and H2 (H1, $\beta = 0.389$, t-value = 3.421, $p < 0.001$; H2, $\beta = 0.436$, t-value = 3.822, $p < 0.001$), with 57.8% of variance. Similar to the results of previous studies related to technology acceptance, these two variables are important factors for the intention to use VPAs. The relatively strong impact of perceived enjoyment can be interpreted in various ways.

Table 6 Validity of constructs

Construct	Items	Factor loading	Std. error	t-value	AVE (> 0.5)	Composite reliability (> 0.6)	Cronbach's alpha (> 0.7)
Perceived usefulness	PU1	0.872	0.021	11.947	0.784	0.948	0.931
	PU2	0.859	0.019	12.494			
	PU3	0.897	0.013	15.741			
	PU4	0.895	0.014	15.589			
	PU5	0.904	0.014	15.237			
Perceived enjoyment	PE1	0.890	0.019	15.582	0.791	0.938	0.912
	PE2	0.897	0.018	14.935			
	PE3	0.883	0.021	13.036			
	PE4	0.886	0.019	14.367			
Portability	PO1	0.922	0.053	9.388	0.869	0.930	0.851
	PO2	0.943	0.050	11.500			
Automation	AT1	0.919	0.047	11.477	0.848	0.918	0.821
	AT2	0.923	0.051	10.854			
Content quality	CQ1	0.910	0.022	16.765	0.814	0.929	0.886
	CQ2	0.903	0.023	16.426			
	CQ3	0.894	0.023	15.356			
Visual attractiveness	VA1	0.887	0.022	13.201	0.785	0.936	0.909
	VA2	0.858	0.023	12.088			
	VA3	0.903	0.022	12.952			
	VA4	0.896	0.022	12.501			
Behavioral intention	BI1	0.935	0.013	28.168	0.855	0.947	0.915
	BI2	0.923	0.013	26.342			
	BI3	0.916	0.020	18.837			

Table 7 Correlations of the constructs and square root of AVE

	PU	PE	PO	AT	CQ	VA	BI
PU	**0.886**						
PE	0.698	**0.889**					
PO	0.394	0.499	**0.932**				
AT	0.523	0.611	0.554	**0.921**			
CQ	0.578	0.546	0.560	0.617	**0.902**		
VA	0.515	0.568	0.615	0.570	0.691	**0.886**	
BI	0.523	0.707	0.561	0.663	0.634	0.617	**0.925**

Bold values indicate the square root of AVE of each construct

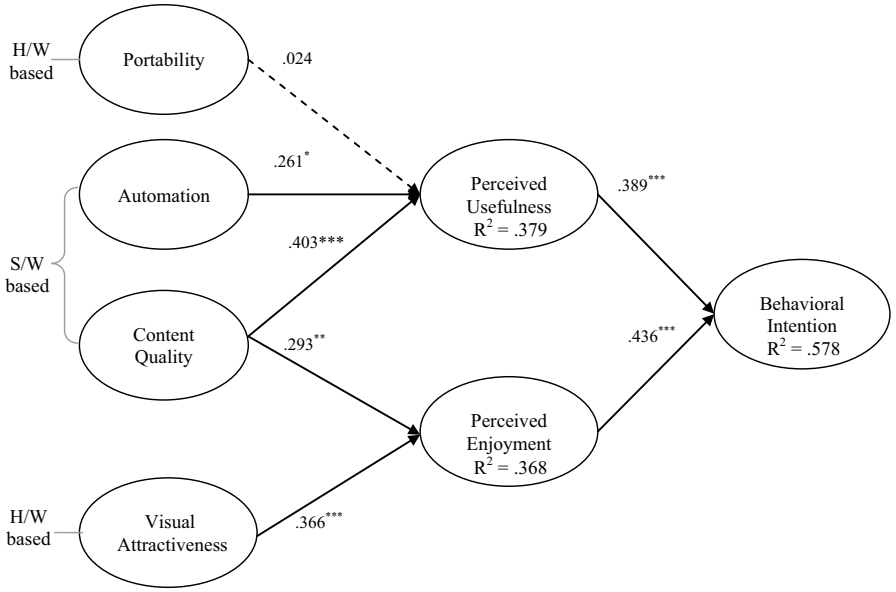

Fig. 3 PLS results of the structural model. Note: $*p<0.05$; $**p<0.01$; $***p<0.001$

As VPA devices comprise an early market, the enjoyment factor that easily attract users' attention works for the adoption behavior. A VPA device can be manipulated by human voice and expects a human-like response. Thus, the hedonic factor of VPAs may be more important because of the innovative features.

All proposed antecedents that reflect VPA devices' software- or hardware-based attributes are also supported, except the relationship between portability and perceived usefulness, thereby rejecting H3 (H3, $\beta=0.024$, t-value$=0.173$, H4, $\beta=0.261$, t-value$=1.894$, $p<0.05$; H5, $\beta=0.403$, t-value$=3.038$, $p<0.001$; H6, $\beta=0.293$, t-value$=2.333$, $p<0.01$; H7, $\beta=0.366$, t-value$=3.100$, $p<0.001$).

While newer VPA devices are portable owing to their small size and compatibility with wireless internet connection, these devices are typically used on a home or company desk, and portability is not a concern. Thus, portability is not a determinant of the perceived usefulness of VPAs. Automation helps home residents to minimize human intervention, and therefore functions as an important antecedent of perceived usefulness. However, the effect is relatively weak, which is attributed to the fact that artificial intelligence has not reached its full technological potential yet. The importance of content quality in accepting new products or services has been proven through several studies (Kim et al. 2016; Yang and Lee 2017). In general, a device plays a platform role for playing contents, and the quality of content therefore defines users' final judgment of usefulness and enjoyment of the device. The visual attractiveness has a significant impact on perceived enjoyment, because VPAs can affect users' aesthetic satisfaction as a tool for house interiors.

In order to provide an alternative model, we tested the direct relationships between exogenous constructs (portability, automation, content quality, and visual

attractiveness) and behavioral intention. Only automation had a significant direct effect on intention (β = 0.204, t-value = 3.397, $p < 0.001$). Automation is the most representative feature of VPAs, and represents a significant difference from other products. Curiosity about automation may directly increase users' intention to use it.

6 Discussion

6.1 Findings

The results mostly support the validity of the proposed research model, which asserts that VPA device adoption is determined by perception of the utilitarian and hedonic values, and that these are composed of perceived usefulness, perceived enjoyment, portability, automation, content quality, and visual attractiveness. Consistent with prior studies, perceived usefulness and perceived enjoyment, two mediating constructs, are significantly associated with behavioral intention (Agarwal and Karahanna 2000). This finding implies that VPA devices can be widely utilized for practical purposes and for fun. Indeed, according to a Business-Insider (2017) survey, people use Amazon Echo for both purposes, such as setting a timer (84.9%), playing songs (82.4%), reading the news (66.0%), checking the time (61.6%), telling a joke (60.4%), controlling smart lighting (45.9%), adding items to shopping lists (45.3%), connecting to paid music services (40.9%), providing traffic information (36.5%), managing a to-do list (32.7%), and buying something on Amazon Prime (32.1%). However, the current study also reveals that perceived enjoyment is more powerful than perceived usefulness for predicting potential users' intentions to use VPA devices. Thus, in order to enhance VPA device usage, potential customers must perceive greater hedonic value than practical utility.

Among the three antecedents that reflect software- and hardware-based utilitarian value, content quality shows the strongest effect on perceived usefulness, a finding that is consistent with Yang and Lee (2017) result. This means that potential users want to use many types of high-quality content and services via VPA devices. VPA device manufacturers already recognize these needs and attempt to offer more content by creating open ecosystems such as those of mobile application markets. Barrett (2017) reported that 10,000 skills (the content and services for Amazon VPA devices) were available in February 2017, a figure that shows an exponential increase in skills since the first release of the devices in the summer of 2016. The current study also shows that automation is an important factor for perceived usefulness. It can be inferred from such a finding that potential users are beginning to recognize the usability of automation. This usability is a long-standing vision whereby automation proactively helps home residents to minimize human intervention (Augusto and Nugent 2006). Today, digital transformation has spread across many industries under names such as "smart factory," "smart energy," "smart farm," "smart city," and "fintech." These trends commonly emphasize that the convenience of automation is based on AI technology. As a result, it is natural that potential users of VPA devices should use automated services for work such as controlling lights, opening and shutting doors and windows, and organizing personal schedules.

Further, the current study has revealed that the portability of VPA devices is unrelated to perceived usefulness. Portability may not be critical because users can place their VPA devices in desired locations or put cheaper devices (e.g., Amazon Tab) in each room. Indeed, VPA device manufacturers recently seem to be more concerned about usability than portability, because they are launching larger display-embedded VPA devices (e.g., Amazon Show).

From the perspective of hedonic value, content quality (which is also a utilitarian attribute of VPA devices) and visual attractiveness are positively associated with perceived enjoyment. Specifically, visual attractiveness has a stronger effect on perceived enjoyment than content quality. In Yang et al. (2016) study, visual attractiveness is a strong exogenous variable that positively affects the perceived enjoyment of wearable devices. VPA devices are among the next generation of consumer electronic devices; as such, their designs should be compatible with other home appliances such as television sets, refrigerators, PCs, and projectors. Indeed, Tzou and Lu (2009) revealed that consumers think that physical design is critical in the overall satisfaction that they have with new electric products.

6.2 Contributions

Our study provides several theoretical and practical insights. First, in terms of theoretical prospects, this study is first empirical attempt to investigate user adoption of VPA devices with general purpose. A study on VPA devices is currently at an early stage, although the market is rapidly growing following the participation of global IT companies and start-up companies. Prior studies only focused on the technical architecture of smart homes (Balta-Ozkan et al. 2014; Chou and Yutami 2014), or undertook qualitative research for future smart homes (Chan et al. 2009; Ehrenhard et al. 2014). Even though Yang et al. (2017) empirically studied user acceptance of smart home services based on a theory of planned behavior (TPB) model, the proposed model is only suitable for general smart home services and does not reflect the specific features of VPA devices. Reis et al. (2017) and Wallace and Morris (2018) only tested the functionalities of VPA devices for specific groups of people such as elderlies or patients.

Second, this study empirically verifies a proposed new research model, with hardware- and software-based attributes, based on perceived value theory. Prior studies have tried to define perceived value as a multidimensional construct that conceptually divides perceived value into dimensions such as social, emotional, functional, epistemic, and conditional (Sheth et al. 1991). However, the current study reveals the effectiveness of considering the characteristics of new products and services in order to develop a more appropriate research model. An R^2 value of 57.8% means that the proposed model has good explanatory power and that it will provide a useful framework to predict the user adoption behavior of VPA devices.

Third, this study shows what the key factors of acceptance of artificial intelligence services are. Existing studies have emphasized the importance of portability in accepting mobile services. However, portability does not affect VPA device adoption in this study, while automation, content quality, and visual attractiveness

do. This result shows that portability in mobile services does not have a significant effect on acceptance, because it is now regarded as a common or basic factor. This also means that, when discussing acceptance of new technologies, it is necessary to expand the theory with a new perspective, rather than adopting the traditional approach.

For practitioners, this study also provides manufacturers of VPA devices with meaningful insights in order to increase adoption rates. In terms of contents, manufacturers should first secure a range of high-quality content. Regardless of how innovative the service is, the quality of content (the most basic requirement) should be secured (Kim et al. 2016). Device makers must establish a larger VPA application market, which is currently at an early stage. For this, it is necessary to provide not only free a SDK, but also other incentives for developers. For example, as in the current mobile application market, companies need to think about ways to ensure revenue for developers through the monetization of some applications. According to an article in Fortune (2016), Amazon has been investigating ways to provide developers with revenue in the long run. In addition, manufacturers also need to have an internal process to verify the quality of their content. If low-quality content enters the VPA application marketplace, users are likely to question the performance of VPA devices and finally not use them. Thus, internal policies should be implemented so that only content that has passed the verification process progresses to the marketplace.

Second, Large-scale R&D and investment are required to implement the automation function, because proactive autonomous services are based on infrastructures that include cloud centers and big data solutions for analysis of residents' personal information; this includes their movements, lifestyles, and emotional changes (Yang et al. 2017). Of course, it is also necessary to invest in the development of advanced natural language processing algorithms and private information protection technology.

Third, VPA devices should be developed with various designs because the structure of users' homes and the locations of VPA devices will vary. Until now, most VPA devices have been in the form of cylindrical speakers; however, external design, color, and material must be diversified. In addition, for a VPA device with a display, the user interface (UI) software and the touch screen should be user-friendly. Finally, manufacturers should continue to deploy SDKs so that consumers can design their own hardware devices using software-type VPAs.

Fourth, in terms of new market development, VPA manufacturers should explore business-to-business (B2B) markets, beyond current business-to-consumer (B2C) markets. Since consumers have behavioral intentions with regard to perceived usefulness and perceived enjoyment, according to this study, VPA manufacturers also need to develop work-specific product development strategies. Indeed, many workers already expect to work with VPAs. According to a recent study (Suki and Suki 2017), 30% of employees in the world selected "digital helper" as potential use of AI. Furthermore, some start-ups are developing VPA devices that make meetings more efficient by creating an accessible record of the meeting's minutes or sending such records autonomously to participants after meeting.

6.3 Limitations and further studies

In spite of its theoretical and practical contributions, this study also has limitations. In order to generalize the results, further studies should include the data of ethnically and geographically diverse groups in several countries. Individual differences among the survey respondents should then be examined to investigate the moderating effects of demographic differences or prior experience. It is also necessary to increase the accuracy of the research results with representative samples from the population. Negative factors that affect the adoption of VPA devices can be included, such as security risk and performance risk. In addition, since the VPA service represents an early market, more practical implications would emerge if later studies discuss the differences in recognition between expected and current user services.

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