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Unraveling the relationship between the dimensions of user experience and user satisfaction: A smart speaker case☆

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ABSTRACT

A smart speaker is a voice command device with a built-in virtual assistant. The virtual assistant provides interactivity and hands-free activation. According to a recent survey, although smart speaker ownership has increased, their users report low satisfaction. This paper investigates the impact of the dimensions of user experience (UX) on user satisfaction with smart speakers. Thus, we investigated two research topics: (1) exploring the UX dimensions of smart speakers and (2) examining the relationship between the explored UX dimensions and user satisfaction. To study the research topics, we first used text mining to explore the UX dimensions of smart speakers through 46,715 reviews. Second, we theoretically matched the UX dimensions with the honeycomb model and measured users' sentiments for each dimension. Lastly, we developed and tested an econometric model to analyze their relationships with their star rating as the dependent variable. Thus, this study has research implications for determining the unique dimensions of UX for smart speakers and the relationship with user satisfaction. In addition, this study has practical implications that present generalized UX dimensions for smart speakers and suggests a management plan and recommendations for each of those UX dimensions.

1. Introduction

Smart speakers such as the Amazon Echo or the Google Home are popular worldwide [1]. A smart speaker is a speaker equipped with a voice recognition artificial intelligence (AI) assistant [2]. Smart speakers are also called smart voice assistant speakers [3] or voice-based smart-home products [4]. The global market for smart speakers is growing continuously and is expected to reach $15.6 billion by 2025, at a compound annual growth rate of 17.1% [5]. According to a report [6], the smart speaker market has already reached the early majority market in the technology adoption lifecycle.

However, despite the market's growth, owners of smart speakers are dissatisfied with the products [7]. According to the survey, 56.7% of the participants reported negative experiences using them [7]. Furthermore, over time the frequency of using smart speakers decreases [6]. In January 2018, about 64% of smart speaker owners said they were daily users, but in January 2019, this number dropped to about 47%. The percentage of users who never or rarely use their smart speakers more than doubled from 13% to 27% during the same period. Also, the early majority remain unfamiliar with smart speakers, so they only use basic features such as listening to music, getting weather information, and setting timers [6,8].

In the information technology (IT) or product context, user experience (UX) is considered one of the critical factors in addressing users' engagement, sentiment [9,10], and behaviors [11]. Furthermore, understanding UX could improve user satisfaction by offering perceived utilitarian and hedonic attributes [12]. Badran & Al-Haddad [13] indicated that UX variables affect user satisfaction with smartphones. Deng et al. [14] also discovered that UX influences user satisfaction with and continued intent to use mobile internet services. Thus, it is necessary to understand the UX dimensions of smart speakers to increase user satisfaction and usage behavior.

Researchers have studied smart speakers in various contexts, for instance, marketing [15,16], privacy [17,18], adoption [19,20], continuation [2,3], and diffusion [21,22]. However, missing from this research is what dimensions of UX lead to their satisfaction with a smart speaker that is voice-controlled device, thus facilitating total usage and creating new users for the smart speaker market. In addition to the gap

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in previous research, the survey methods based on cross-sectional data used in this research are poorly suited to gain a holistic understanding of consumer experiences.

To address these topics and methodological shortcomings, this study explores the UX dimensions of smart speakers and examines the relationship between explored UX dimensions and user satisfaction based on Morville's honeycomb model [23]. This study thus investigated two research topics: (1) exploring the UX dimensions of smart speakers, and (2) examining the relationship between the explored UX dimensions and user satisfaction.

First, we explored the UX dimensions of smart speakers by using text mining and theoretical mapping with the honeycomb model [23]. Second, we identified users' sentiments for each dimension through 46,715 reviews. Lastly, we developed the econometrics model and tested user satisfaction changes over time. This study contributes to the literature to unveil the UX dimensions of smart speakers and their theoretical relationship with user satisfaction. This study also assists smart speaker manufacturers by proposing practical strategies to enhance the UX based on review data reflecting user honest opinions [24,25]. In the following sections, we provide a conceptual background and literature review. We then present the research procedure and data collection. Next, we describe Step 1 *LDA Topic modeling* and Step 2 *Econometric Approach* and report the test results. Finally, we address the implications for research and practice based on our discussion of the findings.

2. Conceptual background

2.1. Smart speakers

Because of the global COVID-19 outbreak, worldwide interest in operating devices via voice commands instead of touch controllers has increased [26]; simultaneously, the market for smart speakers was also growing [27,28]. A smart speaker provides interactive action and hands-free operation via voice commands. In addition, these speakers are also becoming smart home hubs that control multiple devices such as lighting, TVs, and curtains [19].

According to Newman [29], the most used smart speaker features are playing music, obtaining general information (weather, news, and time), and controlling devices. Although the market of smart speakers is growing, studies of their use have found their usage rate has decreased, and only a few of their features are being used [2,19]. Moreover, despite the market success of smart speakers, those who have bought them at later stages of the market have scant experience with them [6].

Most previous studies have relied on experiments and survey methods of four aspects of smart speakers. Table 1 summarizes the relevant literature regarding smart speakers. First came research into the aspects of marketing. For example, Smith [16] studied finding suitable marketing messages using a smart speaker. In another study, Lee and Cho [15] identified users' motives for using smart speakers and tested the relationship between these motives and the effectiveness of their advertising. The second research category involved the privacy aspects of smart speakers, especially how privacy concerns affect users' attitudes and behaviors [17,18]. Third were studies of the behavioral intentions and attitudes of the consumer of smart speakers, such as predictions of user satisfaction [30], consumer acceptance [31], and adoption of smart speakers [4,19,32]. Most of these studies were based on the TAM model [33]. The last category of research involved the continuance of use and diffusion of smart speakers. For example, Shin et al. [22] investigated factors affecting the diffusion of smart speakers by using a multivariate probit model. This study identified that older consumers are more likely to adopt smart speakers within a given time than are younger consumers. As smart speakers reach an early majority market, recent studies have focused on continuation [2,3], diffusion [21,22], and beyond [20].

Despite the numerous studies on smart speakers, few have examined the theoretical relationship between user satisfaction with smart speakers and the UX dimension. Moreover, the approaches with surveys and experiments have limitations such as social desirability bias (i.e., the respondent answers dishonestly) [34] and small sample size issues. In light of these shortcomings, we decided to use the honeycomb model [23] to determine smart speakers' UX dimensions and use panel data to examine the relationship between these dimensions and user satisfaction.

Table 1
Summary of related literature on smart speakers.

Category	Article	Study focus	Theoretical lens	Method/sample
Marketing	[16]	Exploring suitable types of marketing messages using smart speakers	–	Survey (N = 110)
	[15]	Modeling the effectiveness of the advertising for smart speakers	Uses and gratifications	Survey (study 1: N = 130, study 2: N = 330)
Privacy	[17]	Examining the beliefs, attitudes, and concerns regarding the privacy of smart-speaker use	–	Survey (N = 116)
	[18]	Investigating the mediating negative emotions between users' privacy concerns and behavior	Stimuli-organisms-response framework	Survey (N = 359)
Behavioral intention (adoption) and attitude	[30]	Measuring user satisfaction with smart speakers by using query embedding	–	Experiment (N = 88)
	[31]	Develop an acceptance model for using smart speakers by adopting a mixed-methods approach.	Technology acceptance model	Study 1: Text mining (N = 3085) Study 2: Survey (N = 293)
	[32]	Examining the factors related to the adoption of smart speakers from the platform perspective	Technology acceptance model	Survey (N = 330)
	[19]	Exploring the factors affecting customers' intention to purchase a smart speaker	Diffusion of innovation theory and task-technology fit	Survey (N = 249)
	[4]	Analyzing the adoption intention of the smart speaker	Technology acceptance model	Survey 1 (N = 315) Survey 2 (N = 1954)
Continuance of use and diffusion	[2]	Exploring the effects of perceived coolness toward continuance intention in smart-speaker use	Perceived coolness and perceived value theory	Survey (N = 307)
	[22]	Investigating the adoption of smart homes and the diffusion of smart homes	Technology acceptance model	Survey (N = 310)
	[3]	Exploring the perceptual change in group dynamics as a function of satisfaction followed by the continuance of Use.	Technology acceptance model	Survey (218 families)
	[21]	Investigates the influence of the early-stage users' personal traits and ex-post instrumentality perceptions on social diffusion	Expectation-confirmation model	Survey (N = 400)
	[20]	Examining the role of hedonic and utilitarian attitudes on usage and word-of-mouth recommendations	Flow theory and the theory of anthropomorphism	Survey (N = 360)

2.2. User experience (UX) and honeycomb model

User experience refers to the total experience users feel and think about while using a system, product, or service directly or indirectly [35,36]. This study defines *user experience* operationally as the degree of positive or negative emotions users experience after using or using products, services, and systems [37]. The major research streams on UX have been from the standpoint of experiences related to specific devices [38–40] and exploration of their associated dimensions [41–43]. First, a study was done to identify smartphone UX through surveys [38] as an example of a study of device-specific experiences. Yu et al. [39] examined the relationship between response time and UX for mobile applications. In another study, Kim et al. [40] attempted to reveal the characteristics of UX in a virtual reality system through a systematic literature review.

Second, there was a research stream focused on the dimensions of UX. For example, Winckler et al. [43] used interviews and surveys to explore the contextual factors related to the UX dimensions. Research has also been conducted to ascertain the emotional dimensions of UX through laboratory experiments and field studies [41], whereas, Zarour and Alharbi [42] did a systematic literature review to integrate the results of research into UX dimensions.

The initial research on UX dimension was conducted based on the three elements of the Human-Computer Interface (HCI): usefulness, usability, and affect [44]. However, with the advancement of IT technology, there became a limit on the ability to use only three dimensions to find all user experiences. Morville [23] thus proposed a UX honeycomb model that subdivided the three dimensions of the HCI. UX honeycomb model offered the theoretical lens for measuring the UX by logical groupings [45]. We thus adopt the UX honeycomb model [23] to interpret the UX dimensions derived from the user reviews of smart speakers. Morville's model consists of seven dimensions: findable, accessible, useable, desirable, credible, useful, and valuable. According to the UX honeycomb model [23] and previous studies [46–48], *Findable* refers to being locatable and navigable to find what the user needs [47]. *Accessible* means accessibility of the system to users and the possibility to access information [47]. *Useable* relates to the ability to be easy to use a system and perform appropriately [46,48]. *Desirable* means feature an emotional engagement to use the system [47]. *Credible* refers to inspiring users' trust and belief in the system [46,48]. *Useful* refers to making innovative solutions that fulfill needs [47]. The dimension of *Valuable* means advancing the organization's mission behind it [48].

User experience generally affects the use, perceived value, and satisfaction with products and services [14,49,50]. For instance, Deng et al. [14] empirically investigated how UX affects perceived value, satisfaction, and continual usage intention. Therefore, the UX measurement should comprehensively analyze what a user feels and thinks of the product or service. Notably, Kaye [51] argued that the UX measurement should focus on UX. Therefore, we collected users' review data about smart speakers that partially reflect the users' experiences. In addition, we explored the specialized UX dimension of smart speakers based on the honeycomb model because the dimensions may differ depending on the device [52].

3. Research methodology

3.1. Research procedure

The procedure for this study is shown in Fig. 1. First, we collected data by crawling reviews of smart speakers in online stores. Next, we explored the specific UX dimensions of smart speakers based on latent Dirichlet allocation (LDA) topic modeling and aligned this with the honeycomb model [23]. Next, we performed a sentiment analysis of the sentiment score to calculate the explored UX dimensions. An econometric model was then developed using user satisfaction ratings. We sought to determine the relationship between the UX dimension and user satisfaction through econometric analysis. Finally, we suggested strategies to increase user satisfaction with smart speakers and encourage more use of them.

3.2. Data collection

For data collection, we selected Amazon's and Google's brands for the context of the study. According to a 2020 consumer survey of more than 1000 U S. adults, Amazon's brand has a market share of 53.0%, with Google's brand at 30.9% [53]. Therefore, we considered them the leading smart speaker brands because the two brands together account for 83.9% of the market. Notably, this study selected two specific models, the Amazon Echo Dot and the Google Home Mini, each of which has a high market share [6], for data collection. This study investigates the UX of smart speakers and representative AI technology artifacts. We thus used the mini version of the smart speaker to focus on UX dimensions of smart speakers controlled only by voice. Therefore, we focused on mini versions for our research context.

We collected text data by crawling reviews on the Amazon Echo Dot, and the Google Home Mini in the Best Buy online store (https://www.bestbuy.com/), an electronic product retailer in the United States of America[1]. Table 2 shows the results of the data collection and features of the models. We collected 25,752 reviews of the Amazon Echo Dot and 20,963 reviews on the Google Home Mini for a total of 46,715 reviews. The data collection period was from the release date of each smart speaker to November 18, 2020. The Amazon Echo Dot's release date was October 11, 2018, and the Google Home Mini's was October 19, 2017. In 2019, the Amazon Echo Dot's U.S. market share was 31.4%, and the Google Home Mini was at 11.2% [6]. The Amazon Echo Dot's AI platform is Amazon Alexa, and its search engine is Bing; Google Home Mini's AI platform is Google Assistant, and its search engine is Google. Lastly, we collected each review's star ratings, posting periods, and ownership periods (see Fig. 2).

The advantages commonly mentioned in the reviews of smart speakers were sound quality and ease of use (or easy use). One sample review supports the following pros: "The smart function, ease of use, and control of other smart home devices led me to Alexa. Purchased several for different rooms, and the audio quality is excellent for such a small speaker." In contrast, the disadvantages of smart speakers commonly mentioned are errors (or issues) and privacy. An example of reviews related to errors is "I get too many error messages. Tell me, please try that again later. Or sometimes it says, 'having trouble connecting to the internet.'" An example of reviews related to privacy is "Technology is good, but for what I'm getting and the privacy I would be giving up, I just unplugged it."

4. Step 1: topic modeling

4.1. LDA topic modeling

To explore smart speaker's UX dimensions, we conducted topic modeling, a text analysis method that extracts and summarizes information from documents. With the increase in online reviews, a few researchers have attempted information exploration and topic extraction based on text mining [54–56]. The LDA approach is one of the most frequently used topic modeling techniques [57]. Its approach treats keywords as groups on a particular topic by calculating each topic's probability [57]. Probabilistic clustering approaches extract potentially meaningful topics from documents and identify keywords in the groups. The method is practical for collecting and analyzing many people's opinions without the risk of reflexivity.

We conducted LDA topic modeling with the following process. First,

[1] This data is from a single online store. In addition, the reviews are only from English speakers.

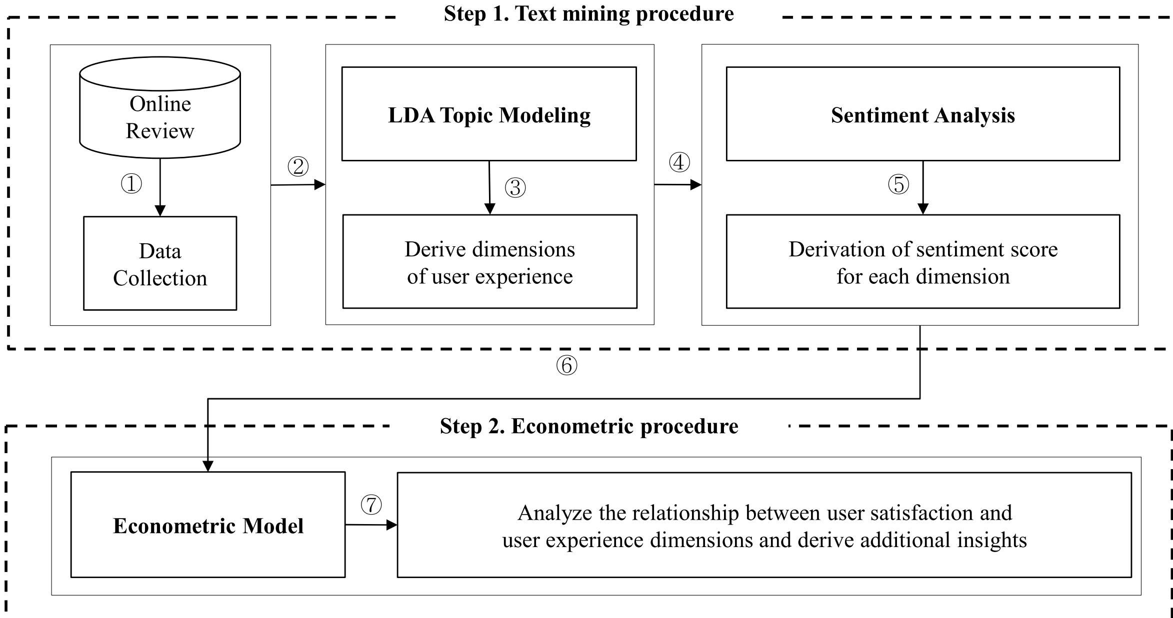

Fig. 1. Research procedure.

Table 2
Description of amazon echo dot and google home mini.

	Amazon Echo Dot	Google Home Mini
# of Reviews	25,752 reviews	20,963 reviews
Release Date	2018.10.11	2017.10.19
Average Star Rating	4.7	4.7
U·S Market Share [6]	31.4%	11.2%
Artificial Intelligence Platform	Amazon Alexa	Google Assistant
Search Engine	Bing	Google
Size (Height, Width, Depth)	1.7 × 3.9 × 3.9 inches	1.65 × 3.85 × 3.85 inches
Price	$39.99	$39.99
Advantages mentioned (word frequency)	Sound quality (4,753), Ease of use (4,485), Size (689),	Ease of use (580), Sound quality (431), Voice recognition (88)
Disadvantages mentioned (word frequency)	Error (203), Privacy (60), Battery (34)	Error (145), Privacy (140), Noise (30)

the collected data were pre-processed through Part-Of-Speech-tagging (POST) and removal of stop words. Next, we used the LDA algorithm for data analysis. The LDA algorithm is necessary to establish the number of topics to be identified. We thus adopted perplexity and coherence scores to determine the number of topics [58]. A perplexity score is a measure of how well topics reflect a document's content; the lower the perplexity score, the better the output [59]. The coherence score analyzes the similarity of words in a topic; the higher the coherence score, the more semantic consistency can be assessed [60]. We determined seven topics by synthesizing the perplexity score (−6.39) and the coherence score (0.55).

4.2. LDA topic modeling results and theoretical mapping

As a result of the LDA topic modeling of online review data for smart speakers, we derived seven names of UX dimensions based on the focus group discussion (FGD). The FGD method refers to group interviewing, a qualitative research approach [61] widely used by many researchers because of its high face validity, economic pros, and speed advantage [62]. Following the FGD guidelines [63], we invited four experts (two IS researchers, one HCI researcher, and one general manager from a smart-speaker manufacturer) to conduct the FGD. The participants named each dimension, based on keywords and review examples. In case of disagreement among experts, the name of the dimension was finally decided through discussion. Furthermore, we checked the external validity of the UX dimensions based on interviews with seven users (two females and five males) who had used smart speakers. We then asked them about their experiences in using the devices. Based on their responses, we checked whether all their experiences matched the seven identified UX dimensions. Next, we showed these seven UX dimensions to the invited users and asked them to check whether all those

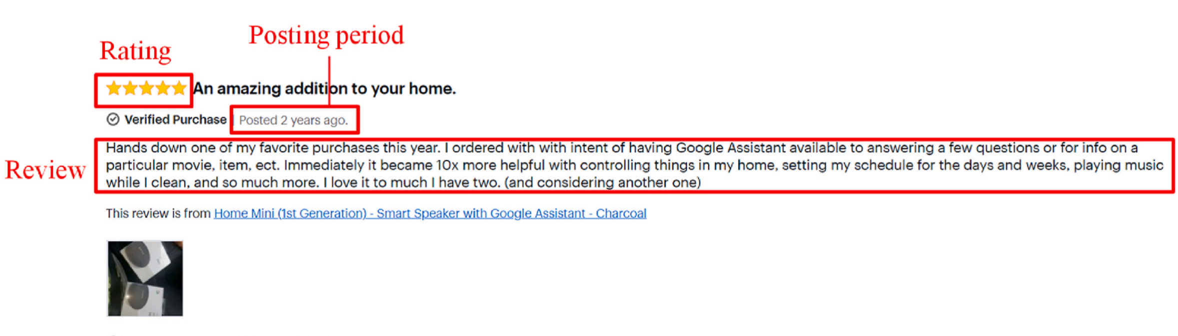

Fig. 2. Screenshot of the Best Buy's review page.

seven dimensions reflected their experiences in using smart speakers. Through this process, we could confirm the external validity of the seven UX dimensions. Table 3 shows the seven dimensions of the UXs with smart speakers, keywords, and interview and review examples for each dimension.

The seven UX dimensions selected are as follows: *device control of smart speakers, usability of smart speakers, informativeness of smart speakers, adaptability of smart speakers, sound quality of smart speakers, home automation of smart speakers, virtual assistant of smart speakers*. We theoretically connected and interpreted the smart speaker's seven UX dimensions with the honeycomb model [23]. Fig. 3 illustrates the relationship between the explored UX dimensions and the honeycomb model. First, *device control of smart speakers* represents the capability to pair with any personal devices or applications and connect quickly and seamlessly. It can be interpreted from *Accessible* in the honeycomb model [23]. The identified keywords (device, control, integration, voice, command) also collectively represent device control. The user has experience with smart speakers in accessing smartphones and other devices.

Second, *usability of smart speakers* means the degree to which the product can be easily installed and used. It can be interpreted as *Useable* in the honeycomb model [23]. The identified keywords (easy, setup, recognition, response, use) also represent ease of use. In the review examples, users experienced easy setup and installation of smart speakers. Third, *informativeness of smart speakers* refers to their capability to provide reliable information properly. It can be interpreted from *Findable* in the honeycomb model [23]. The identified keywords (information, sports results, news, tools, weather) also collectively represent informativeness. In the review examples, users have experience in obtaining the desired information such as news, sports game scores, or weather via a smart speaker.

Fourth, *adaptability of smart speakers* means the capability to use smart speakers in various environments and spaces. The identified keywords are bedroom, kitchen, office, intercom, and bathroom. Fifth, *sound quality of smart speakers* refers to the utility from providing good sound quality and balanced sound. The identified keywords are sound, quality, music, Spotify, and audio. These two dimensions can be interpreted as *Useful* in the honeycomb model [23].

Sixth, *home automation of smart speakers* refers to the capability to establish a smart home environment with the household appliances. The identified keywords are system, automation, hub, ecosystem, and Bluetooth. In the review examples, users are experienced in using smart speakers in various places in the home, listening to high-quality music, and being a useful hub of home automation. Lastly, the *virtual assistant of smart speakers* means the level of performance for various tasks using an AI platform. The identified keywords (alarm, timer, reminder, assistant, call) also collectively represent virtual assistants. In the review examples, users have experienced smart speakers performing various tasks and delivering value to users. These two dimensions can be interpreted as *Useful and Valuable* in the honeycomb model [23]. These are helpful products that satisfy customer needs and contribute to the organization (i.e., Amazon and Google)'s mission.

5. Step 2: econometric approach

5.1. Descriptive statistics

We used a lexicon-based method to perform sentiment analysis on 46,715 reviews. This method uses the sentiment word dictionary to calculate a sentiment score for each of the reviews. We selected the *Valence Aware Dictionary and Sentiment Reasoner* (Vader) as the sentiment word dictionary for this study [64]. Vader calculates the sentiment score from −1 to 1 by considering intensifiers such as *very* and *slightly*. In addition, negative expressions such as no/not are recognized and converted to the sentiment score's sign (±) (e.g., The smart speaker is *not* good). Each review was divided into sentences. Then each one was

Table 3
Explored UX dimensions of smart speakers.

Smart Speaker UX		
Dimensions (Topics)	Keywords	Interview and Review Example (Interview: I, Review: R)
Device control of smart speakers	device, control, integration, voice, command	• I recently bought a smart speaker, and it took less than a minute to connect to my phone. (I) • It also was compatible with all my existing smart- devices. (R) • It was a breeze thinking with our smart TV, and I'm assuming just as easy to connect other smart devices. (R)
Usability of smart speakers	easy, setup, recognition, response, use	• I am pleasantly surprised with the Google Home mini. Like any Google device, it's easy to set up and use. (I) • It was an easy setup when you linked your Google account to it. (R) • Easy to set the alarm by just telling it. (R)
Informativeness of smart speakers	information, score, news, tool, weather	• It gives me news and other sources of information. I have yet to discover what all it can do. (I) • Google is not too bright but gets me news and information without using my phone. (R) • Mainly used to assist with playing music, getting quick updates such as news, weather, and sports, and learning trivial and useful information without looking into any screen. (R)
Adaptability of smart speakers	bedroom, kitchen, office, intercom, bathroom,	• I have bought four for each bedroom (2), my family room and home office. (I) • It is so useful when your hands are full or you're heading out the door and don't want to go back for the remote or turn off the lights. I also have one in my daughter's room. I love the drop-in feature that lets me turn her Echo Dot into an intercom to start talking to her in her room. (R) • They are useful as intercoms and ready sources of information, reminders, and timers. (R)
Sound quality of smart speakers	sound, quality, music, Spotify, audio	• Pleasantly surprised how well this speaker sounds. Speaker is equipped with an auxiliary out if you want to hook it to an external speaker. (I) • The audio was good, with an excellent balanced sound across the spectrum. (R) • Sound quality is the best I've heard on a speaker of this size!!! (R)
Home automation of smart speakers	system, automation, hub, ecosystem, Bluetooth	• I use it for home automation. The various skills allow me to control almost any internet of things device that I have. (I) • We added Echo Dots in a couple of rooms to control home automation: lights, thermostats, and switches. (R) • I have been using the Amazon Echo ecosystem for my smart-home automation since the first-generation Echo. (R)
Virtual assistant of smart speakers	alarm, timer, reminder, assistant, call	• What can I say, it is great voice assistant! My only issue is that if I ask her to skip too many songs,

(*continued on next page*)

Table 3 (*continued*)

Smart Speaker UX		
Dimensions (Topics)	Keywords	Interview and Review Example (Interview: I, Review: R)
		she won't play any more music, and I will have to reset her. (I) • Every morning, the Echo wakes me up with an alarm, and I get the time and the latest weather. • Give me news and weather and some light music after I dismiss my morning alarm. (R) • I ask Alexa to set up my alarm, set up reminders, ask for the weather, the time, etc. Love it! (R)

examined to determine whether it contained a keyword corresponding to the UX dimensions of a smart speaker. If so, it was regarded as a sentence related to that dimension. We then calculated the average to obtain the sentiment score for the UX dimensions of the smart speaker.

We additionally collected user satisfaction scores (i.e., star rating) as a proxy of user satisfaction. According to previous researches, a single star rating could assess user satisfaction in the hotel contexts [25,65,66] and e-commerce environments [67]. For instance, Rajaguru and Hassanli [65] identified that hotel star rating positively influences guest's satisfaction. Benbunan-Fich [67] also argued that star ratings provide an overall measure of user satisfaction and evaluate the UX qualitatively. Thus, we decided that the star rating was operationalized variable for the proxy measure. As for control variables, the brand variable was operationalized as what brand (i.e., Amazon: 0 or Google: 1) the user reviewed. As for the posting period, Best Buy's review pages do not provide the specific dates of postings but display them in a relative manner, such as two years ago, one year ago, or six months ago (see Fig. 2). Therefore, we categorized the posting periods into more than 2 years (Code: 1), more than 1 year (Code: 2), more than 6 months (Code: 3), and less than 6 months (Code: 4). Appendix A shows descriptive statistics and correlation results for each variable.

5.2. Econometric model specification and results

Formula 1 describes the econometric model of this study. We analyzed for each review i per time t (posting period). Thus, $Rating_{it}$ is combined with cross-sectional data and time-series data. α_0 is a constant term, α_i is an individual-specific effect, and ε is a random error.

$$Rating_{it} = \alpha_0 + \alpha_i + \beta_1 DVC_{it} + \beta_2 USB_{it} + \beta_3 INF_{it} + \beta_4 ADP_{it} + \beta_5 SND_{it} + \beta_6 HMA_{it} + \beta_7 VTR_{it} + \gamma_1 Brand_{it} + \varepsilon_{it} \quad (1)$$

This model was estimated, respectively, with a fixed-effect model and a random-effect model, and the model for use was selected based on the Hausman test [68]. The test result showed a significant correlation between the random error and the individual-specific effect (α_i) at the 1% significance level. Hence, we used a fixed-effect model.

Table 4 illustrates the relationship between UX dimensions and user satisfaction with a smart speaker. The ordinary least squares results were similar to the fixed-model results. Five dimensions (usability of smart speakers, informativeness of smart speakers, sound quality of smart speakers, home automation of smart speakers) showed positive significance with user satisfaction. However, the two dimensions remaining

Table 4
Results of econometric model.

	OLS			Fixed effect Model		
	Coefficient		S.E.	Coefficient		S.E.
Constant	4.684	***	(0.005)	4.656	***	(0.010)
Device control of smart speakers (DVC)	−0.001		(0.010)	−0.001		(0.010)
Usability of smart speakers (USB)	0.152	***	(0.009)	0.152	***	(0.009)
Informativeness of smart speakers (INF)	0.043	***	(0.009)	0.044	***	(0.009)
Adaptability of smart speakers (ADP)	0.127	***	(0.010)	0.126	***	(0.010)
Sound quality of smart speakers (SND)	0.024	*	(0.010)	0.025	*	(0.010)
Home automation of smart speakers (HMA)	0.037	**	(0.012)	0.037	**	(0.012)
Virtual assistant of smart speakers (VTR)	−0.009		(0.011)	−0.009		(0.011)
Brand	−0.112	***	(0.006)	−0.098	***	(0.008)
Posting Period						
More than 1 year				0.033	***	(0.009)
More than 6 months				0.028	*	(0.011)
Less than 6 months				0.010		(0.013)

Notes ***, **, and * denote significance at 0.1%, 1%, and 5%, respectively.

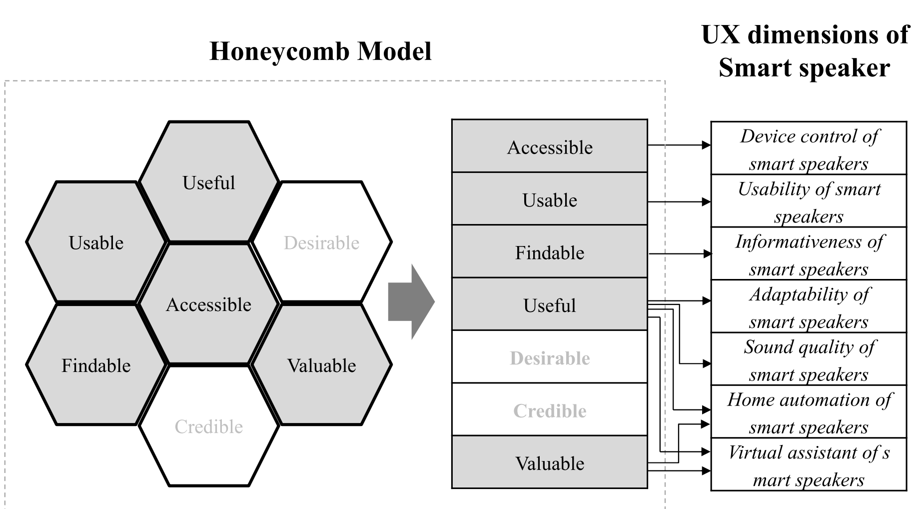

Fig. 3. Honeycomb model and UX dimensions of smart speakers.

(device control of smart speakers, virtual assistant of smart speakers) showed no statistically significant association with user satisfaction.

We also found that the Amazon brand had a positive effect on user satisfaction compared with Google ($\gamma_1 = -0.112$, p-value<0.001). This study also shows that users over one year and over six months have higher satisfaction than users over two years.

6. Discussion and implications

6.1. Discussion of findings

This study made several significant findings. In drawing upon the honeycomb model [23], we identified seven UX dimensions and tested the relationships between explored UX dimensions and user satisfaction. Furthermore, we discovered additional insights related to user satisfaction with smart speakers.

First, a notable result of this study is using topic modeling methods to explore the UX dimension. We extracted *device control of smart speakers, usability of smart speakers, informativeness of smart speakers, adaptability of smart speakers, sound quality of smart speakers, home automation of smart speakers, and virtual assistant of smart speakers* as the explored UX dimensions of smart speakers. We applied the honeycomb model [23] and aligned the explored factors in a smart-speakers context. Although previous research has highlighted the adoption decisions of smart speakers [31,32] and consumer acceptance of smart speakers [31], little research has been devoted to exploring the dimensions of smart speakers from the perspective of UX. User experience is an essential factor leading in the cognitive process of user satisfaction [12,14] and the success of IT products [13]. In this paper we introduced the concept of the UX dimensions of smart speakers to fill some of those gaps in the literature on smart speakers. We also developed a research model to conceptualize the relationships between these UX dimensions as antecedent variables and user satisfaction as consequent variables.

Second, we confirmed the significant relationship between explored UX dimensions and user satisfaction. *Usability of smart speakers, informativeness of smart speakers, adaptability of smart speakers, sound quality of smart speakers,* and *home automation of smart speakers* as major UX dimensions generate strengthened user satisfaction. These five dimensions can be aligned as *Useable*, *Findable*, and *Useful* in the honeycomb model [22]. This result is consistent with previous findings [3,4,22,31,32] based on the technology acceptance model [33] that explains how *Useable*, which is similar to *perceived ease of use*, and *Useful*, which is similar to *perceived usefulness*, leads to user attitudes and behaviors in a smart-speaker context. They also agree with previous studies [69] that *Findable*, like *functional intelligence*, facilitates consumer satisfaction in the context of AI artifacts.

However, we found that *device control of smart speakers and virtual assistant feature of smart speakers* have no direct impact on user satisfaction. These can be interpreted as *Accessible* and *Valuable* in the honeycomb model [23]. This lack of impact could be related to smart-speaker context-specific issues. A potential reason for this lack of *device control of smart speaker*'s significance is that users are reluctant to connect their personal devices and smart speakers because of privacy and security issues [31,32]. Thus, they mainly connect smart speakers to only one primary device and not to multiple devices. On the other hand, the reason that *virtual assistant of smart speakers* has no significance might be that the current virtual assistant features do not meet users' expectations. According to a survey [70], the users who have experience with virtual assistants report that the voice recognition features didn't work well, and these users were dissatisfied because of the difficulty of achieving their goals by using a virtual assistant.

Lastly, we also found additional noteworthy results. For example, users prefer the Amazon brand over the Google brand. Also, satisfaction with smart speakers is increasing over time. They can provide additional functions and features through software updates over wireless internet from time to time. Moreover, compared with the innovator, the early majority have lower expectations for products. According to expectation-confirmation theory [71], low expectations positively affect user satisfaction. Early users have low expectations for new products, so it is relatively easy to meet their expectations. Over time, user expectations for products increase, and it becomes difficult to satisfy users. Therefore, we empirically revealed that user satisfaction positively affected a shift among primary users from innovators to the early majority.

6.2. Limitations and future research

This study is not without limitations, and these may suggest avenues for future research. First, this study focuses on only two smart speakers models (i.e., Amazon Echo Dot, Google Home Mini). Recently, numerous third-party speakers like the Sonos One have been developed [72]. Moreover, with the LCD screens that are part of the latest smart speaker models, voice control and screen touch are possible. The market share of smart speakers with a touch screen (e.g., Amazon Echo Show, Google Nest Hub) has been increasing recently [73]. Future studies are encouraged to examine different UX from other models of the newest specifications.

Second, we only collected data from Best Buy users in the U.S. The use of smart speakers is a global trend [74]. However, each country has different levels of smart speaker technology adoption. Therefore, we call for future research to consider developing a framework of smart-speaker technology adoption [75] or comparing the UX at different levels of technology adoption. In addition, it is necessary to collect users' reviews from other shopping sites or social network services because Best Buy's users' reviews may have unique characteristics compared with other sites. Furthermore, we acknowledge that online reviews do not necessarily reflect all actual UX, although online review data is a good source for collecting an enormous amount of data related to UX.

Furthermore, our data is only from native English speakers. According to previous studies [76,77], native English speakers had a better UX than non-native English speakers. Notably, Pyae and Scifleet [78] identified that users' English proficiency is an essential factor that affects UX of smart speakers. Our study suggests that future studies should collect review data from not only native English speakers but also non-native English speakers. It provides a better understanding of the UX dimensions of smart speakers for different user groups across the countries.

Third, although our samples are panel data, we did not have enough to reveal how the UX differs depending on the stage of technology adoption. Also, the UX dimensions considered important by the users may differ at each stage. Therefore, future studies should keep track of the UX across all phases to provide additional insights into this particular area. Additionally, we used the star rating as a single source of the dependent variable. The star rating is a measure that reflects the user satisfaction with the product itself and all other experiences of purchasing (e.g., delivery, customer service). Future studies should find additional variables to measure user satisfaction. For example, users can measure the rating from 1 to 5 for the *quality*, *value*, and *ease of use* optionally in the review form in Best Buy. These data might be helpful to complement star ratings.

6.3. Implications for research and practice

Our study has several research and practical implications. First, in its research implications, this study endeavors to explore the UX dimensions of smart speakers that previous studies have only touched upon [30,78]. Our study's first research question is (1) What are the UX dimensions of smart speakers that are voice-controlled devices? To seek the answer, we collected online reviews and analyzed the review data by using text-mining techniques. Based on the honeycomb model [23], the text-mining results were analyzed, and the UX dimensions of smart speakers were defined. Keywords corresponding to the UX dimension of smart speakers were also derived. Furthermore, this study can be considered a pioneering attempt to use written UX (i.e., review data), unlike prior studies that relied on surveys or experiments (e.g. Refs. [2,19,28,30]).

Second, we extended the concept of UX dimensions based on Morville's honeycomb model [23] into the smart-speaker context. Understanding the UX dimensions is important because it provides an essential structure of a useful product or service that can fulfill a user's needs [12]. In the literature, a few researchers found that exploring the UX dimensions could improve user satisfaction and intention to use [9,12,13]. Thus, this study aligns with the previously explored dimensions of the five factors of the honeycomb model (i.e., accessible, useable, findable, useful, valuable) to understand the holistic UX dimensions.

Third, we found the relationship between the explored dimensions and user satisfaction related to the second research question. We used an econometric approach to test our model with the panel data. As a result, we confirmed that usability of smart speakers, informativeness of smart speakers, adaptability of smart speakers, sound quality of smart speakers, and home automation dimensions have a positive relationship with user satisfaction. However, two dimensions, device control of smart speakers, virtual assistant of smart speakers, were found to have no significant relation to user satisfaction. In addition, we illustrated how the brand and posting period, which were the control variables, affected user satisfaction. We also demonstrated user satisfaction changes depending on the technology adoption stage [79] with expectation-confirmation theory [71].

This study also provides implications for practice. Significantly, the findings of this study suggest recommendations for improving user satisfaction with the UX dimensions in the context of smart speakers (see Appendix B). We contribute to enhancing user satisfaction by suggesting detailed guidance for each UX dimension from a practical perspective. The presented suggestions can be used when establishing marketing or R&D strategies to improve the UX of smart speakers. The UX dimensions, which have a significant relationship with user satisfaction, can be used for promotional phrases or marketing sources. On the other hand, the UX dimensions, which have no significant association with user satisfaction, require further system development and software upgrades.

7. Conclusion

Although the market for smart speakers with the development of AI technology is predicted to have substantial growth, satisfaction with the product is not very high and needs further investigation. This study explains the impact of the UX dimensions on user satisfaction in smart speakers by adopting a mixed-method approach. First, we used a topic modeling approach to analyze the review data and identify seven UX dimensions. We then developed and tested our research model, which was derived based on an interpretation of the seven UX dimensions in terms of the honeycomb model. Our study thus contributes to research by advancing the theoretical understanding of this promising digital artifact, smart speakers, and its UX dimensions. Practically, this study is helpful in providing recommendations for improving user satisfaction with the UX dimensions.

Appendix A. Correlation matrix

		Mean	S. D	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Star rating	V1	4.716	0.615	1.000									
Device control of smart speakers	V2	0.167	0.291	0.067	1.000								
The usability of smart speakers	V3	0.273	0.331	0.117	0.422	1.000							
Informativeness of smart speakers	V4	0.188	0.304	0.070	0.357	0.376	1.000						
The adaptability of smart speakers	V5	0.228	0.311	0.091	0.427	0.328	0.276	1.000					
The sound quality of smart speakers	V6	0.120	0.263	0.050	0.035	0.334	0.044	0.126	1.000				
Home automation of smart speakers	V7	0.067	0.202	0.023	0.045	0.077	0.096	0.014	0.119	1.000			
Virtual assistant of smart speakers	V8	0.159	0.284	0.057	0.418	0.252	0.608	0.348	0.086	0.098	1.000		
Brand	V9	0.449	0.497	−0.091	0.012	−0.035	0.047	−0.009	−0.064	0.026	0.083	1.000	
Posting Period	V10	2.163	0.925	0.053	0.004	0.027	0.005	−0.009	0.040	−0.027	0.012	−0.554	1.000

Appendix B. Recommendations for smart speakers

UX dimensions	Recommendations
Device control of smart speakers	• Developing an integrated platform that controls various wireless devices • Partnering with various device vendors or application companies
Usability of smart speakers	• Developing user-friendly systems and creating a user interface (UI) that is easy to use • Simplifying the operating manual with a design that makes the device appear intuitive
Informativeness of smart speakers	• Investing in AI technology to deal with complex problems and provide the necessary information to users • Developing continuous self-supervised learning such as BERT
Adaptability of smart speakers	• Increasing the systems' flexibility to permit use in various places • Providing specialized functions for various rooms
Sound quality of smart speakers	• Improving their audio systems to produce a balanced sound • Collaborating with audio manufacturers
Home automation of smart speakers	• Enhancing the features of smart speakers that enable them to function as smart-home hubs • Building a home security system in cooperation with a security company
Virtual assistant of smart speakers	• Increase the overall responsiveness of AI services • Improving the response and reaction speed of AI assistants that rely on cloud services

(1) In terms of *device control of smart speakers*, Providers (i.e., smart-speaker manufacturers) should establish systems to increase compatibility with connected devices. Developing an integrated platform that controls various wireless devices such as smartphones and smartwatches via voice commands is necessary. Providers should also partner with various device vendors or application companies.

(2) In terms of *usability of smart speakers*, providers should continue to develop user-friendly systems. It is necessary to create a user interface (UI) that is easy to use. It is also required to simplify the operating manual with a design that makes the device appear intuitive to operate.
(3) Regarding *informativeness of smart speakers*, providers need to focus on investing in AI technology to deal with complex problems and provide the necessary information to users. However, the smart speaker of the current technology has limitations in combining various pieces of information to solve complex problems. Therefore, providers should invest in developing technologies such as an AI language model to improve the informativeness of smart speakers.
(4) As for *adaptability of smart speakers*, providers need to increase the systems' flexibility so as to permit their use in various places. There is a need to develop a system capable of changing smart-speaker settings to suit the multitude of spaces in offices and houses. It is also necessary to provide specialized functions for various rooms, such as controlling an induction cooktop in the kitchen and adjusting water temperature by voice command.
(5) In terms of the *sound quality of smart speakers*, providers need to improve their audio systems to produce a balanced sound. Hardware reinforcement is required through collaboration with audio manufacturers. To improve the sound quality, it may be considered to release two-channel smart speaker in a stereo pair.[2]
(6) Regarding *home automation of smart speakers*, the provider should enhance the features of smart speakers to enable them to function as smart-home hubs. It is also necessary to build a home security system in cooperation with a security company.
(7) In relation to the *virtual assistants of smart speakers*, the provider should increase the overall responsiveness of AI services. It is necessary to plan a service that allows smart speakers, through deep-learning algorithms, to take preemptive actions before calling AI assistants. In addition, noise reduction systems are needed that can offer a significant enhancement for the speech recognition and performance capabilities of AI assistants.[3]

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