Uncovering the Underlying Factors of Smart TV UX over Time: A Multi-study, Mixed-method Approach

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ABSTRACT
The objective of this research is to explore and identify Smart TV user experience (UX) factors over different time periods employing multiple methods so as to overcome the weakness of a single study approach. To identify the effect of contextual dimensions on the Smart TV UX, we conducted empirical studies exploiting different methods of think-aloud and diary method under two usage conditions: laboratory and real-life in the participants' residence. The factors identified through each study were integrated into a single set and further refined through peer review resulting in a final set of 19 UX factors. Metrics for these 19 UX factors were generated and used in an online survey, in which over 300 Smart TV users participated. The empirical evidences from each study suggest that the UX factors vary with respect to product temporality. The findings indicate practical implications for Smart TV manufacturers, marketing managers, application developers, and service providers.

Author Keywords
User Experience; Smart TV; Laboratory Experiment; Diary Study; Survey; Temporality

ACM Classification Keywords
H.5.2. User Interfaces

INTRODUCTION
As one of the major sources of entertainment, television plays a central role in home environment. People can enhance their relationship with family members by watching movies and shows together. According to the American Time Use Survey produced by the United States Department of Labor, watching TV as a leisure activity occupies the most time (2.8 hours per day), accounting for more than half of leisure time on average for those aged 15 and over.

Currently launched electronic devices including home appliances are now able to connect to Internet, set up an operating system, and support various online functions for convenience. The smartphone, for example, has become a primary device for communication and computing activities and continuously permeates every corner of our daily lives. A smartphone is now equipped with various smart functions, including web browsing, advanced sensors to capture contextual factors, high-speed wireless network, and new application installations, differentiating them from traditional mobile devices (called feature phones). Similarly to the mobile phone, television has rapidly evolved to become much smarter through advanced connectivity and sophisticated functionality. Smart TV, a television set with integrated Internet accessibility and online interactive media capacities with operating systems, has started to attract considerable attention from TV manufactures and consumers worldwide. According to Gartner Inc., all televisions produced in 2016 will belong to a category of smart products [27]. Given the development of the latest Smart TVs functions (e.g., games, three-dimensional (3D) movies, and fitness), maintaining a balance between complexity and diversity has emerged as an important challenge for television designers. In the past, traditional television designers highlighted viewers' relaxation and passivity as important factors in their viewing enjoyment [10, 31]. However, when designing Smart TVs, designers should consider various usability factors of complex entertainment environments such as network connection functions, picture resolution and quality, and the various content sources, such as broadcasting, movies, user created contents, and applications.

User experience (UX) has been studied in diverse fields such as human-computer interaction (HCI), marketing, and product design. Although UX is important, it has been difficult to define or capture its nature and scope effectively, as it involves understanding the human experience in its entirety [24]. In particular, the underlying factors of UX with regard to Smart TV are almost unknown rather than other products or services [4].

A comprehensive set of UX evaluation methods has been developed. Each research method has both positive and negative attributes, and thus, a single-method approach is unlikely to successfully capture the full spectrum of UXs [24]. In this research, we applied three different methods: the think-aloud method under laboratory conditions, the diary method under real-life conditions, and an online survey. The advantage of the think-aloud method is that it captures the UX factors expressed at the moment the user is first introduced to the product. How-

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ever, it is limited because of the difficulty of extending it to a large number of experimental subjects. Further, it inherently suffers from the problems of unnatural user responses and an isolated setting in contrast to a real environment. The diary method can collect various UX factors related to the use of the real product in the home environment. However, it is difficult to conduct a long-term experiment because of the cognitive effort that is required from the subjects. In an online survey, the respondents' memory may be distorted by the time delay; however, a survey can collect the quantitative opinions of diverse users about UX factors. Moreover, UX for the Smart TV, an emerging product, has not been sufficiently studied because of the complex nature of the interactions between users and the various functions of the TV sets. Thus, the nature of Smart TV UX cannot be completely captured if only one of these research methods is applied. In order to gain a comprehensive picture of the Smart TV UX, we believe that various methods to analyze user reactions and behaviors should be employed.

The lifecycle of new electronic products has significantly changed because of the rapid change in consumer usage patterns. Manufacturers should now provide a number of functions on a user-friendly interface while also continuously updating these applications and firmware. In the UX research field, several studies that observe the patterns of user reactions to traditional devices over different time scales have been conducted [20, 21]. However, studies on the new Smart TV UXs using different research methods to observe users during various stage of the technology lifecycle are almost non-existent. Thus, in this study, we focused on determining the Smart TV UX factors over various temporalities using different research methods.

USER EXPERIENCE

For decades, HCI researchers and practitioners have contemplated the concept of UX and its underlying components. For example, McCarthy and Wright [26] defined UX quality as an evaluation of the use of technological artifacts in human life. They stated that UX has four sub-components: compositional, emotional, sensual, and spatio-temporal. Hassenzahl and Tractinsky [15] showed that UX is the outcome of a user's internal state, the system characteristics, and the usage context. Law et al. [24] conducted a literature survey to examine the scope and definition of UX, collecting the views of 275 researchers and practitioners on UX. Their study found a large number of definition statements for UX in various fields, and they concluded that UX is a dynamic, context-dependent, and subjective concept. Alben [3] and other researchers (e.g., [13, 24]), has noted that "experience" means all aspects of interactive use of an end-user product. Specifically, most researchers highlight UX elements as having both hedonic and pregnant aspects [15, 20]. Following the trends of previous UX research, we define UX factors that significantly influence user experience and cover all usage aspects in this study.

UX studies contribute to a theoretical background for the development and design of products and analysis of user behavior. UX research has been applied to various products including mobile applications, smartphones, and websites [4]. However, their analyses of UX factors indicate that certain products have been insufficiently studied. Bargas-Avila and Hornbæk mentioned that the products most frequently addressed in UX studies are art-based applications (such as interactive software and products) and mobile device applications. The forecasting report of Gartner Inc. stated that the Smart TV, an emerging product, will be a market-leading product in the near future [27]. However, an insufficient amount of research on its UX has been conducted because such research is more expensive than research on mobile devices, which are popular objects of UX research. Traditional TVs did not emphasize user experiences because those experiences were focused on simply watching broadcasting. For example, Csikszentmihalyi and Kubey [10] applied experience sampling methods to study the fluctuation of individuals' mood when watching traditional television. Hess et al. [17] conducted a study using the diary method and interviews to discover the interconnection traits between social TV (not Smart TV) and other devices. Our study conducts research on the new Smart TV user experience, utilizing various features based on previous user experience studies for other products.

At the same time, UX researchers also have been interested in the changes in UX and users' reactions with respect to temporality. On the first use, novice users who have little knowledge of the target product judge its perceived ease of use according to general or abstract criteria, whereas experienced users judge it according to specific or concrete attributes using their increased knowledge accumulated through their own experiences [7]. Research conducted by Karapanos et al. [20] suggested that UX moves through three phases: orientation, incorporation, and identification. These phases occur after the anticipation stage, which occurs when the user has expectations before being introduced to the product. In the orientation stage, users encounter the novel features with their learnability flow. Moreover, users may feel excited by these new features as well as frustrated from the target product. Next, the incorporation stage is the process of identifying the meaning of the product in real life. In this stage, the long-term usability of the product's functionality and usefulness become clear to users with increasing familiarity as they continue using the product. Finally, there is the identification stage, during which users' emotional attachment through socialization and personalization of their product interaction occur. Based on these stages, studies have verified the temporality of UX from real user narratives [21, 22]. However, these studies were applied using a single method, and they did not make full use of its advantages and disadvantages. In addition, the User Experience White Paper [32] defines four phases of UX: anticipated UX, which includes prior expectations and experiences; momentary UX, which is the user's feeling on the product as the user interacts with the target object; episodic UX, which consists of the user's feelings during a specific usage episode, and cumulative UX, which consists of the user's feelings over time. As for the temporal aspects of UX, Bargas-Avila and Hornbæk [4] showed that 70% of them were based on an analysis of the user's feelings after using the product, and studies that targeted all phases of UX temporality comprised only 17%. In sum, no previous research study has comprehensively captured the Smart TV UX over the entire temporality of the product since they focused either on user interactions with the

technology or the users' intrinsic state. Traditional televisions have fewer interactive factors than other devices, thus their appearance is the most important factor affecting user satisfaction [10]. Different from conventional TVs, one UX issue of Smart TVs is related to its operating system, such as the effective control of the TV using a remote control device or voice commands or the customization of the user interface to meet user requirements [33].

In the absence of knowledge about the influence of temporality on Smart TV UXs, we combined multiple research methods to explore the complete spectrum of Smart TV UXs without being constrained by the limitations of a single-method approach. In this study, we observed the differences in UX between early and late usage stages in different Smart TV usage contexts through experiments in controlled lab and real-life usage environments, as well as an online survey.

RESEARCH FRAMEWORK

The overall framework of our study is shown in Figure 1. One objective of our study was to empirically identify UX factors while users were experiencing the Smart TV. Another objective was to determine the correlation between different periods in the Smart TV usage stage and the positive or negative UX factors identified by users. Thus, we experimentally targeted Smart TV users to elicit the UX factors of which they were conscious. First, we extracted keywords for the user expectations of Smart TVs from responses to a pre-test survey (Study 1) conducted prior to the laboratory and real-life condition experiments. We performed a laboratory condition experiment using the think-aloud method (Study 2) to extract the UX of first impressions. We next set up Smart TVs in the living rooms of real homes (Study 3). The subjects living in these homes kept a daily diary, and from their diary entries, we extracted keywords for the UX factors. Finally, targeting Smart TV users who had used the product within one year, we conducted an online survey (Study 4) to score the importance of the Smart TV UX factors, which were obtained from the results of the think-aloud and diary methods. Thus, we were able to observe the changes in the UX factors over time, including those UX factors collected prior to actual contact with the product. In Studies 2 and 3, popular Smart TV products produced by two major electronic companies were evaluated. We measured three indices of user consequence (perceived usefulness, satisfaction, and continuous intention to use) to check whether the consequences were different between the two manufacturers.

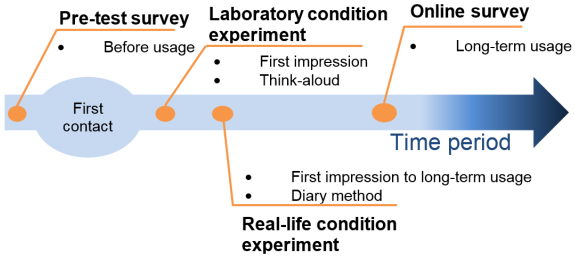

Figure 1. Research framework

Contents	First Coding	Second Coding
Unnecessary buttons	Inconvenience	Perceived helpfulness
Good to excellent picture quality for watching TV	Perceived picture quality	Perceived picture quality
Loading speed is too slow	Responsiveness	Perceived responsiveness

Table 1. Coding examples

We coded the user-mentioned think-aloud and diary data into abstracted keywords. An example of the coding analysis is shown in Table 1. We recruited four coders, two doctoral students and two master students, who had coding analysis experience and a deep understanding of a Smart TV's functionality. The analysis was conducted as follows. First, we transcribed the recorded think-aloud data and converted the written diaries and pre-test responses into a uniform text form. Second, we initially categorized similar codes into groups. Finally, we named each group based on the codes in the group. In the first round, after a detailed explanation of the coding procedure, the four coders independently coded the extracted statements. The correlation among the coders was 75%-a substantial agreement. After the initial coding activities, the coders examined the codes, discussed their discrepancies, and arrived at a consensus. In the case of Study 2, after reviewing sentence of their responses, the coder input users' feelings as positive, neutral, and negative condition. Then, all coders reaffirmed the feelings of all the elements through the discussions. In the case of Study 3, experimental participants responded the feelings as positive, neutral, and negative condition. After the codes were extracted by the coders, a panel comprising four of the authors further categorized the codes into groups such that similar codes were located together in a group. Word frequency is the most important variable in research on human memory and word processing; therefore, the frequency of keywords considered as the importance in each study.

STUDY 1: PRE-TEST SURVEY

Objective and Method

UX is often influenced by user expectations formed from prior knowledge of related products or others' opinions before the first use [32]. We requested users for their expectations of the Smart TV when the participants began the experiments in Study 2 and Study 3.

The survey was completed by a total of 23 participants who took part in one of the 2 user experiments: 15 participants from the laboratory condition experiment and 8 household representatives from the real-life condition experiment.

Results

As shown in Table 2, we extracted keywords from 21 user responses because 2 user responses did not include any keywords. In total, 35 keywords were extracted. Content diversity appeared with the highest frequency. For example, participants mentioned: "I would like to see the program without any payment, not even as pay-per-view," "I think Smart TV should

UX Factors		Frequency
Content diversity	11	30.6%
Perceived picture quality	6	16.7%
Connectivity	6	16.7%
Real-life applicability	5	13.9%
Relative salience	4	11.1%
Others	2	5.6%
No response	2	5.6%

Table 2. Summary of Study 1 Results

recommend an appropriate program to me," and "TV should provide rich video content." In addition, perceived picture quality and connectivity were also frequently included in their expressed expectations. Thus, Smart TV users expected to watch various broadcast and Internet content on a television with a high quality screen connected to a network or other device [18]. In addition, the ability to schedule or replay contents were derived.

STUDY 2: LABORATORY CONDITION EXPERIMENT

Objective

The full UX spectrum includes a user's daily thoughts and feelings. However, user surveys or other methods can only collect responses after a time interval, and they are therefore based on the responder's selective and delayed recall of his/her experiences [9]. Thus, we naturally required a research method to collect user responses that reflect their feelings during the actual use of the product.

In the laboratory experiment in which the think-aloud method was applied, direct observation was performed in a controlled environment to study the behavior of users on the first contact with a product. The objective of this study was to derive new UX factors from freely voiced comments [29]. We set up an environment similar to an actual living room, simulating the environment of home setting. Based on the guidelines given to the subjects, we asked the participants to mention their thoughts and emotions naturally while using the Smart TV. The conversations were recorded and transcribed to text-based data that were later used to derive the UX factors.

Method

Laboratory Design

We took the real usage environment into consideration and set up a laboratory that allowed a relatively natural behavioral observation and data collection process [17]. As shown in Figure 2, we set up a private space with furniture, for example, a sofa with decorations, so that the participants could express their feelings and thoughts in a relatively relaxed and natural manner. Also, two popular Smart TV models produced by different manufacturers were used in this experiment.

Recruiting

A total of 15 participants (7 male and 8 female), undergraduate or graduate students in South Korea, were recruited by advertising on an online community board. The ages of the participants ranged from 20 to 29 years with a mean of 23.67 years. All the participants had smart device usage experience

Figure 2. Laboratory design

(e.g., a smartphone or smart tablet), but no experience using a Smart TV. Participants were given a monetary incentives of 15,000 Korean Won (approximately $13 USD).

Procedures

The participants took part in the think-aloud method experiment, in which they voiced their thoughts and emotions about the Smart TV. They used two Smart TVs sequentially and were provided with step-by-step manuals explaining the functions required for the given tasks. The participants performed the pre-test before they participated in the experiment and the post-test after the experiment. The pre-test consisted of a demographics questionnaire. To determine the effects of the different TVs, the post-test included the items of perceived usefulness, satisfaction, and continuous intention to use.

The participants were required to conduct the eleven most commonly used functions of the Smart TVs: controlling the screen using the remote controller, executing the YouTube application to watch a YouTube video, using the recommended programs menu, controlling the Smart TV by voice, switching external inputs, connecting with smartphones through a wireless network, using social network applications, recording video, surfing the Internet, gaming, and watching 3D movies. It was required to perform the same task for limited time to the experiment participants. Participants should mention the feelings within limited time. It was an average of 20 minutes for a response. The average number of sentence that participant mentioned was 45.6.

Text coding from records to text

The detailed procedures of coding and labeling UX factors mentioned in the previous 'Research Framework' session. The participants' audio response on their thoughts and feelings about the Smart TV were all recorded in the laboratory. The recorded data were transcribed to text and coded into single phrases using the following schema: action, specific features or factors of the Smart TV, and the emotional reaction of the user. Statements that were irrelevant in terms of deriving UX factors (e.g., comments about the manuals, meaningless dialogue, and repeated interjections) were excluded.

UX Factors	POS	NEU	NEG	SUM	
Controllability of the remote control	32	3	107	142	20.8%
Cognitive ease	18	2	92	112	16.4%
Perceived usability of the voice command	23	0	61	84	12.3%
Relative salience	44	4	16	64	9.4%
Perceived responsiveness	8	1	44	53	7.7%
Real-life applicability	24	0	18	42	6.1%
Perceived picture quality	19	0	17	36	5.3%
Perceived helpfulness	6	1	24	31	4.5%
Customized flexibility	1	4	21	26	3.8%
Stability	1	0	22	23	3.4%
Content diversity	6	0	7	13	1.9%
Perceived quality of 3D viewing	3	1	8	12	1.8%
Perceived aesthetics	7	0	3	10	1.5%
Appearance appropriate	3	1	6	10	1.5%
Connectivity	1	0	9	10	1.5%
Ease of adaptation	0	0	3	3	0.4%
Perceived playfulness	0	0	2	2	0.3%
Perceived security	0	0	2	2	0.3%
Perceived sound quality	0	0	1	1	0.1%
Others (price, services..)	4	1	3	8	1.2%

Table 3. Summary of Study 2 Results

Labeling UX factors

We summarized unified UX keywords into a single phrase. Four coders participated in this operation. The purpose was to express the user's feelings about the Smart TV in terms of UX in a form that the user could understand. For inter-coder consistency, the code consistency between statements was derived by discussing each UX factor. As a result, a total of 684 keywords were derived from the voiced sentiments, which were used as the base material for the final derived UX factors.

Results

As shown in Table 3, the most frequently mentioned factor was the controllability of the remote control, which accounted for 20.8% of the factors mentioned. The comments for the controllability of the remote control factor included several negative opinions, such as "using the remote control to click on menus was a little time consuming because of it was not sensitive" or "difficult to manually access the menu." The top three factors, Controllability of the remote control, cognitive ease, and perceived usability of voice command, were mostly mentioned negatively. This reflects the fact that during their first contact with the Smart TV, the participants found the control of its functions inconvenient. In addition, relative salience and perceived responsiveness, which are related to the first impression of the Smart TV, were highly ranked.

A paired samples t-test was performed to examine the effects of usage consequence for two brands of Smart TV. Perceived usefulness ($t = .22$, $p = .82$), satisfaction ($t = .08$, $p = .93$), and continuous intention to use ($t = .47$, $p = .64$) did not differ between the two manufacturers.

Figure 3. Real-life condition experiment

STUDY 3: REAL-LIFE CONDITION EXPERIMENT

Objective and Method

The diaries were directly written by the participants, describing their feelings about the product [19]. The participants were required to participate in a three- or six-week study so that their real feelings about Smart TV usage in their living room could be well captured, as shown in Figure 3. We provided TV which was randomly selected from two popular Smart TV models, the same as Study 2. After recruiting all the participants, the Smart TV was set up in his/her home; the pre-test was also conducted before this experiment and instructions were given to the participants. During the following three or six weeks, the participants were required to use the television for more than one hour per day and write at least three semi-structured diary entries each day. They were instructed that every diary entry should include the date and time of usage, the number of peer viewers, the types of Smart TV function they used, the motivation for using the function, their reactions, and their sentiments regarding the usage [17]. For example, a participant submitted the following report:

- Date: Nov. 30 (Sun)
- Time: 2PM – 3PM
- Number of peer viewers: 3
- Types of Smart TV function: YouTube app.
- Motivation for function usage: After lunch, we wanted to find and watch a "dinosaur" documentary.
- Reactions: I love comfortably watching YouTube content using a wide-screen Smart TV.
- Sentiment of usage: Positive

After keeping diaries using the workbook we provided, participants submitted the workbook to us every week. They also responded to the weekly survey that asked about the UX results, perceived usefulness (USEF), satisfaction (SATF), continued intention to use (CINT) the television [12], and any additional subjective comments. They responded to the survey on a seven-point Likert scale ("Strongly disagree" to "Strongly agree") for each construct.

Participants

We recruited participants who lived with at least two other people in a family. All families had no experience of using a Smart TV, but all the members had experience using smartphones. Six of the recruited families participated in the experiments for three weeks and two for six weeks. The researchers visited the family's home and installed the Smart TV with explaining the instructions for the experiment. In the real-life condition experiment, twenty-six participants (excepting young people under 10 years old) from eight households participated. The average age of the participants was 38.5 years. Four households included children whose ages ranged from 1 to 10 years. Two households included senior people over 60 years old. Participants were given monetary incentives of 100,000 Korean Won for each week (approximately $86 USD).

Results

We collected 689 semi-structured diaries from the participants written during the three- to six-week experimental period. The average duration of television usage was 68 minutes per day, and the major activities participants conducted using the Smart TV included: watching videos, surfing the Internet, connecting with other devices (e.g., smartphones and PCs), and watching live broadcasting. We also examined the differences in UX during different times of day: morning (05:00 – 12:00), afternoon (12:00 – 17:00), evening (17:00 – 21:00), and night (21:00 – 05:00). The most usage occurred at night (n = 230), followed by evening (n = 156), morning (n = 108), and afternoon (n = 76). No response was given in 119 cases (n = 119). Of all the responses, 61.0% (n = 417) were written about unique features of the Smart TV (not conventional TVs) such as video search, payment for content, smart application use, and the ability to view users' smartphone screens.

In the 689 texts that contained UX information gathered from the participants' reports, and Three-week participants were mentioned an average of 71.83 sentences (Max.: 84, Min.: 62). Six-week participants noted an average 107 sentences. Twenty UX factors were found, as shown in Table 4. Similar with Study 2, the most frequently mentioned factor was the most frequently mentioned factor was controllability of the remote control, which accounted for 26.3% of the factors mentioned. The comments on the controllability of the remote control factor included several negative opinions, such as "difficult to focus the cursor of the remote control" and "not easy to control the wheel on the remote control". In addition, real-life applicability and content diversity, which are related to a user's continuous impression of the television, were ranked relatively high.

We also performed a paired samples t-test to test the effects of the two brands of Smart TV. The results showed that the perceived usefulness ($t = 1.06$, $p = .30$), satisfaction ($t = 1.26$, $p = .22$), and continuous intention to use ($t = .69$, $p = .49$) did not differ between the two manufacturers.

The results of the weekly survey showed that the average of scores improved from the first to the last week, as shown in Figure 4. Similar to the quantitative results, the qualitative responses changed from abstract usability to long-term concrete opinions. For example, in the first week of the experiment, there were responses about the difficulties of initial use such as "I think the television had excellent picture quality, but it was difficult to operate the remote controller," or "While there were convenient features in the television, there were some difficult-to-use features. A description is needed." In the second week, there were opinions such as "Now I am a little more familiar with the television," "Overall, I could distinctly recognize the difference from regular TV," and "I used television with functions available in a simple operation." Over the third week, there were opinions about overall satisfaction such as "There were points of the Smart TV that were convenient for me," "I am generally satisfied and appreciate the TV picture and sound quality." However, negative opinions also remained, such as, "The remote control was still uncomfortable, even after using it for six weeks."

UX Factors	POS	NEU	NEG	SUM	
Controllability of the remote control	49	8	124	181	26.3%
Real-life applicability	42	11	24	77	11.2%
Perceived picture quality	40	15	19	74	10.7%
Content diversity	14	4	44	62	9.0%
Perceived helpfulness	14	2	36	52	7.5%
Perceived responsiveness	14	1	26	41	6.0%
Connectivity	18	2	21	41	6.0%
Cognitive ease	5	2	21	28	4.1%
Perceived quality of 3D viewing	13	2	9	24	3.5%
Perceived usability of the voice command	14	2	4	20	2.9%
Perceived sound quality	3	3	7	13	1.9%
Ease of adaptation	6	2	4	12	1.7%
Customized flexibility	1	2	7	10	1.5%
Perceived playfulness	5	0	4	9	1.3%
Perceived security	0	0	5	5	0.7%
Stability	0	0	5	5	0.7%
Relative salience	2	1	0	3	0.4%
Perceived aesthetics	0	1	1	2	0.3%
Others (Price, service..)	5	2	23	30	4.4%

Table 4. Summary of Study 3 Results

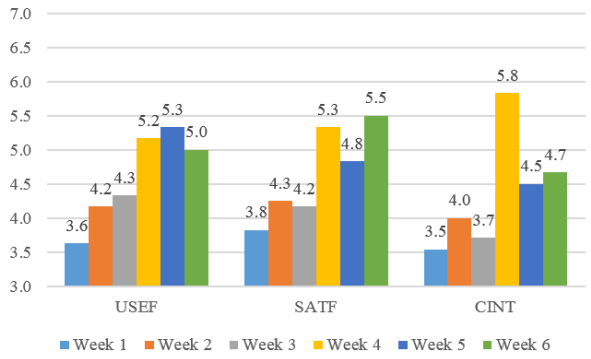

Figure 4. Results of the weekly survey in Study 3

REVIEWING SESSION AND DEFINING UX FACTORS

A validation of the results of the three experiments was performed. The validation was performed by seven subjects (four males and three females) who participated either in the laboratory condition experiment (5 participants) or the real-life condition experiment (2 participants). The difficulty of understanding the factors' names and relationships and any confusion regarding each factor were measured. According to these results, changes were made in the operational definition of some factors by using more easily comprehensible words and writing style.

After reviewing the results, we selected the most appropriate definition of the 19 UX factors based on their references. The usability of the voice command is the perceived ability of the Smart TV voice recognition function to provide sufficient and accurate control [12]. Stability is the degree to which users can use the Smart TV for a long time without defects of the device or completely discharging the remote controller battery [5, 23]. Relative salience is defined as the degree to which Smart TV feels relatively more innovative and prominent [2]. Real-life applicability is the degree to which users can use Smart TV appropriately in various situations [5]. Perceived sound quality is the degree of perceived sound quality output from the Smart TV [6]. Perceived security is the degree to which the Smart TV appears to safely handle personal information and avoid unnecessary exposure [14]. Perceived quality of 3D viewing can be defined as the perceived realism of three dimensional videos on the Smart TV. Perceived responsiveness is the degree of rapidity with which a product loads according to the user's requirement [8]. Perceived playfulness is the degree to which the use of a Smart TV gives the user enjoyment, amusement, or pleasure [8, 11]. Perceived picture quality is the degree of user perception when reading or seeing objects reproduced on a screen [8], and perceived helpfulness is the degree to which the Smart TV provides description or notification services to support user convenience [25]. Perceived aesthetics is the degree of aesthetic beauty of the user interface implemented on the screen [11]. Customized flexibility is the ability to which the user can easily change the setting of the Smart TV to suit his or her personal taste and convenience [28]. Ease of adaptation is the degree to which the Smart TV makes it easy for who to become familiar with watching and controlling the Smart TV [14, 16]. The controllability of the remote control is the degree to which the remote control is perceived as comfortable over a series of Smart TV control operations [30]. Content diversity is the degree to which a Smart TV provides various content (included apps) [23]. Connectivity is the degree to which the Smart TV smoothly connects with other devices or the Internet [5, 18]. Cognitive ease is intuitive or consistent provision of user interface elements (e.g., icons, buttons, or layout) in the Smart TV so that they are easy to understand [25]. Finally, appearance appropriate is the degree of suitability of the device exterior, such as thickness of the screen and its aesthetics [11].

STUDY 4: ONLINE SURVEY

Objective

An online survey targeting a large number of members was conducted to determine how each extracted UX factors contribute to the overall satisfaction level of Smart TV. In order to figure out the relationship between UX factors and users' satisfaction level, referring to the results of our prior studies, we developed a survey questionnaire that included 19 UX factors (perceived picture quality, appearance appropriate, interface aesthetics, relative salience, connectivity, perceived sound quality, controllability of the remote control, perceived quality of 3D viewing, perceived responsiveness, real-life applicability, content diversity, ease of adaptation, perceived usability of the voice command, customized flexibility, helpfulness, cognitive ease, stability, and perceived security) with user satisfaction as the dependent variable. The total number of questionnaire items was 115. Each UX construct included four to seven survey items to measure the effects of latent variables. We generated items on a seven-point Likert scale (with anchors from "Strongly disagree" to "Strongly agree") for each construct.

Method and Participants

After creating the questionnaire, we conducted a pilot test to determine whether the items had been appropriately configured for the purpose of the survey. A pilot test involving 33 Smart TV users was conducted to examine the psychometric properties of the measurement items and ensure their reliabilities and validities, both convergent and discriminant. Data was collected from the online survey responses. A total of 309 Smart TV users (168 males and 142 females) participated in the survey. The average age of the participants was 41.0 years, with a 10.74 year standard deviation.

Results

We tested the reliability and validity of the questionnaire items. First, we examined the reliability of the items and confirmed that all the constructs were highly reliable, i.e., all the reliability scores for Cronbach's alpha were higher than the standard

UX Factors	Mean (Stdev)
Perceived playfulness	4.91 (1.13)
Relative salience	5.24 (1.05)
Content diversity	4.78 (1.17)
Real-life applicability	4.84 (1.10)
Connectivity	5.16 (1.01)
Customized flexibility	4.59 (1.02)
Cognitive ease	4.59 (0.98)
Perceived quality of 3D viewing	4.22 (0.98)
Usability of the voice command	4.62 (0.77)
Perceived picture quality	5.49 (0.88)
Perceived aesthetics	4.77 (1.03)
Stability	4.86 (1.01)
Perceived sound quality	5.09 (0.99)
Ease of adaptation	4.97 (1.09)
Appearance appropriate	5.19 (0.90)
Controllability of the remote control	4.81 (1.20)
Perceived security	4.10 (1.09)
Perceived helpfulness	4.49 (1.10)
Perceived responsiveness	4.62 (1.20)

Table 5. Mean and standard deviation of the Study 4 results (bold: the highest and lowest score)

Predictors	β	t-value
Perceived playfulness	0.44	10.05**
Relative salience	0.26	6.45**
Content diversity	0.16	3.91**
Real-life applicability	0.09	1.91
Connectivity	0.06	1.69
Customized flexibility	0.06	1.46
Cognitive ease	0.06	1.37
Perceived quality of 3D viewing	0.04	1.32
Usability of the voice command	0.03	1.32
Perceived picture quality	0.03	0.88
Perceived aesthetics	0.02	0.71
Stability	0.01	0.23
Perceived sound quality	0.01	0.16
Ease of adaptation	0.00	0.02
Appearance appropriate	-0.01	-0.32
Controllability of the remote control	-0.01	-0.33
Perceived security	-0.02	-0.56
Perceived helpfulness	-0.04	-0.77
Perceived responsiveness	-0.12	-3.45*

Table 6. Multiple regression model for testing result of Study 4 (* p < .01, ** p < .001. Dependent Variable: User satisfaction)

Study	Major UX Factors
Study 1: Pre-test	Content diversity* Perceived picture quality* Connectivity* Real-life applicability*
Study 2: Think-Aloud	Controllability of the remote control Cognitive ease Perceived usability of the voice command Relative salience Perceived responsiveness
Study 3: Diary method	Controllability of the remote control Real-life applicability* Perceived picture quality* Content diversity* Perceived helpfulness
Study 4: Online survey	Perceived playfulness Relative salience Content diversity*

Table 7. Temporality of Smart TV UX: summary (* indicates the UX factors found in the pre-test expectations)

cutoff point of 0.7. The lowest Cronbach's alpha value was that of appearance appropriate(0.89), while the highest value was that of perceived playfulness(0.97). We then checked factor loadings and cross-loadings through factor analysis. All the factors satisfied the assumptions of factor analysis.

The statistical results are shown in Table 5. Perceived picture quality received the highest mean score, while perceived security received the lowest. A multiple linear regression analysis was performed to examine the effects of the UX factors on Smart TV user satisfaction. As listed in Table 6, multiple regression analysis showed that the regression model explains 86.0% of the variance in user satisfaction and the model is significant ($F(19,290) = 94.02$, $p < .001$). Three UX factors, perceived playfulness($t = 10.05$, $p < .001$), relative salience ($t = 6.45$, $p < .001$), and content diversity ($t = 3.90$, $p < .001$) are statistically significant with a positive coefficient. Real-life applicability ($t = 1.91$, $p = .57$) and connectivity ($t = 1.69$, $p = .09$) are marginally significant. Perceived responsiveness, which is the reverse significant with negative t-value, indicated that the perceived product rapidity could not affect the user satisfaction of Smart TV.

OVERALL DISCUSSION

The objective of this study was to explore the elements of the Smart TV UX from various research methods and to identify the primary Smart TV UX factors over various time scales of usage. Specifically, we attempted to determine a comprehensive set of factors for the Smart TV UX by employing multiple qualitative methods and synthesizing the results from different research methods. In addition, we attempted to verify the validity of these factors by applying user satisfaction as the criterion variable in a regression model using data collected from online survey. The regression model results show that three primary Smart TV UX factors determine user satisfaction significantly. The results of the multiple linear regression model reveal that user satisfaction is explained by the Smart TV UX factors identified by this research with a high explanatory power. The R-square value was 86%.

As shown in Table 7, a comparison of the UX factors found in all studies confirmed that the users' expectations were not sufficiently met in the early stage of product usage. Specifically, users usually expected the Smart TV to provide various contents, good picture quality, a high level of connectivity, and wide applicability in real-life. However, these expectations were not met to a satisfactory degree according to the results of the think-aloud laboratory experiment, with several negative responses being given. We confirmed that the users' expectations were satisfied over long-term usage, both in the real-life experiment and online survey.

We observed the different user responses over the usage lifecycle in our three different studies. In the laboratory condition experiment using the think-aloud method, which targeted the participants' first impression of Smart TV, the results showed that the most frequently mentioned factors such as controllability of the remote control, cognitive ease, perceived usability of voice command, and perceived responsiveness were related mostly to the control of the devices for executing Smart TV functions. In the real-life condition experiment using the diary method, which targeted users who had watched a Smart TV for about one month, the results showed that the controllability of the remote control was the most frequently mentioned factor, but factors related to usefulness, such as real-life applicability, content diversity, and perceived helpfulness were mentioned more frequently than in the think-aloud method. We found that long-term Smart TV users are usually interested in the usefulness of a product rather than only its ease of operation. Because the controllability of the remote control is the most commonly mentioned as an important factor of

the Smart TV interface, we conclude that this factor requires continuous monitoring to improve user satisfaction in overall time periods. In the online survey, three significant factors were found to affect user satisfaction: perceived playfulness, relative salience, and content diversity. Previous studies (e.g., [7, 20, 34]) showed that the comments about UX changed from abstract to more concrete as usage time increased. Our results confirmed the prior research findings in terms of the variation of user responses over the product temporality.

In addition, prior UX research has identified affection (also called emotion) and aesthetics as key underlying factors in UX, and most UX guidebooks for designing products and services present design methods that encourage user affection and aesthetics [1, 15]. However, our qualitative studies show that aesthetics had a low percentage in the responses of user expectation (Study 1) and initial mentions (Studies 2 and 3). In addition, the results of our survey in Study 4 show that other factors, such as perceived playfulness ($\beta = .44$) and relative salience ($\beta = .26$), are more important than perceived aesthetics ($\beta = .02$) in the context of Smart TV UX. The results of previous studies show that product manufacturers not only met the customer expectations formed by the existing models and offer stable performance without mechanical errors or battery problems, but also deliver superior features and functions not found in prior and competitor's models. According to our study findings, aesthetics and affection-related factors are not as important as the factors that we extracted.

CONCLUSION

In this research, we empirically identified the primary factors that contribute to the overall Smart TV UX and verified statistically the validity of the discovered factors over various product temporalities. The UX factors revealed by this research together represent a comprehensive view of UX as it varies over different usage time periods, in contrast to prior television studies. In concrete terms, the result of the first study, a pre-test survey, showed that users highly expected a diversity of contents before encountering the product. Next, in Study 2, we conducted an experiment in a laboratory environment that asked users to mention their thoughts when they initially contacted the product. The result of Study 2 found that factors related to usability (e.g., the usability of the remote controller and cognitive ease) were frequently mentioned. In Study 3, we asked users in their living rooms to record a diary that included their emotions and thoughts about the Smart TV. The result of the third study, a real-life condition experiment with a diary, frequently presented not only usability but also various responses such as applicability in real-life, picture quality, and content diversity. Finally, in the online survey, major factors were mentioned, such as playfulness, relative salience, and content diversity, as factors that highly affected the users' satisfaction. Our sections of study followed the time stream from user's first contact with the product to long-term usage, and we found that the expectations of the product could be satisfied over the long-term use of a Smart TV. In addition, our research confirmed the results of existing studies in which elements that users mention gradually change from abstract elements to concrete elements.

Research on determining Smart TV UX factors is in its embryonic stage. To the best of our knowledge, our research is one of the first empirical investigations of Smart TV UX factors that uses a combination approach in which both qualitative and quantitative methods are applied. Our research procedure and model are expected to be easily generalizable to similar smart electronic products and home appliances. In addition, a quality assessment of new Smart TVs can be conducted using the factors and their metrics developed in this research. Future research can build on our studies to determine a tailored set of UX factors for new and innovative products that demand high levels of user engagement and quality experiences.

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