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User Centered Study on User Experience of Voice User Interfaces for Users with Disabilities: Focusing on Intelligent Personal Assistants

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Abstract

User Centered Study on User Experience of Voice User Interfaces for Users with Disabilities: Focusing on Intelligent Personal Assistants

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In recent years, research on Voice User Interfaces (VUIs) has been actively conducted. The VUI has many advantages which can be very useful for the general public as well as for elderly people and people with disabilities. The VUI is considered very suitable for individuals with disabilities to promote universal access to information, decreasing the gap between users with non-disabilities and users with disabilities. In this respect, many researchers have been trying to apply the VUI to various areas for people with disabilities to increase their independence and quality of life.

However, previous studies related to VUIs for people with disabilities usually focused on developments and evaluations of new systems, and empirical studies are limited. There have been a few studies related to User Experience (UX) of VUIs for people with disabilities. This situation is not different with studies related to Intelligent Personal Assistants (IPAs) which one of the most wildly being used VUIs nowadays. Although IPAs have potential to be practically used for users with disabilities because they can perform various tasks than simple VUIs, research related to UX of IPAs for them has been paid little attention to, only focusing on a young adult and middle-aged group among people with non-disabilities as end-users.

Many previous studies referred to that IPAs would be helpful to people with disabilities. However, only a few studies related to IPAs have been conducted from the angle of users with disabilities, especially in terms of UX. It is known for that investigating usability and UX for users with disabilities is more difficult and delicate than that of users with non-disabilities. It can be said that research on UX of IPAs for users with disabilities should be conducted more closely to understand their interactions with IPAs. The purpose of the research in this dissertation is to investigate UX of VUIs for users with disabilities, focusing on IPAs. The research in this dissertation consists of three independent main studies.

Study 1 investigates UX of commercially available VUIs for users with disabilities, by examining acceptance, focusing on the differences between users with different types of disabilities and identifying the reasons why they use or not use VUIs. A questionnaire survey was conducted for users with disabilities having used one or more VUIs. The collected data were analyzed statistically and qualitatively. The results of this study show acceptance of VUIs and the relationships between the acceptance factors for users with disabilities, with some differences between users with different types of disabilities. The results of this study also provide some insights related to UX of VUIs for users with disabilities from their perspective, showing that the acceptance factors can be used as criteria in comprehending the issues.

Study 2 investigates UX of IPAs based on online reviews written by users through semantic network analysis. Before investigating UX of IPAs for users with disabilities, important factors for UX of IPAs were proposed by investigating UX of IPAs for users with non-disabilities in this study. As a case study, online reviews on smart speakers from the internet were collected. Then, the collected text data were preprocessed and structured in which words having similar meaning were clustered into one representative keyword. After this, the frequency of the keywords was calculated, and keywords in top 50 frequency were used for the analysis, because they were considered core keywords. Based on the keywords, a network was visualized, and centrality was measured. The results of this study show that most of the users were satisfied with the use of IPAs, although they felt that the performance of them was not completely reliable. In addition, the results of this study show aesthetic aspects of IPAs are also important for users' enjoyment, especially for the satisfaction of users. This study proposes eleven important factors to be considered for UX of IPAs and among them, suggests ten factors to be considered in the design of IPAs to improve UX of IPAs and to satisfy users.

Study 3 investigates UX of IPAs for users with disabilities and identifies how the use of IPAs affects quality of life of them, based on Study 1 and Study 2. In this study, comparisons with users with non-disabilities are also conducted. A questionnaire survey and a written interview were conducted for users with disabilities and users with non-disabilities having used one or more smart speakers. The collected data were analyzed statistically and qualitatively. The results of this study show that, regardless of disability, most users are sharing the main UX of IPAs and can benefit the use of IPA. The results of this study also show that the investigation on qualitative data is essential to the study for users with disabilities, offering various insights related to UX of IPAs from the angle of them and clear differences in UX of IPAs between users with disabilities and users with non-disabilities. This study proposes important factors for UX of IPAs for users with disabilities and users with non-disabilities based on the discussed factors for UX of IPAs in Study 2. This study also discusses various design implications for UX of IPAs and provides three important design implications which should be considered to improve UX, focusing on the interaction design of IPAs for not only users with disabilities but also all potential users.

Each study provides design implications. Study 1 discusses design implications for UX of VUIs for users with disabilities. Study 2 suggests design implications for UX of IPAs, focusing on users with non-disabilities. Study 3 discusses various design implications for UX of IPAs and proposes three specific implications focusing on the interaction design of IPAs for all potential users. It is possible to expect that reflecting the implications in the interaction design of IPA will be helpful to all potential users, not just users with disabilities.

Keywords: Human computer interaction, User experience, Voice user interface. Intelligent personal assistant, Accessibility
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Chapter 1 Introduction

1.1. Research Background

Today, we live in a world surrounded by digital devices. Various computation devices are working wherever we go (Gregório & Santos, 2019; C. Kim et al., 2019; Satyanarayanan, 2001). Most of the systems have an Artificial Intelligent (AI) and provide users with the Voice User Interface (VUI) to support the natural interaction, which has been making the daily life of people more convenient than before (Gil et al., 2004; Kaasinen et al., 2013).

The VUI is an interface that enables Human Computer Interaction (HCI) based on voice recognition technology (Pearl, 2016). Speech is a very common and a natural way of communication for exchanging information between human beings (Cui & Xue, 2009; Granata et al., 2010; Portet et al., 2013; Saz Torralba et al., 2011). In this respect, the user interface based on a conversation is considered the most natural form of the interface (Moore et al., 2018; Nishida, 2008).

Although there have been many issues which must be solved, VUIs have been in the main stream with the public interest. As a consequence, various forms of VUIs are wildly being used in our everyday life (Porcheron et al., 2018). For example, a recent study showed that about half of the U.S. teens have used voice search every day (Google Inc., 2014). According to the report, the majority of teens commonly used various VUIs in their everyday life. It was also reported that about 89% of teens and 85% of adults expected that user interfaces based on speech will be commonly used in the future.

VUIs have various advantages. The strength of the VUI compared with the Graphic User Interface (GUI) which is the interface most wildly used is that it does not need additional input devices. It is known for that hands and eyes-free interactions based on VUIs are natural and intuitive (Corbett & Weber, 2016; Pearl, 2016). The advantages can be very helpful for the general public as well as for elderly people and people with disabilities (Corbett & Weber, 2016; Reis et al., 2017). VUIs require less visual attention and minimal physical movements (Wu et al., 2015), which can make people who have little visual, physical and cognitive ability convenient in controlling systems, compared with other traditional input devices (Baldauf et al., 2018; Branham & Mukkath Roy, 2019; Brinkley et al., 2019; Caltenco et al., 2012; Cook, 2008; Leporini et al., 2012; Portet et al., 2013; Su & Chung, 2001; Teixeira et al., 2009; Vacher et al., 2015; Verma et al., 2013). It is reported that VUIs are very suitable for individuals with disabilities to promote universal access to information, decreasing the gap between users with disabilities and users with non-disabilities (Saz Torralba et al., 2011).

The Intelligent Personal Assistant (IPA) is one of the most wildly being used VUIs nowadays. The IPA is *"an application that uses input such as user's voice... and contextual information to provide assistance by answering questions in natural language, making recommendations and performing actions"* (Baber, 2002). It can be also defined as *"a software agent that provides professional/administrative, technical, and social assistance to huma users by automating and easing many day to day activities"* (Han & Yang, 2018). There are many interchangeable terms to describe the IPA such as 'conversational agent', 'voice activated personal assistant', 'virtual personal assistant' and 'smart automated assistant' etc (Abdolrahmani et al., 2018; Cowan et al., 2017).

IPAs have become a daily home appliance. Various IPA products such as Apple's Siri, Google's Google Home, Samsung's Bixby, Microsoft's Cortana and Amazon's Echo etc are commercially available. The company Amazon reported that half a million users were satisfied with its IPA product, Echo (Risley, 2015). It is expected that worldwide IPA market will grow 32.8% per year from 2016 to 2024 (Han & Yang, 2018), and that at least one IPA product such as a smart speaker would be placed per room by a user (Gartner, 2016).

IPAs become a part of people's daily life and are making their life easier (Alqurashi, 2018; Y. Gao et al., 2018; Han & Yang, 2018; Hoy, 2018; Kepuska & Bohouta, 2018; Kiseleva et al., 2016; Knote et al., 2019). Although each commercialized IPA products have unique features and functions distinguishing themselves from the others, they have some similarities. IPAs can answer basic informational questions. This allows users to access information, which is a different way from the traditional way. IPAs can also perform various tasks to assist users (Rodolitz et al., 2019). Users can send messages, make phone calls, play music, set alarms, control Internet of Thing (IoT) devices, and even have a joke with IPAs (Hoy, 2018; Saad et al., 2017).

The various functions of IPAs have potential to be usefully used for users with disabilities even without any additional modification only for them (Abdolrahmani et al., 2018; Gao et al., 2018; Pradhan, Mehta, & Findlater, 2018; Roy, Rishin, Abdolrahmani, Kuber, & Branham, 2019). A recent study reported that about 38% users of Amazon's Echo considered that it would be useful for people with disabilities, and actually individuals with visual impairments were using it very usefully (Pradhan et al., 2018). Another study also showed that IPAs have given users with disabilities a sense of control and independence in their daily life (Gao et al., 2018), and that IPAs can be used to improve accessibility in controlling digital devices for users with visual impairments (Abdolrahmani et al., 2018).

In recent years, research on VUIs has been actively conducted. This is same for research on VUIs for people with disabilities. Many researchers have been trying to apply the VUI to various areas for them to increase their independence and quality of life, focusing on the advantages of the VUI (Suk & Kojima, 2008). However, many previous studies related to VUIs for people with disabilities usually focused on developments and evaluations of new systems. As a result, empirical studies are limited. In addition, there are few studies related to User Experience (UX) of VUIs for people with disabilities. This situation is not different from studies related to IPAs. Although IPAs have potential to be usefully used than simple VUIs for users with disabilities, research related to UX of IPAs for them has been paid little attention to, only focusing on a young adult and middle-aged group among people with non-disabilities as end-users (Balasuriya et al., 2018; Branham & Mukkath Roy, 2019).

The standard definition of UX is *"a person's perceptions and responses that result from use and/or anticipated use of a product, system or service"* (ISO, 2008). Experience is conscious and unconscious cumulative feelings which human being gets through every day (Mclellan, 2000; Shedroff & Nathan, 2001). It can be said that UX is a consequence of the accumulation of a user's past, present and future experience and the interactions with a product (Pucillo & Cascini, 2014). Compared with usability, *"the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"*

(ISO, 1998), which is defined objective criteria to evaluate a product and service, UX is user-dependent, unique and subjective criterion (Hassenzahl & Tractinsky, 2006). These characteristics of UX make it difficult to define exactly what UX is (Law et al., 2014). However, all researchers agree that UX of a product and service is very important in engagements and satisfaction for a user It is considered that comprehending UX and reflecting it in the design can lead to the success of a product and service (Kujala et al., 2011; Law et al., 2009; O'Brien & Toms, 2008; Shedroff & Nathan, 2001).

The first step investigating UX of a product is to understand how people interact with it, which is considered that it is necessary to comprehend the interaction to improve a future product, taking into account real users in the term of the User Centered Design (UCD) (Mariño et al., 2018). Understanding users' opinions and reflecting them in the development and design should be accompanied to fulfill users' expectations. However, only few studies related to IPAs have been conducted from the angle of users with disabilities to investigate UX.

It is known for that investigating usability and UX for users with disabilities is more difficult and delicate than that of users with non-disabilities (Biswas & Bhattacharya, 2005; Kroll et al., 2007; Wilkinson & De Angeli, 2014) in that disabilities which people with disabilities have made them interact with their surroundings differently comparing with people with non-disabilities (Bajcar et al., 2020). In addition, there are some difficulties to apply methods which are commonly used in the study for usability and UX to people with disabilities (Kroll et al., 2007; Petrie et al., 2006; Prior, 2010). As the reasons, people with disabilities are frequently excluded from the study (Kroll et al., 2007; M. Lee et al., 2017). It can be said that research on UX of IPAs for users with disabilities should be conducted more closely to understand their interactions with IPAs and how the use of IPAs affects their life. This kind of research can contribute to improvement on UX of IPAs for them.

1.2. Research Objective

The purpose of the research in this dissertation is to investigate UX of VUIs for users with disabilities, focusing on IPAs. The research in this dissertation consists of three independent main studies which have its objective to achieve the goal. The studies are summarized in Table 1.1. Brief explanations of each study are following.

In Study 1, UX of VUIs is investigated for users with disabilities. The purpose of Study 1 is to investigate UX of commercially available VUIs for users with disabilities, by examining acceptance. The VUI, the fundamental technology for IPAs, is a useful interface for people with disabilities. However, most of the previous studies related to VUIs for people with disabilities were conducted in the fields related to assistive technology by developing and evaluating a new system (Gisela Reyes-Cruz et al., 2019). It is necessary to develop and provide a proper new system for people with disabilities, but it is also needed to comprehend how they are using available technologies and products. It seems like that efforts to understand how users with disabilities actually perceive and use commercially available VUIs are commonly neglected in previous studies. To overcome the limitation, before investigating UX of IPAs for users with disabilities, in Study 1, UX of commercially available VUIs for users with disabilities is investigated, by focusing on the differences between users with different types of disabilities. In addition, the reasons why they use or not use VUIs are examined in this study. It is considered that investigating user acceptance of a product is one of the useful ways to measure UX (Law et al., 2014; Seol et al., 2017). Identifying acceptance is also regarded as an important issue which has to be considered in improving a future product and service (Bernsdorf et al., 2016; Davis et al., 1989; Venkatesh et al., 2003). In this line, in Study 1, a questionnaire survey was conducted for users with disabilities having used one or more VUIs, and the collected data were analyzed statistically and qualitatively.

In Study 2, UX of IPAs is investigated based on online reviews written by users. The purpose of Study 2 is to investigate UX of IPAs through semantic network analysis, identifying what factors are important to UX of IPAs for users. Before investigating UX of IPAs for users with disabilities, important factors for UX of IPAs were proposed by investigating UX of IPAs for users with non-disabilities in this study. The aim of conducting this study is to found a concrete background for investigating UX of IPAs for users with disabilities. There are various methods to study UX, and one of them is to analyze online reviews written by users. It is also known that semantic

Table 1.1. Summary of the studies in this dissertation

Study	Objective	Subject	Used method
Study 1	To investigate UX of commercially available VUIs for users with disabilities	Users with physical disabilities and users with visual impairments	Questionnaire survey
Study 2	To investigate UX of IPAs through semantic network analysis	Online reviews (written by users with non-disabilities)	Semantic network analysis
Study 3	To investigate UX of IPAs for users with disabilities and identify how the use of IPAs affects their life	Users with physical disabilities and users with non-disabilities	Questionnaire survey and written interview

network analysis is the most relevant method for identifying UX issues, helping for researchers to find out user values for a given subject (Lim et al., 2019; Rhie et al., 2017). In this line, in Study2, as a case study, UX of smart speakers which are a kind of embodied IPAs was investigated through semantic network analysis from online reviews.

Study 3 is the main study in the research in this dissertation. In Study 3, UX of IPAs and effects of the use of IPAs on quality of life are investigated for users with disabilities. The purpose of Study 3 is to investigate UX of IPAs for users with disabilities and to identify how the use of IPAs affects their daily life. It is very important to make real users be subjects for the study on usability and UX (Carter, 1999; Stanton et al., 2017). Meanwhile, it was pointed out that just investigating usability and UX of a product and service is not enough to identify issues for users with disabilities, saying that quality of life which can be defined as well-being across multiple domains of life (Andresen & Meyers, 2000) should be also considered (Agree & Freedman, 2011). It is considered that enhancing quality of life of an individual with disabilities can be achieved when a suitable technology is appropriately used (Cook, 2008). Considering these, in Study 3, UX of IPAs and effects of the use of IPAs on quality of life of users with disabilities are investigated, by comparing with users with non-disabilities. In Study 3, a questionnaire survey and a written interview were conducted for users with disabilities and users with non-disabilities having used a smart speaker, and the collected data were analyzed statistically and qualitatively.

1.3. Outline of this Dissertation

This dissertation is composed of six chapters including this one. Chapter 1 is the part of the introduction in this dissertation. Chapter 2 is the literature review for this dissertation. From Chapter 3 to Chapter 5 are the main body of this dissertation. Chapter 6 which is the final chapter is the part of the conclusion in this dissertation. The outline of this dissertation is shown in Figure 1.1. Brief explanations of each chapter are described below.

Chapter 1 introduces the research background. The objective of this research is also explained with used overall methodologies. Finally, the outline of this dissertation is presented in this chapter.

Chapter 2 provides a literature review for this dissertation. The definition of people with disabilities and research methods which can be used to include them are described. Then, conceptual frameworks on UX for VUIs and design approaches for accessibility are summarized. Finally, previous studies related to VUIs and IPAs for users with disabilities are reviewed. The results of the literature review become a foundation in the research design of this dissertation.

Chapter 3 describes Study 1 of which the purpose is to investigate UX of commercially available VUIs for users with disabilities, by examining acceptance, focusing on the differences between users with different types of disabilities and identifying the reasons why they use or not use VUIs. A questionnaire survey was conducted for users with disabilities having used one or more VUIs. The collected data were analyzed statistically and qualitatively. The results of this study show acceptance of VUIs and relationships of acceptance factors for users with disabilities, with some differences between users with different types of disabilities. The results of this study also provide some insights related to UX of VUIs for users with disabilities from their perspective, showing that the acceptance factors can be used as criteria in comprehending the issues.

Chapter 4 describes Study 2 of which the purpose is to investigate UX of IPAs through semantic network analysis, identifying what factors are important to UX of IPAs for users. As a case study, UX of smart speakers which are a kind of embodied IPAs was investigated through semantic network analysis from online reviews. Online reviews on smart speakers from the internet were crawled. Then, the collected text data were preprocessed and structured in which words having similar meaning were clustered into one representative keyword. After this, the frequency of the keywords was calculated, keywords in top 50 frequency were used for the analysis, because they were considered core keywords. Based on the keywords, a network was visualized, and centrality was measured. The results of this study show that most of the users were satisfied with the use of IPAs, although they felt that the performance of them was not completely reliable. In addition, the results of this study show the aesthetic aspects of IPAs are also important for users' enjoyment, especially for the satisfaction of users. This study proposes eleven important factors to be considered for UX of IPAs and among them, suggests ten factors to be considered in the design of IPAs to improve UX of IPAs and to satisfy users.

Chapter 5 describes Study 3 which has two aims. The first purpose is to investigate UX of IPAs for users with disabilities. The second purpose is to investigate how the use of IPAs affects quality of life of users with disabilities. In this study, comparisons with users with non-disabilities were also conducted. A questionnaire survey and a written interview were conducted for users with disabilities and users with non-disabilities having used a smart speaker. The collected data were analyzed statistically and qualitatively. The results of this study show that, regardless of disability, most users are sharing the main UX of IPAs and can benefit the use of IPA. The results of this study also show that the investigation on qualitative data is essential to the study for users with disabilities, offering various insights related to UX of IPAs from the angle of them and clear differences in UX of IPAs between users with disabilities and users with non-disabilities. This study proposes important factors for UX of IPAs for users with disabilities and users with non-disabilities based on the discussed factors for UX of IPAs in Study 2. This study also discusses various design implications for UX of IPAs and provides three important design implications which should be considered to improve UX, focusing on the interaction design of IPAs for not only users with disabilities but also all potential users.

Chapter 6 summarizes the results of this research. The contributions of this research are also discussed. Finally, the limitations of this research and future studies are presented.

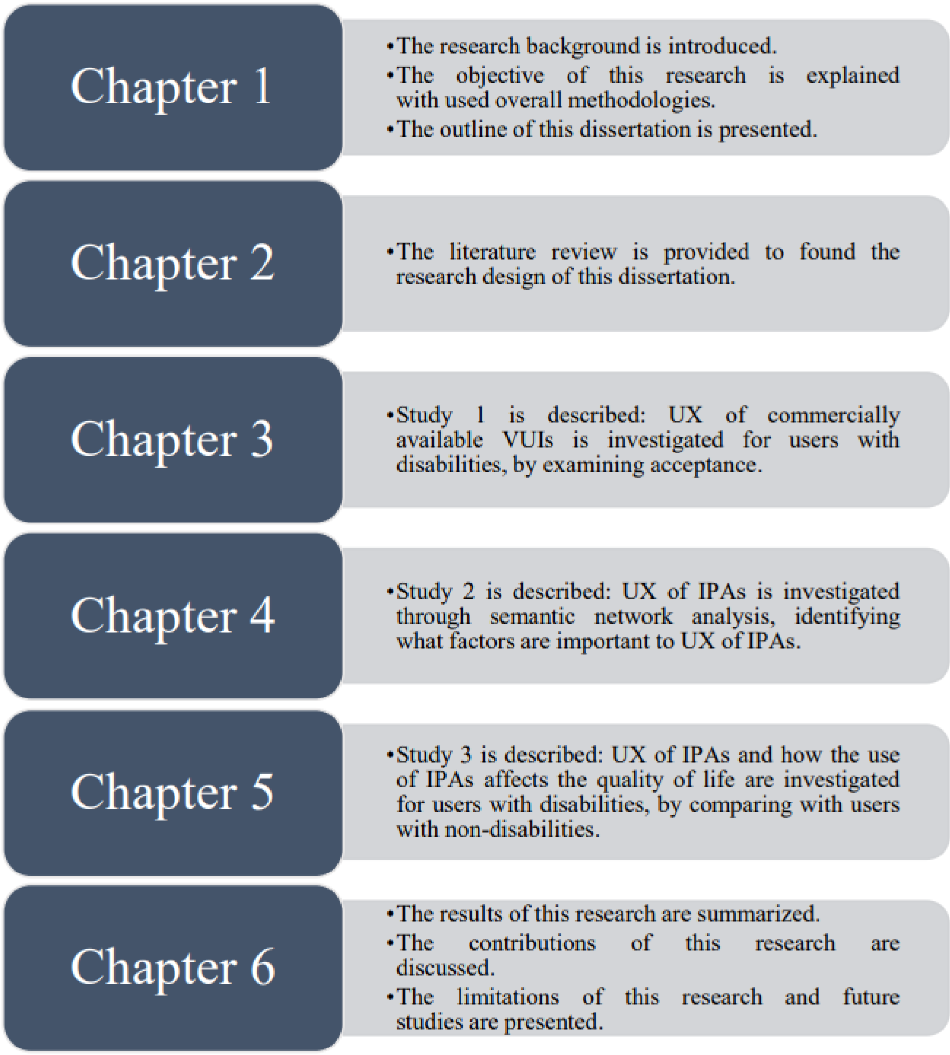


Figure 1.1. Outline of this dissertation

Chapter 2 Literature Review

2.1. People with Disabilities and Research Methods for Them

2.1.1. People with Disabilities

World Health Organization (WHO) reported that about 15% of the world's population lives with some forms of disability, and about 2~4% of them experiences significant difficulties in functioning (WHO, 2011). According to a recent report, the number of individuals who live with disabilities has been increasing over the past decades and the overall rate of them was estimated as 12.8% in the United States (Kraus et al., 2018). In Korea, it was also reported that about 267 million people, rate of 5.3% of the whole population, have disabilities and that the number of people with disabilities has been increasing (KOSIS, 2018).

WHO defines a disability as *"a complex phenomenon, reflecting the interaction between features of a person's body and features of the society in which he or she lives"* (WHO, 2017). Disabilities are any continuing conditions that restrict everyday activities. The term, 'disabilities' is used to cover impairments, activity limitations, and restrictions of participation (Hartley & Muhit, 2003).

In many previous studies, people with disabilities and elderly people are commonly considered the same subject group (Hersh, 2015; Vacher et al., 2015). Elderly people can be defined as a group of people who belong 65 years and over (WHO, 2001). They may have disabilities accompanied by psychological and/or physical changes due to aging. However, disabilities of them may or may not appear, and significant differences also exist between people with disabilities and elderly people. In this research, elderly people are excluded in the group of people with disabilities to focus on characteristics of users with disabilities more exactly.

It is known for that investigating usability and UX for users with disabilities is more difficult and delicate than that of others (Biswas & Bhattacharya, 2005; Kroll et al., 2007; Wilkinson & De Angeli, 2014). It is also known for that people with severe disabilities are commonly excluded from the study (Kroll et al., 2007; M. Lee et al., 2017). To understand UX from the angle of them, research for real users with disabilities should be conducted more thoroughly. In this research, considering theses, studies on UX of IPAs users with disabilities are conducted, especially users with severe disabilities are focused on as subjects.

2.1.2. Research Methods for People with Disabilities

It is very important to make real users be subjects for the study in the Human Computer Interaction (HCI) (Carter, 1999; Stanton et al., 2017). If this principle is not observed, a gap between designers and users could occur (Norman, 1986). Various methods were developed to prevent the gap (Lazar et al., 2017; Stanton et al., 2017). However, limitations and restrictions came from disabilities can hinder people with disabilities from taking part in the study. In addition, it would be some difficulties to apply the methods as they are to the study for people with disabilities (Kroll et al., 2007; Petrie et al., 2006; Prior, 2010). People with severe disabilities may also have some difficulties to come to a designated place such as a laboratory and to take part in tasks and programs for an experiment. Appropriate rearrangements or modifications about the methods are inevitable for their participation in the study. These kinds of hurdles make people with disabilities be frequently excluded from the inclusion of the study, even in the study for them (Kroll et al., 2007).

No doubtfully, testing a system with people with disabilities is important in the evaluation for usability and UX. Many researchers focused on remote evaluation methods for usability and UX to cover participants with various demographics, and showed the usefulness of the methods (Andreasen et al., 2007; Castillo et al., 1998; Petrie et al., 2006; Thompson et al., 2004), and several methods have been presented to encourage researchers to include users with disabilities for the study. Table 2.1 summarizes remote evaluation methods for people with disabilities discussed in previous studies and their descriptions.

Kroll et al. (2007) emphasized that a focus group interview is very useful to gather opinions from people with disabilities, recommending some advices in conducting the focus interview for them. The authors said that the focus group interview could be conducted via internet, if it would be needed.

They said that the internet-based focus group interview has various merits such as that participants can take part in the place where they want, and they are less concerned about the moderator's opinions.

Petrie et al. (2006) presented seven remote evaluation methods for the study related to usability and UX for people with disabilities, and classified the methods based on four criteria such as synchronous/asynchronous, participant independence, the evaluation process and requirement of training to the participant. The study of the authors showed ways of conducting the remote evaluation methods for people with disabilities and proved usefulness of the methods based on the results of two case studies which they conducted.

The main objective of this dissertation is to conduct research on UX of IPAs for users with disabilities. Therefore, considerations on the recommended methods are included in the research design of this dissertation, and some of them are used. The aim of the reason adopting the methods in this research is to encourage users with disabilities to participate in the study and to minimize their inconvenience.

Table 2.1. Remote evaluation methods discussed in previous studies for people with disabilities

Reference	Remote evaluation method	Descriptions
Kroll et al. (2007)	Computer mediated, networked, or internet-based focus group interview	Focus group interview can be conducted mediated by computer via the internet.
Petrie et al. (2006)	Portable evaluation	A portable evaluation unit is used, which is taken to users in their normal environments.
	Local evaluation at remote site	The system to be evaluated is transferred to a remote site.
	Remote questionnaire/survey	A system can be augmented to display a questionnaire to collect data from users.

	Remote control evaluation	An evaluation involves data being transferred from users' normal environments to a usability facility for synchronous or asynchronous observation and analysis.
	Video conferencing as an extension of the usability facility	Users undertake the evaluation remotely while communicating with the evaluator via a video conference connection.
	Instrumented remote evaluation	An application can be augmented to collect usage data occurring in user's normal environment.
	Semi-instrumented remote evaluation	An evaluation uses selective data collection triggered directly by users performing tasks in their normal interaction with the system.

2.2. Conceptual Frameworks

2.2.1. User Experience of Voice User Interfaces

UX is *"a person's perceptions and responses that result from use and/or anticipated use of a product, system or service"* (ISO, 2008). Conceptual frameworks on UX shows that UX has dynamic, context-dependent and subjective nature (Hassenzahl & Tractinsky, 2006) and has to be comprehended in terms of 'user', 'system', 'context of use' and 'interaction between them' (Arhippainen & Tähti, 2003). The important aspect of UX is its multidimensionality (Bargas-Avila & Hornbæk, 2011), which makes it difficult to apply UX to the study. Because of this reason, it can be said that there is no consensus on what standards should be used to evaluate UX of VUIs.

It is crucial to understand UX in developing and evaluating a product and system from the angle of real users, because UX can affect users' satisfaction (Kujala et al., 2011; Law et al., 2009; O'Brien & Toms, 2008;

Shedroff & Nathan, 2001). The importance of UX has made researchers conduct studies to definitize elements of UX which are sometime differently called such as UX dimensions, UX factors and UX attributes etc. In this dissertation, they are called UX factors. In this section, UX factors for VUIs majorly discussed in previous studies are described. Table 2.2 summarizes factors related to UX of VUIs with their definitions.

Usefulness which can be defined as the degree how the system would be useful and helpful (Simon, 2007; Venkatesh et al., 2003) is a basic factor affecting technology acceptance (Davis, 1985; Davis et al., 1989; Kaasinen et al., 2013; Simon, 2007; Venkatesh et al., 2018, 2003). Usefulness is an important factor to be considered when evaluating usability (ISO, 1998) because it can be measured for the will of a user to use the system as the purpose it was designed for (Kouroupetroglou & Spiliotopoulos, 2009). Kaasinen et al. (2013) emphasized that usefulness is also a crucial UX factor related to pragmatic aspects, defining it as something positive such as a value and benefit that users can get, using the system. The anticipation of usefulness on new technology is very important in technology acceptance, and, like the same, it has been considered that usefulness is a fundamental UX factor for VUIs (Kouroupetroglou & Spiliotopoulos, 2009; C. Lee et al., 2015; Lewis, 2016; Simon, 2007). It is expected that increasing usefulness of IPAs can help people efficiently decreasing efforts required for various activities in their daily life (Orehovački et al., 2018). Considering the fact that usefulness is the major motivation encouraging people with disabilities to use technology (Cook, 2008), it may be said that usefulness is the most important UX factor for IPAs for users with disabilities.

Ease of use which can be defined as the required level of effort when using the system (Venkatesh et al., 2003) is another significant factor affecting technology acceptance (Davis, 1985; Davis et al., 1989; Kaasinen et al., 2013; C. Lee et al., 2015; Simon, 2007; Venkatesh et al., 2018, 2003). Ease of use is a significant UX factor related to pragmatic aspects (Kaasinen et al., 2013; Orehovački et al., 2018). It is known that ease of use is one of the critical factors for complex systems, including a sense of being in control and learnability (Kaasinen et al., 2013; Kouroupetroglou & Spiliotopoulos, 2009), which can facilitate the use of VUIs (C. Lee et al., 2015; Orehovački et al., 2018; Simon, 2007). Many researchers reported that ease of use is the main reason making people with disabilities use VUIs compared to other traditional input devices (Aguirre-Munizaga et al., 2018; Pradhan et al., 2018; Gisela Reyes-Cruz et al., 2019).

Behavioral control has a similar concept with ease of use (Kaasinen et al., 2013), but it is a different thing (L. Gao & Bai, 2014; Venkatesh et al., 2018, 2003). It can be said that one has behavioral control on the system if one has the necessary resources, capabilities, and a sense of control in successfully performing tasks. Giving a user construability on a system and providing enough information and tools to control the system is essential to encourage him/her to use the system willingly (Assad et al., 2007; Orehovački et al., 2018). Behavioral control can be more important for users with disabilities because it can guarantee their independence in their daily activities (Agree & Freedman, 2011).

Trust which can be defined as the belief that the system performs with personal integrity and reliability (Venkatesh et al., 2018, 2003) is a complex factor related to control, privacy and monitoring on the system (Kaasinen et al., 2013). Although It has been not considered one of fundamental UX factors for IPAs (Orehovački et al., 2018), the lack of trust of users on the system can negatively affect the usefulness of the system (L. Gao & Bai, 2014) and technology acceptance in a long-term period (Heerink et al., 2010; Koskela & Väänänen-Vainio-Mattila, 2004).

Social influence which can be defined as the perceptions of significant people regarding the use of the system (Heerink et al., 2010; Venkatesh et al., 2018, 2003) is the subjective norm related to the perceptions of general social pressure and underlying normative beliefs (Simon, 2007). Social influence is not a technical feature, rather than it is a factor related to the social and cultural context depending on specific groups or social and cultural contexts (Arhippainen & Tähti, 2003; Kaasinen et al., 2013). Social influence can affect technology acceptance and has been also considered one of the factors influencing UX of VUIs (Botha et al., 2012; Simon, 2007).

Enjoyment which can be defined as feelings of pleasure associated with using the system (L. Gao & Bai, 2014; Venkatesh et al., 2018, 2003) or the perceptions of pleasure and involvement came from playful interactions with the system (Webster et al., 1993) is a factor related to hedonic aspects. Enjoyment was commonly neglected in usability, but it has been considered an important factor in the interaction with VUIs (Botha et al., 2012; Khan et al., 2017; Kocaballi et al., 2019; Sali et al., 2012). In addition, it is considered that enjoyment can influence various other emotional aspects such as affect, aesthetics engagement, which ultimately affect satisfaction on the system (Sali et al., 2012).

Aesthetics which can be defined as physical and sensory features of a product or interaction addressed by attractiveness or appeal, emphasizing clean and orderly design (Hassenzahl, Schöbel, & Trautmann, 2008; Hassenzahl, 2001) is a factor related to hedonic aspects (Hassenzahl, 2001). Aesthetics is the most important factor in the first impression of a product (G.-W. Kim, 2016; G. W. Kim et al., 2016). it is known that many of standardized questionnaires wildly used for the evaluation on UX of VUIs covered aesthetic aspects (Kocaballi et al., 2019). Although factors related to hedonic quality are considered less important in usability, it was reported that aesthetic features are also required to be reflected in the design of IPAs (Orehovački et al., 2018).

System and infrastructure are also important in VUIs. The system is one of the elements building UX (Arhippainen & Tähti, 2003). According to Botha et al. (2012), capabilities of the system supporting the interaction and performance issues can be divided into two aspects such as hardware and software. These two aspects are top priority components of UX for various voice-based services (Ketola, 2002). It can be said that if appropriate business practices and infrastructures are not supported for VUIs, good UX cannot be provided (Ballard, 2007; Botha et al., 2012).

User characteristics include various backgrounds depending on an individual such as gender and age etc. Individual's characteristics have been considered one of the important factors beyond technical features affecting UX with the social and cultural context (Kaasinen et al., 2013; C. Nowacki & Gordeeva, 2020). For example, previous experience and preference of a user can impact on the performance of VUIs, especially an unfamiliar VUI (C. M. Myers et al., 2019). Characteristics due to aging of elderly people can influence UX of VUIs (Kim, 2018; Kowalski, Jaskulska, & Marasek, 2019). It is known that differences of accent and pronunciation between people also affect the performance of VUIs (Pyae & Scifleet, 2018). Users with disabilities face different accessibility issues depending on the type and degree of their disability. Considering the facts, user characteristics of people with disabilities such as the type and level of disability should be considered in the interaction design for IPAs.

The nine factors described in this section were considered important in UX of VUIs in many previous studies. The previous studies mainly just introduced and described them. In other words, the discussed factors for UX of VUIs were rarely used for the empirical study on UX of IPAs. In this research, the factors become a foundation for studying UX of IPAs for users with disabilities. They are firstly considered at the stage of designing each study in this research. In addition, they are used as one of the criteria to collect and analyze data.

Table 2.2. Factors for user experience of voice user interfaces and their definitions

Factor	Definition	Reference
Usefulness	Somethings positive such as value and benefit that users can get, by using the system, and the degree how the system would be useful and helpful	Kaasinen et al. (2013) Orehovački et al. (2018) Simon (2007) Venkatesh et al. (2003)
Ease of Use	The required level of effort when using the system	Kaasinen et al. (2013) Lee et al. (2015) Orehovački et al. (2018) Simon (2007) Venkatesh et al. (2003)
Behavioral Control	The necessary resources, capabilities, and a sense of being in control on the system	Assad et al. (2007) Kaasinen et al. (2013) Orehovački et al. (2018) Venkatesh et al. (2003)
Trust	The belief that the system performs with personal integrity and reliability	Kaasinen et al. (2013) Orehovački et al. (2018) Venkatesh et al. (2018, 2003)
Social Influence	The perceptions of significant people regarding the use of the system	Heerink et al. (2010) Kaasinen et al. (2013) Simon (2007) Venkatesh et al. (2018, 2003)

Enjoyment	Feelings of pleasure associated with using the system, and the perceptions of pleasure and involvement came from playful interactions with the system	Gao & Bai (2014) Kocaballi et al. (2019) Venkatesh et al. (2018, 2003) Webster et al. (1993)
Aesthetics	Physical and sensory features of a product or interaction addressed by attractiveness or appeal, emphasizing clean and orderly design	Hassenzahl et al. (2016) Hassenzahl (2011) Kocaballi et al. (2019) Orehovački et al. (2018)
System & Infrastructure	Capabilities of the system supporting the interaction and performance issues, and providing appropriate infrastructures such as available networks	Botha et al. (2012) Ketola (2002)
User Characteristics	Various backgrounds of an individual such as gender and age etc	Botha et al. (2012) Kaasinen et al. (2013) Myers et al. (2019) Nowacki & Gordeeva (2020) Venkatesh et al. (2018, 2003)

2.2.2. Design Approaches for Accessibility

With the situation in which the population with disabilities has been increasing (section 2.1.1), issues related to accessibility for people with disabilities have been being important. Meaning of accessibility is *"the fact of being able to be reached or obtained easily"* and *"the quality of being easy to understand"*, so, it can be summarized as *"the quality or characteristic of something that makes it possible to approach, enter, or use it"* (Cambridge English Dictionary). The issues related to accessibility were addressed as important things by Americans with Disabilities Act (ADA) in 1990. ADA became law, with the purpose to make sure that individuals with disabilities have the same rights and opportunities as everyone else (Perritt, 2003; Tucker, 1989). It was legislated to guarantee equal opportunity for them. However, until yet, people with disabilities have faced various challenges such as poverty, lack of opportunity and access to education and employment, and issues related to social inclusion (Ullmann et al., 2018).

Information and Communication Technology (ICT) is considered a facilitator for encouraging social inclusion (Manzoor & Vimarlund, 2018; Vanderheiden, 2006). They can be used to reduce existing social gaps and increase quality of life for people with disabilities, improving accessibility (Cook, 2008; Mariño et al., 2018). As a result, accessibility is considered an important requirement for access to ICT, which can promote inclusion in the digital society. Various design approaches for accessibility have been introduced to meet the requirements of accessibility and to improve it. The frameworks of design approaches for accessibility have similarity, but there are also some differences between them (Deardorff & Birdsong, 2003; Persson et al., 2015). Table 2.3 summarizes design approaches for accessibility and their definitions.

Barrier-free design may be the first introduced as a design principle to guarantee accessibility It was addressed for supporting accessibility of buildings, taking into account the wide range of potential users such as the temporarily or chronically people with disabilities (Berube, 1981), and it was extended to products (Wilkoff & Abed, 1994).

Universal design is the term which is one of the most wildly accepted in this field (Deardorff & Birdsong, 2003). It also started from accessibility for architecture (Mace, 1991; Story, 1998), and was expanded to various fields. Universal design can be defined as *"the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design"* (The Center for Universal Design, 1997). It comprises of the seven principles developed by the Center for Universal Design at North Carolina State University to maximize usability for the all. The seven principles are used in various fields to improve usability and UX for people with various backgrounds nowadays. The seven principles of universal design were summarized in Table 2.4 with descriptions.

Design for all is "*the design for human diversity, social inclusion and equality"* (EIDD, 2004). This conceptual framework is much more applied to various fields than other concepts. Design for all is similar with the concept of universal design in considering the wide range of potential users. However, it more emphasizes the importance of the inclusion of people with various backgrounds into society, considering everyone (Harper, 2007; Persson et al., 2015).

Inclusive design is the term wildly used in the United Kingdoms. The concept of inclusive design is similar with that of universal design and design for all, but it contains the concept of reasonability in the definition (BSI, 2005). This makes the main difference of inclusive design from the other approaches, considering the efforts or costs that are required in the inclusion of people with disabilities, and focusing on pragmatics.

Accessible design was rooted from the ADA standard for accessible design. Accessible design is defined by ISO (ISO, 2017) as "*the design focused on principles of extending standard design to persons with some type of performance limitation to maximize the number of potential customers….*" It tries to cover the wide range of people as users, as far as possible, based on specific ergonomic data.

Ability-based design is a relatively lately introduced design approach for accessibility. Ability-based design is the design that is aware of the abilities of users and provides interactions better suited to those abilities (Wobbrock et al., 2011). Comparing with the other approaches for accessibility focusing on people's disabilities, it urges designers to pay attention to people's abilities that they have, by throwing a question such as "What can a person do?" (Wobbrock et al., 2011, 2018). In the perspective of ability-based design, it is required to focus on the functional abilities of an individual as the starting point of solving technological issues related to accessibility (G. Reyes-Cruz et al., 2020).

All the design approaches for accessibility have the same goal to guarantee accessibility for people with disabilities. Observing the design approaches for accessibility is helpful to people with non-disabilities, not just people with disabilities. In the research in this dissertation, considerations in the design approaches are included to improve UX of IPAs for not only users with disabilities but also all potential users. Especially, among them, universal design with the seven principles and ability-based design are mainly considered in each study to identify and solve issues, as the reason that they are appropriate to cover all potential users. It can be said that identifying and solving issues related to the accessibility of IPAs can lead to providing all potential users with improved UX of IPAs.

Table 2.3. Design approaches for accessibility and their definitions

Framework on design for accessibility	Definition	Reference
Barrier-free design	The design of eliminating obstacles in a space or product taking into account the wide range of potential users	Berube (1981) Wilkoff & Abed (1994)
Universal design	The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design	The Center for Universal Design (1997)
Design for all	The design for human diversity, social inclusion and equality	EIDD (2004)
Inclusive design	The design of mainstream products and/or services that are accessible to, and usable by, as many people as reasonably possible on a global basis, in a wide variety of situations and to the greatest extent possible without the need for special adaptation or specialized design.	BSI (2005)
Accessible design	The design focused on principles of extending standard design to persons with some type of performance limitation to maximize the number of potential customers who can readily use a product, building or service	ISO (2017)
Ability-based design	The design that is aware of the abilities of users and provides an interface better suited to those abilities	Wobbrock et al. (2011) Wobbrock et al. (2018)

Table 2.4. The seven principles of universal design

Principle of universal design	Description
Equitable Use	The design is useful and marketable to people with diverse abilities.
Flexibility in Use	The design accommodates a wide range of individual preferences and abilities.
Simple and Intuitive Use	Use of the design is easy to understand, regardless of the user’s experience, knowledge, language skills or current concentration level.
Perceptible Information	The design communicates necessary information effectively to the user, regardless of ambient conditions or the user’s sensory abilities.
Tolerance for Error	The design minimizes hazards and the adverse consequences of accidental or unintended actions.
Low Physical Effort	The design can be used efficiently and comfortably and with a minimum of fatigue.
Size and Space for Approach and Use	Appropriate size and space are provided for approach, reach, manipulation and use regardless of the user’s body size, posture or mobility.

2.3. Related Work

2.3.1. Previous Studies Related to Voice User Interfaces

The VUI is one of Natural User Interfaces (NUIs) which have been considered alternative input devices for people with disabilities (Hennig, 2016; Liu, 2010; Teixeira et al., 2009). There are numerous studies related to VUIs. However, previous studies related to VUIs usually focused on the general population as end-users (Branham & Mukkath Roy, 2019; Guo et al., 2019; Metatla et al., 2019). It can be said that a few of researchers conducted the study for people with disabilities. Table 2.5 summarizes previous studies related to UX of VUIs for people with disabilities with their objectives, investigated systems and subjects. Previous studies related to IPAs are excluded in this section, and those are reviewed in the next section.

VUIs are mainly used in mobile devices because of the advantages such as hands and eyes-free interaction, which can be help people in the mobile interaction in busy situations where they cannot afford to use their hands and eyes (Abdolrahmani et al., 2018; Strayer et al., 2017; Wu et al., 2015). Usefulness of VUIs in mobile devices can be maximized for people with disabilities, because disabilities they have make them difficult use their hands and eyes.

Corbett & Weber (2016) developed VoiceNavigator which is the application supporting the voice-based interactions in mobile devices. People with a variety of motor impairments participated in the experiment in which the participants used the system and took part in a post-interview. The authors reported that the VUI can improve accessibility for people with disabilities in the use of mobile devices and emphasized the importance of initial experience during the use of VUIs.

Leporini et al. (2012) investigated usability of VoiceOver for mobile devices. VoiceOver is the screen reader application available in Mac OS and IOS operating systems for users with visual impairments. They conducted a questionnaire survey for users with visual impairments to explore accessibility and usability issues of mobile devices. The results of their study showed that voice feedbacks are very helpful to users with visual impairments in interactions with mobile devices.

The smart home is also one of the targeted systems which adopt VUIs. The smart home can be defined as any technologies that automate a home-based activity (Gentry, 2009). In the smart home, various home devices can work automatically, and people can control the devices remotely, which improve quality of life of its occupants (Aguirre-Munizaga et al., 2018). VUIs are commonly used in the smart home to control various home devices.

Aguirre-Munizaga et al. (2018) developed a smart home system. The system allowed users to control various home activities such as opening doors or on/off lights based on the VUI. The authors conducted several tasks in the laboratory with people with physical disabilities and reported that the use of the VUI in the smart home can reduce the time of performance for the tasks.

Vacher et al. (2015) developed a smart home system named SWEET HOME. The authors conducted several tasks in the laboratory and interviewed elderly people and people with visual impairments. They investigated users' interest, accessibility, usefulness and usability of the system. They reported that although the performance of the speech processing system was not good, most of the participants did not have any difficulty in using the system. The results of their study showed that elderly people and people with visual impairments accepted the VUI well and could use the system very usefully.

Meanwhile, VUIs can be also used in other various systems to improve accessibility for people with disabilities. Goette (2000) interviewed people with disabilities to identify the reasons why they use or do not use VUIs. Reyes-Cruz et al. (2019) conducted an ethnographic study with people with visual impairments to listen to their thoughts on VUIs, emphasizing the necessity of field studies including users with disabilities. Verma et al. (2013) developed a system which was a voice-enabled web for users with visual impairments and reported that the voice-based web navigation system made them comfort in performing web-based tasks.

The previous studies showed that usefulness of VUIs for people with disabilities. However, there were some limitations. Most objectives of the previous studies related to VUIs for people with disabilities were to develop and evaluate a new VUI system. Because of this, studies on VUIs for people with disabilities remain on a simple level. In addition, studied topics were usually focused on usability, and broad issues such as UX were less investigated. This situation has been pointed out by some researchers saying that studies related to VUIs for people with disabilities have been usually conducted within the assistive technology field (Gisela Reyes-Cruz et al., 2019). It is necessary to develop and provide a proper new system for people with disabilities, but it is also needed to comprehend how they are using available technologies. It seems like that this consideration is missed in the previous studies.

By defining the problem in the matter, studies in this research focus on generally available VUIs. In Study 1, UX of commercially available VUIs is investigated for users with disabilities, and, in Study 3, UX of smart speakers which are a kind of embodied IPAs is investigated for users with disabilities. Through the studies, the research in this dissertation tries to identify how people with disabilities use available VUI products and how the use affects their quality of life. In addition, in the research, design implications are suggested based on the acquired results from the studies for all potential users, from the perspective saying that if people with disabilities can use a product, people with non-disabilities can use it more easily.

Table 2.5. Summary of previous studies related to usability and user experience of voice user interfaces for people with disabilities

Reference	Objective	Targeted system	Subject
Aguirre-Munizaga et al. (2018)	To evaluate usability	Smart home	People with physical disabilities
Corbett & Weber (2016)	To evaluate usability	Mobile devices	People with physical disabilities
Goette (2000)	To investigate acceptance	(Not defined)	(Not defined)
Leporini et al. (2012)	To investigate accessibility and usability issues	Mobile devices	Users with visual impairments
Reyes et al. (2019)	To explore accessibility and usability issues	(Not defined)	Users with visual impairments
Vacher et al (2015)	To evaluate usability and acceptance	Smart home	Elderly people and people with visual impairments
Verma et al. (2013)	To evaluate usability	Web	Users with visual impairments

2.3.2. Previous Studies Related to Intelligent Personal Assistants

With the interest of AI and the VUI being arose, research on IPAs has been the subject extensively. Many previous studies related to IPAs focused on features and functions of them. The main objective of these studies is to investigate the features and functions, and to compare performance between commercially available IPA products (Alqurashi, 2018; G Elera & Grant, 2018; Ji & Rau, 2019; López et al., 2018). These studies contributed to understanding what IPAs can do for us and what should be improved in IPAs for better usability and services. However, it can be said that they neglected users' needs and the aspect of UX, which was pointed out by some researchers (Lopatovska et al., 2019).

To overcome the limitations, some of previous studies conducted research related to IPAs from the perspective of users. These studies explored how people use the systems. Some researchers conducted an online questionnaire survey (Pyae & Joelsson, 2018), conducted an experiment and interview (Cowan et al., 2017; Koon et al., 2020; Kowalski et al., 2019; Lopatovska et al., 2019; Orehovački et al., 2018; Vtyurina & Fourney, 2018), analyzed online reviews written by users (Gao et al., 2018; Hwang, Shim, & Choi, 2016; Lee, Kim, & Choi, 2019), and observed users' interactions with IPAs (Beneteau et al., 2019; Cho, 2018; C. Myers et al., 2018). The aim of these studies is to definitize the pros and cons of the use of IPAs and to investigate UX of them from the angle of users.

Most of the previous studies mentioned above referred to that IPAs would be helpful and useful to people with disabilities. However, it is true that studies related to IPAs for them have received little attention (Branham & Mukkath Roy, 2019; Guo et al., 2019). As a result, only a few of researchers conducted the empirical study related to IPAs for people with disabilities. Table 2.6 summarizes previous studies related to IPAs for people with disabilities with their objectives, used methods and subjects.

Abdolrahmani et al. (2018) interviewed users with visual impairments who had the experience of home and/or mobile-based IPAs. The authors reported that the use of IPAs gave people with visual impairments opportunities to access to a variety of digital devices. Based on the findings, the authors suggested design implications such as accounting for privacy and situational factors in design and presentation of visual and non-visual cues during the interactions, emphasizing users' needs. Abdolrahmani, Storer, Roy, Kuber, & Branham (2020) also interviewed users with visual impairments who had experience of home and/or mobile-based IPAs and analyzing podcast content from 28 episodes relating to blind interactions with IPAs. The authors concluded that IPAs need to support a variety of types of tasks and need to improve in voice interaction for both usability and accessibility, arguing that, regardless of whether or not one has disabilities, all users can get benefits from the use of IPAs.

Baldauf et al. (2018) conducted a group interview with people with cognitive impairments to explore how they perceive conversational interfaces including IPAs and investigate the special requirements of them. The study of the authors showed that people with cognitive impairments had high expectations on VUIs including IPAs. The authors said that VUIs should be improved accordingly with users' expectations.

Branham & Mukkath Roy (2019) reviewed previous studies related to VUIs and offered some guidelines of IPAs for users with visual impairments based on the result of their study. The authors pointed out that previous studies related to IPAs usually have focused on the general population as end users and accessibility guidelines of IPAs for users with disabilities are frequently missed. They emphasized the needs of studies on IPAs, considering users with disabilities.

Metatla et al. (2019) investigated how VUIs can support inclusive education for pupils with visual impairments. The authors conducted a focused interview with children with blindness, and also had a workshop based on Wizard of OZ with sighted and visually impaired pupils in a school to examine how VUIs including IPAs could be used to support inclusive education for students with visual impairments. The study of the authors showed that, although there were some challenges, VUIs, especially IPAs could be used in co-designing for the inclusion with visually impaired and sighted students in the school environment.

Pradhan et al. (2018) examined online reviews of Echo products from Amazon. The authors also interviewed users with blindness to understand how they are using IPA devices. The online reviews showed that about 38% users of Echo considered it would be useful for people with disabilities and that users with disabilities were using the device very usefully including unexpected use cases such as speech therapy and support for caregivers. The findings of the authors also showed that, although there were some accessibility challenges, VUIs including IPAs had been very usefully used by users with visual impairments, increasing their independence.

Rodolitz et al. (2019) addressed accessibility issues for people who are deaf or hard of hearing. The authors said that VUIs including IPAs are inaccessible to users with deaf or hard of hearing because they usually rely on spoken-modality input and output, which makes users with deaf or hard of hearing hardly use. The authors suggested alternative input methods such as text to speech, American sign language, and gestures for users with deaf or hard of hearing of VUIs. In the article, they emphasized the importance of providing an option of customizable input methods to support accessibility for all potential users.

IPAs can help people completing various tasks in their everyday activities easily and can be also companion for users, which have been reported by many previous studies related to IPAs with empirical results. However, many researchers usually focused on people with non-disabilities as end users (Metatla et al., 2019). The previous studies related to IPAs for people with disabilities showed that IPAs could be used very usefully for people with disabilities, but it is hard to say that they thoroughly covered UX of IPAs for them. Many of the previous studies just described how people with disabilities had used IPAs, and usually considered people with visual impairments users. As a result, sufficient suggestions were not provided for various potential users with disabilities to improve UX based on specific reasons in the previous studies. It is needed to conduct research on UX of IPAs for users with disabilities more closely to suggest design guidelines. To overcome the limitations of the previous studies, in the research in this dissertation, Study 2 suggests important factors in the design of IPAs for users with non-disabilities, which become a foundation for users with disabilities. Study 3 validates the suggested factors for users with disabilities and users with non-disabilities. In addition, Study 3 investigates UX of IPAs, focusing on users with physical disabilities, considering the limitation of the previous studies related to IPAs for people with disabilities.

Meanwhile, it is known for that investigating usability and UX of a system by comparing with people with disabilities and people with non-disabilities can be practical in drawing meaningful insights for users with disabilities (Bajcar et al., 2020; Burton et al., 2008; Zimmermann et al., 2005). It was reported that the evaluation approach of reality aspects made by people with disabilities for their surroundings would be different with that of people with non-disabilities (Albrecht & Devlieger, 1999) and comprehending the mechanisms could be suitable for developing effective assistive technologies (Bajcar et al., 2020). As the reason, although it has been considered that there is the lack of experimental results, many studies conducted cross-evaluations between people with disabilities and people with non-disabilities to provide more inclusive solutions for assistive devices (Bajcar et al., 2020; Polacek et al., 2017).

In that point, in Study 3 of this research, comparisons between users with disabilities and users with non-disabilities are also conducted. The ultimate goal of the research in this dissertation is to suggest design implications considering various users, not just users with disabilities to improve UX of

IPAs. Based on the comparisons, this research provides design implications for all potential users.

Table 2.6. Summary of previous studies related to intelligent personal assistants for people with disabilities

Reference	Objective	Method	Subject
Abdolrahmani et al. (2018)	To understand how IPAs are used by individuals with blindness	Interview	Users with visual impairments
Abdolrahmani et al. (2020)	To understand how IPAs are used by individuals with blindness	Interview and analyzing podcast content	Users with visual impairments
Baldauf et al. (2018)	To explore how people with cognitive impairments perceive conversational interfaces and about the special requirements of them	Group interview	People with mild to moderate cognitive impairments
Branham & Mukkath Roy (2019)	To provide accessibility guidelines of IPAs for users with visual impairments	Review on previous studies	
Metatla et al. (2019)	To investigate how VUI could support inclusive education for pupils with visual impairments	Focus interview, and a workshop based on Wizard of OZ	Children and pupils with visual impairments
Pradhan et al (2018)	To examine the accessibility of IPAs and to understand how users with disabilities are making use of these devices	Review analysis and interview	Users with visual impairments

Rodolitz et al. (2019)	To examine and to report the accessibility and usability of alternative accessible input methods of IPAs for users with deaf and hard of hearing	Questionnaire survey based on the experiment	Users with deaf and hard of hearing

Chapter 3 Investigation on User Experience of Voice User Interfaces for Users with Disabilities by Examining Acceptance

3.1. Introduction

Technology acceptance is a very important factor which must be considered to improve a future product and service (Bernsdorf et al., 2016; Davis et al., 1989; Venkatesh et al., 2018, 2003). Understanding why some people accept technology and others do not is one of the most challenging issues in ICT research, It is considered that investigating user acceptance of a product and service is one of the useful ways to measure UX (Law et al., 2014; Seol et al., 2017).

Various factors including internal and external can impact people's acceptance of a product and service. Many researchers have been interested in technology acceptance, and several theoretical models were developed to investigate factors influencing acceptance and to identify relationships between them. The Technology Acceptance Model (TAM) which was first introduced by Davis (1985) is the most well-known model for the study on acceptance. The goal of the TAM is to predict the behavior intention based on perceived usefulness and perceived ease of use. The TAM is considered a very powerful model to predict the actual use of a system, consequently, it has been applied to many research fields. However, it has been frequently pointed out that considering only two factors as independent variables is not sufficient to predict the intention to use. The Unified Theory of Acceptance and Use of Technology (UTAUT) expended from the TAM was developed to overcome the limitation (Venkatesh et al., 2003), by integrating various factors. Many other models, such as the Almere model (Heerink et al., 2010) and the Car Technology Acceptance Model (CTAM) (Osswald et al., 2012), rooted on the TAM and the UTAUT were also proposed to investigate technology acceptance.

These models were widely used in many previous studies to investigate people's acceptance of various VUIs, sometimes by being modified.

However, a few of empirical studies related to VUIs for people with disabilities have been conducted. Most of previous studies related to VUIs for them usually focused on the development and the evaluation of a new system and have neglected how they are using available VUIs. It is required to conduct studies identifying how people with disabilities use available VUIs.

It is known for that people's acceptance of VUIs is worse than we expect (Choe & Kim, 2017; Cowan et al., 2017). The VUI is the fundamental technology for IPAs and is the very useful interface for people with disabilities, but acceptance of commercially available VUIs for users with disabilities has been paid little attention to (Jin et al., 2018). Identifying the reasons why some people accept VUIs and others do not is a top priority in the interaction design of VUIs. It can be said that the study on the acceptance of commercially available VUIs for users with disabilities should be taken as precedence in order for the study on UX of IPAs for them, because the first step investigating UX of a product and service is to identify acceptance, by understanding how users perceive and use them (Soronen et al., 2008).

It is considered that investigating acceptance of a product is an useful way to examine UX (Law et al., 2014; Seol et al., 2017). In this respect, this chapter describes Study 1. The purpose of this study is to investigate UX of commercially available VUIs for users with disabilities, by examining acceptance. Previous studies related to acceptance mainly just examined relationships between acceptance factors statically. Meanwhile, this study tried to investigate the acceptance of commercially available VUIs for users with disabilities in the broader sense.

In this study, UX of commercially available VUIs for users with disabilities was investigated, by examining acceptance, based on major seven acceptance factors such as ‘Perceived Usefulness (PU)’, ’Perceived Ease of Use (PEOU)’, ’Trust (TR)’, ’Social Influence (SI)’, ’Perceived Enjoyment (PE)’, ’Perceived Behavioral Control (PBC)’ and ’Intention to Use (ITU)’ (Table 3.1). In this study, differences between users with different types of disabilities were focused on, and the reasons for using VUIs or not were identified.

The seven factors are considered major factors affecting acceptance of Internet of Thing (IoT) (L. Gao & Bai, 2014) and influencing UX of

Table 3.1. Acceptance factors used in Study 1

Acceptance factor	Definition
Perceived Usefulness (PU)	The degree to which one believes that the system would be useful and helpful
Perceived Ease of Use (PEOU)	The degree to which one believes that using the system is free of effort
Trust (TR)	The belief that the system performs with personal integrity and reliability
Social Influence (SI)	The perceptions of significant people regarding the use of the system
Perceived Enjoyment (PE)	Feelings of pleasure associated with using the system
Perceived Behavioral Control (PBC)	The perceptions to which one has the necessary resources, capability, and a sense of control in successfully performing the behavior
Intention to Use (ITU)	The intention to use the system over time

intelligent systems (Kaasinen et al., 2013). The factors were selected in this study as the reason that most recent VUIs are based on IoT and AI technology and most of the factors corresponds to the factors for UX of VUIs described in the section 2.2.1 in the literature review.

Based on the acceptance factors, a questionnaire survey was conducted for users with disabilities having used one or more VUIs. The analysis was carried out in the following order. First, the differences of UX of VUIs between users with different types of disabilities were statistically investigated based on the factors. Then, relationships between the factors were examined. Finally, the reasons for using VUIs or not were also identified based on the factors.

In this study, three hypotheses were addressed based on related previous studies, and they were tested to examine the relationships between the factors (Table 3.2 & Figure 3.1). Through testing the hypotheses, the differences between users with different types of disabilities were compared. Hypothesis 1 (H1) was addressed to identify the relationships of the basic acceptance factors based on the assumptions of the TAM. It was reported that PU and PEOU are the main factors positively influencing ITU VUIs for people with non-disabilities (C. Lee et al., 2015; Simon, 2007). This relationship was tested for users with disabilities through H1. Hypothesis 2 (H2) was addressed to identify overall relationships between the major acceptance factors based on the part of the UTAUT. As already mentioned,

Table 3.2. Tested hypotheses in Study1

Hypothesis	Description
H1	Perceived usefulness and perceived ease of use have a positive impact on intention to use VUIs for users with disabilities
H2	Perceived usefulness, perceived ease of use, trust, social influence perceived enjoyment and perceived behavioral control have a positive impact on intention to use VUIs for users with disabilities
H3	Perceived usefulness and intention to use VUIs have a positive impact on use of VUIs for users with disabilities

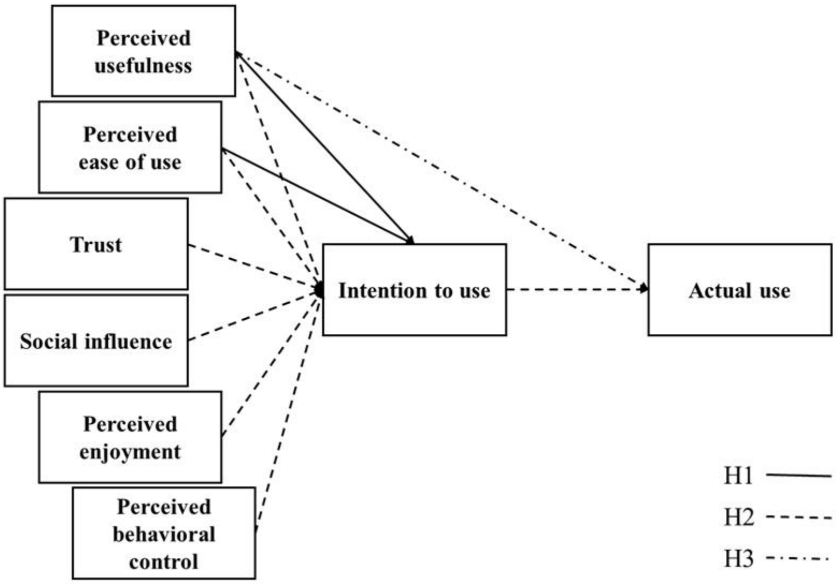


Figure 3.1. Tested hypotheses in Study1

the seven factors are considered important in UX of VUIs, and the relationships between them were frequently investigated in other areas in the previous studies for people with non-disabilities (L. Gao & Bai, 2014; Heerink et al., 2010; Venkatesh et al., 2018). Meanwhile, if some other factors are added, it may be possible that the relationships between the existing factors are changed (Venkatesh et al., 2003). Considering the related previous studies, through H2, the relationships between the major acceptance factors on VUIs were investigated for users with disabilities. Hypothesis 3 (H3) was addressed to identify factors directly affecting the actual use of VUIs. In many previous studies, it was reported that ITU VUIs influences the actual use of VUIs for people with non-disabilities (C. Lee et al., 2015; Simon, 2007) and usefulness is considered that it can encourage people with disabilities to use VUIs (Cook, 2008) The relationships of the two factors to the actual use of VUIs were investigated for users with disabilities through H3. Of course, it may be possible to address more hypotheses to examine other relationships and even to add other factors. However, in this study, they were not considered. As I know, this study may be the first study investigating UX of VUIs for users with severe disabilities, by examining acceptance, focusing on the differences between users with different types of disabilities. As this reason, this study focused only on the major acceptance factors and identifying the relationships verified repeatedly in previous studies related to VUIs for people with non-disabilities.

3.2. Method

3.2.1. Participants

With the help of the Disability Student Support Center in the Seoul National University, the Korean Blind Union and others, 49 people with disabilities were voluntarily recruited, including 29 people with physical disabilities and 20 people with visual impairments. There were 27 males and 22 females ranged from 16 to 58 years, with the average age of 31.70 years (*SD* = 9.195). About 86% of the participants had severe disabilities. They have used one or more VUIs, and the most used VUIs was IPAs installed in the smartphone. Table 3.3 summarizes demographic information and use experience of the participant in using VUIs.

3.2.2. Procedure

Users with disabilities who used one or more VUIs were recruited voluntarily with the help of the Disability Student Support Center in the Seoul National University, the Korean Blind Union and others. Each participant was explained the objective and the procedure of this study via an email or a mobile messenger. The participants were free to ask questions at any time. The link of the questionnaire which was made by the Google-questionnaire form was sent to the participants via an email or a mobile

Table 3.3. Summary of demographic information and use experience of the participant in using voice user interfaces

	Participants with physical disabilities	**Participants with visual impairments**
Gender		
Male	19	8
Female	10	12
Average Age	29.97 (*SD*=7.790)	34.20 (*SD*=10.63)
VUIs in use		
IPAs installed in the smartphone	27	17
IPAs installed in the computer	0	0
Smart speakers	2	4
VUIs for editing documents	5	3
VUIs for the smart home	4	1
The others	1	0

messenger. To encourage the participants with disabilities to take part in the study and to minimize their inconvenience during the study, all the procedures were conducted remotely (Petrie et al., 2006). The collected data were analyzed statistically and qualitatively.

3.2.3. Questionnaire

The questionnaire consisted of four sections, having total of thirty items (Appendix A). In the first section, basic demographic information was asked. In the second section, use experience in using VUIs was asked. In the third section, UX of VUIs was evaluated with a Likert 7-point scale, based on the seven acceptance factors. Each acceptance factor was measured by multiple items which were designed based on the previous studies (Bernsdorf et al., 2016; Davis et al., 1989; L. Gao & Bai, 2014; Heerink et al., 2010; E. Park et al., 2017; Venkatesh et al., 2003). As a result, total twenty-two items were asked to the participants to evaluate UX of VUIs (Table 3.4). All the items were designed to mean that the higher the score in response, the more positive it is. In the finally section, comments on the use of VUIs were collected.

Table 3.4. The questionnaire items to evaluate user experience of voice user interfaces

Acceptance factor	Item
Perceived Usefulness (PU)	PU1: Using the voice user interface would enable me to accomplish the execution of desired functions more quickly.
	PU2: Using the voice user interface would make it easier for me to accomplish the execution of desired functions.
	PU3: Using the voice user interface would significantly increase the quality or output of my life.
	PU4: Overall, I would find using the voice user interface to be advantageous.
Perceived Ease of Use (PEOU)	PEOU1: Learning to use the voice user interface is easy for me.
	PEOU2: Interaction with voice user interface systems is clear and understandable.
	PEOU3: I think using the voice user interface is easy.
Trust (TR)	TR1: Performance of the voice user interface is reliable.
	TR2: I can get reliable results using the voice user interface.
	TR3: The voice user interface continues to be supplemented and developed for the user.
Social Influence (SI)	SI1: I would recommend using the voice user interface to others.
	SI2: People who are important to me would find using the voice user interface beneficial.
	SI3: People who are important to me would find that using the voice user interface is a good idea
Perceived Enjoyment (PE)	PE1: I have fun with using the voice user interface.
	PE2: Using the voice user interface is pleasurable.
Perceived Behavioral Control (PBC)	PBC1: Using the voice user interface is entirely within my control.
	PBC2: I have the resource, knowledge and ability to use the voice user interface.
	PBC3: I am able to skillfully use the voice user interface.
Intention to Use (ITU)	ITU1: Given the chance, I intend to use the voice user interface.
	ITU2: I am willing to use the voice user interface in the near future.
	ITU3: I will frequently use the voice user interface.
	ITU4: I will continue using the voice user interface in the future.

3.2.4. Analysis

3.2.4.1. Statistical Analysis

SPSS version 25 and AMOS version 22 were used to statistically analyze the questionnaire data. First, reliability analysis was performed to verify inter-reliability between items for the factors. Validity analysis was also performed to verify the appropriateness of the data for the factors. Then, descriptive analysis and independent two-sample t-test were performed to examine whether there are differences in the factors between users with different types of disabilities or not. Finally, multiple regression analysis was performed to investigate the relationships between the factors.

3.2.4.1. Qualitative Analysis

The comments on the use of VUIs collected from the participants were qualitatively investigated to find out the reasons why they use or do not use VUIs. The comments containing contents related to UX issues were classified into the seven acceptance factors according to their contents to identify specific reasons on the use of VUIs (Koon et al., 2020).

3.3. Results

3.3.1. Reliability Analysis and Validity Analysis

Reliability analysis was conducted to verify inter-reliability between the items for the factors. In general, It is said that the Cronbach's alpha value of at least 0.6 is acceptable for constructs with a small number of data (Gliem & Gliem, 2003; Moss et al., 1998; Sturmey et al., 2005). Meanwhile, validity analysis was also conducted to verify the appropriateness of the data for the factors. As a way of validity analysis, a value of Average Variants Extracted (AVE) and Composite Reliability (CR) was calculated as the index for convergent validity and discriminant validity. In order to obtain the indexes, the factor loading value and the unique variance of each variable were used through confirmatory factor analysis. In general, It is said that the AVE value of at least 0.5 is acceptable and the CR value of at

Table 3.5. The results of reliability analysis and validity analysis

Factor	Cronbach's alpha	AVE	CR
PU	.831	0.514269	0.804989
PEOU	.712	0.567917	0.777779
TR	.742	0.57468	0.78956
SI	.929	0.820545	0.931982
PE	.931	0.870813	0.930922
PBC	.775	0.54444	0.781822
ITU	.978	0.919399	0.978549

least 0.7 is acceptable (Bagozzi & Yi, 1988; Gefen et al., 2000; Raman et al., 2014). The results of reliability analysis showed that all the factors were acceptable with a higher Cronbach's alpha value than required (Table 3.5). The results of validity analysis also showed that all the factors were acceptable with a higher value of AVE and CR than required (Table 3.5).

3.3.2. Descriptive Analysis and Independent Two-Sample T-Test

Descriptive analysis and independent two-sample t-test were conducted to investigate if there are differences between users with different types of disabilities. The results of descriptive analysis showed that, among seven factors, the average score of ITU was the highest and followed by the average scores of PBC, SI, PU, PEOU, PE and TR (Table 3.6 & Figure 3.2). The results of descriptive analysis also showed the average score of use frequency (Table 3.6 & Figure 3.2). The average scores of all the factors and use frequency of the participants with visual impairments were higher than those of the participants with physical disabilities (Table 3.6 & Figure 3.2). Meanwhile, the results of independent two sample t-test showed that there was a significant difference at the 95% confidential level between the participants with different types of disabilities in PU, SI, PBC and use frequency ($p<.05$) (Table 3.7).

3.3.3. Multiple Regression Analysis

Stepwise multiple regression analysis was conducted to investigate relationships between the factors. For all the participants, the results of the stepwise multiple regression analysis showed that, when considering the

Table 3.6. The results of descriptive analysis for acceptance factors and use frequency

Variable	Participants with physical disabilities		Participants with visual impairments		Total participants	
	Average	SD	Average	SD	Average	SD
PU	4.069	1.307	5.188	1.350	4.526	1.424
PEOU	4.081	1.211	4.717	1.356	4.340	1.297
TR	4.012	1.261	4.650	1.057	4.272	1.213
SI	4.023	1.321	5.117	1.638	4.469	1.541
PE	4.293	1.398	4.600	1.691	4.418	1.515
PBC	4.299	1.432	5.183	1.387	4.660	1.466
ITU	4.336	1.763	5.388	1.903	4.765	1.876
Use Frequency	2.897	1.739	4.650	1.981	3.612	2.019

Table 3.7. The results of independent two-sample t-test for acceptance factors and use frequency between the participants with different types of disabilities

Variable	**t**	**Sig.**
PU	-2.905	.006*
PEOU	-1.721	.092
TR	-1.857	.070
SI	-2.582	.013*
PE	-.693	.492
PBC	-2.152	.037*
ITU	-1.986	.053
Use Frequency	-3.277	.002**

* $p<.05$
** $p<.005$

three factors PU, PEOU and ITU, PU and PEOU affect ITU significantly at the 95% confidential level, with 18.566 of F value ($p<.05$) (Table 3.8). This regression model had 44.7% of the explanation power with .447 of R^2 value, implying that the variables were suitable for multiple regression analysis with 2.274 of Durbin-Watson (Table 3.8). However, considering all the factors, the results of the stepwise multiple regression analysis showed that SI, TR and PBC affect ITU significantly at the 95% confidential level, with 45.916 of F value ($p<.05$) (Table 3.8). This regression model had 75.4% of the explanation power with .754 of R^2 value, with 2.153 of Durbin-Watson (Table 3.8). Meanwhile, considering the two factors PU and ITU, the results

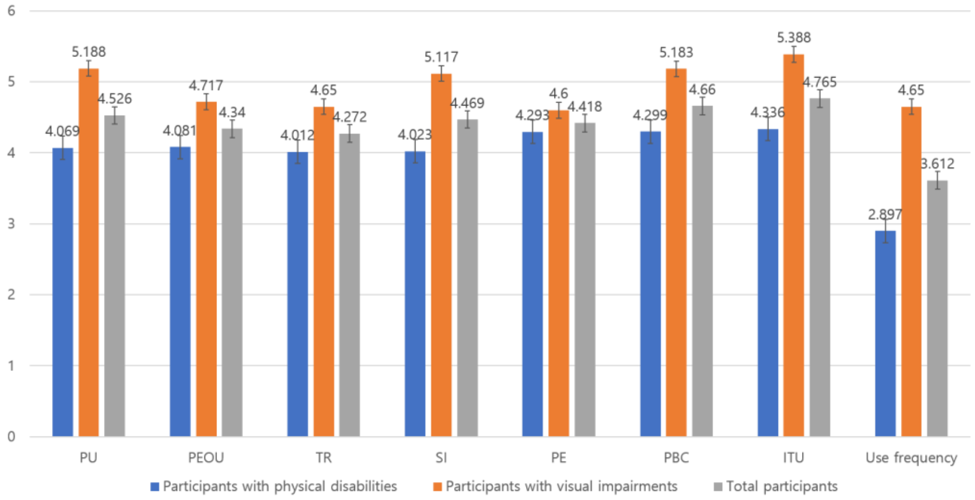


Figure 3.2. The results of descriptive analysis for acceptance factors and use frequency

of the stepwise multiple regression analysis showed that only PU affects use frequency significantly at the 95% confidential level, with 15.521 of F value (p<.05) (Table 3.8). This regression model had 24.8 of the explanation power with .248 of R^2 value and 1.761 of Durbin-Watson (Table 3.8).

For the participants with physical disabilities, the results of the stepwise multiple regression analysis showed that, by considering the three factors PU, PEOU and ITU, only PU affects ITU significantly at the 95% confidential level, with 25.994 of F value (p<.05) (Table 3.9). This regression model had 49.1% of the explanation power with .491 of R^2 value, showing the variables were suitable for multiple regression analysis with 1.237 of Durbin-Watson (Table 3.9). Considering all the factors, the results of the stepwise multiple regression analysis showed that only SI affects ITU significantly at the 95% confidential level, with 47.240 of F value (p<.05) (Table 3.9). This regression model had 63.6% of the explanation power with .636 of R2 value, implying that the variables were suitable for multiple regression analysis with 1.461 of Durbin-Watson (Table 3.9). Meanwhile, considering the two factors PU and ITU, the results of the stepwise multiple regression analysis showed that only PU affects use frequency significantly confidential level, with 25.994 of F value (p<.05) (Table 3.9). This regression model had 49.1% of the explanation power with .491 of R^2 value, showing the variables were suitable for multiple regression analysis with 1.237 of Durbin-Watson (Table 3.9). Considering all the factors, the results

Table 3.8. The results of multiple regression analysis for acceptance factors and use frequency for all the participants

Dependent variable	Independent variable	B	Std. Error	Beta	t	Sig.	Tolerance
ITU	(Constant)	.239	.782		.306	.761	
	PU	.618	.178	.469	3.472	.001**	.659
	PEOU	.399	.195	.276	2.040	.047*	.659
	R=.668, R^2=.447 F=18.566, p=.000, Durbin-Watson=2.274						
ITU	(Constant)	-.046	.554				
	PU			.042	.366	.716	.417
	PEOU			-.050	-.396	.694	.343
	TR	-.327	.154	-.211	-2.12	.039*	.553
	SI	.913	.124	.750	7.343	.000**	.525
	PE			.078	.881	.383	.709
	PBC	0.456	.119	.357	3.843	.000**	.635
	R=.868, R^2=.754 F=45.916, p=.000, Durbin-Watson=2.153						
Use Frequency	(Constant)	.415	.850		.488	.628	
	PU	.707	.179	.498	3.940	.000**	1.000
	ITU			.009	.055	.956	.603
	R=.498, R^2=.248 F=15.521, p=.000, Durbin-Watson=1.761						

* *p*<.05
** *p*<.005

of the stepwise multiple regression analysis showed that only SI affects ITU significantly at the 95% confidential level, with 47.240 of F value (*p*<.05) (Table 3.9). This regression model had 63.6% of the explanation power with .636 of R2 value, implying that the variables were suitable for multiple regression analysis with 1.461 of Durbin-Watson (Table 3.9). Meanwhile, considering the two factors PU and ITU, the results of the stepwise multiple regression analysis showed that only PU affects use frequency significantly at the 95% confidential level, with 10.515 of F value (*p*<.05). This regression model had 28% of the explanation power with .280 of R^2 value and 1.721 of Durbin-Watson (Table 3.9).

For the participants with visual impairments, the results of the stepwise multiple regression analysis showed that, by considering the three factors PU, PEOU and ITU, only PEOU affects ITU significantly at the 95%

Table 3.9. The results of multiple regression analysis for acceptance factors and use frequency for the participants with physical disabilities

Dependent variable	Independent variable	B	Std. Error	Beta	t	Sig.	Tolerance
ITU	(Constant)	.493	.790		.624	.538	
	PU	.944	.185	.700	5.098	.000**	1.000
	PEOU			.216	1.321	.198	.684
	$R=.700$, $R^2=.491$ F=25.994, p=.000, Durbin-Watson=1.237						
ITU	(Constant)	.054	.655		.082	.935	
	PU			.270	1.690	.103	.495
	PEOU			.181	1.356	.187	.737
	TR			-.085	-.602	.553	.692
	SI	1.064	.155	.798	6.873	.000**	1.000
	PE			.226	1.492	.148	.560
	PBC			.254	2.048	.051	.783
	$R=.798$, $R^2=.636$ F=47.240, p=.000, Durbin-Watson=1.461						
Use Frequency	(Constant)	.031	.927		.033	.974	
	PU	.704	.217	.529	3.243	.003**	1.000
	ITU			.004	.017	.986	.509
	$R=.529$, $R^2=.280$ F=10.515, p=.003, Durbin-Watson=1.721						

* $p<.05$
** $p<.005$

confidential level, with 5.594 of F value ($p<.05$) (Table 3.10). This regression model had 23.7% of the explanation power with .237 of R^2 value, implying that the variables were suitable for multiple regression analysis with 2.959 of Durbin-Watson (Table 3.10). Considering all the factors, the results of the stepwise multiple regression analysis showed that PEOU, SI and PBC affect ITU significantly at the 95% confidential level, with 10.169 of F value ($p<.05$) (Table 3.10). This regression model had 85% of the explanation power with .850 of R^2 value, implying that the variables were suitable for multiple regression analysis with 2.019 of Durbin-Watson (Table 3.10). Meanwhile, considering the two factors PU and ITU, stepwise multiple regression analysis could not be performed and the results of the enter multiple regression analysis did not show significance ($p>.05$) (Table 3.10).

Table 3.10. The results of multiple regression analysis for acceptance factors and use frequency for the participants with visual impairments

Dependent variable	Independent variable	B	Std. Error	Beta	t	Sig.	Tolerance
ITU	(Constant)	2.167	1.415		1.531	.143	
	PU			.257	1.065	.302	.720
	PEOU	.683	.289	.487	2.363	.030*	1.000
	$R=.487$, $R^2=.237$ $F=5.594$, $p=.030$, Durbin-Watson=2.959						
ITU	(Constant)	-.418	.759		-.550	.590	
	PU			-.115	.391	.391	.369
	PEOU	-.696	.218	-.496	-3.189	.006*	.388
	TR			.016	.107	.916	.323
	SI	.947	.163	.815	5.796	.000**	.475
	PE			-.021	-.201	.843	.381
	PBC	.818	.183	.596	4.478	.000**	.529
	$R=.922$, $R^2=.850$ $F=10.169$, $p=.006$, Durbin-Watson=2.019						
Use Frequency	(Constant)	3.002	1.941		1.546	.140	
	PU			.257	.978	.342	.804
	ITU			-.055	-.209	.837	.804
	$R=.238$, $R^2=.057$ $F=.509$, p=610, Durbin-Watson=1.852						

* $p<.05$
** $p<.005$

3.3.4. Analysis on Comments of the Participants

The comments on the use of VUIs were qualitatively investigated to find out the reasons why they use or not use VUIs. Twenty-nine comments were collected, and forty meaningful contents containing UX issues were identified. They were classified into the seven acceptance factors according to their contents, and were divided into two dimensions such as positive and negative. These classifications helped drawing meaningful insights from the users' comments. The comments of the participants are summarized in Table 3.11.

Many participants said that VUIs were useful and convenient. However, overall, there were many negative comments than positive. Most negative comments were related to the difficulty of obtaining desired results by using

Table 3.11. Summary of the comments of the participants on the use of voice user interfaces

Acceptance factor	Positive	Negative
PU	Various services available (P1) Useful in situations where other modalities cannot be used (P1, V1) Fast input speed (V1)	Low compatibility (P1) Low input speed (P1) Simple functions only available (P1, V3)
PEOU	Convenient (P2, V2)	Unintuitive interface (P2) Customization required according to the user (P1, V3)
TR		Unable to get the desired results (P4, V2)
SI		Hard to use in public (P2, V1)
PE		
PBC		Low rate of recognition (P6, V2)
ITU	Intention to use continuously (P2)	Does not feel the need (P1)

P: Participants with physical disabilities
V: Participants with visual impairments
The number refers to the total number of the participants who commented.

VUIs and the low rate of voice recognition. Other negative comments showed that features of VUIs were unsatisfactory, unfamiliar and reluctant to use in public. It could be said that most negative comments belonged to PEOU, TR and PBC.

3.4. Discussion

3.4.1. User Experience of Voice User Interfaces for Users with Disabilities

The results of reliability analysis and validity analysis showed that all the seven factors were suitable for being used in the study at a significant level.

According to the descriptive analysis, the average scores of all the factors and use frequency of the participants with visual impairments were higher than that of the participants with physical disabilities. Meanwhile, the results of independent two sample t-test showed that there was a significant difference in PU, SI, PBC and use frequency at the 95% confidential level. The results of descriptive analysis and independent two sample t-test suggest that users with visual impairments have used VUIs more actively and usefully than users with physical disabilities. Especially, considering the factors showing the significant difference, it can be said that users with visual impairments more value pragmatic aspects in the use of VUIs.

There are some previous studies reporting that users with visual impairments prefer and are satisfied with the use of VUIs than those with non-disabilities (H. N. Kim & Oumarou, 2020; Leporini et al., 2012; Pradhan et al., 2018). Sometimes the auditory channel is the only way of interacting with a system for people with visual impairments, which might be reflected in the attitude difference towards the use of VUIs between the user groups. The results of descriptive analysis and independent two-sample t-test in this study showed similar results to the previous studies, even though the compared subject was different as users with physical disabilities. It is needed to note the previous study reporting that people with visual impairments may be less sensitive to usability issues and tend to provide higher ratings than others when evaluating accessibility (Trewin et al., 2015). It may be said that the positive evaluation of UX of VUIs by users with visual impairments than other user groups is their characteristics. However, it cannot be concluded quickly. Close examinations of this are required. The differences between the participants with physical disabilities and the participants with visual impairments are more discussed by considering relationships between the acceptance factors in following paragraphs. In addition, the reasons of the differences between them will be also discussed in the next section, by qualitatively considering the reasons why they use or do not use VUIs.

The results of the stepwise multiple regression analysis showed that all the hypotheses tested in this study could be partially accepted. According to the basic assumption of the TAM, PU and PEOU directly affect ITU (Davis, 1985; Davis et al., 1989). In this study, PU and PEOU also affected ITU VUIs for all the participants, which was the same result of the previous study (Simon, 2007). Consequently, H1 could be accepted. However, there was a difference between the participants with different types of disabilities. Only PU affected ITU VUIs significantly at the 95% confidential level for the participants with physical disabilities, and only PEOU affected ITU

VUIs significantly at the 95% confidential level for the participants with visual impairments. People with physical disabilities often face situations where they cannot control a system by themselves. VUIs can be an useful alternative input devices controlling the system for people with physical disabilities (Aguirre-Munizaga et al., 2018; Corbett & Weber, 2016). It is possible to consider that this advantage of VUIs make users with physical disabilities focus on usefulness of them and encourage them to use VUIs. Meanwhile, there are many commercially available VUIs including assistive devices for people with visual impairments. For them, it may be natural to use VUIs in their everyday life than others (Pradhan et al., 2018), so they may think less about usefulness of VUIs itself, and it can be inferred that ease of use plays an important role in determining the intention to use VUIs.

Meanwhile, considering all the major factors for intelligent systems, the results of the stepwise multiple regression analysis showed that only SI, TR and PBC affected ITU VUIs with the strong explanation power for all the participants. Therefore, H2 could be partially accepted. The difference was also identified between the participants with different types of disabilities. Only SI affected ITU VUIs significantly at the 95% confidential level for the participants with physical disabilities, and PEOU, SI and PBC affected ITU VUIs significantly at the 95% confidential level for the participants with visual impairments. The results of H2 showed that there are important factors to ITU VUIs than PU and PEOU for users with disabilities, when considering various things. Especially, it seems like that SI is important regardless of types of disabilities of users. People with disabilities face various obstacles in their everyday life. Sometime, help from others is inevitable for people with severe disabilities. It may be considered that the influence of SI to ITU VUIs regardless of types of disabilities of users is the reflected result of this. The results of H2 also showed that there is the difference between the participants with physical disabilities and the participants with visual impairments. This can be interpreted that users with visual impairments value pragmatic aspects of VUIs more, similarly with the results of the descriptive analysis and independent two sample t-test in this study. However, caution is needed before interpreting this. Because although the influences of SI, TR and PBC to ITU have been frequently validated in many studies related to acceptance (L. Gao & Bai, 2014; Heerink et al., 2010; Venkatesh et al., 2018, 2003), but, in this study, it is hard to provide adequate explanations on the results of the other factors and inverse relationships of some factors to ITU VUIs.

Considering the two factors PU and ITU, the results of the stepwise multiple regression analysis showed that only PU affects use frequency significantly at the 95% confidential level for all the participants. Therefore, H3 could be partially accepted. There was also the difference between the participants with different types of disabilities. Only PU affected use frequency significantly at the 95% confidential level for the participants with physical disabilities, and the significance was not found out for the participants with visual impairments, which was in the similar line of the previously analyzed results in this study. ITU has been considered the main factor influencing the actual use of a technology (Bernsdorf et al., 2016; Davis, 1985; Davis et al., 1989; Heerink et al., 2010; E. Park et al., 2017; Venkatesh et al., 2003), and PU has been considered the crucial factor influencing the use of assistive technology for people with disabilities (Cook, 2008). The result of H3 can be interpreted that, although there are many issues to be solved which decrease ITU, usefulness of VUIs has made people with disabilities use VUIs, especially for people with physical disabilities. In addition, it can be inferred that users with disabilities may be less willing to use commercially available VUIs than expected, which is similar to the previous studies for people with non-disabilities (Choe & Kim, 2017; Cowan et al., 2017).

3.4.2. Reasons of Users with Disabilities for Using Voice User Interfaces or not

More detail explanations on the results of the statistical analyses for UX of VUIs can be provided, considering the comments of the participants. The comments were classified into the acceptance factors according to their contents with two dimensions such as positive and negative. The acceptance factors were used as criteria to investigate strengths and weaknesses on the use of VUIs (Koon et al., 2020), which helped drawing meaningful insights from the perspective of users with disabilities.

Many participants regardless of types of disabilities considered that using VUIs is useful and convenient in their daily life. VUIs were great help when it was difficult to use a system by other modalities such as hands and eyes.

Most comments containing positive meanings suggest that it is convenient to operate the system by speech. These are very important advantages of VUIs, because people with disabilities face many confronting situations where they cannot use their body and sensory. The VUI requires less visual attention and minimal physical movements (Wu et al., 2015), which is convenient for users with disabilities in controlling various systems for daily use. For users with physical disabilities, commercially available VUIs played an important role in performing a number of tasks on behalf of their hands and legs, and this usefulness seemed to be highlighted. As a result, issues of compatibility of VUIs with other devices and limited functions of VUIs were frequently pointed out by the participants with physical disabilities in the comments related to PU and PBC. Meanwhile, for users with visual impairments, commercially available VUIs played a role of not only their body but also sensory. Fast and accurate. It is the most important task of VUIs for them to deliver information about their surroundings (Leporini et al., 2012). Corresponding to this, issues of speed of VUIs and requests for customization were frequently mentioned by the participants with visual impairments in the comments related to PU and PEOU.

There were also many negative comments on the use of VUIs regardless of types of disabilities of the participants. It can be said that there were many negative comments than positive. When the reasons why the participants do not use VUIs were investigated, most mentioned negative comments belonged to PEOU, TR and PBC such as the difficulty of getting the desired results and the low rate of voice recognition by using VUIs. Other negative comments mentioned that some features of VUIs were unsatisfactory, unfamiliar and reluctant to use in public. Problems related to issues of trust on the systems could be considered the major issues negatively influencing ITU and use frequency for users with disabilities. In addition, although there were not big differences in the types of issues raised by the participants with different types of disabilities, negative comments, especially issues related to TR and PBC, were frequently mentioned by the participants with physical disabilities. VUIs can allow users with disabilities to control their environment more easily, which can provide them with more independence (Abdolrahmani et al., 2020, 2018; Pradhan et al., 2018). Considering the fact that VUIs play a role in performing various tasks on behalf of hands and legs of users with physical disabilities, issues of VUIs related to TR and PBC may came seriously for them than others, because not trusting the system can mean difficulty to control (Kaasinen et al., 2013).

It is hard to identify clear differences in the reasons for using VUIs or not between the participants with physical disabilities and the participants with visual impairments from the comments which they gave. However, the comments helped drawing meaningful insights related to UX of VUIs from the perspective of users with disabilities. Especially they provided some grounds for the results of the statistical analyses. The participants with physical disabilities mentioned relatively many negative issues. Among them, it can be inferred that issues related to TR and PBC negatively influence ITU VUIs and use frequency for them, which may lead directly to hindering them from getting independence in using VUIs. It may be said that this is the reason of yielding the difference in UX of commercially available VUIs between the participants with different types of disabilities.

3.4.3. Design Implications on Voice User Interfaces for Users with Disabilities

According to the seven principles of universal design (The Center for Universal Design, 1997) (section 2.2.2), it seems like that commercially available VUIs are good at ‘Equitable Use’ for users with disabilities, in that they provide users with disabilities, even regardless of types of disabilities, with more chance to control their surroundings independently. However, the most deficient points of them are ‘Flexibility in Use’ and ‘Tolerance for Error’. Although there are no big differences in the participants with different types of disabilities, it seems like that users with physical disabilities considered ‘Tolerance for Error’ more important and users with visual impairments considered ‘Flexibility in Use’ more important. Negative issues of commercially available VUIs related to these can be considered the main reasons making it difficult for user with disabilities to trust VUIs and to have complete control over the systems. Meanwhile, according to the framework of ability-based design (Wobbrock et al., 2011, 2018) (section 2.2.2), the fact, that while ‘Equitable Use’ is good, ‘Flexibility in Use’ and ‘Tolerance for Error’ are not good, can be interpreted that, regardless of types of disabilities of users, commercially available VUIs are very useful for them, but it is still insufficient to fully utilize each user's abilities.

Therefore, considering all the results in this study, it can be expected that the design of VUIs to accurately recognize the commands and to provide appropriate results that users expected will greatly encourage and help users with disabilities to use VUIs. Especially, the design of VUIs considering types of disabilities of users and focusing on available abilities of them will guarantee more improved ‘Flexibility in Use’ and ‘Tolerance for Error’ in the use of VUIs for them. For example, it is necessary to improve voice recognition performance and to allow it to be customized by an individual user. In addition, it is required in the design of VUIs to offer various functions integrating with other devices. Reflecting the implications in the design of VUIs can be play a role offering advanced independence to users with disabilities in their everyday life.

3.5. Conclusion

In this study, UX of commercially available VUIs for users with disabilities was investigated based on major acceptance factors. In this study, the differences between users with different types of disabilities were focused on, and the reasons for using or not using VUIs were identified. The questionnaire survey was conducted for users with disabilities having used one or more VUIs. The collected data were analyzed statistically and qualitatively.

The results of reliability analysis and validity analysis showed that all the seven factors were suitable for being used in the study at a significant level. The results of descriptive analysis showed that the average scores of all the factors and use frequency of the participants with visual impairments were higher than those of the participants with physical disabilities, and the results of independent two sample t-test showed that there was a significant difference in PU, SI, PBC and use frequency at the 95% confidential level between the participants with different types of disabilities. The results of the stepwise multiple regression analysis showed that the relationships of the factors were different from the reported results of previous studies for users with non-disabilities, and there were also some differences between users with different types of disabilities.

The results of this study showed that the participants with disabilities regardless of types of disabilities have used VUIs usefully in their daily life. Usefulness of VUIs was considered the main reason to encourage users with disabilities to use VUIs. Meanwhile, problems of VUIs related to PEOU, TR and PBC such as the difficulty of getting the desired results and the low rate of voice recognition were considered the main reasons for the reluctant use of the systems. Especially, it seemed like that the issues related to TR and PBC more negatively influence ITU VUIs and use frequency for users with physical disabilities.

The limitations of this study include a fewer number of participants recruited for the study compared to other studies related to acceptance, and few relationships between the factors not being confirmed from the analyzed results. This makes it difficult to provide appropriate explanations on some analyzed results. Another limitation of this study is that although people with disabilities having used one or more VUIs were recruited as participants, many of them did not use VUIs frequently. This makes it hard to generalize the acquired results. If more representative participants for the study were included, similar to previous studies related to acceptance, the results might be different and more suitable explanations would be suggested. However, considering that this study was conducted for actual users with disabilities, it can be said that the number of participants in this study is neither small nor meaningless. In addition, this study has a limitation in that all the data used in this study were based on the subjective evaluations of the participants and experiments were not accompanied, which made it difficult to derive insights on tasks performance. However, considering that this study focused on users with severe disabilities and provided insights related to UX of VUIs from the angle of them, it can be said that this study contributes to understanding UX of VUIs for them.

It may be said that this study is the first study investigating UX of VUIs for users with severe disabilities, by examining acceptance and relationships between acceptance factors. This study contributed to investigating UX of commercially available VUIs, by examining acceptance of them for users with disabilities from their perspective based on the quantitative and qualitative analysis. The results of this study showed that it is essential to study VUIs for users with disabilities thoroughly, presenting the differences of acceptance of VUIs between users with disabilities and users with non-disabilities, and between users with different types of disabilities. In addition, the results of this study provided insights related to UX of VUIs for users with disabilities, showing that the acceptance factors can be used as criteria in comprehending the issues. The results of the study in this chapter will be discussed more concretely to identify which factors should be considered important in the design of IPAs and to discuss how the factors can be applied to the study and the design of IPAs for users with disabilities in the following chapters.

Chapter 4 Investigation on User Experience of Intelligent Personal Assistants from Online Reviews by Identifying Important Factors

4.1. Introduction

The concept of UX has been widely accepted in various fields to develop and evaluate a product and service, considering real users. The aim of investigating UX is to identify UX issues from users' opinions (Lim et al., 2019). UX consists of various elements beyond the instrumental, emotion and affect, and the experiential (Hassenzahl & Tractinsky, 2006). It is known that identifying clear a value which can be defined as *"desirable states of existence or modes of behavior which are satisfied when using a certain product or service"* (Park & Han, 2018) from users based on appropriate standards is a very important process for investigating UX.

As awareness of UX increases, it becomes more important to identify UX issues from data. There are various methods to investigate UX, and one of them is to analyze online reviews written by users. User-generated online reviews which are a kind of unstructured text-type data can be usefully used to study UX, because they reflect users' thoughts such as feelings and preferences associated with a product and service (Fang & Zhan, 2015; Netzer et al., 2012).

There are a few of the previous studies using online reviews to examine UX issues of IPAs (Y. Gao et al., 2018; Hwang et al., 2016; J. Lee et al., 2019; Pradhan et al., 2018), but semantic network analysis has been less applied to the study on UX of IPAs (J. Lee et al., 2019). Although semantic network analysis is considered the most relevant method for the UX assessment and has been widely employed to explore UX (Chung et al., 2015; Lim et al., 2019; Rhie et al., 2017), it has been less used in investigating UX of IPAs.

Semantic network analysis is *"a study in which word associations in text are analyzed, and those word associations represent the meaning inherent to the data"* (Doerfel, 1998), which is rooted from the concept of social network analysis to a text. Social network analysis can show interpersonal relationships of individuals in which individuals are expressed by a set of nodes and all relationships between the individuals are connected with links (Scott & Carrington, 2011). In the analysis, words containing semantic contents such as noun, adjective, and verb are mainly used, and each word is represented by a node, and the words are connected with links.

Semantic network analysis can be applied to any topics, if there are enough data to be used. This method can visualize a network consisting of words and their relationships, which is similar with the cognitive process of human beings. It is considered that this method can show the structured concepts of a given subject in the cognitive map of users (Chung et al., 2015). Through the analysis, frequency of words can be calculated by checking how often a given word was mentioned in the data, which is the method wildly used to understand how people consider a subject important in the given context (D. A. Balota & Chumbley, 1984, 1985). Additionally, centrality can be measured to identify which words are more likely to be influential or powerful in the network of the data through the analysis (Valente et al., 2008). It can be said that a specific word with a high value of word frequency and centrality can be considered the key value of a targeted subject for people. The results obtained through this series of analyses are considered relevant for comprehending UX of a product and service. Especially, semantic network analysis is very powerful in identifying important values for UX of a product and service which users consider from qualitative data (G. W. Kim et al., 2016; Lim et al., 2019; Rhie et al., 2017).

This chapter describes Study 2. The purpose of the study in this chapter is to investigate UX of IPAs, identifying what factors are important to UX of IPAs. As this reason, semantic network analysis is adopted in this study. Although interests in VUIs have been increased, studies beyond the technology aspects has been paid little attention to even for users with non-disabilities (Sutton et al., 2019). Before investigating UX of IPAs for users with disabilities, UX of IPAs is investigated for users with non-disabilities in this study. Through this study, important factors which users consider in UX of IPAs are identified. The aim of conducting this study is to found a concrete background for investigating UX of IPAs for users with disabilities, by proposing factors to be considered in the design of IPAs.

UX of IPAs was investigated for users with non-disabilities through semantic network analysis in this study, by identifying what factors are important to UX of IPAs. As a case study, UX of smart speakers which are a kind of embodied IPAs was investigated through semantic network analysis from online reviews. The analysis was carried out in the following order (Figure 4.1). First, online reviews on smart speakers from the internet were crawled. Then, the collected text data were preprocessed and structured in which words having similar meaning were clustered into one representative keyword. After this, the frequency of the keywords was calculated, and, keywords in top 50 frequency were used for the analysis. Based on the keywords, a network was visualized, and centrality was measured.

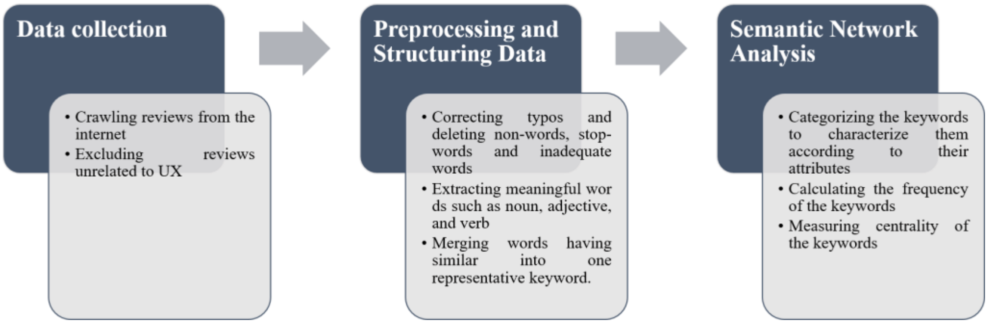


Figure 4.1. Overview of the processes in Study 2

4.2. Method

4.2.1. Data Collection

R version 3.6.1 with Rstudio was used to collect data for this study. Online reviews on smart speakers were crawled from the website Danawa (Danawa.com) which is a website providing prices, information and reviews of products sold in Republic of Korea. It is possible to crawl reviews uploaded in other e-commerce websites in Republic of Korea in Danawa. The scope of collected data was reviews about 20 smart speakers widely sold in Republic of Korea, including Nugu of SK, Gigagenie of KT, Clova of Naver, Kakaomini of Kakao and Google Home of Google etc to exclude biases that may occur when a specific product is focused on. Total 2510 reviews written over a period of three years from May 12, 2016 to August 24, 2019 were collected. Among the collected reviews, reviews unrelated to UX were excluded. If there was a review containing sentences or phrases unrelated to UX, they were also excluded. As a result, total 664 reviews were remained, and these reviews were used for this study.

4.2.2. Preprocessing and Structuring Data

To preprocess and to structure the collected text data. Korean Natural Language Processing (KoNLP) which is a package of R was used. Including the author, four graduate students majoring cognitive science and human factor took part in the processes. The collected 664 reviews were preprocessed, by correcting typos and deleting non-words, stop-words and inadequate words for this study. Then, meaningful words such as noun, adjective, and verb were extracted from the reviews based on propositional theory (Anderson & Bower, 1974). Propositional theory is a theory wildly accepted in the linguistic field. This theory can be applied to a sentence to eliminate unnecessary contents in a systematic form and to identify characteristics of a similar response based on syntactic and semantic knowledge. There are some previous studies adopting propositional theory to get more qualitative data for semantic network analysis for investigating UX (G. W. Kim et al., 2016; S. Park et al., 2019), and it was also used in this study.

Among the obtained meaningful words, words having similar meaning were clustered together. For example, words such as ‘fun’, ‘pleasure’ and ‘enjoy’ were represented as ‘fun’. In addition, compound words and expressions which frequently appeared in the data were recognized as one word. For example, ‘voice recognition’ was recognized as one word. The aim of this process is to prevent distortion of results of semantic network analysis (S. Park et al., 2019). If words having similar meaning are recognized as different words and assigned to different nodes, analyzed results may be distorted. To prevent this, grouping words into a representative keyword was conducted by the graduate students. Through the process, total 364 keywords were obtained.

4.2.3. Analysis

There are two approaches for semantic network analysis: one is the hierarchical way and the other is the nonhierarchical way. The difference is whether it requires an additional process for structuring and preparing a set of data labeled with attributes, consequences, or values (G. W. Kim et al., 2016). The hierarchical method can be used to draw the logical flow of information from the data, but there are shortcomings of it such as needing a complex process in which data are classified as attributes, consequences, and values for the application. The method requires a considerable amount of time and sometimes prevents researchers from getting real insights from the angle of users. Meanwhile, the nonhierarchical method does not require the complex process in structuring data and can provide researchers with new perspectives. In this study, the nonhierarchical method was used for semantic network analysis.

R version 3.6.1 with Rstudio was used for the analysis. First, the frequency of the keywords was calculated, and, keywords in top 50 frequency were used for the analysis, because they were considered core keywords in the data, by the author and the graduate students. The calculation on the frequency of the keywords is conducted to identify what users consider important in the use of smart speakers. In addition, a co-occurrence matrix was generated based on the result of the frequency analysis of the keywords, which can be used to identify the relationship between given two keywords. Based on the keywords, a network was visualized, and centrality was measured. There are various centralities, and four of them are majorly used: degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality (Rhie, 2017; Valente et al., 2008). Degree centrality can show the number of directly linked nodes. Betweenness centrality can show the number of the shortest paths between nodes. Closeness centrality can show the distance to each node. Eigenvector centrality can show an important node, reflecting the centrality of adjacent nodes. The four centralities were measured in this study.

Before visualizing a network, eleven categories were set for this study to characterize the keywords according to their attributes. This is because it is considered that grouping keywords according to their meanings and attributes is a useful way in investigating UX through semantic network analysis and identifying important values of a given targeted product for users (S. Park et al., 2019). The categories are summarized with their definitions in Table 4.1.

‘Usefulness’ can be defined as somethings positive such as value and

Table 4.1. Categories for grouping the keywords in semantic network analysis and their definitions

Category	Definition
Usefulness	Somethings positive such as value and benefit that users can get, by using the system, and the degree how the system would be useful and helpful
Ease of Use	The required level of effort when using the system
Available Function	Functions which users can use in the current system
Behavioral Control	The necessary resources, capabilities, and a sense of being in control on the system
Trust	The belief that the system performs with personal integrity and reliability
Social Influence	The perceptions of significant people regarding the use of the system
Enjoyment	Feelings of pleasure associated with using the system, and the perceptions of pleasure and involvement came from playful interactions with the system
Aesthetics	Physical and sensory features of a product or interaction addressed by attractiveness or appeal, emphasizing clean and orderly design
Compatibility	Capabilities of the system working well together or existing together successfully with others
System & Infrastructure	Capabilities of the system supporting the interaction and performance issues, and providing appropriate infrastructures such as available networks
User Characteristics	Various backgrounds of a user such as gender and age etc

benefit that users can get, by using the system, and the degree how the system would be useful and helpful. ‘Ease of Use’ can be defined as the required level of effort when using the system. ‘Available Function’ can be defined as functions which users can use in the current system. ‘Behavioral Control’ can be defined as the necessary resources, capabilities, and a sense of being in control on the system. ‘Trust’ can be defined as the belief that the system performs with personal integrity and reliability. ‘Social Influence’ can be defined as the perceptions of significant people regarding the use of the system. ‘Enjoyment’ can be defined as feelings of pleasure associated with using the system, and the perceptions of pleasure and involvement came from playful interactions with the system. ‘Aesthetics’ can be defined as physical and sensory features of a product or interaction addressed by attractiveness or appeal, emphasizing clean and orderly design.

‘Compatibility’ can be defined as capabilities of the system working well together or existing together successfully with others. Keywords related to other devices which can be used together with smart speakers were also assigned to ‘Compatibility’. ‘System & Infrastructure’ can be defined as capabilities of the system supporting the interaction and performance issues and providing appropriate infrastructures. ‘User Characteristics’ can be defined as various backgrounds of a user such as gender and age etc.

Among the eleven categories, nine categories such as ‘Usefulness’, ‘Ease of Use’, ‘Behavioral Control’, ‘Trust’, ‘Social Influence’, ‘Enjoyment’, ‘Aesthetics’, ‘System & Infrastructure’ and ‘User Characteristics’ were set based on the factors for UX of VUIs discussed in the literature review (section 2.2.1). IPAs are one of the most wildly used VUIs recently. It is easy to think that if the factors are important to UX of VUIs, they should be also considered in UX of IPAs. Based on this assumption, the nine categories were set for this study to validate the results of the literature review to UX of IPAs. and to identify the importance of the factors in UX of IPAs. Meanwhile, other two categories such as ‘Available Function’ and ‘Compatibility’ were set based on the acquired data in this study, considering distinct characteristics of IPAs. There were relatively many keywords related to functions and compatibility of IPAs in the data obtained for this study. IPAs can perform various tasks than simple VUIs. Many previous studies focused on what IPAs can do (Alqurashi, 2018; G Elera & Grant, 2018; Ji & Rau, 2019; López et al., 2018). It can be said that available functions which IPAs can perform for users are one of things to be importantly considered in UX of IPAs. Compatibility with other devices is also important, because it is necessary for IPAs integrating with other devices to perform various tasks. Considering that IPAs can play a role of the hub in the smart home (Aguirre-Munizaga et al., 2018; Pyae & Joelsson, 2018), it is enough to consider compatibility of IPAs one of important factors for UX of IPAs.

4.3. Results

4.3.1. Analysis on Frequency of the Keywords and Categorizing the Keywords

A total of 4445 words appeared in the data, and keywords in top 50 frequency occupied about 69.8% of the total. The keywords in top 50 frequency were used for the analysis, because they were considered core keywords. (Table 4.2 & Figure 4.2). The keywords in top 50 frequency were translated from Korean to English (Appendix B) by a bilingual on Korean and English who is the graduate student majoring human factor.

The keywords in top 50 frequency were divided into the eleven categories according to their meanings and attributes by the four graduate students including the author (Table 4.3). Five keywords were assigned to 'Usefulness': 'use', 'vary', 'useful', 'study' and 'purchase'. Two keywords were assigned to 'Ease of Use': 'convenient', and 'easy'. Eight keywords were assigned to 'Available Function': 'music', 'light', 'weather', 'speaker', 'radio', 'alarm', 'news' and 'audiobook'. Four keywords were assigned to 'Behavioral Control': 'control', 'impossible', 'understanding' and 'response'. Eight keywords were assigned to 'Trust': 'lack', 'want', 'error', bad', 'need', 'sorry', 'absence' and 'appropriate'. Two keywords were assigned to 'Social Influence': 'child' and 'present'. Four keywords were assigned to 'Enjoyment': 'good', 'satisfy', 'like', 'fun' and 'amazing'. Five keywords were assigned to 'Aesthetics': design', 'pretty, 'display' and 'size'. Five keywords were assigned to 'Compatibility': 'connection', 'television', 'pairing', 'wi-fi' and 'phone'. Seven keywords were assigned to 'System & Infrastructure': 'voice recognition', 'sound', 'function', 'voice user interface', 'update', 'English' and 'artificial intelligent'. There were not keywords assigned to 'User Characteristics'.

4.3.2. Visualization of the Network

Based on the keywords in top 50 frequency, the semantic network was visualized (Figure 4.3). The degree of the size of the nodes in the semantic network represented frequency of the keywords. The degree of the size of the links in the semantic network represented the relationship between two keywords. Nine keywords were most frequently mentioned over 100 times in the data. 'good' was the keyword most frequently appeared in the data,

Table 4.2. List of the keywords in top 50 frequency and their frequencies

Rank	Keyword	Frequency	Rank	Keyword	Frequency
1	good	325	26	pretty	41
2	music	204	27	news	40
3	voice recognition	183	28	display	39
4	sound	163	29	fun	38
5	child	148	30	English	37
6	light	141	31	impossible	37
7	use	123	32	bad	33
8	function	101	33	amazing	33
9	convenient	83	34	useful	33
10	connection	78	35	need	33
11	satisfy	77	36	wi-fi	30
12	like	72	37	control	30
13	design	71	38	artificial intelligent	30
14	television	63	39	study	28
15	pairing	62	40	understanding	27
16	lack	57	41	phone	26
17	want	55	42	present	25
18	update	54	43	sorry	25
19	weather	51	44	audiobook	25
20	vary	49	45	purchase	24
21	speaker	47	46	response	24
22	voice user interface	47	47	easy	24
23	radio	47	48	absence	23
24	error	45	49	size	23
25	alarm	44	50	appropriate	23

being mentioned 325 times (Table 4.2). ‘music’ (204 times), ‘voice recognition’ (183 times), ‘sound’ (163 times), ‘child’ (148 times), ‘light’ (141 times), ‘use’ (123 times) and ‘function' (101 times) were followed as the most appeared keywords, being mentioned over 100 times (Table 4.2). Meanwhile, four sets of co-occurrences were most frequently mentioned over 100 times in the data. 'good' was in all the four sets and was mentioned together in the order of 'sound' (173 co-occurrence times), ‘voice recognition’ (159 co-occurrence times), 'music' (134 co-occurrence times) and 'light' (127 co-occurrence times).

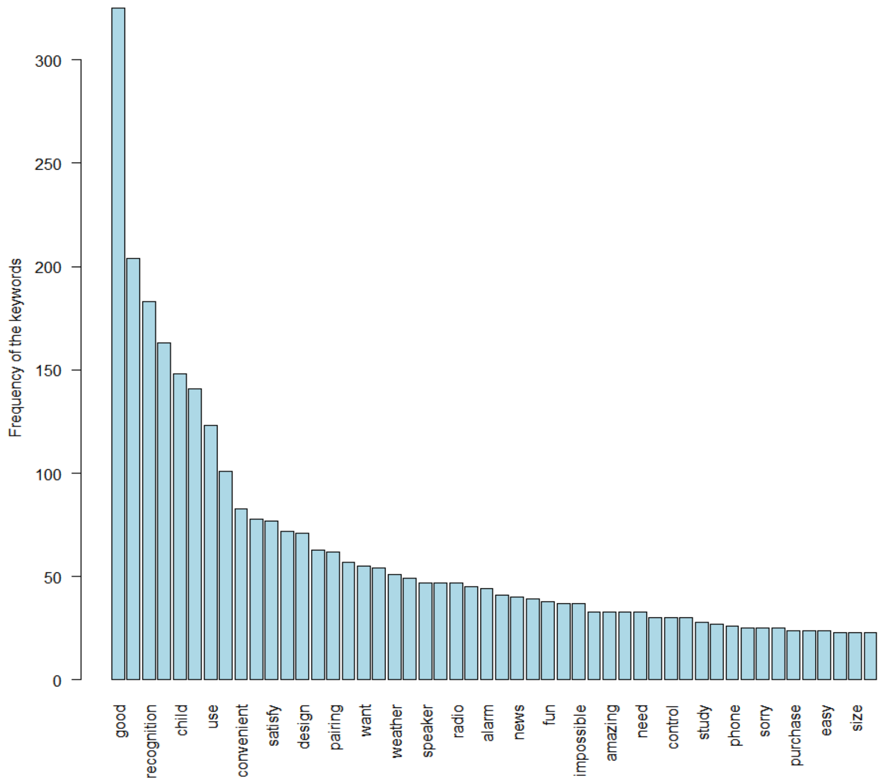


Figure 4.2. The keywords in top 50 frequency and their frequencies

Table 4.3. List of the keywords in top 50 frequency by the categories

Category	Keywords
Usefulness	use, vary, useful, study, purchase
Ease of Use	convenient, easy
Available Function	music, light, weather, speaker, radio, alarm, news, audiobook
Behavioral Control	impossible, control, understanding, reaction
Trust	lack, want, error, bad, need, sorry, absence, appropriate
Social Influence	child, present
Enjoyment	good, satisfy, like, fun, amazing
Aesthetics	design, pretty, display, size
Compatibility	connection, television, pairing, wi-fi, phone
System & Infrastructure	voice recognition, sound, function, update, voice user interface, English, artificial intelligent

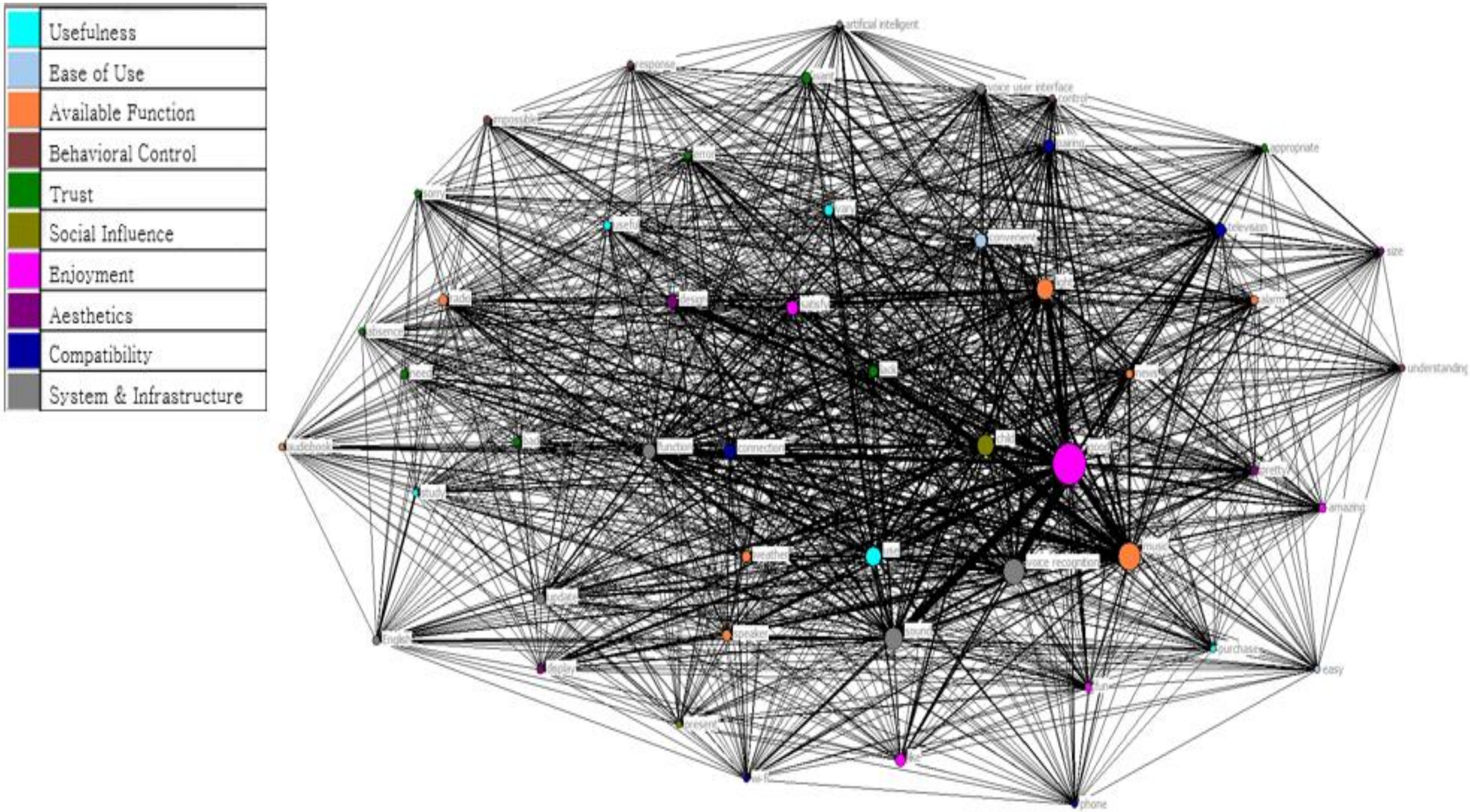


Figure 4.3. The semantic network based on the keywords in top 50 frequency by the categories

4.3.3. Analysis on Centrality of the Keywords

The four centralities above mentioned were measured (Table 4.4, Table 4.5, Table 4.6 & Table 4.7). According to degree centrality, six keywords such as 'good' (0.233), 'music' (0.154), 'light' (0.121), 'voice recognition' (0.114), 'sound' (0.11) and 'child' (0.101) were in the highest rank, showing a value over 0.1 (Table 4.4). According to betweenness centrality, eleven keywords such as 'good', 'music', 'voice recognition', 'sound', 'child', 'use', 'function', 'satisfy', 'connection', 'weather' and 'lack' were in the highest rank, showing the same value of 0.302 (Table 4.5). According to closeness centrality, eleven keywords which are the same in betweenness centrality were in the highest rank, showing a value of 1 (Table 4.6). According to eigenvector centrality, seven keywords such as 'good' (0.481), 'music' (0.333), 'voice recognition' (0.289), 'light (0.288), 'sound' (0.286), 'child' (0.227) and 'use' (0.224) were in the highest rank, showing a value over 0.2 (Table 4.7). 'good' was the keyword showing the highest value in all the four centralities. In addition, although the order was a little different, the keywords such as 'music', 'voice recognition', 'sound' and 'child' were in the highest rank in all the four centralities. This result was similar with the analyzed results of the frequency of the keywords.

4.4. Discussion

4.4.1. User Experience of Intelligent Personal Assistants through Semantic Network Analysis from Online Reviews

The high value of degree centrality can be interpreted that the given keyword has the highest number of the direct connections with others, and the high value of betweenness centrality can be interpreted that the given keyword plays the mediator role in the semantic network (Valente et al., 2008). Meanwhile, the high value of closeness centrality can be interpreted that the given keyword has the advantage making the keyword connect to others in the semantic network, and the high value of eigenvector centrality which is considered the most important (J. Lee et al., 2019; Lim et al., 2019) can be interpreted that the given keyword is the important keyword in the

Table 4.4. The results of the analysis of degree centrality

Rank	Keyword	Degree centrality	Rank	Keyword	Degree centrality
1	good	0.233	26	control	0.03
2	music	0.154	27	display	0.029
3	light	0.121	28	want	0.028
4	voice recognition	0.114	29	like	0.026
5	sound	0.11	30	useful	0.026
6	child	0.101	31	study	0.024
7	use	0.098	32	absence	0.023
8	function	0.083	33	fun	0.023
9	convenient	0.057	34	bad	0.023
10	satisfy	0.057	35	sorry	0.023
11	connection	0.055	36	English	0.023
12	television	0.053	37	artificial intelligent	0.022
13	weather	0.048	38	need	0.022
14	design	0.048	39	wi-fi	0.021
15	pairing	0.046	40	amazing	0.021
16	lack	0.044	41	phone	0.02
17	update	0.043	42	impossible	0.019
18	vary	0.043	43	purchase	0.019
19	voice user interface	0.04	44	response	0.018
20	news	0.039	45	present	0.016
21	error	0.038	46	audiobook	0.016
22	radio	0.037	47	easy	0.015
23	speaker	0.036	48	understanding	0.015
24	alarm	0.035	49	appropriate	0.015
25	pretty	0.035	50	size	0.014

semantic network (Valente et al., 2008).

Considering these characteristics of the centralities, it is possible to consider ‘good’ was the most important keyword in the semantic network because it showed a highest value in all the four centralities in the data. ‘good’ is a very positive word toward the subject. Although it may be hard to assert because users tend to write comments many of which can be written in a favorable way in online reviews (Meyer et al., 2008), it can be said that the majority of the users have used IPAs usefully and evaluated

Table 4.5. The results of the analysis of betweenness centrality

Rank	Keyword	Betweenness centrality	Rank	Keyword	Betweenness centrality
1	good	0.302	26	display	0.205
2	music	0.302	27	study	0.203
3	voice recognition	0.302	28	fun	0.189
4	sound	0.302	29	radio	0.18
5	child	0.302	30	voice user interface	0.172
6	use	0.302	31	want	0.17
7	function	0.302	32	wi-fi	0.169
8	satisfy	0.302	33	present	0.169
9	connection	0.302	34	like	0.162
10	weather	0.302	35	alarm	0.156
11	lack	0.302	36	amazing	0.152
12	vary	0.283	37	artificial intelligent	0.15
13	news	0.282	38	need	0.143
14	light	0.271	39	purchase	0.143
15	convenient	0.271	40	sorry	0.127
16	speaker	0.271	41	absence	0.126
17	design	0.264	42	response	0.12
18	error	0.248	43	English	0.118
19	pretty	0.247	44	easy	0.115
20	pairing	0.24	45	impossible	0.111
21	useful	0.237	46	understanding	0.099
22	update	0.227	47	size	0.095
23	bad	0.213	48	appropriate	0.081
24	control	0.21	49	phone	0.071
25	television	0.208	50	audiobook	0.067

them well. This is in the similar line with previous studies investigating online reviews of IPAs (Y. Gao et al., 2018; Hwang et al., 2016).

The keyword ‘good’ was the most frequently mentioned and mentioned together with other keywords in the co-occurrences. The semantic network showed that the keyword ‘good’ was strongly linked with others, especially four keywords such as ‘music’, ‘voice recognition’, ‘sound’ and ‘light’ (Figure 4.4-a). These keywords also showed a high value in all the four centralities. ‘music’ and ‘light’ are the keywords related to the function, and

Table 4.6. The results of the analysis of closeness centrality

Rank	Keyword	Closeness centrality	Rank	Keyword	Closeness centrality
1	good	1	26	study	0.925
2	music	1	27	voice user interface	0.907
3	voice recognition	1	28	control	0.907
4	sound	1	29	want	0.891
5	child	1	30	absence	0.891
6	use	1	31	fun	0.891
7	function	1	32	present	0.891
8	satisfy	1	33	alarm	0.875
9	connection	1	34	display	0.875
10	weather	1	35	need	0.875
11	lack	1	36	amazing	0.875
12	light	0.98	37	like	0.86
13	convenient	0.98	38	sorry	0.86
14	design	0.98	39	artificial intelligent	0.86
15	vary	0.98	40	wi-fi	0.86
16	news	0.98	41	purchase	0.86
17	error	0.961	42	response	0.86
18	speaker	0.961	43	impossible	0.845
19	pretty	0.961	44	English	0.803
20	pairing	0.942	45	audiobook	0.803
21	update	0.942	46	appropriate	0.803
22	useful	0.942	47	size	0.803
23	bad	0.942	48	phone	0.79
24	television	0.925	49	understanding	0.79
25	radio	0.925	50	easy	0.778

‘sound’ and ‘voice recognition’ are the keywords related to the capability of the system, especially ‘voice recognition’ is the fundamental keyword related to performance of IPAs. Therefore, this result can be interpreted that the users regarded factors related to functions of IPAs and capabilities supporting them as important and evaluated them more positive. It can be said that functions and performance of IPAs are important evaluation criteria for users when choosing an IPA product. The reason why keywords are concentrated on ‘music’ and ‘sound’ can be inferred that the collected

Table 4.7. The results of the analysis of eigenvector centrality

Rank	Keyword	Eigenvector centrality	Rank	Keyword	Eigenvector centrality
1	good	0.481	26	alarm	0.08
2	music	0.333	27	want	0.072
3	voice recognition	0.289	28	control	0.071
4	light	0.288	29	like	0.069
5	sound	0.286	30	fun	0.064
6	child	0.227	31	useful	0.059
7	use	0.224	32	artificial intelligent	0.057
8	function	0.189	33	absence	0.055
9	convenient	0.139	34	phone	0.055
10	satisfy	0.138	35	sorry	0.054
11	television	0.127	36	study	0.052
12	design	0.127	37	need	0.052
13	connection	0.125	38	amazing	0.052
14	weather	0.109	39	bad	0.051
15	pairing	0.109	40	wi-fi	0.051
16	vary	0.104	41	purchase	0.049
17	update	0.102	42	English	0.048
18	lack	0.101	43	response	0.045
19	pretty	0.098	44	impossible	0.041
20	voice user interface	0.097	45	understanding	0.041
21	error	0.093	46	easy	0.039
22	speaker	0.093	47	audiobook	0.038
23	news	0.091	48	appropriate	0.038
24	radio	0.087	49	size	0.034
25	display	0.082	50	present	0.031

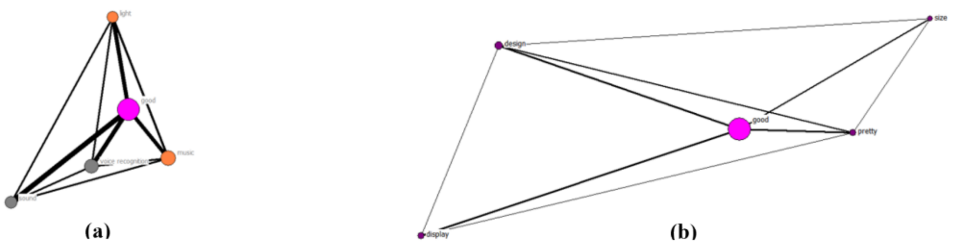


Figure 4.4. The semantic network focusing on the keyword 'good'

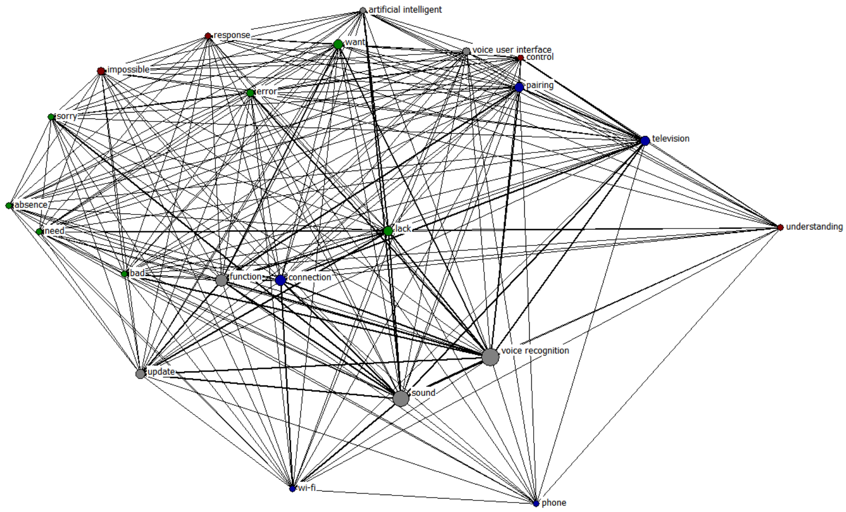


Figure 4.5. The semantic network focusing on the keywords having negative meanings

reviews are about smart speakers. Meanwhile, the semantic network also showed that the keyword ‘good’ was frequently referred with the keywords related to physical features of IPAs such as ‘design’, ‘pretty’, ‘display’ and ‘size’ (Figure 4.4-b). It is possible to say that physical features of IPAs are also important for the users and they are positively evaluated.

Of course, not all users were positive about IPAs. It was found out that there were also some keywords having negative meanings. Although many of them did not show a high value in the four centralities, considering that only the keywords in top 50 frequency of the total were used in this study, the keywords with negative meanings cannot be ignored. The keywords seemed distinguishable from those associated with subjective complaints by users such as ‘lack’, ‘want’, ‘bad’, ‘need’, ‘sorry’ and ‘absence’ and what appeared to be practical problems such as ‘error’ and ‘impossible. They were frequently mentioned together with the keywords related to working issues of IPAs (Figure 4.5). It is easy to infer that the users have also face various issues in using IPAs.

4.4.2. Important Factors for User Experience of Intelligent Personal Assistants and Design Implications

Further discussions on the results of the semantic network are likely to be possible, by considering all the 50 keywords. The keywords in top 50 frequency made us consider these keywords as core keywords in the semantic network for IPAs. Breaking down the keywords by the eleven categories set, five keywords were related to ‘Usefulness’, two keywords were related to ‘Ease of Use’, eight keywords were related to ‘Available Function’. four keywords were related to ‘Behavioral Control’, eight keywords were related to ‘Trust’, two keywords were related to ‘Social Influence’, five keywords were related to ‘Enjoyment’, four keywords were related to ‘Aesthetics’, five keywords were related to ‘Compatibility’, and seven keywords were related to ‘System & Infrastructure’. It is possible to consider that these ten categories are key factors in UX of IPAs. What is different from the initial expectation is that any keyword was not assigned to ‘User Characteristics’. However, it cannot be concluded quickly that ‘User Characteristics’ is not a factor to be considered in UX of IPAs, because although there were not keywords assigned to ‘User Characteristics’ in the keywords in top 50 frequency, it was possible to find out some keywords related to ‘User Characteristics’ such as ‘pronunciation’ when considering all the 364 keywords. Therefore, there is plenty of room left to think about considering ‘User Characteristics’ as one of factors for UX of IPAs. However, as this study was conducted based on the keywords in top 50 frequency, this section focuses on the ten categories in the following paragraphs, and ‘User Characteristics’ will be discussed more in the next chapter.

There were eight keywords which were relatively many keywords related to ‘Available Function’, with a high value in all the four centralities. In addition, the keywords were strongly linked with the keywords related to ‘Usefulness’ and ‘Ease of Use’ (Figure 4.6). It is possible to say that users use various functions of IPAs and consider them useful and convenient in their daily life. Meanwhile, previous studies investigating usability and UX of IPAs reported that many users interested in various functions of IPAs (Y. Gao et al., 2018; Hwang et al., 2016), but mostly used functions were simple and even some of them were not identified and not used properly by users (Alqurashi, 2018; López et al., 2018). The results of this study showed the similar results with the previous studies, but functions related to the smart home seemed to be relatively rarely used, compared to other related previous studies reported in foreign countries. It can be inferred, from this, that, in the Republic of Korea, functions related to the smart home using

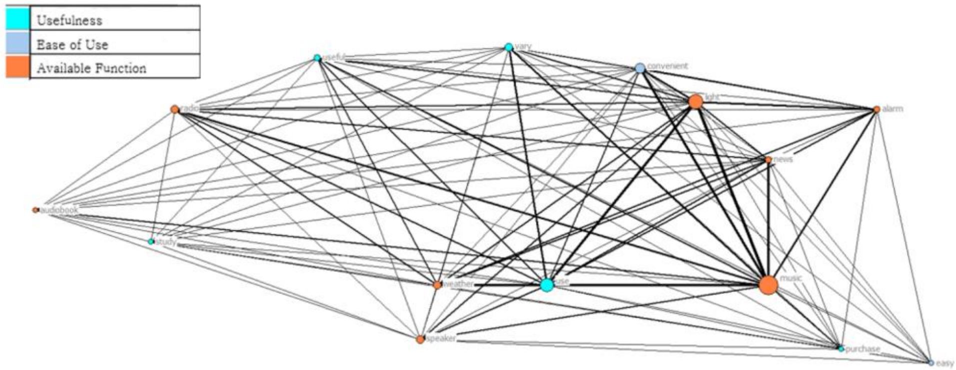


Figure 4.6. The semantic network focusing on three factors: ‘Usefulness’, ‘Ease of Use’ and ‘Available Function’

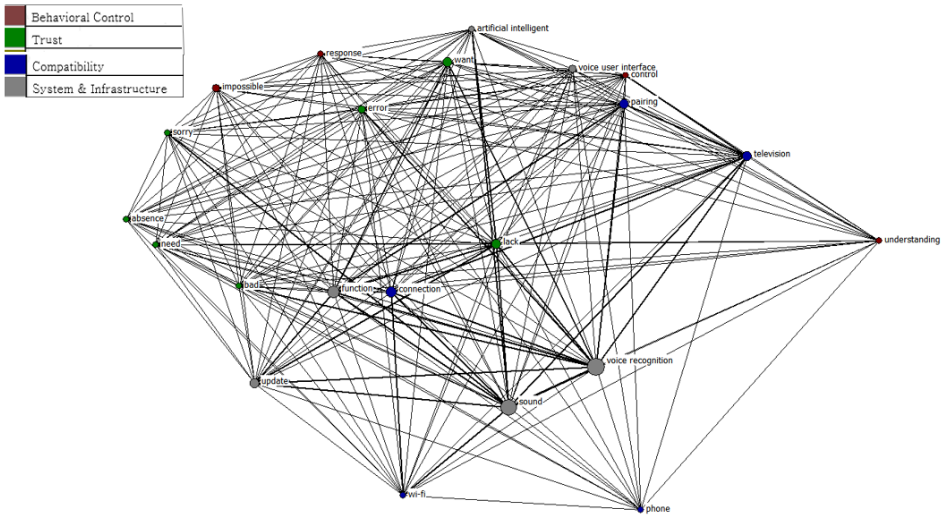


Figure 4.7. The semantic network focusing on four factors: ‘Trust’, ‘Behavioral Control’, ‘Compatibility’ and ‘System & Infrastructure’

IPAs have been less popularized.

There were also eight keywords related to ‘Trust’, and there were four keywords related to ‘Behavioral Control’. Most of the keywords had the negative meanings and were strongly linked with the keywords related to ‘Compatibility’ and ‘System & Infrastructure’ (Figure 4.7). The limitation of performance of voice recognition has been consistently pointed out in many previous studies, which was also raised from the use of IPAs. The results of this study showed that the users are dissatisfied with capability of current IPAs and compatibility with other devices and have complaints on them. It can be inferred that the problems related to capability and compatibility of

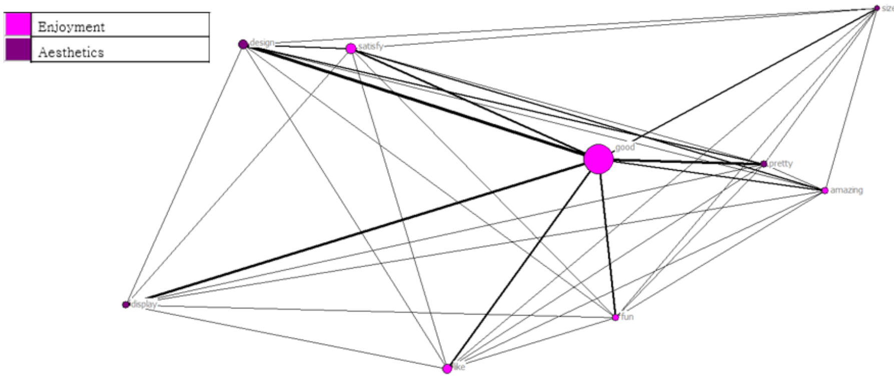


Figure 4.8. The semantic network focusing on two factors: 'Enjoyment' and 'Aesthetics'

IPAs are the main reason making the users reluctant to use them. It seems like that improving not only capability but also the compatibility of current IPAs is an urgent priority. Especially, considering the fact that IPAs can play a role of the hub in the smart home (Aguirre-Munizaga et al., 2018; Pyae & Joelsson, 2018), it can be said that solving the issues related to compatibility of IPAs should be considered a top priority in constructing an improved environment for the smart home.

In addition, although not showing a high value in all the four centralities, the keywords related to 'Aesthetics' showed relatively a high value in the centralities and strongly linked with the keywords related to 'Enjoyment' (Figure 4.8). In previous studies investigating UX of IPAs, hedonic aspects including aesthetics have been frequently ignored or been not mentioned. Many of previous studies related to IPAs usually focused on the features and functions of them. However, many studies reported that hedonic quality of a product is also important for enjoyment and satisfaction of users (Batra & Ahtola, 1991; M. Hassenzahl et al., 2010; Partala & Kallinen, 2012). The semantic network in this study showed that, although they may be not important than functions and performance of IPAs, aesthetics aspects of IPAs, especially, features related to the physical design are crucial for the satisfaction of the users. It can be inferred that hedonic aspects are also important as well as pragmatic aspects for users of IPAs. Considering the previous study (Sand et al., 2020), it is also expected that providing with good aesthetic features can lead to improving overall Customer Experience (CX) including UX of IPAs for users.

Meanwhile, there were relatively few keywords related to 'Social

Influence', and it was difficult to identify specific relationships with other factors. Therefore, it can be said that further inspections on the factor are more required in the future.

4.5. Conclusion

In this study, UX of smart speakers which are a kind of embodied IPAs was investigated. The purpose of the study in this chapter was to investigate UX of IPAs through semantic network analysis, identifying what factors are important to UX of IPAs. Before investigating UX of IPAs for users with disabilities, UX of IPAs was investigated for users with non-disabilities in this study.

In this study, online reviews for smart speakers were collected and preprocessed. Words having a similar meaning were clustered and represented by a keyword. Total 364 keywords were obtained and keywords in top 50 frequency were used in this study, because they were considered core keywords in the data. The keywords were divided according to their attributes based on the categories which were set by the researchers. Based on the keywords, semantic network analysis was conducted with measuring centrality.

The analyzed results showed that the keyword 'good' was the most frequently mentioned and mentioned together with other keywords in the data. Especially, the keyword was strongly linked with the keywords related to 'Available Function' and 'System & Infrastructure'. There were many keywords related to 'Available Function' and 'Trust', showing a high value of the centralities, which indicated that performance of IPAs was most important for users when choosing an IPA product. There were strong relationships between the keywords related to 'Usefulness', 'Ease of Use' and 'Available Function'. Meanwhile, there were many keywords having negative meanings in 'Behavioral Control' and 'Trust', and those were strongly linked with the keywords related to 'Compatibility' and 'System & Infrastructure'. The results could be interpreted that, although there were many issues which must be solved, the majority of users have used IPAs usefully and evaluated them well. In addition, the results of semantic network analysis also showed that the keywords related to 'Aesthetics' with relatively a high value in the centralities and were strongly linked with the keywords related to ‘Enjoyment’. Especially, it was possible to say that features of IPAs related to the physical design were crucial for the satisfaction of the users. It could be inferred that hedonic aspects were also important as well as pragmatic aspects for users of IPAs.

This study has some limitations. Although the data structuring and the analysis were conducted by many researchers to get rid of subjectivity, it may be not said that the subjectivity of the researchers was completely excluded. In addition, this study only focused on smart speakers, sold in the Republic of Korea, which are a kind of embodied IPAs, which would be a hurdle in generalizing the results to all kinds of IPAs and users living in other countries.

Nevertheless, this study contributed to the understanding of UX of IPAs, by showing that most of the users were satisfied with the use of IPAs, although they felt that performance was not completely reliable, which was similar with previous studies related to IPAs. This study proposed eleven important factors to be considered for UX of IPAs and among them, suggested ten factors to be considered in the design of IPAs to improve UX of IPAs and to satisfy users. In the following chapter, UX of IPAs will be investigated for users with disabilities based on the factors proposed in this study. In addition, the differences of UX of IPAs between users with disabilities and users with non-disabilities will be also discussed.

Chapter 5 Investigation on User Experience of Intelligent Personal Assistants and Effects on Quality of Life for Users with Disabilities by Comparing with Users with Non-Disabilities

5.1. Introduction

UX becomes more important in various fields. However, people with disabilities have been rarely considered the subject for the study on UX (M. Lee et al., 2017). A person gets information for the action from the relationship between the environment and oneself (Gibson, 1979). Disabilities which people with disabilities have cause them interacting with their surroundings differently comparing with people with non-disabilities (Bajcar et al., 2020). For this reason, it is necessary to conduct a study on UX for people with disabilities thoroughly through user-centered approaches, and to compare the evaluation with that of people with non-disabilities (Bajcar et al., 2020).

Many previous studies related to IPAs referred to that they would be helpful to people with disabilities. However, many researchers usually focused on people with non-disabilities as users (Metatla et al., 2019), and have rarely conducted the empirical study on UX of IPAs for people with disabilities. Only few of studies related to IPAs have been conducted for people with disabilities from the angle of them. To comprehend UX of IPAs for users with disabilities and to provide them with the more improved design of IPAs, it is required to investigate UX of IPAs for them more thoroughly.

Comprehending and identifying UX issues from the angle of users are very important for the interaction design. Meanwhile, some researchers pointed out that just investigating usability and UX of a product is not enough to identify crucial issues for people with disabilities, saying that it should be considered how the use of technologies and products actually affects their daily lives (Agree & Freedman, 2011). In other words, it can be said that quality of life should be also considered in studying UX for users with disabilities.

There are many definitions of quality of life, because it can be defined as well-being across multiple domains of life including various values of an individual (Andresen & Meyers, 2000; Felce & Perry, 1995). There is none to deny that enhancing quality of life of an individual is the top priority in leading to satisfaction of life for the one. In the line with this, technology is considered the key to enhancing quality of life for everyone in their lifetime (S. Park & Jayaraman, 2003), especially for people with disabilities by giving them more chance to control their environments and to increase their independence (Cook, 2008). If a user gets good experience during the use of a system in their daily life, it would mean that the user is using the system well and satisfied with it (M. Kim, 2018; Zahidi et al., 2014), which can lead to enhancing quality of life of the user (Agree & Freedman, 2011; Cook, 2008; S. Park & Jayaraman, 2003).

IPAs can perform various tasks to assist users (Rodolitz et al., 2019). Users can send messages, make phone calls, play music, set alarms, control IoT devices, and even have a joke with IPAs (Hoy, 2018; Saad et al., 2017), which is very helpful to people with disabilities in their everyday life. However, researchers rarely focused on how the use of IPAs affects quality of life of them. The study on UX of IPAs for people with disabilities should be accompanied with the investigation of impacts of the use of IPAs on their daily life.

This chapter describes Study 3 which has two aims. The first purpose is to investigate UX of IPAs for users with disabilities. The second purpose is to investigate how the use of IPAs affects quality of life of them. In this study, comparisons with users with non-disabilities were also conducted for a deeper understanding of UX and getting inclusive implications (Bajcar et al., 2020; Polacek et al., 2017). In this study, a questionnaire survey and a written interview were conducted for users with disabilities and users with non-disabilities.

Same with Study 1, acceptance factors were adopted to investigate UX of IPAs. In addition to those used in Study 1, three additional acceptance factors such as ‘Perceived Aesthetics (PA)’, ‘Compatibility (COM)’ and ‘System Capabilities (SC)’ were selected to investigate UX of IPAs for this

Table 5.1. Acceptance factors used in Study 3

Acceptance factor	Definition
Perceived Usefulness (PU)	The degree to which one believes that the system would be useful and helpful
Perceived Ease of Use (PEOU)	The degree to which one believes that using the system is free of effort
Trust (TR)	The belief that the system performs with personal integrity and reliability
Social Influence (SI)	The perceptions of significant people regarding the use of the system
Perceived Enjoyment (PE)	Feelings of pleasure associated with using the system
Perceived Behavioral Control (PBC)	The perceptions to which one has the necessary resources, capabilities, and a sense of control in successfully performing the behavior
Perceived Aesthetics (PA)	The perceptions of physical and sensory features of the system with interaction addressed by attractiveness or appeal
Compatibility (COM)	Capabilities of the system working well together or existing together successfully with others
System Capabilities (SC)	Capabilities of the system supporting the interaction and performance issues, and providing appropriate infrastructures
Intention to Use (ITU)	The intention to use the system over time

study (Table 5.1). These factors used in this study were adopted based on the results of Study 1 and Study 2 in this dissertation.

The analysis was carried out in the following order. First, UX of IPAs and the effects of the use of IPAs on quality of life were statistically investigated. For this, the differences between users with disabilities and users with non-disabilities were statistically investigated. Then, the acquired data were qualitatively examined. In the investigation, the data of the written interview were analyzed.

5.2. Method

5.2.1. Participants

For this study, 19 people who have used one or more smart speakers which are a kind of embodied IPAs, considering themselves an active user for IPAs, were recruited voluntarily. There were 12 males and 7 females ranged from

16 to 33 years, with the average age of 23.68 years (*SD* = 5.218). Among them, 9 participants were users with disabilities (*M*=4, *F*=5) having physical disabilities (8 participants were severe) with the average age of 25.44 (*SD* = 4.531), and 10 participants were users with non-disabilities (*M*=8, *F*=2) with the average age of 22.10 (*SD* = 5.507).

About 50% of all the participants have used one or more smart speaker products for more than 6 months, and about half of them have used them more than one year. About half of all the participants placed smart speakers in their private room. The most frequently used functions of smart speakers by the participants in their daily life were 'listening to music' and 'checking the weather'. Table 5.2 summarizes demographic information and use experience of the participants in using smart speakers.

In section 2.3.2, it was already discussed that many previous studies related to IPAs for people with disabilities focused on people with visual impairments. Considering the limitation of the previous studies, this study decided to focus on users with physical disabilities

5.2.2. Procedure

Users with disabilities and users with non-disabilities who have used one or more IPAs were recruited voluntarily. Each participant was explained the objective and the procedure of this study via an email or a mobile messenger. Participants were free to ask questions at any time. The link of the questionnaire including items for the written interview which was made by the Google-questionnaire form was sent to the participants via an email or a mobile messenger. All of the procedures were conducted remotely, considering the participants with disabilities, to encourage them to take part in the study and to minimize their inconvenience (Petrie et al., 2006). The collected data were analyzed statistically and qualitatively.

5.2.3. Questionnaire

The questionnaire consists of five sections and had two versions: one having total fifty-five items was for users with disabilities (Appendix C) and another having total fifty-three items was for users with non-disabilities (Appendix D).

Table 5.2. Summary of demographic information and use experience of the participants in using smart speakers

	Participants with disabilities	Participants with non-disabilities
Gender		
Male	4	8
Female	5	2
Average Age	25.44 (*SD* = 4.531)	22.10 (*SD* = 5.507)
Period of use		
Over 1 year	4	2
Less than 1 year	5	8
IPAs in use		
Nugu	2	1
Gigagenie	4	5
Clova	3	1
Kakaomini	1	1
Google Home	0	4
Place in use		
Private room	4	5
Living room	6	4
Kitchen	0	1
Mainly used functions		
Listening to music	8	6
Listening to audiobooks	1	0
Listening to news	2	0
Checking the weather (including fine dust)	7	7
Asking questions for information	3	2
Gaming	0	0
Time / Alarm Setting	3	3
Ordering goods (shopping)	0	0
Controlling a TV	6	3
Controlling IoT devices (including smart homes, lights etc.)	1	2
Calling and texting	2	2
Chatting	0	0

In the first section, basic demographic information was asked. In the second section, use experience in using IPAs were asked. In the third section, UX of IPAs was evaluated with a Likert 7-point scale based on the acceptance factors. Each acceptance factor was measured by multiple items which were designed based on the previous studies (Bernsdorf et al., 2016; Davis et al., 1989; L. Gao & Bai, 2014; Heerink et al., 2010; E. Park et al., 2017; Venkatesh et al., 2003; Yang et al., 2016). The items were similar with those of Study 1, but they were slightly modified and some were added for this study. As a result, total of thirty items were asked to the participants to evaluate UX of IPAs (Table 5.3).

In the fourth section, the effects of the use of IPAs on quality of life were evaluated with a Likert 7-point scale. Quality of life was measured by seven items which were designed based on the previous study investigating the impact of assistive technologies on quality of life (Agree & Freedman, 2011) (Table 5.4). Each item represents a factor of quality of life which should be considered to increase it in people's daily activities (Table 5.4). All the questionnaire items in this study were designed to mean that the higher the score in response, the more positive it is.

5.2.4. Written Interview

Questions for the written interview were also included in the final section of the questionnaire. The aim of the written interview was to collect qualitative data to identify detail issues related to UX from the angle of users. Reviews written by users are very important to identify issues related to UX which was shown in Study 2. However, it was impossible to collect reviews for IPAs written by users with disabilities in that study. To compensate it, qualitative data were gathered through the interview in this study. Considering the participants with disabilities, the interview was conducted in writing.

First Impression Elicitation Method (FIEM) which is an interview method (G.-W. Kim, 2016) was adopted in this study. FIEM consists of four components such as 'Before-use impression', 'During-use impression', 'Underlying frame' and 'After-use impression'. These four components help to comprehend UX in the dynamic perspective such as before, during, after, and overtime periods of usage (Roto et al., 2011) (Table 5.5), The aim of the component, 'Before-use impression' is to collect the first image of a product. The aim of the component, 'During-use impression' is to capture users'

Table 5.3. The questionnaire items to evaluate user experience of intelligent personal assistances

Acceptance factor	Item
Perceived Usefulness (PU)	PU1: Using the smart speaker would enable me to accomplish execution of desired functions more quickly.
	PU2: Using the smart speaker would make it easier for me to accomplish execution of desired functions.
	PU3: Overall, I would find using the smart speaker to be advantageous.
Perceived Ease of Use (PEOU)	PEOU1: Learning to use the smart speaker is easy for me.
	PEOU2: Interaction with voice user interface systems is clear and understandable.
	PEOU3: I think using the smart speaker is easy.
Trust (TR)	TR1: Performance of the smart speaker is reliable.
	TR2: I can get reliable results using the smart speaker.
	TR3: The smart speaker continues to be supplemented and developed for the user.
Social Influence (SI)	SI1: I would recommend using the smart speaker to others.
	SI2: People who are important to me would find using the smart speaker beneficial.
	SI3: People who are important to me would find that using the smart speaker is a good idea
Perceived Enjoyment (PE)	PE1: I have fun with using the smart speaker.
	PE2: Using the smart speaker is pleasurable.
Perceived Behavioral Control (PBC)	PBC1: Using the smart speaker is entirely within my control.
	PBC2: I have the resource, knowledge and ability to use the smart speaker.
	PBC3: I am able to skillfully use the smart speaker.
Perceived Aesthetics (PA)	PA1: The user interface of the smart speaker (eg. color, control panel, voice etc.) is attractive.
	PA2: The overall look and feel of the smart speaker is appealing.
	PA3: Overall, the smart speaker looks attractive.
Compatibility (COM)	COM1: The smart speaker is well compatible with other existing devices (eg. TV, smart phone etc.).
	COM2: Using the smart speaker is compatible with all aspects of my work.
	COM3: Using the smart speaker fits into my life style.
System Capabilities (SC)	SC1: The smart speaker provides various functions that can be used.

	SC2: Performance of the smart speaker (eg. voice recognition, artificial intelligence etc.) is enough to use the functions provided.
	SC3: Infrastructure services, including updates of the smart speaker are enough to use the functions provided.
Intention to Use (ITU)	ITU1: Given the chance, I intend to use the smart speaker.
	ITU2: I will frequently use the smart speaker.
	ITU3: I will continue using the smart speaker in the future.
Satisfaction (SAT)	Overall, I am satisfied with the use of smart speakers.

Table 5.4. The questionnaire items to evaluate effects of the use of intelligent personal assistances on quality of life

Factor of quality of life	Item
Safety	Because you use the smart speaker, how much safer do you feel when you do your daily activities?
Controllability	Because you use the smart speaker, how much more control do you have over your daily activities?
Enjoyment	Because you use the smart speaker, how much more often do you take part in activities you enjoy?
Effort	Because you use the smart speaker, how much less painful is it for you to do your daily activities?
Tiredness	Because you use the smart speaker, how much less tiring is it for you to do your daily activities?
Independence	Because you use the smart speaker, how much less do you rely on others in your daily activities?
Time Consuming	Because you use the smart speaker, how much less time does it take for you to do your daily activities?

thoughts, avoiding the distortion. The aim of the component, 'Underlying frame' is to identify the value that users have in mind. The aim of the component, 'After-use impression' is to gather users' expectation of the improvement of a product.

Although FIEM is useful to understand UX in the broaden aspect, it focuses on the first impression of a product and is based on a face-to-face interview. As this reason, FIEM was slightly modified for this study, by including more questions. Based on the framework of FIEM, nine question items for the written interview were designed based on the previous studies (Ammari et al., 2019; G.-W. Kim, 2016) (Table 5.5).

Table 5.5. The components to investigate user experience in the dynamic perspective and the items for the written interview

Component of user experience	Item
Before-use impression	1. What were your feelings or thoughts when you first know the smart speaker?
During-use impression	2. What did you think while using the smart speaker?
Underlying frame	3. What are the advantages and disadvantages of the smart speaker you currently have?
	4. What is the role and meaning of the smart speaker you have in mind?
	5. What are your memorable anecdotes related to the smart speaker?
	6. What functions do you frequently use when using the smart speaker? Why do you mainly use such functions?
	7. Have you ever had difficulties or problems when using the smart speaker? If you have experienced them, what are they and how did you try to solve them?
After-use impression	8. What is your ideal type of the smart speaker?
	9. What will you consider when you give the smart speaker to your friends as a gift?

5.2.5. Analysis

5.2.5.1. Statistical Analysis

SPSS version 25 and AMOS version 22 were used to statistically analyze the questionnaire data. First, same with Study 1, reliability analysis and validity analysis was conducted. Then, descriptive analysis and Mann-Whitney U-test were performed to examine whether there are differences between users with disabilities and users with non-disabilities. Instead of t-test, Mann-Whitney U-test was used, as the reasons that the sample of the data in this study was small and the normality of the data did not appear.

5.2.5.2. Qualitative Analysis

In this study, the interview data were qualitatively investigated. Although the statistical analysis was performed, this study relied more on the analysis for the qualitative data to draw in-depth understandings and insights, which is considered very useful in obtaining users' thoughts and needs (Schirr, 2013), especially for users with disabilities (Burton et al., 2008; H. N. Kim & Oumarou, 2020). For this, all the data were closely looked into and analyzed by, including the author, three graduate students majoring cognitive science and the human factor.

The interview data containing contents related to UX issues were classified into the acceptance factors according to their contents to identify UX issues on the use of IPAs (Koon et al., 2020). Semantic network analysis on the interview data was also conducted, because this method is considered useful in identifying important values of the subject for users through visualizing qualitative data (G. W. Kim et al., 2016; Lim et al., 2019; Rhie et al., 2017). The analysis was carried out in the same ways as Study 2.

5.3. Results

5.3.1. Reliability Analysis and Validity Analysis

Reliability analysis was conducted to verify inter-reliability between the items for the factors. Meanwhile, validity analysis was also conducted to verify the appropriateness of the data for the factors. As a way of validity analysis, a value of AVE and Composite Reliability CR was calculated as the index for convergent validity and discriminant validity, by using the factor loading value and the unique variance of each variable through confirmatory factor analysis. The results of reliability analysis showed that all the factors except SC were acceptable with a higher Cronbach's alpha values than required (Table 5.6). The results of validity analysis showed that all the factors except PEOU and SC were acceptable with a higher value of AVE and CR than required (Table 5.6). In this study, SC which showed the unacceptable result in both reliability analysis and validity analysis was excluded in the following statistical analyses.

5.3.2. Descriptive Analysis and Mann-Whitney U-test

5.3.2.1. User Experience of Intelligent Personal Assistants

The results of descriptive analysis showed that among seven factors, the average scores of PEOU and PBC were the highest and followed by the

Table 5.6. The results of reliability analysis and validity analysis

Factor	Cronbach's alpha	AVE	CR
PU	.872	0.66279	0.852288454
PEOU	.601	0.28644	0.416057
TR	.789	0.55426	0.778034
SI	.900	0.828158	0.934724
PE	.816	0.777809	0.870717
PBC	.834	0.582574	0.795778
PA	.858	0.697958	0.870501
COM	.699	0.526924	0.768899
SC	.057	0.151282	0.229558
ITU	.740	0.61659	0.815127
Quality of Life	.905	0.604913286	0.913050169

average scores of SI, PE, PA, ITU, TR, COM and PU (Table 5.7 & Figure 5.1). The results of descriptive analysis also showed the average scores of SAT and use frequency (Table 5.7 & Figure 5.1). The average scores of PEOU, SI, COM and use frequency of the participants with disabilities were higher than those of the participants with non- disabilities (Table 5.7 & Figure 5.1). Meanwhile, the results of Mann-Whitney U-test showed that there was a significant difference at the 95% confidential level between the participants with disabilities and the participants with non-disabilities only

Table 5.7. The results of descriptive analysis for acceptance factors and use frequency

Variable	Participants with disabilities		Participants with non-disabilities		Total participants	
	Average	SD	Average	SD	Average	SD
PU	4.6296	1.68691	5.2000	.99629	4.9298	1.35892
PEOU	5.6667	1.05409	5.2667	.94019	5.4561	.98889
TR	4.9630	1.44765	5.3333	.73703	5.1579	1.11316
SI	5.4444	1.29099	5.4333	1.13366	5.4386	1.17617
PE	5.1667	1.62019	5.5000	.62361	5.3421	1.17913
PBC	5.1852	1.55556	5.7000	.86709	5.4561	1.23334
PA	5.1481	1.46355	5.2000	1.13529	5.1754	1.26378
COM	5.1111	1.00000	4.8667	1.12437	4.9825	1.04512
ITU	5.0370	.84071	5.1333	.84911	5.1754	1.23413
SAT	5.2222	1.61589	5.50	.972	5.42	1.121
Use Frequency	5.33	1.323	2.40	1.174	3.32	1.797

Table 5.8. The results of Mann-Whitney U-test for acceptance factors and use frequency between the participants with disabilities and the participants with non-disabilities

Variable	Sig.
PU	.661
PEOU	.400
TR	.720
SI	.968
PE	.842
PBC	.447
PA	.780
COM	.604
ITU	.447
SAT	.780
Use Frequency	.017*

* *p*<.05

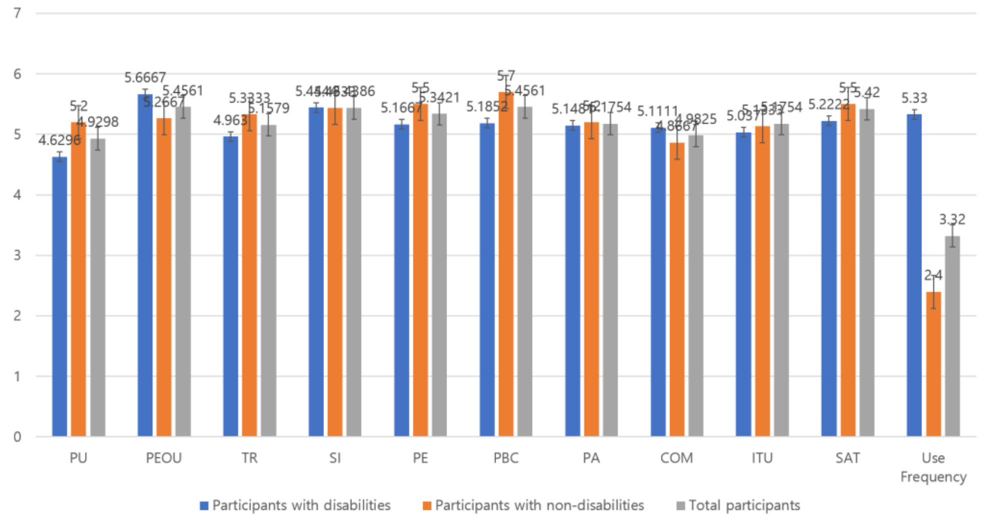


Figure 5.1. The results of descriptive analysis for acceptance factors and use frequency

in use frequency ($p<.05$) (Table 5.8).

5.3.2.2. Effects of the Use of Intelligent Personal Assistants on Quality of Life

The results of descriptive analysis showed that the average score of quality of life of the participants with disabilities was higher than that of the

Table 5.9. The results of descriptive analysis for the effects of the use of intelligent personal assistants on quality of life

Variable		Participants with disabilities		Participants with non-disabilities		Total participants	
		Average	SD	Average	SD	Average	SD
Quality of Life	Safety	4.67	1.414	4.40	1.350	4.26	1.485
	Controllability	4.22	2.048	5.10	1.595	4.32	1.668
	Enjoyment	5.00	1.225	5.40	.699	5.05	1.393
	Effort	4.78	2.224	4.20	1.751	5.11	1.595
	Tiredness	4.67	1.803	3.10	2.378	4.42	1.742
	Independence	4.33	2.449	4.30	1.567	3.68	2.428
	Time Consuming	4.89	1.900	4.40	1.350	4.58	1.710
	Average	4.6508	1.6814	4.3429	1.1452	4.4887	1.3918

Table 5.10. The results of Mann-Whitney U-test for the effects of the use of intelligent personal assistants on quality of life between the participants with disabilities and the participants with non-disabilities

Variable	Sig.
Safety	.243
Controllability	.968
Enjoyment	.905
Effort	.968
Tiredness	.447
Independence	.400
Time Consuming	.356
Average	.780

participants with non-disabilities (Table 5.9 & Figure 5.2). Considering the factors of quality of life, the average score of ‘Effort’ was the highest and followed by the average scores of ‘Enjoyment’, ‘Time Consuming’, ‘Tiredness’, ‘Controllability’, ‘Safety’ and ‘Independence’ (Table 5.9 & Figure 5.2). The average scores of ‘Safety’, ‘Effort’, ‘Tiredness’, ‘Independence’ and ‘Time Consuming’ of the participants with disabilities were higher than those of the participants with non-disabilities (Table 5.9 & Figure 5.2). Meanwhile, the results of Mann-Whitney U-test showed that there was not a significant difference between the participants with disabilities and the participants with non-disabilities (p>.05) (Table 5.10).

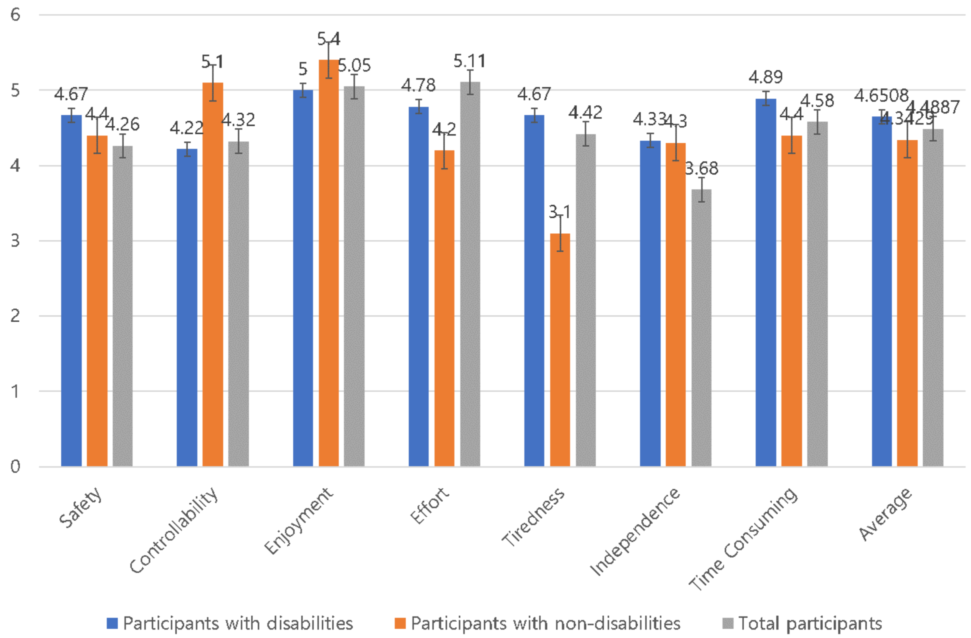


Figure 5.2. The results of descriptive analysis for the effects of the use of intelligent personal assistants on quality of life

5.3.3. Analysis on the Written Interview

5.3.3.1. Analysis on Issues Related to User Experience from the Written Interview

Through the written interview, total 186 sentences were collected; 89 sentences were from the participants with disabilities and 97 sentences were from the participants with non-disabilities. Among them, 140 sentences contained contents related to usability and UX; 69 sentences were from the participants with disabilities and 71 sentences were from the participants with non-disabilities. The comments containing contents related to UX issues were classified into the acceptance factors according to their contents and were divided into two dimensions such as positive and negative (Table 5.11). If a participant said same contents repeatedly, they were counted as one.

Many participants said that it is amazing in using IPAs and they are useful and convenient. Especially, the participants with disabilities frequently said that IPAs are useful in various aspects. However, there were also many negative contents. Most of the negative comments were related to the low rate of voice recognition and the difficulty of obtaining desired results by

Table 5.11. Summary of the written interview

Acceptance factor	Positive	Negative
PU	Useful (PWD7, PND1) Make me more independent (PWD4) Useful in situations where other modalities cannot be used (PWD2, PND2) Fast input speed (PWD1, PND2) Able to control other devices (PWD7, PND1)	Simple functions only available (PWD2)
PEOU	Convenient (PWD5, PND7)	Customization required according to the user (PWD1, PND1) Unintuitive interface (PND2) Limited visual feedbacks (PND3)
TR		Unable to get the desired results (PWD1, PND3)
SI		
PE	Amazing (PWD4, PND5) Fun (PWD2, PND2)	
PBC	Good rate of recognition (PND1)	Low rate of recognition (PWD6, PND4)
PA	Satisfying with design (PWD2, PND2)	Sound quality is not good (PND1)
COM		Need to improve compatibility with other devices (PWD4, PND2)
SC		Need a new setting after update (PD1)
ITU	Intention to use continuously (PWD1)	Does not feel the need (PWD1, PND1)

PWD: Participants with disabilities
PND: Participants with non-disabilities
The number refers to the total number of the participants who mentioned.

using IPAs. In addition, problems related to compatibility with other devices were pointed out, especially by the participants with disabilities. Meanwhile the unintuitive interface of IPAs such as limited visual feedbacks was also frequently pointed out by the participants with non-disabilities. It could be said that most of the negative comments belonged to PEOU, TR, PBC and COM.

5.3.3.2. Semantic Network Analysis on the Written Interview

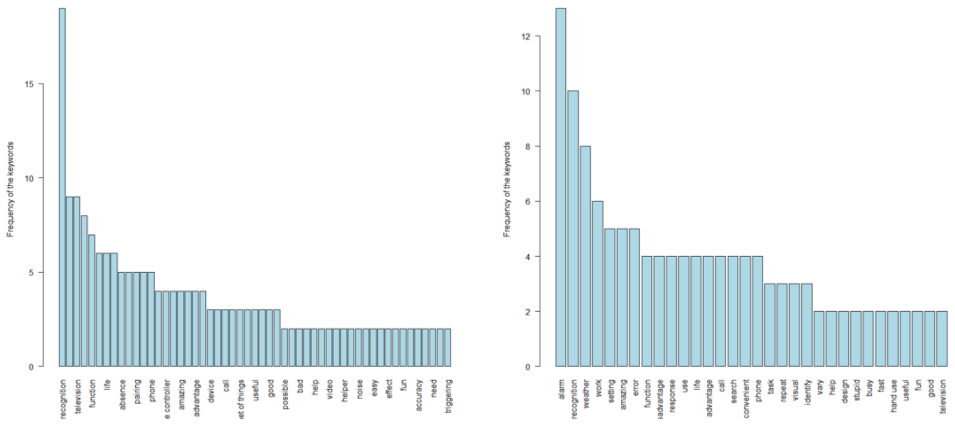
To identify specific issues related to UX and important values of IPAs for users from the data of the written interview, semantic network analysis was carried out. The analysis was conducted by dividing the data by the two user groups to compare the analyzed results between the participants with disabilities and the participants with non-disabilities. The analysis was conducted as the same ways as Study 2. From all the written interview data, 135 different keywords were extracted; 95 keywords were from the participants with disabilities and 81 keywords were from the participants with non-disabilities. Among the keywords, keywords that appeared at least twice in the data of each user group were used for the analysis (Table 5.12 & Figure 5.3). As a result, 53 keywords which occupied about 83.26% of the total keywords for the participants with disabilities and 32 keywords which occupied about 74.56% of the total keywords for the participants with non-disabilities were used for the analysis. The keywords appeared at least twice in the data of each user group were translated from Korean to English (Appendix E & Appendix F).

The keywords appeared at least twice in the data were divided according to their attributes (Table 5.13). Eleven categories were set based on Study 2. The definitions of the categories were already described in the previous chapter (section 4.2.3). Nine keywords were assigned to ‘Usefulness’ for the participants with disabilities: ‘use’, ‘disadvantage’, ‘advantage’, ‘quality of life’, ‘useful’, ‘improving’, ‘help’, ‘independence’ and ‘effect’, and eight keywords assigned for the participants with non-disabilities: ‘disadvantage’, ‘use’, ‘advantage’, ‘task’, ‘vary’, ’help’, ‘fast’ and ‘useful’. Three keywords were assigned to ‘Ease of use’ for the participants with disabilities: ‘difficult’, ‘convenient’ and ‘easy’, and one keyword was assigned for the participants with non-disabilities: ‘convenient’. Seven keywords were assigned to ‘Available Function’ for the participants with disabilities: ‘music’, ‘search’, ‘call’, ‘weather’, ‘video’, ‘alarm’ and ‘light’, and four keywords were assigned for the participants with non-disabilities: ‘alarm’,

Table 5.12. List of the keywords appeared at least twice in the written interview data and their frequencies

Rank	Keyword from the participants with disabilities	Frequency	Keyword from the participants with non-disabilities	Frequency
1	voice recognition	19	alarm	13
2	control	9	voice recognition	10
3	television	9	weather	8
4	use	8	work	6
5	function	7	setting	5
6	search	6	amazing	5
7	life	6	error	5
8	speech	6	function	4
9	absence	5	disadvantage	4
10	error	5	response	4
11	pairing	5	use	4
12	music	5	life	4
13	phone	5	advantage	4
14	disadvantage	4	call	4
15	remote controller	4	search	4
16	impossible	4	convenient	4
17	amazing	4	phone	4
18	difficult	4	task	3
19	advantage	4	repeat	3
20	convenient	4	visual	3
21	device	3	identifying	3
22	pronunciation	3	vary	2
23	call	3	help	2
24	lack	3	design	2
25	internet of things	3	stupid	2
26	quality of life	3	busy	2
27	useful	3	fast	2
28	people with disabilities	3	hand use	2
29	good	3	useful	2
30	improving	3	fun	2
31	possible	2	good	2

32	personal assistant	2	television	2
33	bad	2		
34	weather	2		
35	help	2		
36	independence	2		
37	video	2		
38	design	2		
39	helper	2		
40	user	2		
41	noise	2		
42	hand use	2		
43	easy	2		
44	alarm	2		
45	effect	2		
46	work	2		
47	fun	2		
48	light	2		
49	accuracy	2		
50	volume	2		
51	need	2		
52	learning	2		
53	triggering	2		



(a) (b)

Figure 5.3. The keywords appeared at least twice in the written interview data and their frequencies: (a) is from the participants with disabilities and (b) is from the participants with non-disabilities

Table 5.13. List of the keywords appeared at least twice in the written interview data by the categories

Category	Keywords from the participants with disabilities	Keywords from the participants with non-disabilities
Usefulness	use, disadvantage, advantage, quality of life, useful, improving, help, independence, effect	disadvantage, use, advantage, task, vary, help, fast, useful
Ease of use	difficult, convenient, easy	convenient
Available Function	music, search, call, weather, video, alarm, light	alarm, weather, call search
Behavioral Control	control, speech, remote controller, impossible, possible, hand use	response, repeat, busy, hand use
Trust	absence, error, lack, personal assistant, bad, work, accuracy, need	work, error, identify, stupid
Social Influence	life, helper	life
Enjoyment	amazing, good, fun	amazing, fun, good
Aesthetics	design	visual, design
Compatibility	television, pairing, phone, device, internet of things	phone, television
System & Infrastructure	voice recognition, function, noise, volume, learning, triggering	voice recognition, setting, function
User Characteristics	pronunciation, people with disabilities, user	

‘weather’, ‘call’ and ‘search’. Six keywords were assigned to ‘Behavioral Control’ for the participants with disabilities: ‘control’, ‘speech’, ‘remote controller’, ‘impossible’, ‘possible’ and ‘hand use’, and four keywords were assigned for the participants with non-disabilities: ‘response’, ‘repeat’, ‘busy’ and ‘hand use’. Eight keywords were assigned to ‘Trust’ for the participants with disabilities: ‘absence’, ‘error’, ‘lack’, ‘personal assistant’, ‘bad’, ‘work’, ‘accuracy’ and ‘need’, and four keywords were assigned for the participants with non-disabilities: ‘work’, ‘error’, ‘identify’ and ‘stupid’. Two keywords were assigned to ‘Social Influence’ for the participants with disabilities: ‘life’ and ‘helper’, and one keyword was assigned for the participants with non-disabilities: ‘life’. Three keywords were assigned to

‘Enjoyment’ for the participants with disabilities: ‘amazing’, ‘good’ and ‘fun’, and three keywords were assigned for the participants with non-disabilities: ‘amazing’, ‘fun’ and ‘good’. One keyword was assigned to ‘Aesthetics’ for the participants with disabilities: ‘design’, and two keywords were assigned for the participants with non-disabilities: ‘visual’ and ‘design’. Five keywords were assigned to ‘Compatibility’ for the participants with disabilities: ‘television’, ‘pairing’, ‘phone’, ‘device’ and ‘internet of things’, and two keywords were assigned for the participants with non-disabilities: ‘phone’ and ‘television’. Six keywords were assigned to ‘System & Infrastructure’ for the participants with disabilities: ‘voice recognition’, ‘function’, ‘noise’, ‘volume’, ‘learning’ and ‘triggering’, and three keywords were assigned for the participants with non-disabilities: ‘voice recognition’, ‘setting’ and ‘function’. Three keywords were assigned to ‘User Characteristics’ for the participants with disabilities: ‘pronunciation’, ‘people with disabilities’ and ‘user’. There were not keywords assigned to ‘User Characteristics’ for the participants with non-disabilities.

Based on the keywords, the semantic network was visualized (Figure 5.4 Figure 5.5). The degree of the size of the nodes in the semantic network represented frequency of the keywords. The degree of the size of the links in the semantic network represented the relationship between two keywords.

In addition, the four centralities such as degree centrality, betweenness centrality, closeness centrality, and eigenvector centrality were measured based on the keywords (Table 5.14, Table 5.15, Table 5.16 & Table 5.17). According to degree centrality, two keywords such as ‘voice recognition’ (0.16) and ‘use’ (0.1) were in the highest rank for the participants with disabilities, and ten keywords such as ‘alarm’ (0.189), ‘use’ (0.157), ‘setting’ (0.124), ‘disadvantage’ (0.124), ‘advantage’ (0.124), ‘phone’ (0.124), ‘weather’ (0.12), ‘voice recognition’ (0.111), ‘function’ (0.111) and ‘call’ (0.111) were in the highest rank for the participants with non-disabilities, showing a value over 0.1 (Table 5.14). According to betweenness centrality, two keywords such as ‘voice recognition’ (22.098) and ‘use’ (10.584) were in the highest rank for the participants with disabilities, and four keywords such as ‘work’ (21.381), ‘convenient’ (13.388), ‘alarm’ (12.56) and ‘voice recognition’ (10.516) were in the highest rank for the participants with non-disabilities, showing a value over 10.0 (Table 5.15). According to closeness

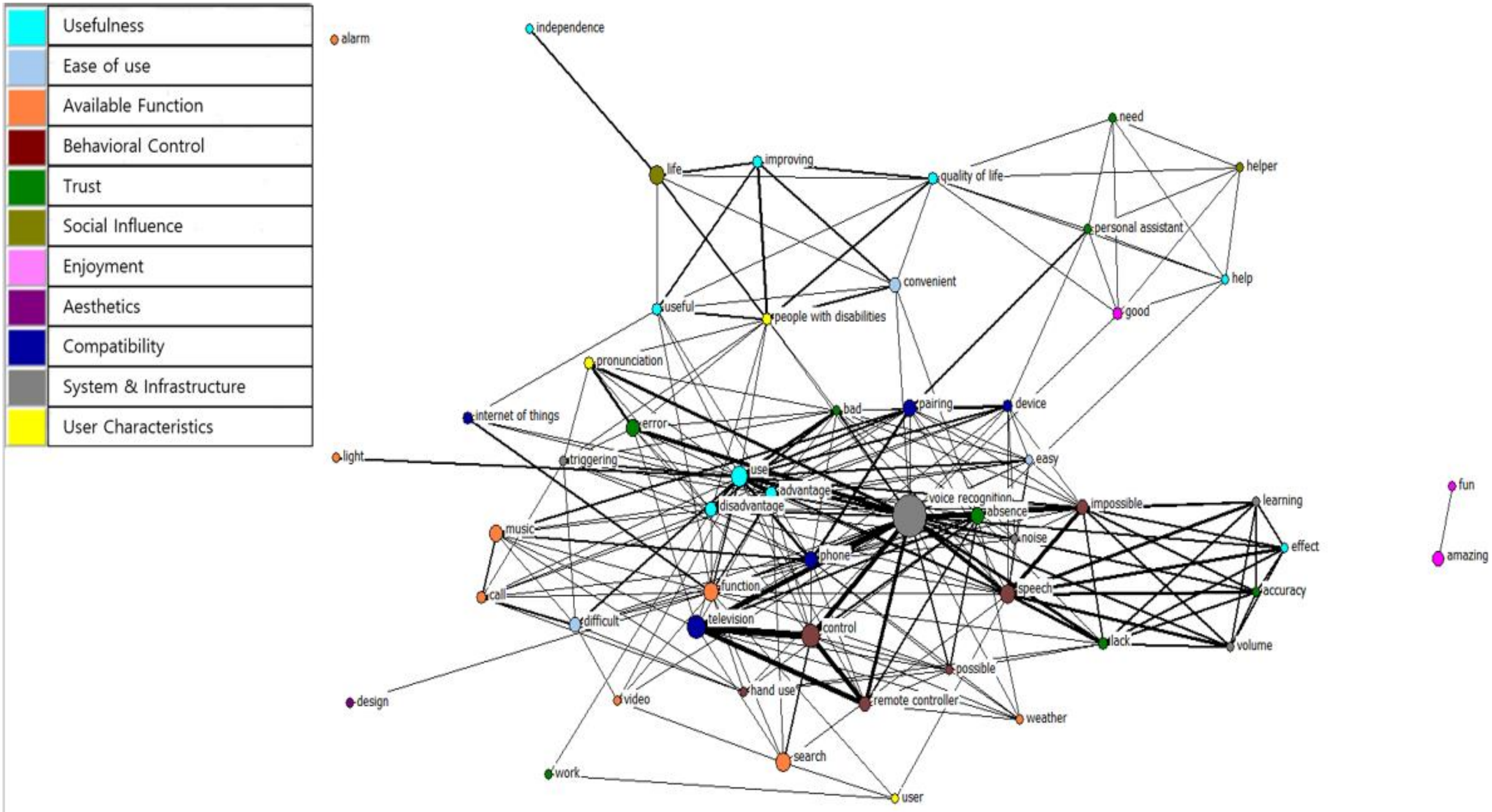


Figure 5.4. The semantic network based on the written interview data for the participants with disabilities by the categories

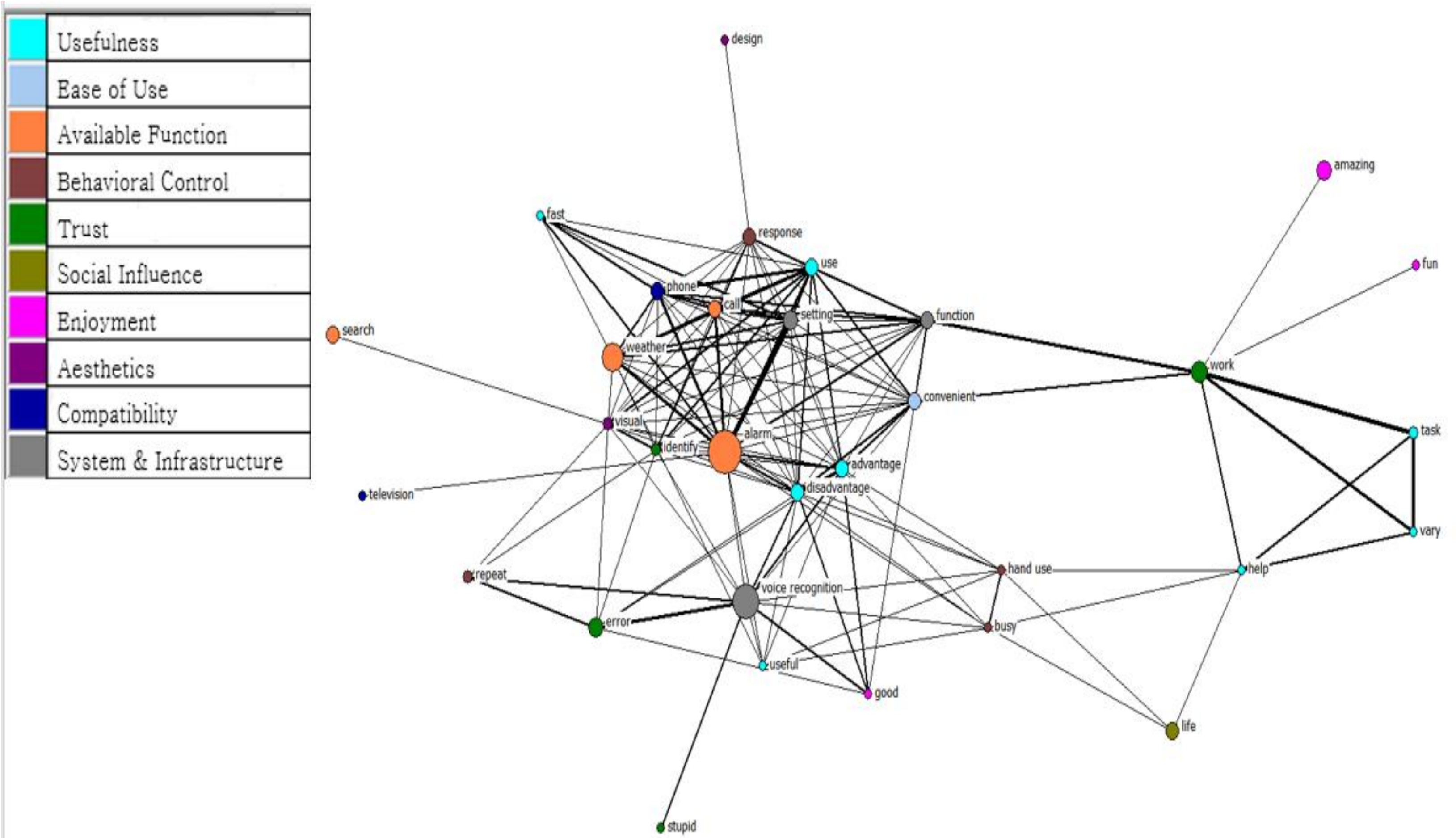


Figure 5.5. The semantic network based on the written interview data for the participants with non-disabilities by the categories

Table 5.14. The results of the analysis of degree centrality

Rank	Keyword from the participants with disabilities	Degree centrality	Keyword from the participants with non-disabilities	Degree centrality
1	voice recognition	0.16	alarm	0.189
2	use	0.1	use	0.157
3	speech	0.092	setting	0.124
4	control	0.066	disadvantage	0.124
5	television	0.066	advantage	0.124
6	impossible	0.06	phone	0.124
7	phone	0.058	weather	0.12
8	disadvantage	0.051	voice recognition	0.111
9	remote controller	0.049	function	0.111
10	advantage	0.049	call	0.111
11	function	0.047	convenient	0.097
12	lack	0.045	work	0.092
13	pairing	0.043	visual	0.083
14	absence	0.041	identify	0.083
15	people with disabilities	0.041	response	0.069
16	bad	0.041	task	0.069
17	effect	0.034	error	0.055
18	accuracy	0.034	vary	0.055
19	volume	0.034	help	0.046
20	learning	0.034	busy	0.041
21	error	0.032	fast	0.041
22	device	0.032	hand use	0.041
23	noise	0.028	good	0.037
24	music	0.026	useful	0.032
25	quality of life	0.026	repeat	0.028
26	improving	0.026	life	0.014
27	possible	0.026	stupid	0.009
28	easy	0.026	amazing	0.005
29	difficult	0.024	search	0.005
30	pronunciation	0.024	design	0.005
31	calling	0.024	fun	0.005
32	useful	0.024	television	0.005
33	triggering	0.024		
34	life	0.019		
35	convenient	0.019		

36	search	0.017		
37	personal assistant	0.017		
38	hand use	0.017		
39	weather	0.015		
40	good	0.013		
41	help	0.013		
42	internet of things	0.011		
43	video	0.011		
44	helper	0.011		
45	need	0.011		
46	user	0.009		
47	independence	0.004		
48	work	0.004		
49	light	0.004		
50	amazing	0.002		
51	design	0.002		
52	fun	0.002		
53	alarm	0		

centrality, one keyword such as ‘voice recognition’ (0.634) was in the highest rank for the participants with disabilities, and five keywords such as ‘alarm’ (0.646), ‘disadvantage’ (0.646), ‘advantage’ (0.646), ‘convenient’ (0.646) and ‘function’ (0.608) were in the highest rank for the participants with non-disabilities, showing a value over 0.6 (Table 5.16). According to eigenvector centrality, three keywords such as ‘voice recognition’ (0.482), ‘control’ (0.306) and ‘television’ (0.306) were in the highest rank for the participants with disabilities, and five keywords such as ‘alarm’ (0.415), ‘use’ (0.366), ‘setting’ (0.326), ‘phone’ (0.313) and ‘weather’ (0.302) were in the highest rank for the participants with non-disabilities, showing a value over 0.3 (Table 5.17).

5.4. Discussion

5.4.1. User Experience of Intelligent Personal Assistants

5.4.1.1. Discussion on the Statistical Analysis

The results of the reliability analysis showed that all the factors except SC

Table 5.15. The results of the analysis of betweenness centrality

Rank	Keyword from the participants with disabilities	Betweenness centrality	Keyword from the participants with non-disabilities	Betweenness centrality
1	voice recognition	22.098	work	21.381
2	use	10.584	convenient	13.388
3	function	8.925	alarm	12.56
4	people with disabilities	5.967	voice recognition	10.516
5	absence	5.285	visual	9.464
6	disadvantage	5.285	function	8.832
7	speech	4.45	response	6.452
8	useful	4.45	disadvantage	6.444
9	life	3.62	advantage	6.444
10	advantage	3.62	help	5.607
11	good	3.266	busy	5.605
12	quality of life	3.188	hand use	5.605
13	phone	3.164	identify	3.013
14	convenient	2.308	weather	1.366
15	pairing	2.239	setting	0.593
16	personal assistant	2.183	use	0.593
17	device	1.716	call	0.593
18	impossible	1.656	phone	0.593
19	help	1.266	error	0.344
20	lack	1.065	useful	0.266
21	television	0.892	good	0.127
22	bad	0.868	amazing	0
23	control	0.613	life	0
24	search	0.47	task	0
25	user	0.443	repeat	0
26	triggering	0.43	vary	0
27	possible	0.402	design	0
28	hand use	0.392	stupid	0
29	difficult	0.385	fast	0
30	music	0.383	fun	0
31	error	0.322	television	0
32	call	0.261	search	0
33	video	0.128		
34	remote	0.057		

	controller			
35	work	0.057		
36	amazing	0		
37	pronunciation	0		
38	internet of things	0		
39	improving	0		
40	weather	0		
41	independent	0		
42	design	0		
43	helper	0		
44	noise	0		
45	easy	0		
46	alarm	0		
47	effect	0		
48	fun	0		
49	light	0		
50	accuracy	0		
51	volume	0		
52	need	0		
53	learning	0		

were suitable, and the results of the validity analysis showed that all the factors except PEOU and SC were suitable for being used in the study at a significant level. All the items used in this study are based on previous studies in which they were already validated. PEOU was also validated in the previous study in this dissertation (section 3.3.1). However, it was shown that PEOU is unsuitable in the validity analysis, and SC is unsuitable in both the reliability analysis and the validity analysis. The factor, SC was proposed in this study based on the results of Study 2. There might be problems in selecting items for SC. There may be many reasons for the results of the reliability analysis and the validity analysis, but it is also possible to assume that the lack of samples of the data is the greatest (Gefen et al., 2000; Weston & Gore, 2006). Considering these, in this study, PEOU was used, and SC which showed the unacceptable result in both reliability analysis and validity analysis was excluded in descriptive analysis and Mann-Whitney U-test.

According to the descriptive analysis for UX of IPAs, the average scores of PEOU, SI, COM and use frequency of the participants with disabilities were higher than those of the participants with non-disabilities. However,

Table 5.16. The results of the analysis of closeness centrality

Rank	Keyword from the participants with disabilities	Closeness centrality	Keyword from the participants with non-disabilities	Closeness centrality
1	voice recognition	0.634	alarm	0.646
2	use	0.578	disadvantage	0.646
3	disadvantage	0.531	advantage	0.646
4	advantage	0.531	convenient	0.646
5	function	0.525	function	0.608
6	phone	0.52	visual	0.596
7	speech	0.51	identify	0.585
8	absence	0.51	voice recognition	0.574
9	bad	0.505	weather	0.564
10	people with disabilities	0.5	setting	0.554
11	pairing	0.495	response	0.554
12	impossible	0.491	use	0.554
13	device	0.491	call	0.554
14	useful	0.473	phone	0.554
15	television	0.468	busy	0.534
16	error	0.468	hand use	0.534
17	noise	0.468	work	0.492
18	easy	0.468	useful	0.484
19	triggering	0.468	good	0.463
20	control	0.464	error	0.449
21	lack	0.464	repeat	0.431
22	convenient	0.46	fast	0.425
23	possible	0.46	help	0.419
24	difficult	0.456	television	0.397
25	pronunciation	0.456	life	0.383
26	hand use	0.452	search	0.378
27	remote controller	0.448	stupid	0.369
28	good	0.448	design	0.36
29	video	0.441	task	0.356
30	music	0.437	vary	0.356
31	weather	0.433	amazing	0.333
32	call	0.43	fun	0.333
33	internet of things	0.43		
34	effect	0.426		
35	accuracy	0.426		

36	volume	0.426		
37	learning	0.426		
38	search	0.423		
39	quality of life	0.406		
40	user	0.403		
41	personal assistant	0.394		
42	help	0.391		
43	life	0.388		
44	improving	0.385		
45	light	0.377		
46	work	0.364		
47	design	0.354		
48	helper	0.349		
49	need	0.349		
50	independence	0.286		
51	amazing	0.203		
52	fun	0.203		
53	alarm	0.2		

Mann-Whitney U-test showed that there was a significant difference at the 95% confidential level between the user groups only in use frequency. The results of the analysis suggest that, with or without disabilities, many users were satisfied with the use of IPAs (Abdolrahmani et al., 2020), Meanwhile, the significant difference in use frequency can be interpreted that users with disabilities are using IPAs very actively and usefully than users with non-disabilities.

Although there was not a significant difference in UX of IPAs between the participants with disabilities and the participants with non-disabilities, it is needed to note the significant difference of use frequency between them. The reason for the difference may be inferred, by taking a close look at the factors showing a higher average score from the participants with disabilities. Although a significant difference was not statistically confirmed, the factors showing a higher average score from the participants with disabilities than those of the participants with non-disabilities are worth noting. It is true that most of the products are easy for people with non-disabilities to use (Bajcar et al., 2020). However, in the situation where people with disabilities face various obstacles in their everyday life and help from others are inevitable, IPAs can be considered one of the practical

Table 5.17. The results of the analysis of eigenvector centrality

Rank	Keyword from the participants with disabilities	Eigenvector centrality	Keyword from the participants with non-disabilities	Eigenvector centrality
1	voice recognition	0.482	alarm	0.415
2	control	0.306	use	0.366
3	television	0.306	setting	0.326
4	speech	0.285	phone	0.313
5	use	0.267	weather	0.302
6	remote controller	0.253	call	0.286
7	impossible	0.208	function	0.236
8	phone	0.171	disadvantage	0.221
9	lack	0.161	advantage	0.221
10	absence	0.153	convenient	0.193
11	error	0.143	identify	0.166
12	disadvantage	0.142	visual	0.16
13	advantage	0.137	response	0.152
14	effect	0.131	fast	0.124
15	accuracy	0.131	voice recognition	0.118
16	volume	0.131	work	0.063
17	learning	0.131	error	0.06
18	bad	0.13	useful	0.056
19	pairing	0.11	good	0.056
20	function	0.108	busy	0.046
21	noise	0.104	hand use	0.046
22	possible	0.097	repeat	0.028
23	device	0.095	task	0.021
24	pronunciation	0.092	television	0.017
25	easy	0.087	vary	0.016
26	triggering	0.067	help	0.013
27	weather	0.064	stupid	0.01
28	difficult	0.057	search	0.007
29	people with disabilities	0.055	design	0.006
30	search	0.054	life	0.004
31	music	0.052	amazing	0.003
32	call	0.042	fun	0.003
33	hand use	0.042		
34	video	0.035		
35	convenient	0.029		

36	useful	0.026		
37	internet of things	0.023		
38	good	0.019		
39	light	0.019		
40	user	0.016		
41	improving	0.013		
42	personal assistant	0.013		
43	quality of life	0.009		
44	life	0.007		
45	help	0.007		
46	work	0.006		
47	design	0.004		
48	helper	0.002		
49	need	0.002		
50	independence	0.001		
51	amazing	0		
52	alarm	0		
53	fun	0		

tools to use by people with disabilities and make them more convenient in their life. IPAs can play a role of the hub in the smart home (Aguirre-Munizaga et al., 2018; Pyae & Joelsson, 2018). If they work well with other devices, the use of them can allow people with disabilities to control their environment more easily. In other words, it can be said that IPAs can provide users with disabilities with more independence (Abdolrahmani et al., 2020, 2018; Pradhan et al., 2018). It is considered that pragmatic aspects are the major motivation encouraging people with disabilities adopting the technology (Cook, 2008). The significant difference in use frequency may be interpreted that pragmatic aspects of IPAs offer users with disabilities chance to control their surroundings more independently, which makes them use IPAs actively than users with non-disabilities.

Of course, the reasons for why there was not a significant difference in UX of IPAs between the participants with disabilities and the participants with non-disabilities should be further explored. It was reported that people with disabilities tend to relatively evaluate positively usability in subjective measures than people with non-disabilities (Bajcar et al., 2020). Considering the study, it is difficult to give a proper explanation on the fact that there was not a distinct difference in UX of IPAs between the user groups.

However, considering that the previous study was conducted for people who are not actual users, there is room for explanation. It may be possible to say that the experienced users with disabilities in this study made a more realistic assessment based on their experience in using IPAs. Actually, although not common, there is a case where clear differences were not identified in the usability evaluation with subjective measures focusing on accessibility between users with disabilities and users with non-disabilities (Alvarado-Alcantar et al., 2018).

5.4.1.2. Discussion on the Analysis on the Written Interview

More in-depth discussions on UX of IPAs are possible by analyzing the written interview data. The interview data containing contents related to UX issues were classified into the acceptance factors according to their contents with two dimensions such as positive and negative to identify meaningful insights from the participants. Semantic network analysis on the interview data was also conducted to draw user values and to compare them between the two user groups.

Similar to the results of the statistical analysis, it was found out that, regardless of disability, most of the participants considered that the use of IPAs is very useful and convenient. In addition, the participants said that it was amazing and fun to use IPAs. However, they consistently pointed out problems related to voice recognition such as the difficulty in getting the desired results and the low rate of recognition. These results were to be expected, by considering the results of Study 1 as well as the previous studies discussed in the literature review. Meanwhile, comparing the user groups, a difference was identified. It was that the participants with disabilities frequently raised the issues related to compatibility, and the issues related to unintuitive interface was also frequently addressed by the participants with non-disabilities.

Further discussions on the commonalities and the differences between the user groups are possible, when the semantic network analysis on the written interview data is considered and the answers to the questions for the written interview were closely looked into. Considering the keywords appeared at least twice in the data of each user group, it was possible to group them

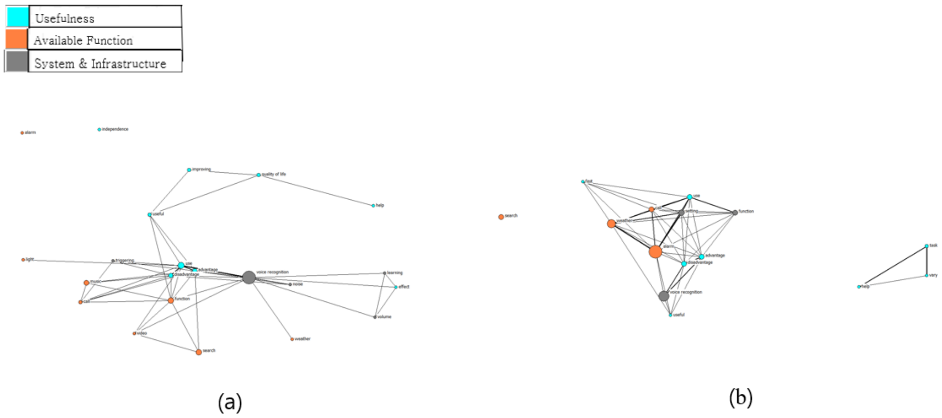


Figure 5.6. The semantic network focusing on three factors: 'Usefulness', 'Available Function' and 'System & Infrastructure': (a) is for the participants with disabilities and (b) is for the participants with non-disabilities

according to their meanings and attributes based on the proposed categories in Study 2, which implies the eleven categories can be considered factors for UX of IPAs.

According to the frequency of the keywords, regardless of the two user groups, the keyword 'voice recognition' which was related to 'System & Infrastructure' frequently appeared and was mentioned together with other keywords. In addition, considering the measured value of the four centralities, regardless of the two user groups, the keywords related to 'Usefulness', 'Available Function' and 'System & Infrastructure' were in common high rank, and those keywords were strongly linked with each other in the semantic network (Figure 5.6). This is considered to be interpreted that users with or without disabilities consider performance of the system important and the functions of IPAs useful, which support the results showing that there were not significant differences in UX of IPAs.

Meantime, it is also possible to say that although its importance is relatively less than other factors, it seems like that aspects related to 'Aesthetics' are also needed to be considered to provide better UX of IPAs for not only users with non-disabilities but also users with disabilities, considering comments of one participant with disabilities and participant with non-disabilities saying, in response to the question 9, *"Design of IPAs is a top priority for me."*. In many previous related to IPAs for users with disabilities, the features and functions of them were usually focused on and hedonic aspects have been ignored. However, it is known that aesthetic

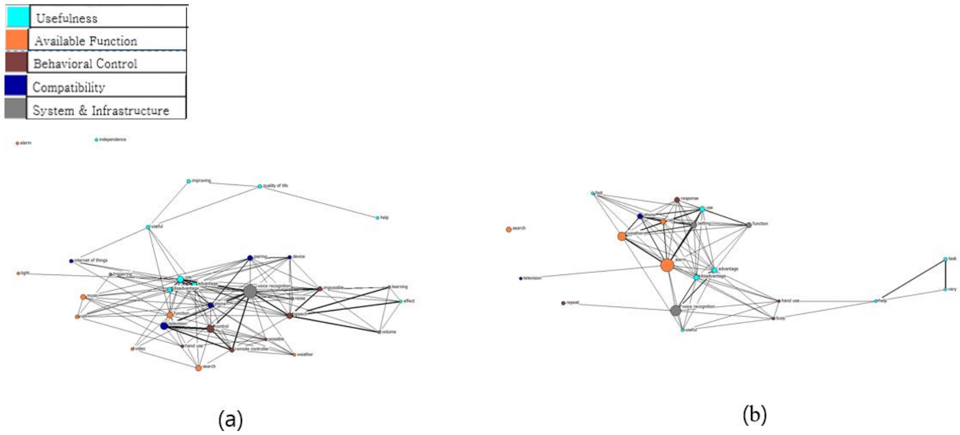


Figure 5.7. The semantic network focusing on five factors: ‘Usefulness’, ‘Available Function’, ‘Behavioral Control’, ‘Compatibility’ and ‘System & Infrastructure’: (a) is for the participants with disabilities and (b) is for the participants with non-disabilities

aspects should be also considered in the evaluation on UX of VUIs (Kocaballi et al., 2019), and it is also identified that aesthetics aspects of IPAs, especially, features related to the physical design are crucial for the satisfaction of users in Study 2. It can be said that the factor ‘Aesthetics’ should be considered regardless of disability of users. One regret thing is that the connection between ‘Enjoyment’ and ‘Aesthetics’ which was shown in Study 2 was not identified in the semantic network in this study. Small data in this study may be the reason of this, but this should be further explored.

However, there are clear differences in the semantic network between the user groups. many keywords related to ‘Compatibility’ and ‘Behavioral Control’ were relatively mentioned from the participants with disabilities than the participants with non-disabilities (Figure 5.7). In addition, it was found out that they were also strongly linked with each other and the keywords related to ‘Usefulness’, ‘Available Function’ and ‘System & Infrastructure’ for the participants with disabilities, while the strong connections were not identified for the participants with non-disabilities (Figure 5.7). Unlike VUIs which offer simple functions, IPAs can perform various tasks. However, integrating other systems and devices should be premised to be available for various functions of IPAs. If the original functions of IPAs are not fully available, of course their usefulness will be significantly reduced, which is very critical for all users of IPAs. Especially,

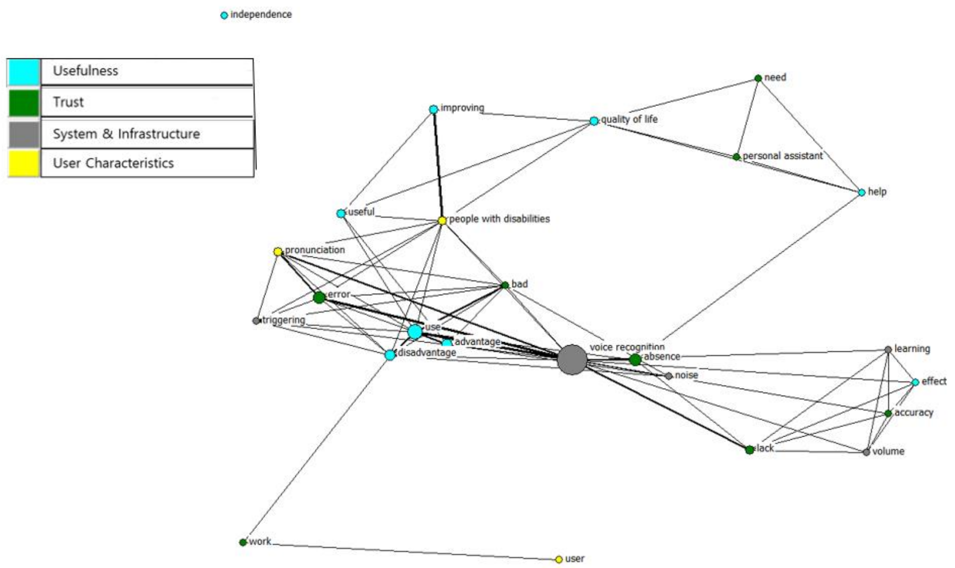


Figure 5.8. The semantic network focusing on four factors: 'Usefulness', 'Trust', 'System & Infrastructure' and 'User Characteristics' for the participants with disabilities

considering a mention which one participant with disabilities gave saying *"If the smart speaker works with my house, I might be able to sit and do everything with a word."*, it can be said that compatibility issues of IPAs to control other devices are crucial in UX of IPAs and the factor 'Compatibility' is important for users with disabilities than others.

In addition, there was one to note. Breaking down the keywords by the categories according to their attributes, it was found out that the keywords related to 'User Characteristics' frequently appeared in the interview data for the participants with disabilities, while, same with Study 2, they were not mentioned for the participants with non-disabilities. Meanwhile, the keywords were strongly linked with the keywords related to 'Usefulness', 'Trust' and 'System & Infrastructure' (Figure 5.8). This result may be interpreted that although IPAs are helpful to users with disabilities, the lack of consideration for specific user characteristics is one of the reasons that degrades UX of IPAs for users with disabilities. When the answers to the questions for the written interview were closely looked into, the needs of reflecting an individual's characteristics in the design of IPAs were also only mentioned by the participants with disabilities. For example, in response to the question 3, one participant with disabilities wrote *"It is not easy for* *people with disabilities who have poor pronunciation even to trigger IPAs because voice recognition does not work well.”*, and, in response to the question 7, one participant with disabilities answered *“The voice recognition accuracy is somewhat poor because the system cannot learn my voice, and it seems like that it is greatly influenced by the loudness of the voice.”*. It is considered that a common attribute of keywords which appeared in the interview data only for a user group, comparing with the others, can be regarded as an important value of the user group for the given subject (G.-W. Kim, 2016). Therefore, it can be inferred that it is important for users with disabilities to reflect individual’s characteristics in the interaction design of IPAs. Although the factor ‘User Characteristics’ is not considered in UX of IPAs for users with non-disabilities according to Study 2 and this study, it should be said the factor is important in UX of IPAs for users with disabilities. The reason why the factor was not regarded may be estimated to some extent because most of the subjects with non-disabilities were young. It is also true that most commercialized IPAs focus on the general population as end users, and not offer options reflecting in specific user characteristics. However, this should not be the reason to ignore the characteristics of an individual user.

5.4.2. Effects of the Use of Intelligent Personal Assistants on Quality of Life

5.4.2.1. Discussion on the Statistical Analysis

The results of the reliability analysis and the validity analysis showed that the data for quality of life was suitable for being used in the study. According to the descriptive analysis, the average score of quality of life of the participants with disabilities was higher than that of the participants with non-disabilities, and, considering the factors of quality of life, the average scores of ‘Safety’, ‘Effort’, ‘Tiredness’, ‘Independence’ and ‘Time Consuming’ of the participants with disabilities were higher than those of the participants with non-disabilities. However, same with the results of the statistical analysis for UX of IPAs, the result of the Mann-Whitney U-test showed that there was not a significant difference. This can be interpreted that, with or without disabilities, users considered the use of IPAs useful in their life.

However, it is still difficult to reach this conclusion and the reason of the no significant difference should be further explored. It was known for that although people with disabilities have many obstacles in their life, they tend to report positive quality of life in the subjective evaluation, which is called the disability paradox (Albrecht & Devlieger, 1999; Drum et al., 2008). Considering the studies, it is difficult to give a clear explanation on the fact that there was not a significant difference in the effects on quality of life by the use of IPAs between the participants with disabilities and the participants with non-disabilities. However, taking a close look at the factors showing a higher average score from the participants with disabilities, there are traces of the difference between the two user groups. It is able to find out something in common in the factors. They are related to pragmatic aspects. It is obvious that people with non-disabilities are easy to use a system and have a sense of control on it than people with disabilities (Bajcar et al., 2020). However, it may be possible to infer, from the commonality of the factors, that the use of IPAs provides users with disabilities with more opportunities to control their environments and increase their independence in everyday activities (Abdolrahmani et al., 2018; Pradhan et al., 2018).

5.4.2.2. Discussion on the Analysis on the Written Interview

It is able to identify evidences of the inference on the statistical analysis for effects of the use of IPAs on quality of life from the written interview data. As already mentioned, the participants with disabilities wrote various reasons why IPAs are useful. Many of the participants with disabilities said that controlling other devices by IPAs is useful and convenient, and only the participants with disabilities frequently mentioned that IPAs can make themselves more independent in their life. Usefulness of IPAs for users with disabilities in their daily life can be represented by the comment of one participant with disabilities saying *"The improvements are clearly required, but certainly more comfortable than when there is no the smart speaker."*.

The positive effects of the use of IPAs on daily life of the participants with disabilities can be confirmed in detail through the episodes they wrote, while only a few of the participants with non-disabilities provided simple episodes related to 'listening to music' and 'setting alarm'. In response to question 5, many participants with non-disabilities said that there was no special episode. Even a few of the participants with non-disabilities who wrote stories were limited to listening to music and setting alarms. Comparing with this, the participants with disabilities said some notable episodes. For example, one participant with disabilities wrote *“It's hard to use a cell phone when I lie down straight, but I could call someone by the smart speaker.”*, and another participant with disabilities answered *“I remember the day I was alone in the dark when the activity assistant left without turning on the light. The day when I used the smart speaker to turn on the light by myself at first is the most memorable.”*.

Most of the participants with disabilities evaluated the use of IPAs very positive. Even, one participant with disabilities *said “I think I rely less on my family than before.”*, and another participant with disabilities commented *“The IPA makes my daily life easier by being my hand.”*. This clear difference in the effects of the use of IPAs on quality of life between the participants with disabilities and the participants with non-disabilities may look like the disability paradox. However, it should be said that the episodes are realistic experience of the users with disabilities on the use of IPAs, considering the whole results in this study. The qualitative analysis on the opinions of people with disabilities is considered very meaningful in drawing their underlying thoughts (Burton et al., 2008; Jensen, 2014; H. N. Kim & Oumarou, 2020). It is enough to conclude that the use of IPAs is very positively affecting quality of life of users with disabilities.

Meanwhile, considering what was discussed in the section 5.4.1.2, it can be said that IPAs will be much more helpful to people with disabilities, if they provide more diverse functions and are more easily compatible with other devices.

5.4.3. Design Implications for User Experience of Intelligent Personal Assistants for Users with Disabilities

According to the seven principles of universal design (The Center for Universal Design, 1997) (section 2.2.2), it seems like that IPAs are good at ‘Equitable Use’, in that they can be used usefully and provide users with convenience in their daily life regardless of disability of users. However, there are also deficient points of IPAs. They are poor at ‘Flexibility in Use’ and ‘Tolerance for Error’, which sometime makes users difficult trust and control the systems. Especially for users with disabilities, it is likely that the limitations of IPAs related to ‘Flexibility in Use’ came seriously. In addition, although it was not pointed out by users with disabilities, issues related to ‘Perceptible Information’ are identified by users with non-disabilities such as the lack of visual feedback during the interaction, which is also related to ‘Simple and Intuitive Use’. According to ability-based design (Wobbrock et al., 2011, 2018) (section 2.2.2), these can be interpreted that IPAs are still insufficient in providing appropriate ways for the interaction to fulfill individual’s given abilities exactly.

The results of this study, especially the results of the written interview offer some important design implications for UX of IPA for not only users with disabilities but also all potential users. The results of the statistical analysis in this study show that, regardless of disability, most users are sharing the main UX of IPA and can benefit the use of IPA. It is expected that providing an improved design of IPA for users with disabilities will satisfy all potential users, not just them.

It seems like that enabling users to use various functions and improving the performance of voice recognition and making the environment where IPA work with other devices may be a top priority for all users. Especially, the issues of performance of voice recognition have been frequently pointed out in many previous studies, and they were also frequently identified in the studies in this research. Meanwhile, it was possible to infer that, from Study 2 and Study 3, compatibility of IPA is also often make users frustrated in using them. Especially, the issues related to compatibility of IPA were considered more important by users with disabilities. This is a natural result, considering that users with disabilities need various functions, which require high compatibility. It can be said that solving the two issues a top priority, but there are technical difficulties to reflect them in IPAs immediately. Therefore, based on the results of Study 1, Study 2 and Study 3, implications focusing on the interaction design of IPAs to improve UX for users with disabilities that can be considered realistically are presented. It is expected that the design implications are also helpful to users with non-disabilities. The three design implications for UX of IPAs are explained following.

First, providing various ways for settings considering the abilities of an individual user is necessary. This means to allow a user to customize settings of IPAs according to his/her abilities, which includes providing alternative options to change command-words and fixed settings for users. People with severe physical disabilities even have the difficulty in articulation several pronunciations. It can be also difficult for them to clearly distinguish similar pronunciations in speaking. This is often seen in children who have not yet developed an oral structure and in elderly people who suffer from dysfunction due to age (David A Balota & Duchek, 1988; Kowalski et al., 2019; Moore, 2017). The similar thing is also seen in dialect users and non-native speakers (Pyae & Scifleet, 2018). These problems can make it difficult for users to use certain commands required for the interaction with IPAs, and, in severe cases, prevent them from triggering IPAs. One of good ways to solve the issues is to allow users, if they need, to set up appropriate trigger words and commands for themselves. Meanwhile, similar to this, fixed settings such as the threshold for voice recognition may not be suitable for those who cannot speak loudly because of disability etc. For example, although there are individual differences, the sound pressure when people talk to each other is generally considered 60 to 70 decibel (Wickens et al., 2015). However, such a fixed setting focusing on general users can be negative and inappropriate for users who are not normally considered in using IPAs. Therefore, it is needed to provide the right options depending on the different abilities of users.

Second, guaranteeing transparency of the interaction is required. This means offering users clear information during the interaction which users need. In other words, it can be said that it is needed that letting users know how the interaction can happen and what is going on (Kirschthaler et al., 2020). Problems of discoverability in VUIs have been continuously pointed out and considered a fundamental challenge (Corbett & Weber, 2016; Kirschthaler et al., 2020). It was reported that users are confused about when they should speak and have difficulty perceiving what they can do in using VUIs (Luger & Sellen, 2016; Caroline Nowacki et al., 2020; Yankelovich, 1996), which can be an obstacle in the interaction with VUIs. The issues have not been fully resolved in IPAs, Sometimes, the problems of discoverability in VUIs are considered the nature of speech itself, but rather these are due to ignoring the social nature of conversations such as body language and facial expression. Similar to real-life conversations, providing proper and clear cues and visual feedbacks based on multi-modalities can play an important role in solving the problems of discoverability when using IPAs (J. Kim et al., 2020; J. Lee et al., 2019; Caroline Nowacki et al., 2020). Considering a recent study reporting that users may be relatively tolerant to the voice misrecognition than the failures understanding reasons of the work of VUIs (Goetsu & Sakai, 2020), letting users know what they can do and what is going on when using IPAs will be very helpful to enhance UX of IPAs than just improving performance of voice recognition.

Third, hedonic aspects should be also considered. In previous studies investigating UX of IPAs, hedonic aspects have been frequently not mentioned. Many of previous studies related to IPAs usually focused on the features and functions of them. Especially, previous studies investigating UX of IPAs for users with disabilities hedonic aspects have been ignored. However, it is known that aesthetic aspects should be also considered in the evaluation on UX of VUIs (Kocaballi et al., 2019), and it is also identified that aesthetics aspects of IPAs, especially, features related to the physical design are crucial for the satisfaction of users through the results of Study 2. In the written interview for not only users with non-disabilities but also users with disabilities, it was mentioned that the design of IPAs is an important factor when considering to buy IPAs and to recommend them to others. Of course, pragmatic aspects of assistive systems are a top priority for people with disabilities, but attention on hedonic aspects of technology for them has been increased (Bittner et al., 2016; Leikas, 2020; Zimmermann et al., 2005). It is reported that aesthetics quality of assistive devices should be considered in that it can affect UX of them (Bittner et al., 2016) and boost social acceptability by reducing stereotypes of people with disabilities (Close, 2001). Considering the fact that a user with disabilities is also one of the ordinary users, hedonic aspects should not be ignored. It can be said that reflecting better hedonic quality in the design of IPAs positively affects UX for not only users with non-disabilities but also users with disabilities.

5.5. Conclusion

In this study, UX of smart speakers which are a kind of embodied IPAs was investigated with the two aims. The first purpose is to investigate UX of IPAs for users with disabilities. The second purpose is to investigate how the use of IPAs affects quality of life of users with disabilities. In this study the comparison with users with non-disabilities was also conducted. The questionnaire survey and the written interview were conducted for users with disabilities and users with non-disabilities having used a smart speaker and the collected. The collected data were analyzed statistically and qualitatively.

The results of reliability analysis and validity analysis showed that some factors are unsuitable for being used in the study at a significant level. As a result, SC which showed the unacceptable result in both was excluded in the descriptive analysis and Mann-Whitney U-test. The results of descriptive analysis for UX of IPAs showed that the average scores of PEOU, SI, COM and use frequency of the participants with disabilities were higher than those of the participants with non-disabilities. The results of descriptive analysis for quality of life showed that the average score of the participants with disabilities was higher than that of the participants with non-disabilities, and, considering factors, the average scores of all the factors of the participants with disabilities, excluding 'Controllability' and 'Enjoyment', were higher than those of the participants with non-disabilities. However, the results of Mann-Whitney U-test showed that there was a significant difference at the 95% confidential level between the user groups only in use frequency.

Meanwhile, the results of the written interview showed several commonalities between the two user groups, but there were clear differences in UX of IPAs. The results of the written interview suggest that IPAs can be used usefully and provide users with convenience in their daily life regardless of disability of users. However, the results of the written interview showed that users with disabilities can have more benefits of the use of IPAs in daily life. In addition, there were differences in the factors and the relationships between them to be considered in UX of IPAs between the participants with disabilities and the participants with non-disabilities.

This study has some limitations. First, although this study was conducted based on the previous studies (Study 1 & Study 2), more validations are required in the used factors and items for the questionnaire, because some of the factors were not accepted in reliability analysis and validity analysis. Second, the number of participants in this study is small. Although the participants in this study could be viewed as active users, the number was small, so it was impossible to statistically investigate the relationship between the factors through regression analysis due to lack of data. This also seems to limit the generalization of the results of this study. In addition, this study only focused on smart speakers, which would be a hurdle in generalizing the results to all kinds of IPAs. Therefore, further exploration on the results of this study is needed.

Nevertheless, this study made a contribution in comprehending UX of IPAs for users with disabilities and how the use of IPAs affects their daily life, by comparing with users with non-disabilities. The results of this study showed that, regardless of disability, most users are sharing the main UX of IPA and can benefit the use of IPA. The results of this study also showed that the investigation on qualitative data is essential to the study for users with disabilities, offering various insights related to UX of IPAs from the angle of users. This study proved that the proposed factors for UX of IPAs are appropriate to be considered and there are clear differences in them between the participants with disabilities and the participants with non-disabilities. This study also discussed various design implications for UX of IPAs and provided three design implications which can be considered realistically to improve UX, focusing on the interaction design of IPAs. It is possible to expect that reflecting the implications in the design of IPA will be helpful to all potential users, not just users with disabilities.

Chapter 6 Discussion and Conclusion

6.1. Summary of this Research

The research in this dissertation started with an attempt to investigate UX of VUIs for users with disabilities from their perspective. In this research, focused on IPAs among the numerous VUIs for two reasons. One is because one of the most popular VUIs in recent years is IPAs, and the other is because IPAs are considered to be of great help to people with disabilities. In the research in this dissertation, the literature review and three main studies were conducted to achieve the goal.

Before the main studies, the literature review was provided to establish the backgrounds for this research and to found the research design. First, the definition of people with disabilities and the research methods which can be used to include them were described. Through this, the necessity of the research for people with disabilities and the methods which can be used to encourage them to take part in the study and to minimize their inconvenience were considered. Second, the conceptual frameworks on UX for VUIs and the design approaches for accessibility were summarized. This helped to identify the factors to be considered in studying UX of VUIs and the points of view that can be applied to this research. Finally, related previous studies were reviewed, in which the necessity of this research was also discussed. The literature review presented the necessity and direction of this research.

In Study 1, UX of VUIs for users with disabilities was investigated. The purpose of this study was to investigate UX of commercially available VUIs for users with disabilities, by examining acceptance. The differences between users with different types of disabilities and the reasons why they use or not use VUIs were focused on in this study. Users with physical disabilities and users with visual impairments who have used one or more VUIs were recruited. The questionnaire survey was conducted and comments on the use of VUIs were gathered from them. The collected data were analyzed statistically and qualitatively. The collected data were analyzed statistically and qualitatively. The results of the statistical analysis showed that there were significant differences at the 95% confidential level in UX of VUIs between the participants with different types of disabilities, presenting that the average scores of all the factors and use frequency of the participants with visual impairments were higher than those of the participants with physical disabilities. The results of the statistical analysis also showed the relationships between the acceptance factors in which the differences were identified between the user groups. It was possible to infer that users with visual impairments more positively value pragmatic aspects of VUIs than users with physical disabilities. Meanwhile, the results of the qualitative analysis showed that, although the use of VUIs has made the participants with disabilities more convenient in their life, they have many complaints related to PEOU, TR and PBC. Especially negative comments related to TR and PBC, were frequently mentioned by the participants with physical disabilities, and many negative comments related to PEOU were raised by the participants with visual impairments. Based on all the results in this study, the design implications such as providing the improved design in the aspect of ‘Flexibility in Use’ and ‘Tolerance for Error’ were suggested to enhance UX of VUIs for users with disabilities in the framework of universal design. This study proved that it is essential to study VUIs for users with disabilities thoroughly, showing the differences in UX between users with different types of disabilities. This study also provided insights related to UX of VUIs for users with disabilities. This study presented the basic direction of the study on UX of IPAs for users with disabilities.

In Study 2, UX of IPAs was investigated based on online reviews written by users. The purpose of this study was to investigate UX of IPAs through semantic network analysis, identifying what factors are important to UX of IPAs for users. Before investigating UX of IPAs for users with disabilities, important factors for UX of IPAs were proposed by investigating UX of IPAs for users with non-disabilities in this study. Online reviews on smart speakers from internet were crawled. After preprocessing and structuring the data, the semantic network was visualized with calculating the frequency of the keywords and measuring centrality of them. The results of the semantic network showed that the keyword ‘good’ was the most frequently mentioned and appeared together with other keywords, but also showed that the keywords with negative meanings frequently were referred together with the keywords related to working issues of IPAs. It was possible to infer, from the results, that most of the users satisfied with the use of IPAs, although they felt that the performance of them was not completely reliable. Meanwhile, this study proposed eleven important factors to be considered for UX of IPAs and among them, suggested ten factors to be considered in the design of IPAs to improve UX of IPAs and to satisfy users. The semantic network showed the relationships between the factors in which the fact that hedonic aspects are also important as well as pragmatic aspects were identified. This study became a foundation for Study 3 investigating UX of IPAs for users with disabilities.

In Study 3, UX of IPAs was investigated for users with disabilities. The results of Study 1 and Study 2 became a foundation for Study 3. The purpose of this study was to investigate UX of IPAs for users with disabilities and identify how the use of IPAs affects their daily life, by comparing with users with non-disabilities. Users with physical disabilities and users with non-disabilities who have used one or more IPAs were recruited. The questionnaire survey and the written interview were conducted for them. The collected data were analyzed statistically and qualitatively. The results of the statistical analysis showed that, among the factors and use frequency, there was a significant difference at the 95% confidential level between the participants with disabilities and the participants with non-disabilities only in use frequency. The results of the statistical analysis also showed that there was not a significant difference between the two user groups in the effects of the use of IPA on quality of life. These results might be interpreted that, regardless of disability, most users are sharing the main UX of IPA and can benefit the use of IPA. Meanwhile, the results of the written interview showed several commonalities between the two user groups, but there were clear differences in UX of IPAs. Although most of the participants regardless of disability answered that the use of IPAs is useful and convenient in their daily life, comparing with the participants with non-disabilities, many of the participants with disabilities said various reasons for it with detail episodes. The results of the written interview showed that users with disabilities can have more benefits of the use of IPAs in daily life. The semantic network based on the written interview suggested that ‘Compatibility’ was considered more important by the participants with disabilities and ‘User Characteristics’ should be also regarded as a factor for UX of IPA for them. The results implied that there are differences in the factors and the relationships between them to be considered in UX of IPAs between users with disabilities and users with non-disabilities. It could be said that the use of IPAs is very positively affecting quality of life of users with disabilities, and considering all the results, it could be possible to conclude that IPAs would be much more helpful to people with disabilities, if they provide more diverse functions and are more easily compatible with other devices, with reflecting abilities of a user in the interaction. According to the framework of universal design, the results of this study could be interpreted that the design of IPAs should be improved in the aspect of ‘Flexibility in Use’, ‘Tolerance for Error’, ‘Perceptible Information’ and ‘Simple and Intuitive Use’ to guarantee advanced accessibility not only for users with disabilities but also for all potential users. This study suggested that the eleven factors should be considered in UX of IPA. This study also discussed various design implications and proposed three design implications which can be considered realistically to improve UX, focusing on the interaction design of IPAs.

The research in this dissertation tried to evaluate accessibility of IPAs based on the principles of universal design, and to draw various issues related to UX of IPAs based on the acceptance factors. In addition, the research proposed the factors to be considered in UX of IPAs and validated them. Each study in this research provided design implications. Study 1 discussed design implications for UX of VUIs for users with disabilities. Study 2 suggested design implications for UX of IPAs, focusing on users with non-disabilities. Study 3 discussed various design implications for UX of IPAs and proposed three specific implications focusing on the interaction design of IPAs for all potential users. The design implications offered in each study are similar, but there are some differences. Table 6.1 summarizes them. It is possible to expect that reflecting the implications in the interaction design of IPA will be helpful to all potential users, not just users with disabilities.

6.2. Contributions of this Research

The research in this dissertation makes contributions in comprehending UX of IPAs for users with disabilities. There are three major contributions of

Table 6.1. Summary of the design implications for user experience of intelligent personal assistances suggested in this research

Study	Design implication
Study 1	- Making a system accurately recognize the commands and provide appropriate results is needed. - Users should be able to customize options, if they need. - Offer various functions integrating with other devices is required.
Study 2	- Users should be able to use the various functions. In particular, it is necessary to spread functions related to smart home. - Improving not only the performance of voice recognition but also compatibility is an urgent priority. - Aesthetics aspects, especially, features related to the physical design are crucial for the satisfaction of the users.
Study 3	- Users should be able to use various functions. - Improving the performance of voice recognition and making the environment where IPA work with other devices is a top priority - Providing various ways for settings considering abilities of an individual user is necessary. - Guaranteeing transparency of the interaction is required. - Hedonic aspects should be also considered.

this research.

First contribution of this research is that UX of IPAs was investigated in detail and how IPAs were used in their daily life was examined from the perspective of real users with disabilities. Many previous studies referred to that IPAs would be useful for people with disabilities, but only a few of researchers conducted the empirical study related to IPAs for people with disabilities. Even such studies mostly just described how they had used and felt IPAs. To overcome these limitations, in this research, data for users with disabilities was collected, analyzed and discussed based on specific criteria. In addition, the comparisons between users with disabilities and users with non-disabilities were also conducted to understand the characteristics of users with disabilities. One of the contributions of this research is that UX of IPAs and the effects of the use of IPAs on quality of life were investigated for users with disabilities from the angle of them. This research presents that an example for conducting the study on UX including users with disabilities. The results of this research can be a foundation to improve accessibility and UX of IPAs for users with disabilities.

Second contribution of this research is that important factors which should be considered in UX of IPAs were identified. Through the literature review, nine important factors for UX of VUIs were summarized. Through the research, eleven factors for UX of IPAs such as ‘Usefulness’, ‘Ease of Use’, ‘Available Function’, ‘Behavioral Control’, ‘Trust’, ‘Social Influence’, ‘Enjoyment’, ‘Aesthetics’, ‘Compatibility’, ‘System & Infrastructure’ and ‘User Characteristics’ were proposed. It was identified that, among them, the ten factors except ‘User Characteristics’ could be consistently derived from the data for users with non-disabilities. Meanwhile, when considering users with various backgrounds including disabilities, all the proposed factors were regarded appropriate. Previous studies related to IPAs mainly focused on features and functions of them. As a result, there was a lack of in-depth discussion on UX of IPAs and factors for it. To overcome these limitations, important factors for UX of IPAs were drawn and validated in this research. One of the contributions of this research is that the factors to be considered in UX of IPAs were identified and some relationships between them were explored. These factors can serve as a basic reference point for studying UX of IPAs in the future.

Third contribution of this research is that the design implications for UX of IPAs were suggested for not only users with disabilities but also all potential users. In each study of the research in this dissertation, design implications were proposed. Study 1 discussed the design implications for UX of VUIs for users with disabilities. Study 2 suggested the design implications for UX of IPAs, focusing on users with non-disabilities. Study 3 proposed the three specific design implications focusing on the interaction design of IPAs for all potential users. In this research, data for UX of IPAs were collected, analyzed and discussed based on specific criteria. The effects of the use of IPAs on quality of life were also investigated in detail. Considering not only all the results of the studies but also conceptual frameworks on design for accessibility, various design implications were discussed, and important design implications for UX of IPAs were proposed for users with disabilities. Especially, the three design implications proposed in Study 3 were realistically considerable for users with various backgrounds in the interaction design of IPAs. One of the contributions of this research is that the important design implications to improve UX of IPAs were proposed, considering not only users with disabilities but also all potential users. It can be expected that reflecting the implications in the design of IPAs will be helpful to all potential users, not just users with disabilities.

6.3. Limitations of this Research and Future Studies

Although there are several contributions, the research in this dissertation entails some limitations. There are two major limitations in this research. Therefore, further studies are needed to complement them.

First, studies considering users with various types of disabilities and other kinds of IPAs are needed. Although Study 1 investigated UX of VUIs in the consideration in differences of different types of disabilities of users, there was the limitation that only users with physical disabilities and users with visual impairments participated in the study. In Study 3, only users with physical disabilities participated in the study. Thus, it cannot be said that users with all types of disabilities were considered in this research. In addition, this study focused on smart speakers which are a kind of embodied IPAs among various kinds of IPAs. The research in this dissertation provided the design implications to improve UX of IPAs for all potential users. However, those limitations would be a hurdle in generalizing the results to all potential users and in applying the proposed design implications to all kinds of IPAs. Therefore, it is necessary to conduct more studies investigating UX of IPAs, considering users with various types of disabilities and other kinds of IPAs to generalizes the results in this research.

Second, studies with experiments focusing on characteristics of users in the interaction with IPAs are needed. Although the research in this dissertation covered UX of IPAs broadly and concretely and suggested the design implications for it, many relied on the data with the subjective evaluations of the participants. In addition, all of the procedures in this research were conducted remotely, considering the participants with disabilities. As a result, in this research, there was a lack of conducting analyses based on objective measures such as effectiveness and efficiency, which led difficult to providing precise design guidelines for UX of IPAs in the interaction aspect. In other words, the research in this dissertation lacks empirical evaluations and cannot develop detailed design models including specific measures for guidelines in improving quality of the interaction with

IPAs for users with disabilities in terms of usability. UX includes usability, and an experiment with the objective measures is inevitable to evaluate usability. It is true that it is difficult to conduct an experiment with people with severe disabilities. However, in order to suggest specific design implications for the usability of IPAs, it is also required to identify characteristics of users with disabilities based on the objective measures during the interaction with IPAs. It would be possible to provide more precious design guidelines for the interaction with IPAs for users with disabilities, if experiments focusing on their specific characteristics in the interaction are accompanied, which leads to improving UX of IPAs.

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Appendix

Appendix A. The questionnaire used in Study 1 (ver. Korean)

음성 인터페이스들에 대한 장애인 사용자들의 수용도 조사

* 필수항목

1 인적사항

1. 1.1. 귀하의 성별은 어떻게 되시나요? *

   한 개의 타원형만 표시합니다.

   - 남
   - 여

2. 1.2. 귀하의 (만) 연령은 어떻게 되시나요? *

   ____

3. 1.3. 귀하의 장애 유형은 어떻게 되시나요? *

   한 개의 타원형만 표시합니다.

   - 지체장애 (뇌병변 포함)
   - 시각장애
   - 기타: ____________________

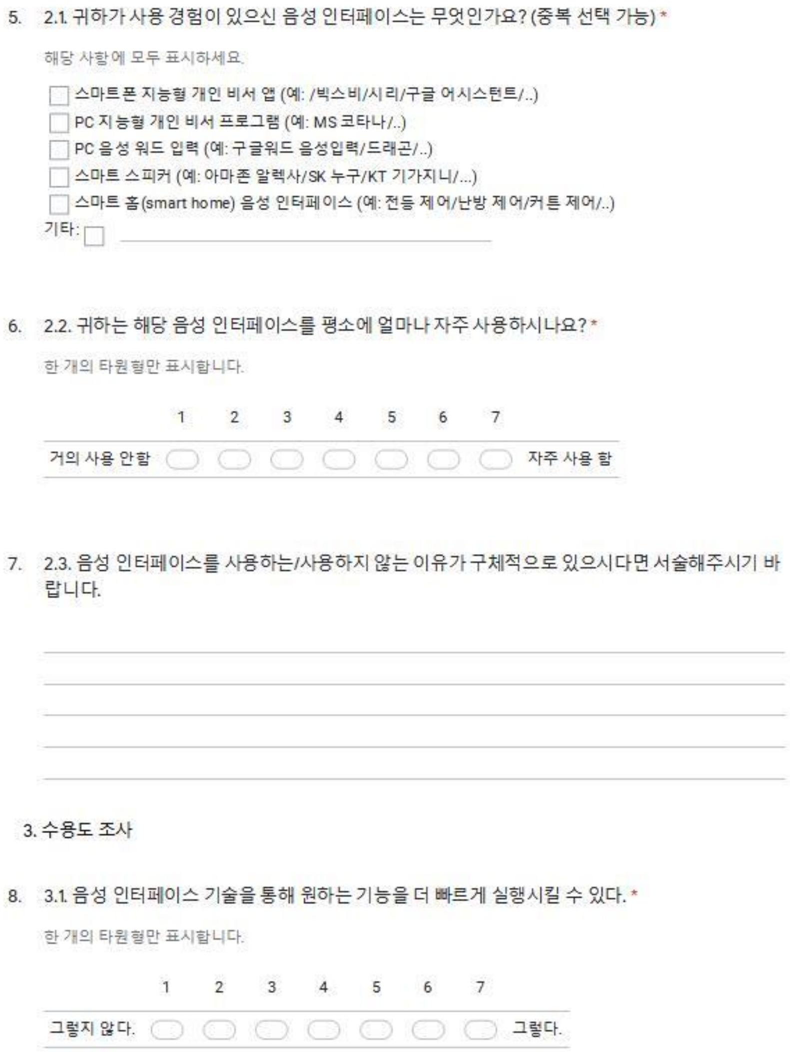
4. 1.4. 귀하의 장애등급은 어떻게 되시나요? *

   한 개의 타원형만 표시합니다.

   - 1 급
   - 2 급
   - 3 급
   - 4 급
   - 5 급
   - 6 급

2 사전 경험 조사

Figure A. The questionnaire for user experience of voice user interfaces for users with disabilities in Korean



5. 2.1. 귀하가 사용 경험이 있으신 음성 인터페이스는 무엇인가요? (중복 선택 가능) *

해당 사항에 모두 표시하세요.

- [ ] 스마트폰 지능형 개인 비서 앱 (예: /빅스비/시리/구글 어시스턴트/..)
- [ ] PC 지능형 개인 비서 프로그램 (예: MS 코타나/..)
- [ ] PC 음성 워드 입력 (예: 구글워드 음성입력/드래곤/..)
- [ ] 스마트 스피커 (예: 아마존 알렉사/SK 누구/KT 기가지니/...)
- [ ] 스마트 홈(smart home) 음성 인터페이스 (예: 전등 제어/난방 제어/커튼 제어/..)

기타: [ ] ______

6. 2.2. 귀하는 해당 음성 인터페이스를 평소에 얼마나 자주 사용하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
거의 사용 안함	◯	◯	◯	◯	◯	◯	◯	자주 사용 함

7. 2.3. 음성 인터페이스를 사용하는/사용하지 않는 이유가 구체적으로 있으시다면 서술해주시기 바랍니다.

______

3. 수용도 조사

8. 3.1. 음성 인터페이스 기술을 통해 원하는 기능을 더 빠르게 실행시킬 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	◯	◯	◯	◯	◯	◯	◯	그렇다.

Figure A. (Continued)

9. 3.2. 음성 인터페이스 기술을 통해 원하는 기능을 더 쉽게 실행할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	○	○	○	○	○	○	○	그렇다.

10. 3.3. 음성 인터페이스 기술을 통해 내 삶의 질이 개선되었다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	○	○	○	○	○	○	○	그렇다.

11. 3.4. 음성 인터페이스를 사용하는 것은 나에게 도움을 준다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	○	○	○	○	○	○	○	그렇다.

12. 3.5. 음성 인터페이스 사용법은 쉽게 배울 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	○	○	○	○	○	○	○	그렇다.

13. 3.6. 음성 인터페이스를 통한 기기와의 상호작용이 명확하고 믿을만하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	○	○	○	○	○	○	○	그렇다.

Figure A. (Continued)

14. 3.7. 음성 인터페이스를 사용하는 것은 쉽다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	⬭	⬭	⬭	⬭	⬭	⬭	⬭	그렇다.

15. 3.8. 음성 인터페이스의 성능은 믿을만하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	⬭	⬭	⬭	⬭	⬭	⬭	⬭	그렇다.

16. 3.9. 음성 인터페이스를 사용해 신뢰할만한 결과를 얻을 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	⬭	⬭	⬭	⬭	⬭	⬭	⬭	그렇다.

17. 3.10. 음성 인터페이스는 사용자를 위해 계속해서 보완, 발전되고 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	⬭	⬭	⬭	⬭	⬭	⬭	⬭	그렇다.

18. 3.11. 나는 지인들에게 음성 인터페이스의 사용을 추천할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	⬭	⬭	⬭	⬭	⬭	⬭	⬭	그렇다.

Figure A. (Continued)

19. 3.12. 내 지인들은 음성 인터페이스의 사용을 통해 도움을 얻을 수 있을 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.								그렇다.

20. 3.13. 내 지인들은 음성 인터페이스를 사용하는 것이 좋은 아이디어라고 생각할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.								그렇다.

21. 3.14. 음성 인터페이스를 사용하면서 재미를 느낀다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.								그렇다.

22. 3.15. 음성 인터페이스를 사용하는 것은 즐거운 일이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.								그렇다.

23. 3.16. 내 의지대로 음성 인터페이스를 실행시킬 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.								그렇다.

Figure A. (Continued)

24. 3.17. 나는 음성 인터페이스를 사용할 자산과 지식, 능력이 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	◯	◯	◯	◯	◯	◯	◯	그렇다.

25. 3.18. 나는 숙련된 음성 인터페이스 사용자이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	◯	◯	◯	◯	◯	◯	◯	그렇다.

26. 3.19. 음성 인터페이스를 사용할 기회가 생긴다면 음성 인터페이스를 사용할 생각이 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	◯	◯	◯	◯	◯	◯	◯	그렇다.

27. 3.20. 나는 머지않은 미래에 음성 인터페이스를 사용해보고 싶 다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	◯	◯	◯	◯	◯	◯	◯	그렇다.

28. 3.21. 나는 음성 인터페이스를 자주 사용할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	◯	◯	◯	◯	◯	◯	◯	그렇다.

Figure A. (Continued)

29. 3.22. 나는 음성 인터페이스를 계속해서 사용할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
그렇지 않다.	◯	◯	◯	◯	◯	◯	◯	그렇다.

4. 의견 조사

30. 4.1. 음성 인터페이스에 대한 기타 의견 등이 있으시다면 자유롭게 서술해주시기 바랍니다.

Figure A. (Continued)

Appendix B. The keywords in top 50 frequency used in Study 2

Table B. The keywords in top 50 frequency from online reviews of smart speakers (ver. Korean & English)

Rank	Keyword (Korean)	Keyword (English)	Frequency
1	좋다	good	325
2	음악	music	204
3	음성인식	voice recognition	183
4	소리	sound	163
5	아이	child	148
6	조명	light	141
7	사용	use	123
8	기능	function	101
9	편한	convenient	83
10	연결	connection	78
11	만족	satisfy	77
12	좋아하다	like	72
13	디자인	design	71
14	텔레비전	television	63
15	연동	pairing	62
16	부족하다	lack	57
17	원하다	want	55
18	업데이트	update	54
19	날씨	weather	51
20	다양하다	vary	49
21	스피커	speaker	47
22	음성 인터페이스	voice user interface	47
23	라디오	radio	47
24	오류	error	45
25	알람	alarm	44
26	예쁘다	pretty	41
27	뉴스	news	40
28	화면	display	39
29	재미	fun	38
30	영어	English	37
31	불가능	impossible	37

32	나쁘다	bad	33
33	신기한	amazing	33
34	유용한	useful	33
35	필요하다	need	33
36	와이파이	wi-fi	30
37	제어하다	control	30
38	인공지능	artificial intelligent	30
39	공부	study	28
40	이해	understanding	27
41	휴대폰	phone	26
42	선물	present	25
43	아쉽다	sorry	25
44	오디오북	audiobook	25
45	구매	purchase	24
46	반응하다	response	24
47	쉽다	easy	24
48	부재	absence	23
49	사이즈	size	23
50	적당한	appropriate	23

Appendix C. The questionnaire for users with disabilities used in Study 3 (ver. Korean)

지능형 개인 비서 사용에 대한 장애인 사용자들의 사용자경험 조사

* 필수항목

1. 인적 사항

1. 1.1. 귀하의 성별은 어떻게 되시나요? *

   한 개의 타원형만 표시합니다.

   - ◯ 남
   - ◯ 여

2. 1.2. 귀하의 (만) 연령은 어떻게 되시나요? *

   ____

3. 1.3. 귀하의 장애 유형은 어떻게 되시나요? *

   한 개의 타원형만 표시합니다.

   - ◯ 지체장애 (뇌병변, 척수장애 등 포함)
   - ◯ 시각장애
   - ◯ 청각장애
   - ◯ 발달장애
   - ◯ 기타: ______________________

4. 1.4. 귀하의 장애 정도는 어떻게 되시나요? *

   한 개의 타원형만 표시합니다.

   - ◯ 1급
   - ◯ 2급
   - ◯ 3급
   - ◯ 4급
   - ◯ 5급
   - ◯ 6급

Figure C. The questionnaire for user experience of intelligent personal assistants and effects on quality of life for users with disabilities in Korean

2. 사전 경험 조사

5. 2.1. 귀하가 사용하고 계신 스마트 스피커는 무엇 이신가요? *

해당 사항에 모두 표시하세요.

- ☐ 기가지니
- ☐ 누구
- ☐ 카카오미니
- ☐ 클로버
- ☐ 구글홈
- ☐ 알렉사
- 기타: ☐ ________________

6. 2.2. 귀하가 스마트 스피커를 사용하신 기간은 어느 정도이신가요? *

한 개의 타원형만 표시합니다.

- ◯ 0~3개월
- ◯ 4~6개월
- ◯ 7~9개월
- ◯ 10개월~1년
- ◯ 1년이상

7. 2.3. 귀하는 스마트 스피커를 어디에 두고 사용하고 계신가요? *

해당 사항에 모두 표시하세요.

- ☐ 개인 방
- ☐ 거실
- ☐ 부엌
- 기타: ☐ ________________

8. 2.4. 귀하는 평소 얼마나 자주 스마트 스피커를 사용하고 계신가요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
거의 사용하지 않는다	◯	◯	◯	◯	◯	◯	◯	매우 자주 사용한다

Figure C. (Continued)

9. 2.5. 귀하가 주로 사용하고 계신 스마트 스피커의 기능은 무엇이신가요? *

해당 사항에 모두 표시하세요.

- ☐ 음악 듣기
- ☐ 오디오북 듣기
- ☐ 뉴스 듣기
- ☐ 날씨 확인 (미세먼지 포함)
- ☐ 각종 정보를 얻기 위해 질문하기
- ☐ 게임
- ☐ 시간/알람 세팅
- ☐ 물건 주문 (쇼핑)
- ☐ TV 컨트롤
- ☐ 사물인터넷 기기 컨트롤 (스마트홈, 전등 등 포함)
- ☐ 전화 및 문자하기
- ☐ 잡담하기

기타: ☐ ______________________

3. 수용도 및 만족도 조사

10. 3.1. 나는 스마트 스피커를 사용하여 원하는 기능을 보다 빠르게 실행할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

11. 3.2. 나는 스마트 스피커를 사용하여 원하는 기능을 보다 쉽게 수행할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

12. 3.3. 스마트 스피커를 사용하는 것은 나에게 도움이 된다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure C. (Continued)

13. 3.4. 스마트 스피커의 사용법을 배우는 것은 나에게 쉬었다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

14. 3.5. 스마트 스피커와의 상호 작용은 명확하고 이해 가능하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

15. 3.6. 스마트 스피커를 사용하는 것은 쉽다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

16. 3.7. 스마트 스피커의 성능은 믿을 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

17. 3.8. 나는 스마트 스피커를 사용하여 신뢰할 수 있는 결과를 얻을 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure C. (Continued)

18. 3.9. 스마트 스피커는 사용자를 위해 계속 보완 및 개발되고 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

19. 3.10. 나는 다른 사람들에게 스마트 스피커를 사용하는 것을 추천할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

20. 3.11. 내 지인들은 스마트 스피커 사용을 통해 도움을 얻을 수 있을 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

21. 3.12 내 지인들은 스마트 스피커를 사용하는 것이 좋은 아이디어라고 생각할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

22. 3.13. 나는 스마트 스피커를 사용하는 것이 재밌다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure C. (Continued)

23. 3.14. 스마트 스피커를 사용하는 것은 즐겁다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

24. 3.15. 나는 내 의도대로 스마트 스피커를 사용할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

25. 3.16. 나는 스마트 스피커를 사용할 자산과 지식, 능력이 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

26. 3.17. 나는 능숙하게 스마트 스피커를 사용할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

27. 3.18. 스마트 스피커의 사용자 인터페이스(예: 색상, 조작부, 음성 등)는 매력적이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

Figure C. (Continued)

28. 3.19. 스마트 스피커의 전체적인 모양과 느낌은 매력적이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

29. 3.20. 스마트 스피커는 전반적으로 매력적으로 보인다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

30. 3.21. 스마트 스피커는 기존의 다른 기기들(예: TV, 스마트 폰 등)과 잘 호환된다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

31. 3.22. 스마트 스피커를 사용하는 것은 내가 작업을 하는데 있어 모든 측면과 잘 어울린다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

32. 3.23. 스마트 스피커를 사용하는 것은 내 라이프 스타일에 적합하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

Figure C. (Continued)

33. 3.24. 스마트 스피커는 사용가능한 다양한 기능들을 제공한다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

34. 3.25. 스마트 스피커의 성능(예: 음성인식, 인공지능 등)은 내가 스마트 스피커에서 제공하는 기능들을 사용하기에 충분하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

35. 3.26. 스마트 스피커의 업데이트 등을 비롯한 인프라 서비스는 내가 스마트 스피커에서 제공하는 기능들을 사용하기에 충분하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

36. 3.27. 나는 기회가 된다면 스마트 스피커를 사용하려고 한다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

37. 3.28. 나는 스마트 스피커를 자주 사용한다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure C. (Continued)

38. 3.29. 나는 앞으로도 계속해서 스마트 스피커를 사용할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

39. 3.30. 나는 스마트 스피커를 사용하는데 있어 전반적으로 만족하고 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

4. 삶의 질 개선도 조사

40. 4.1. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 안전해졌다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

41. 4.2. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 독립적인 활동이 가능해졌다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure C. (Continued)

42. 4.3. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 즐거워졌다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

43. 4.4. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 수고스러움이 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

44. 4.5. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 피곤함이 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

45. 4.6. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 타인에 대한 의존도가 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure C. (Continued)

46. 4.7. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 시간 소모가 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

5. 사용자 경험 조사

해당 섹션은 인터뷰로 총 9개의 질문으로 이루어져 있습니다. 인터뷰가 서면으로 진행되는 만큼 가능한 자세히 질문에 대한 응답을 작성해주면 감사하겠습니다.

47. 5.1. 스마트 스피커에 대해 처음 알게 되었을 때 귀하는 어떠한 느낌 또는 생각이 드셨나요? *

48. 5.2. 스마트 스피커를 사용하면서 귀하는 무엇 또는 어떠한 생각이 드셨나요? *

49. 5.3. 현재 사용하고 계신 스마트 스피커의 장점 및 단점은 무엇이라고 생각하시나요? *

Figure C. (Continued)

50. 5.4. 귀하에게 있어 스마트 스피커의 중요한 역할 및 의미는 무엇이라고 생각하시나요? *

51. 5.5. 귀하에게 있어 스마트 스피커와 관련해 기억에 남는 일화(에피소드)는 무엇이신가요? *

52. 5.6. 귀하가 스마트 스피커 사용 시 자주 이용하는 기능은 무엇이신가요? 그러한 기능을 주로 사용하시는 이유는 무엇이신가요? *

53. 5.7. 귀하는 스마트 스피커 사용 시 어려움 또는 문제를 겪으신적이 있으신가요? 만약 겪으신적이 있으시다면 무엇이며, 어떻게 해결하려 하셨나요? *

54. 5.8. 귀하에게 있어 스마트 스피커의 이상적인 유형 및 기능은 무엇이라고 생각하시나요? *

Figure C. (Continued)

55. 5.9. 귀하가 스마트 스피커를 지인에게 추천 및 선물로 준다면 무엇을 고려할 생각이십니까? *

Figure C. (Continued)

Appendix D. The questionnaire for users with non-disabilities used in Study 3 (ver. Korean)

지능형 개인 비서 사용에 대한 비장애인 사용자들의 사용자경험 조사

* 필수항목

1. 인적 사항

1. 1.1. 귀하의 성별은 어떻게 되시나요? *

한 개의 타원형만 표시합니다.

- ( ) 남
- ( ) 여

2. 1.2. 귀하의 (만) 연령은 어떻게 되시나요? *

____

2. 사전 경험 조사

3. 2.1. 귀하가 사용하고 계신 스마트 스피커는 무엇 이신가요? *

해당 사항에 모두 표시하세요.

- [ ] 기가지니
- [ ] 누구
- [ ] 카카오미니
- [ ] 클로버
- [ ] 구글홈
- [ ] 알렉사
- 기타: [ ] ____________________

4. 2.2. 귀하가 스마트 스피커를 사용하신 기간은 어느 정도이신가요? *

한 개의 타원형만 표시합니다.

- ( ) 0~3개월
- ( ) 4~6개월
- ( ) 7~9개월
- ( ) 10개월~1년
- ( ) 1년이상

Figure D. The questionnaire for user experience of intelligent personal assistants and effects on quality of life for users with non-disabilities in Korean

5. 2.3. 귀하는 스마트 스피커를 어디에 두고 사용하고 계신가요? *

해당 사항에 모두 표시하세요.

☐ 개인 방
☐ 거실
☐ 부엌
기타: ☐ ______________________

6. 2.4. 귀하는 평소 얼마나 자주 스마트 스피커를 사용하고 계신가요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
거의 사용하지 않는다	◯	◯	◯	◯	◯	◯	◯	매우 자주 사용한다

7. 2.5. 귀하가 주로 사용하고 계신 스마트 스피커의 기능은 무엇이신가요? *

해당 사항에 모두 표시하세요.

☐ 음악 듣기
☐ 오디오북 듣기
☐ 뉴스 듣기
☐ 날씨 확인 (미세먼지 포함)
☐ 각종 정보를 얻기 위해 질문하기
☐ 게임
☐ 시간/알람 세팅
☐ 물건 주문 (쇼핑)
☐ TV 컨트롤
☐ 사물인터넷 기기 컨트롤 (스마트홈, 전등 등 포함)
☐ 전화 및 문자하기
☐ 잡담하기
기타: ☐ ______________________

3. 수용도 및 만족도 조사

8. 3.1. 나는 스마트 스피커를 사용하여 원하는 기능을 보다 빠르게 실행할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure D. (Continued)

9. 3.2. 나는 스마트 스피커를 사용하여 원하는 기능을 보다 쉽게 수행할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

10. 3.3. 스마트 스피커를 사용하는 것은 나에게 도움이 된다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

11. 3.4. 스마트 스피커의 사용법을 배우는 것은 나에게 쉬었다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

12. 3.5. 스마트 스피커와의 상호 작용은 명확하고 이해 가능하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

13. 3.6. 스마트 스피커를 사용하는 것은 쉽다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure D. (Continued)

14. 3.7. 스마트 스피커의 성능은 믿을 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

15. 3.8. 나는 스마트 스피커를 사용하여 신뢰할 수 있는 결과를 얻을 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

16. 3.9. 스마트 스피커는 사용자를 위해 계속 보완 및 개발되고 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

17. 3.10. 나는 다른 사람들에게 스마트 스피커를 사용하는 것을 추천할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

18. 3.11. 내 지인들은 스마트 스피커 사용을 통해 도움을 얻을 수 있을 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure D. (Continued)

19. 3.12 내 지인들은 스마트 스피커를 사용하는 것이 좋은 아이디어라고 생각할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

20. 3.13. 나는 스마트 스피커를 사용하는 것이 재밌다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

21. 3.14. 스마트 스피커를 사용하는 것은 즐겁다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

22. 3.15. 나는 내 의도대로 스마트 스피커를 사용할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

23. 3.16. 나는 스마트 스피커를 사용할 자산과 지식, 능력이 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

Figure D. (Continued)

24. 3.17. 나는 능숙하게 스마트 스피커를 사용할 수 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

25. 3.18. 스마트 스피커의 사용자 인터페이스(예: 색상, 조작부, 음성 등)는 매력적이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

26. 3.19. 스마트 스피커의 전체적인 모양과 느낌은 매력적이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

27. 3.20. 스마트 스피커는 전반적으로 매력적으로 보인다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

28. 3.21. 스마트 스피커는 기존의 다른 기기들(예: TV, 스마트 폰 등)과 잘 호환된다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	○	○	○	○	○	○	○	매우 그렇다

Figure D. (Continued)

29. 3.22. 스마트 스피커를 사용하는 것은 내가 작업을 하는데 있어 모든 측면과 잘 어울린다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

30. 3.23. 스마트 스피커를 사용하는 것은 내 라이프 스타일에 적합하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

31. 3.24. 스마트 스피커는 사용가능한 다양한 기능들을 제공한다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

32. 3.25. 스마트 스피커의 성능(예: 음성인식, 인공지능 등)은 내가 스마트 스피커에서 제공하는 기능들을 사용하기에 충분하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

33. 3.26. 스마트 스피커의 업데이트 등을 비롯한 인프라 서비스는 내가 스마트 스피커에서 제공하는 기능들을 사용하기에 충분하다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure D. (Continued)

34. 3.27. 나는 기회가 된다면 스마트 스피커를 사용하려고 한다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

35. 3.28. 나는 스마트 스피커를 자주 사용한다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

36. 3.29. 나는 앞으로도 계속해서 스마트 스피커를 사용할 것이다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

37. 3.30. 나는 스마트 스피커를 사용하는데 있어 전반적으로 만족하고 있다. *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

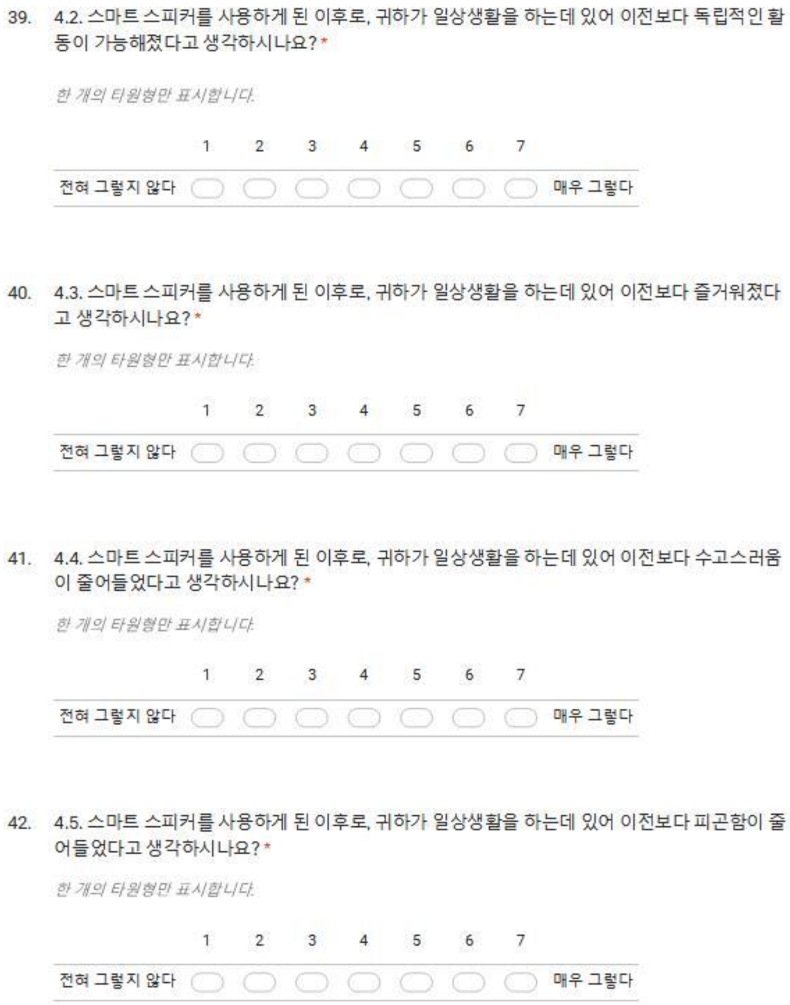
4. 삶의 질 개선도 조사

38. 4.1. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 안전해졌다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure D. (Continued)



39. 4.2. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 독립적인 활동이 가능해졌다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

40. 4.3. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 즐거워졌다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

41. 4.4. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 수고스러움이 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

42. 4.5. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 피곤함이 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

Figure D. (Continued)

43. 4.6. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 타인에 대한 의존도가 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

44. 4.7. 스마트 스피커를 사용하게 된 이후로, 귀하가 일상생활을 하는데 있어 이전보다 시간 소모가 줄어들었다고 생각하시나요? *

한 개의 타원형만 표시합니다.

	1	2	3	4	5	6	7	
전혀 그렇지 않다	◯	◯	◯	◯	◯	◯	◯	매우 그렇다

5. 사용자 경험 조사

해당 섹션은 인터뷰로 총 9개의 질문으로 이루어져 있습니다. 인터뷰가 서면으로 진행되는 만큼 가능한 자세히 질문에 대한 응답을 작성해주면 감사하겠습니다.

45. 5.1. 스마트 스피커에 대해 처음 알게 되었을 때 귀하는 어떠한 느낌 또는 생각이 드셨나요? *

46. 5.2. 스마트 스피커를 사용하면서 귀하는 무엇 또는 어떠한 생각이 드셨나요? *

Figure D. (Continued)

47. 5.3. 현재 사용하고 계신 스마트 스피커의 장점 및 단점은 무엇이라고 생각하시나요? *

48. 5.4. 귀하에게 있어 스마트 스피커의 중요한 역할 및 의미는 무엇이라고 생각하시나요? *

49. 5.5. 귀하에게 있어 스마트 스피커와 관련해 기억에 남는 일화(에피소드)는 무엇이신가요? *

50. 5.6. 귀하가 스마트 스피커 사용 시 자주 이용하는 기능은 무엇이신가요? 그러한 기능을 주로 사용하시는 이유는 무엇이신가요? *

51. 5.7. 귀하는 스마트 스피커 사용 시 어려움 또는 문제를 겪으신적이 있으신가요? 만약 겪으신적이 있으시다면 무엇이며, 어떻게 해결하려 하셨나요? *

Figure D. (Continued)

52. 5.8. 귀하에게 있어 스마트 스피커의 이상적인 유형 및 기능은 무엇이라고 생각하시나요? *

53. 5.9. 귀하가 스마트 스피커를 지인에게 추천 및 선물로 준다면 무엇을 고려할 생각이십니까? *

Figure D. (Continued)

Appendix E. The keywords appeared at least twice in the written interview data for the participants with disabilities in Study 3

Table E. The keywords appeared at least twice in the written interview data from the participants with disabilities (ver. Korean & English)

Rank	Keyword (Korean)	Keyword (English)	Frequency
1	음성인식	voice recognition	19
2	제어	control	9
3	텔레비전	television	9
4	사용	use	8
5	기능	function	7
6	검색	search	6
7	생활	life	6
8	음성	speech	6
9	부재	absence	5
10	오류	error	5
11	연동	pairing	5
12	음악	music	5
13	휴대폰	phone	5
14	단점	disadvantage	4
15	리모콘	remote controller	4
16	불가능	impossible	4
17	신기한	amazing	4
18	어려움	difficult	4
19	장점	advantage	4
20	편한	convenient	4
21	기기	device	3
22	발음	pronunciation	3
23	전화	call	3
24	부족하다	lack	3
25	사물인터넷	internet of things	3
26	삶의 질	quality of life	3
27	유용한	useful	3
28	장애인	people with disabilities	3
29	좋다	good	3
30	향상	improving	3

31	가능	possible	2
32	개인비서	personal assistant	2
33	나쁘다	bad	2
34	날씨	weather	2
35	도움	help	2
36	독립	independence	2
37	동영상	video	2
38	디자인	design	2
39	도우미	helper	2
40	사용자	user	2
41	소음	noise	2
42	손 사용	hand use	2
43	쉬운	easy	2
44	알람	alarm	2
45	영향	effect	2
46	작동	work	2
47	재미	fun	2
48	전등	light	2
49	정확도	accuracy	2
50	(소리) 크기	volume	2
51	필요하다	need	2
52	학습	learning	2
53	호출	triggering	2

Appendix F. The keywords appeared at least twice in the written interview data for the participants with non-disabilities in Study 3

Table F. The keywords appeared at least twice in the written interview data from the participants with non-disabilities (ver. Korean & English)

Rank	Keyword (Korean)	Keyword (English)	Frequency
1	알람	alarm	13
2	음성인식	voice recognition	10
3	날씨	weather	8
4	작동	work	6
5	설정	setting	5
6	신기한	amazing	5
7	오류	error	5
8	기능	function	4
9	단점	disadvantage	4
10	반응하다	response	4
11	사용	use	4
12	생활	life	4
13	장점	advantage	4
14	전화	call	4
15	검색	search	4
16	편한	convenient	4
17	휴대폰	phone	4
18	과업	task	3
19	반복하다	repeat	3
20	시각적	visual	3
21	확인하다	identify	3
22	다양하다	vary	2
23	도움	help	2
24	디자인	design	2
25	멍청한	stupid	2
26	바쁜	busy	2
27	빠른	fast	2
28	손 사용	hand use	2
29	유용한	useful	2
30	재미	fun	2

31	좋다	good	2
32	텔레비전	television	2

Abstract in Korean (국문 초록)

장애인 사용자들을 대상으로 한 음성 사용자 인터페이스의 사용자 경험에 대한 사용자 중심 연구: 지능형 개인 비서를 중심으로

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최근에 들어와 음성 사용자 인터페이스들(Voice User Interfaces, VUIs)에 대한 연구가 활발히 진행되고 있다. VUI는 일반적인 사람들은 물론, 고령자 및 장애인들에게도 매우 유용한 많은 장점들을 가지고 있다. VUI는 장애인들에게 보편적 정보 접근을 용이하게 한다는 점에서 장애인과 비장애인 간 존재할 수 있는 정보 격차를 줄이는 매우 유용한 역할을 할 수 있다. 이러한 관점에서, 많은 연구자들은 장애인들의 독립성과 삶의 질을 높이기 위해 VUI를 다양한 영역에 적용하려고 하고 있다.

하지만, 장애인들을 위한 VUIs와 관련된 선행연구들은 대부분 새로운 시스템의 개발 및 평가에 중점을 두고 있으며 경험적 연구는 제한적이다. 특히, 장애인을 위한 VUIs와 관련된 연구들 중 사용자경험(User Experience, UX)에 대한 연구는 상당히 드물다. 이러한 상황은 오늘날 가장 많이 사용되는 VUIs 중 하나인 지능형 개인 비서들(Intelligent Personal Assistants, IPAs)에 대한 연구에서도 마찬가지이다. IPAs는 단순한 VUIs보다 다양한 작업을 수행할 수 있기 때문에 장애가 있는 사용자들에게 매

우 실용적으로 사용될 수 있다. 하지만, IPAs의 UX 관련된 연구는 거의 주목받지 못 하고 있으며, 비장애인 중 청년 및 중년층만이 최종 사용자들로 고려되고 있다.

이전의 많은 선행연구들은 IPAs가 장애가 있는 사람들에게 큰 도움이 될 수 있다고 입을 모아 말한다. 그러나 실재로 장애인 사용자들의 입장에서 진행된 IPAs와 관련된 연구는 별로 없으며 IPAs의 UX 관련된 연구는 더욱 부족한 상황이다. 비장애인 사용자들과 비교했을 때 장애인 사용자들의 입장에서 사용성(usability) 및 UX를 조사하는 것은 복잡하고 어려운 일이다. 그렇기에 장애가 있는 사용자를 위한 IPAs의 UX에 대한 연구가 보다 철저히 이루어져야 한다고 볼 수 있다. 이러한 배경을 두고, 본 학위논문의 연구 목적은 장애인 사용자들을 대상으로 IPAs에 중점을 두고 VUIs의 UX를 조사하는 것이다. 본 학위논문은 크게 세 개의 독립적인 연구로 이루어져 있다.

연구 1에서는 다른 장애를 가지고 있는 장애인 사용자들의 차이들과 그들이 VUIs을 사용하거나 사용하지 않는 이유를 파악하는데 중점을 두고, 상용화된 VUIs의 UX를 조사한다. 하나이상의 VUIs를 사용한 경험이 있는 장애인 사용자들을 대상으로 설문조사를 하였다. 수집된 데이터는 통계적으로 그리고 정성적으로 분석하였다. 이 연구의 결과들은 장애인 사용자들의 장애유형에 따라 VUIs의 수용도(acceptance)와 수용도 요인들 간 관계에 차이가 있다는 것을 보여준다. 또한, 이 연구의 결과들은 수용도 요인들이 VUIs의 UX 이슈들을 이해하는데 사용될 수 있다는 것을 보여줌과 함께 장애인 사용자들을 위한 VUIs의 UX와 관련된 다양한 인사이트들(insights)을 제공해준다.

연구 2에서는 의미 신경망(semantic network) 분석을 통해 사용자가 작성한 온라인 리뷰를 기반으로 IPAs의 UX를 조사한다. 해당 연구는 장애인 사용자들에 대한 IPAs의 UX를 조사하기 전에 비장애인 사용자들에 대한 IPAs의 UX를 조사하여 IPAs의 UX와 관련하여 중요하게 고려해야 할 요인들을 제안하였다. 이를 위해 사례 연구로, 인터넷에서 스마트 스피커에 대한 온라인 리뷰들을 수집하였다. 그 후, 텍스트 데이터를 전처

리 및 구조화였고, 이 과정에서 유사한 의미를 갖는 단어들이 있을 경우 하나의 대표 키워드로 변환하였다. 이 과정을 거친 후, 키워드들에 대한 빈도수를 계산하여, 빈도수 상위 50개의 키워드들이 핵심 키워드들로 보였기에, 빈도수 상위 50개의 키워드들을 분석에 사용했다. 이 키워드들을 바탕으로 네트워크를 시각화 하였고 중심성(centrality)을 계산했다. 이 연구의 결과들은 비록 IPAs의 성능에 대해서 완전히 신뢰하지는 못 하고 있더라도 대부분의 사용자들이 IPAs 사용에 만족하고 있었다는 것을 보여준다. 또한 이 연구의 결과들은 IPAs의 심미적 측면들이 사용자들의 즐거움과 만족에 중요하다는 것을 보여준다. 이 연구는 IPAs의 UX를 위해 고려해야 할 열 한 개의 중요 요인들을 제안하고, 그 중에서 사용자들을 만족시키고 IPAs의 디자인 시 고려해야 할 필요가 있는 열 개의 요인들을 시사해준다.

연구 3에서는, 연구 1과 연구 2를 바탕으로, 장애인 사용자들을 대상으로 IPAs의 UX에 대해 조사하고 IPAs의 사용이 그들의 삶의 질(quality of life)에 어떠한 영향을 주는지에 대해서 알아보고자 한다. 이 과정에서 비장애인 사용자들과 비교 또한 이루어졌다. 하나이상의 IPAs를 사용하고 있는 장애인 사용자들과 비장애인 사용자들을 대상으로 설문조사와 서면 인터뷰를 진행하였다. 수집된 데이터는 통계적으로 그리고 정성적으로 분석하였다. 이 연구의 결과들은, 장애 유무와 상관없이, 대부분의 사용자들이 주요 IPAs의 UX를 공유하고 있으며 IPAs 사용에 혜택을 누리고 있다는 것을 보여준다. 또한, 이 연구의 결과들은 장애인 사용자들의 입장에서 IPAs의 UX와 관련된 다양한 인사이트들과 함께 두 사용자 그룹 간 명확한 차이가 있다는 것을 보여줌으로써 이들을 대상으로 한 연구에서 정성적 데이터에 대한 분석이 필수적이라는 사실을 보여준다. 이 연구는, 연구 2에서 논의된 요인들을 바탕으로, 장애인 사용자들과 비장애인 사용자들을 위한 IPAs의 UX에 있어 중요 요인들을 제안한다. 또한 이 연구는 IPA의 UX에 대한 다양한 디자인 함의들(implications)을 논의하고, 장애가 있는 사용자들뿐만 아니라 모든 잠재적 사용자들을 고려한 IPA의 상호 작용 설계에 중점을 둔 구체적인 세 개의 디자인 함의들을

제공한다.

각 연구는 디자인 함의들을 제공한다. 연구 1에서는 장애인 사용자들을 대상으로 VUIs의 UX를 위한 디자인 함의들을 논의한다. 연구 2에서는 비장애인 사용자들에게 초점을 두고 IPAs의 UX를 위한 디자인 함의들을 제시한다. 연구 3에서는 장애인 사용들만이 아닌 모든 잠재적 사용자들에게 도움이 될 수 있는 다양한 디자인 함의들을 논의하고 IPA의 상호 작용 설계에 중점을 둔 구체적인 세 개의 디자인 함의들을 제안한다. 이러한 함의들을 IPAs의 디자인에 반영하는 것은 장애인 사용자들뿐만 아니라 잠재적인 모든 사용자들에게 도움이 될 것이다.

주요어: 인간 컴퓨터 상호작용, 사용자경험, 음성 사용자 인터페이스. 지능형 개인 비서, 접근성
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