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Companionship with smart home devices: The impact of social connectedness and interaction types on perceived social support and companionship in smart homes

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A B S T R A C T

A home is not only a technical space according to each individual's role but also a social space where family members interact with each other. However, the number of single-person households has recently shown an exponential increase. At the same time, the smart home technology has been growing in order to provide at-home rest to individuals. In this situation, a home's role as a social space is diluted, and many people cannot receive the social support they need at home. In this study, we introduce the concept of social connectedness for the interaction between users and smart home devices. It can be divided into two types. One is the Inner Social Connectedness (ISC) that is generated through connections between the user and the devices in their smart home. The other is the Outer Social Connectedness (OSC) that is generated through connections between the user and the smart home devices in other people's houses. We also introduce two types of interaction. One is the unmediated interaction, in which users interact with each device and the individual device reveals its presence. The other one is the mediated interaction, in which users interact with a single agent that represents various smart home devices. In order to investigate the impact of both inner/outer social connectedness and mediated/unmediated interaction types, we conducted a controlled experiment using a prototype smart home system. The results indicate that both types of social connectedness increase the user's perceived social support. In terms of the effects of social connectedness and each integration type, unmediated interaction was found to be more effective with inner social connectedness, whereas mediated interaction was more effective with outer social connectedness. Furthermore, perceived social support increased companionship with smart home devices. The findings of this study will help design interaction methods between users and objects in smart homes in the future.

1. Introduction

A home is a space where the concepts of individual and family interconnect to each other. In other words, it is a social space where family members interact. At the same time, a home is a technical space that represents each family member's role (Venkatesh, 1996). Moreover, an individual's home is emotionally crucial because it provides familiarity and emotional stability (Kraybill, 2005). At home, people expect to rest without being disturbed and to stay comfortable even when doing nothing (Kraybill, 2005). Moreover, a home has a very important meaning in terms of an individual's relationships with other family members (Mallett, 2004). According to Giddens (1984), a home is both an individual space and a unit of social interaction, a socio-spatial system that represents basic forms of social relations. Communication and interaction among family members is important to what constitutes a healthy family (Davey & Paolucci, 1980). Thus, people need to receive physical and emotional relaxation and comfort at home, along with social support.

However, single-person households have recently increased exponentially. According to the Korean government agency, the proportion of single-person households is expected to increase annually and reach 34.3% in 2035(KOSTAT, 2016). The number of single-person households has steadily increased globally,

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accounting for more than 27% of all American households in 2016 (U.S Census Bureau, 2016). This situation dilutes the role of the home as a social space, as many people cannot receive the necessary social support at home.

Simultaneously, smart home technology, aiming to provide some rest at home to people, has been growing. The term *smart home* refers to a home with various information and communication technologies, such as intelligent automatic systems and home appliances (Strese, Seidel, Knape, & Botthof, 2010). Smart items and smart home systems are fully connected and systematically integrated to provide suggestions to the user or automatically control the home's functions (Schiefer, 2015). Using these technologies, the user can control several smart devices, including home appliances, lighting, energy management, networks, security, air-conditioning, ventilation and home entertainment (Kidd et al., 1999). Many services or products have been recently included in the smart home area and the market is continuously expanding. Electronics companies, e.g. Samsung and LG, are realizing the potential of smart home technologies such as SmartThings, Family Hub and SmartThinQTM Hub (Cnet, 2015). With these smart home technologies, people are expected to have more time to relax and spend less time on doing routine household chores.

Despite several previous studies on smart homes, few have been conducted to investigate the smart homes' role of providing social support to people from a Human–Computer Interation (HCI) perspective. Recent studies on the Internet of Things or smart homes in the Human-Computer Interaction field are based on existing smartphone-based interaction methods such as the notification mechanism (Voit et al., 2016) and the new interaction techniques (Turunen et al., 2015, pp. 633–636). Other studies have also focused on user experience in a smart home environment from the technological perspective, not only in academic research (e.g., Alan et al., 2016; Ni, Al Mahmud, & Keyson, 2015) but also in practical projects. For example, SmartThings (*https://www.smartthings.com/*) controls all household devices with one TV remote control. Family Hub (*www.samsung.com/global/ces2016/familyhub*) allows the user to check the status of his refrigerator on a smartphone via an internal camera. Lastly, smart home research and products have dealt with the convenience of personal space but have been indifferent toward enhancing their role in social space. Even though an enhanced convenience can provide more personal benefits, a single-person home will still have no social support because there is no person from whom someone can receive social support at home. In this situation, we believe that providing social connectedness (SC) between users and smart home devices, i.e. creating social support to users from smart home devices, is important. And, we believe that social connectedness, defined in previous studies as a sense of belonging or interpersonal closeness (Lee & Robbins, 1995, 1998), can be sufficiently manifested through the users' connection with smart home devices. Social connectedness (SC) can be divided into two types depending on whether the users have connections with smart home devices in their smart home or with other smart home devices in other people's houses: inner social connectedness (ISC) and outer social connectedness (OSC). This social connectedness will provide social support, a very important component in the home context.

Furthermore, depending on the interaction type, various effects arise from when a user feels connected to devices. The quality of human–device interaction may vary depending on whether the user interact with devices mediately or unmediately (Kim, 2016). In information processing, direct and unmediated interactions with multiple sources are more likely to be perceived positively than those with an indirect and mediated single source (Biocca, 1997; Lee, 2004; Nass & Moon, 2000; Sundar, 2008). Moreover, the influence of information transfer depends on tie strength (Kim, An, & Kim, 2006). Prior studies have revealed that tie strength is associated with assistance motivation (Hirsch, 1980; Wellman, 1992). And tie strength depends on whether the interaction is mediated or not. However, the efforts to investigate the effects of each interaction type on social support in a smart home context have been lacking.

People will soon be able to use smart home technology or IoT, cooperating with diverse smart devices. From HCI perspective, it will be more important than ever that smart home devices do not act as strangers but as at-home companions which can provide social support. Therefore, the user's perceived companionship with smart home devices can also play a very important role during the use of intelligent systems such as smart homes. In this study, we introduce the concept of social connectedness related to the interaction between smart home devices and people. In particular, social connectedness can be naturally applied to a home environment through traditional home tasks. Exploring different interaction methods in a smart home context is important because of its practical significance and potential contribution to future research. This study's goal is to propose and validate new interaction methods between human and smart-home devices that can help people see such devices as life companions, by enhancing the social support received from them in a smart home environment. Thus, our research questions are the following:

1. How does social connectedness influence perceived social support in a smart home environment?
2. How does social support influence companionship with smart home devices?
3. What are the differences in the user's depending on the type of interaction with smart home agents?

To answer these research questions, we conducted an experimental study. We divided social connectedness into two types (Inner vs. Outer) and investigated how they affected the user's experience in smart home environments. Furthermore, we attempted to compare in an empirical way two different interaction types (mediated interaction with a single agent vs. unmediated interaction with various devices) in a smart home environment.

The remainder of this paper is organized as follows: Section 2 introduces and reviews relevant research and theories. Based on Section 2, Section 3 develops hypotheses according to the goal of this study. Section 4 explains the experimental method in a controlled-living laboratory environment. Section 5 presents the experiment's results, while Section 6 discusses the study's findings and limitations.

2. Related works

2.1. Social connectedness

Social connectedness is defined as "an aspect of the self that reflects a subjective awareness of interpersonal closeness with the social world" (Lee & Robbins, 2000, p. 484) or an individual's sense of enduring interpersonal closeness with the social world (Lee, Draper, & Lee, 2001). Furthermore, it is defined as the short-term experience of belonging and relatedness, which is based on quantitative and qualitative social appraisals and relationship salience (van Bel, Smolders, IJsselsteijn, & de Kort, 2009). Based on core definitions contained in previous studies, *Sense of Belongingness* and *Interpersonal Closeness*, the operational definition of social connectedness in this study is 'the degree of intimacy and sense of belonging that users feel toward smart home devices in a smart home environment'.

Social connectedness can be increased by providing recent interaction and awareness information that emphasizes short-term social information (Van Baren, IJsselsteijn, Markopoulos, Romero, & de Ruyter, 2004). This concept also addresses a broad scope of short-term social experiences originating from mediated and unmediated interaction about awareness information (Van Baren et. al., 2004). A strong sense of social connectedness can provide a foundation for goal-directed behavior, which can subsequently lead to a greater possibility of achieving life goals (Kohut, 1984). In contrast, a low sense of social connectedness has been linked to loneliness, anxiety, and interpersonal problems (Lee & Robbins, 1995; Lee et al., 2001).

Kohli, Karsten, and Künemund (2009) distinguished three dependent variables representing different dimensions of social connectedness. The first one—formal social relations—represents non-kin social relationships arising from the membership of a formal group. The second one—informal social relations—refers to non-kin social interactions that occur outside the boundaries of formal organizations (e.g., neighbors or friends). The third dimension is conceptualized as a broad measure of family relations. Social connectedness can be especially effective in unfamiliar environments. For example, perceived social connectedness can help reduce international students' psychological stress due to being in a new campus (Lee, Keough, & Sexton, 2002) and predict their acculturation (Yeh & Inose, 2003).

We believe that social connectedness can be naturally expressed by providing information on the status of the household or the devices in a smart home. Social connectedness is an emotional experience that can be evoked by the other's presence. And presence of others is a concept that includes awareness of a person, as well as awareness of an object (Rettie, 2003). Social connectedness can also be evoked by exchanging simple text messages such as "Good night"(Rettie, 2003). Based on these prior studies, social connectedness can be fully experienced through the interaction with smart home devices, particularly in an unfamiliar environment such as a smart home.

In the super-connected IoT or a smart home environment, SC can be divided into two types: *inner social connectedness* and *outer social connectedness*. Inner social connectedness (ISC) is generated through connections between the user and the devices in their smart home. In the user's home, inner social connectedness is the degree of intimacy and sense of belonging generated through sharing status and operation information with smart home devices such as the television, refrigerator and washing machine. Outer social connectedness (OSC) is generated through connections between the user and the smart home devices in other people's homes. Outer social connectedness is the degree of intimacy and sense of belonging generated through sharing the user's status and operation information with smart home devices in other people's homes, such as the house of your parents or a friend. Based on the three dimensions of social connetedness (formal, informal, and family relationships) (Kohli et al., 2009), the family relationship dimension is related to inner social connectedness, in other words, with smart home devices located in the user's own home (whether he lives alone or not). On the other hand, formal and informal relationships are related to outer social connectedness with smart home devices in other people's homes.

2.2. Social support

Social support, a positive resource usually obtained from interpersonal relationships, comprises behaviors that alleviate the negative effects of various stress situations (Cohen & Wills, 1985). Social support can be experienced not only from behavior but also from verbal and nonverbal communication (Vaux, 1988). Social support can be categorized into 3 types: informational, emotional, and instrumental (Cohen & Wills, 1985). *Informational support* helps one define, understand, and cope with problematic events. Primarily related to self-esteem (whether one is esteemed and accepted), *emotional support* is nurturant and provides comfort and consolation through expressions of care and concern. Finally, *instrumental support* comprises the provision of financial aid, material resources and essential services.

Among these three types, emotional support and informational support are more likely to show buffering effects regardless of the stressor (Cohen & Wills, 1985). In contrast, instrumental support is only effective when it is closely linked to the specific need elicited by a stressful event (Cohen & Wills, 1985). However, in the smart home context, additional physical and human resources should not be required to maintain an optimal home environment. Interestingly, Rozzell et al. (2014) analyzed and classified Facebook messages according to the abovementioned categories of social support, and discovered that informational and emotional support had the largest share. Therefore, in a smart home context, where users exchange messages with devices, informational and emotional support would be the primary formative factor of social support.

As previously mentioned, in the context of the increasing number of single-person households, smart home in the present is mainly focused on convenience and technology. The importance of receiving social support at home has not been properly considered. In this study, we attempt to verify whether social support could be a key element of smart homes.

2.3. Companionship

Companionship is defined as the combination of attachment, commitment and intimacy (Hatfield, Pillemer, O'Brien, & Le, 2008). Rook (1987, 1990) defined companionship as the social involvement pursued for intrinsic reasons of satisfaction or enjoyment. In other words, social involvement is required to achieve the satisfaction or enjoyment caused by sharing activities. Benyon and Mival (2010) also suggested the term *companion technology* and argued that simple interaction between humans and robots should evolve into a "relationship" for sustainability. Likewise, companion technology allows humans to establish sustainable relationships with intelligent systems such as smart homes (Benyon & Mival, 2010; Bickmore & Picard, 2005).

According to Rook (1987), companionship is not an overall social connection or emotion and is mainly used for pleasurable purposes. According to other studies, however, it is an important factor for establishing friendships with various objects and is not limited to pleasure (Demir, Özdemir, & Weitekamp, 2007). In a broad sense, perceived companionship best predicts happiness in life (Baldassare, Rosenfield, & Rook, 1984). In particular, companionship can lead to an individual experiencing positive feelings, and it can eventually affect satisfaction (Mendelson & Aboud, 1999).

As described above, various objects can express companionship under various circumstances, and companionship can also play a very important role during the long-term use of intelligent systems such as smart homes. Companionship is a fundamental dimension of friendship, which is also associated with social support. In this study, companionship is defined as a combination of attachment, commitment, and intimacy between users and smart home devices in a smart home environment. We also used companionship as an index to predict sustainable satisfaction with new smart home technology, and we applied social support as a way to enhance companionship.

2.4. Mediated and unmediated interaction

We previously mentioned that both mediated and unmediated methods in human–machine interaction can generate social connectedness (Van Baren et al., 2004; Rettie, 2003). However, the effects of the two methods may differ. According to various studies on information processing, unmediated and direct interaction with multiple sources is more likely to be positively perceived than mediated and indirect interaction with only a single source (Biocca, 1997; Lee, 2004; Nass & Moon, 2000; Sundar, 2008). The unmediated approach more positively affects social presence, perceived expertise, attitude, and perceived informational quality than the mediated approach (Kim, 2016).

According to existing research, many differences exist between direct interaction with several devices and indirect interaction mediated by a single agent. However, insufficient research has been conducted on interactions in a smart home environment. In this study, we suggest that interaction can be typified according to whether or not the presence of agent controlling various smart home devices. The unmediated interaction method, in which users interact with each device and the individual device reveals its presence; and the mediated interaction method, in which users interact with a single agent that represents various smart home devices.

3. Hypotheses

This study's goal is to suggest a new interaction method that help users consider a smart home device as a life companion by enhancing social support coming from the device in a smart home environment. To accomplish this goal, we assumed that two types of social connectedness play key roles in improving companionship through social support. And we assumed that these effects can vary depending on the interaction type, so we propose six hypotheses.

The social support theory asserts that various types of support relationships can be expressed by a sense of connectedness (Cutrona et al., 1986; Newcomb, 1990). Moreover, social connectedness can be expressed by sharing contextual information (Van Baren et al., 2004). In other words, a user's sense of connectedness, generated by sharing contextual information, is reflected in the form of social support. Social support can eventually be manifested through connectedness between the user and others.

Increasing connectedness with household members, such as family members or housemates, enhances perceived social support (Procidano & Heller, 1983; Vinokur & Van Ryn, 1993; Zimet, Dahlem, Zimet, & Farley, 1988). These effects can also be obtained through connectedness with smart home devices, and such connectedness can be explained through anthropomorphism (Aggarwal & McGill, 2007; Epley, Waytz, & Cacioppo, 2007), which is the human's cognitive process of inference of a nonhuman agent. Previous studies of computers as social actors (CASA) have shown that human–machine interactions have basically the same social characteristics as human–human interactions (Nass, Steuer, & Tauber, 1994). Therefore, inner social connectedness can be increased by sharing situational information between smart home devices and users. It can also increase perceived social support as the user would see the smart home devices as family members or housemates living in the same space. Therefore, we have the following hyphotesis:

H1. *Inner social connectedness (ISC) between the user and smart home devices at home could positively affect his perceived social support (PSS) in a smart home context.*

A user's perceived social support can also be enhanced through connections with people outside home. Indeed, users can perceive social support through relatives, friends, classmates, and others who do not live with them (Procidano & Heller, 1983; Zimet et al., 1988). As described above, these effects can also be observed through smart home devices. In other words, outer social connectedness can be increased through the sharing of information between smart home devices outside home and users at home. Outer Social Connectedness can increase perceived social support as the user feels that outside smart home devices are similar to relatives and friends. Therefore, our second hypothesis is the following:

H2. *Outer social connectedness (OSC) between the user and smart home devices outside the user's home could positively affect the user's perceived social support (PSS) in a smart home context.*

A negative interaction may exist between living together at home (family relationship) and not living together (informal social relationships). This can be explained in three ways. First, according to Banfield (1967), we assume that family support and informal support are mutually exclusive. That is, strong family relationships may prevent informal relationships with other relatives and friends because of normative orientations and social organization. Second, receiving informal social support may be more necessary and common when an individual's family cannot provide the required support. Thus, the negative association is the result of informal relationships acting as a substitute of the inefficient or missing family support. Third, the association between family relations and informal social relations tends to be negative or substitutive (Kohli et al., 2009). Therefore, the effects of inner social connectedness and outer social connectedness conflict with each other and may also reduce each other's effects. Our third hypothesis is the following:

H3. *The interaction effect of inner social connectedness (ISC) and outer social connectedness (OSC) on perceived social support (PSS) is the following: In the context of a smart home, the effect of inner social connectedness (ISC) on perceived social support (PSS) will be reduced when outer social connectedness (OSC) is high as compared to when it is low.*

Social support is embedded in social relationships (Reis & Collins, 2000). According to Weiss's (1974) categorization of the provisions of social relationships, one of them is the provision of intimacy. As mentioned above, intimacy is a component of companionship, and a social network can enhance companionship (Heaney & Israel, 2008). Therefore, social support can provide intimacy, which can in turn increase companionship.

More directly, companionship is affected by social support received from a companion at home, and this is usually effective for women living alone (Klaus, Kennell, Robertson, & Sosa, 1986). Furthermore, intermittent intervention with a companion helps increase social support (Klaus et al., 1986). Finally, studies have shown that social support and companionship are correlated (Rook, 1990; Sorkin, Rook, & Lu, 2002). Based on the results of several previous studies, we reached our following fourth hyphotesis:

H4. *Perceived social support (PSS) from smart home devices could positively affect users' perceived companionship (CS) in a smart home context.*

According to the construal level theory (CLT), an individual's overall representation of a target object or person of interest differs depending on their perceived level of psychological distance (Bar-Anan, Liberman, Trope, & Algom, 2007; Kardes, Cronley, & Kim, 2006; Liberman & Trope, 1998; Stephan, Liberman, & Trope, 2010; Trope & Liberman, 2003). Research distinguishes three types of psychological distance: spatial, temporal and social. According to the concept of *spatial distance*, objects close to the user can be psychologically perceived as more detailed and concrete (Bar-Anan et al., 2007; Fujita, Henderson, Eng, Trope, & Liberman, 2006; Trope & Liberman, 2003). *Social distance* refers to the perceived significance of the relationship (Bar-Anan et al., 2007; Trope & Liberman, 2003) and the fact that people form more abstract construals of unfamiliar others than of familiar others (Aron, Aron, Tudor, & Nelson, 1991; Idson & Mischel, 2001; Prentice, 1990). The specific formation of the subject naturally enhances social presence, which has a greater effect on social support (Chattaraman, Kwon, & Gilbert, 2012).

When inner social connectedness is high, many smart home devices in the user's home are at a short psychological distance from the user. Furthermore, users are constantly sharing information with smart home devices, thus generating inner social connectedness and increasing perceived social support. However, if a mediator interrupts the interaction between the user and the smart home devices, the psychological distance between them increases. This dilutes the positive effect of inner social connectedness on perceived social support. Therefore, we get to our fifth hypothesis:

H5. *The effects of inner social connectedness (ISC) on perceived social support (PSS) with smart home devices will be greater with unmediated interaction than with mediated interaction.*

When outer social connectedness is high, the user and smart home devices outside the user's home are distant from each other. Social distance is also great because it is relatively less familiar as the devices belong to someone else. Therefore, psychological distance is relatively greater in this situation compared to when inner social connectedness is high. As a result, the effect of outer social connectedness on social support is less than that of inner social connectedness.

However, if the user's close mediator at homeinterrupts an interaction between the user and the smart home devices outside the user's home, psychological distance between the user and the smart home devices is reduced. This amplifies outer social connectedness's positive effect on perceived social support. Therefore, our sixth hypothesis is stated as follows:

H6. *The effects of outer social connectedness (OSC) on perceived social support (PSS) by smart home devices will be greater in mediated interaction than in unmediated interaction.*

After a review of the literature and the establishment of the eight hypotheses, we present our research model as illustrated in Fig. 1.

4. Method

4.1. Pre-test and pilot tests

It was critical to ensure that people could feel the differences in the levels of independent variables, either inner social connectedness or outer social connectedness, that were derived from the experiment. We needed to verify that our experimental setting accurately represented each independent variable's characteristics and that its rule for manipulation was valid. Full scripts of experimental scenarios and a questionnaire for the independent variables' manipulation check were administered as a pre-test with four participants (two males and two females).

Based on pretest results, we revised and elaborated experimental stimuli and conducted a pilot study to test measurement items before the final experiment. For the pilot test, 15 participants (5 males and 10 females), age range 19–28 (M = 23.93, SD = 2.15), were recruited from offline boards at the university. After they completed the entire procedure, they received a monetary reward equivalent to 8 USD.

The pilot test had three goals. First, we verified the validity of the implementation of both types of social connectedness (inner and outer social connectedness). The validity and reliability of the measurements for manipulation and measuring dependent variables were tested as well. Second, the experiment's entire process and stimuli were revised—altering tasks, adding interaction, and changing television content. Third, as we adopted the Wizard-of-Oz technique, the experimentors had to practice until we could implement the technique without any mistakes and we did our job smoothly, so participants did not notice that apparatus were not automatically acting or answering.

The pilot test's entire process and apparatus were nearly the same as those of the final experiment. However, compared to the final experiment, the pilot test had an additional step: a brief follow-up interview. During the interview, we not only checked whether the experimental stimuli and procedure were suitable but also whether participants understood our new smart home system. The final experiment reflected new understandings gained from the pilot test.

4.2. Experimental design

To examine the proposed hypotheses, we conducted a 2 (high vs. low inner social connectedness) × 2 (high vs. low outer social connectedness) x 2 (Mediated vs. Unmediated Interaction) factorial between-subjects experiment. However, low inner social connectedness and low outer social connectedness conditions could not be differentiated according to the interaction type (mediated or unmediated), as they send dummy messages (short news) rather than messages from smart home devices or an agent. Therefore, the same stimulus was used for low inner social connectedness and low outer social connected conditions regardless of the type of interaction.

4.3. Participants

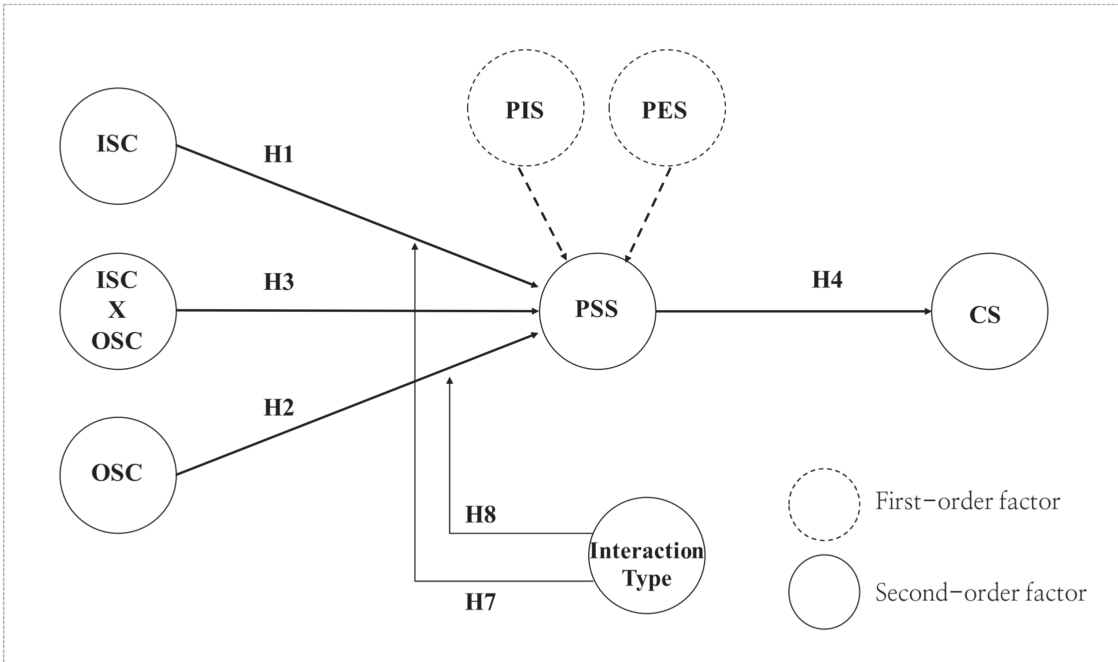
Through university bulletin boards and several online communities of local universities, 96 participants were recruited, 40 males and 56 females, whose age ranges from 19 to 32 years ($M = 24.3$). Participants were randomly and almost equally assigned to seven conditions (see Table 1). Each participant was tested individually.

4.4. Manipulation

4.4.1. Inner social connectedness (ISC) and outer social connectedness (OSC)

In a smart home environment, TV can play an important role. People think that the “heart” of the house is the relaxing combination of a sofa and a television, and their favorite pastime at home is still watching TV (Leppënen & Jokinen, 2003). Thus, digital TV could be the control terminal for a smart house. Occupants could adjust their house's daily functions with a remote control (Nurmela et al., 2000). Therefore, we decided that in a smart home a TV would serve as the main device for interaction with the user, and the exchange of text messages would create social connectedness (Rettie, 2003).

Therefore, we showed messages from smart home devices on the TV to provide social connectedness from the devices to the users. Through these messages, the TV provided operations for the smart home devices and contextual information about the home environment. Based on this information, users presented their opinions, and the devices operated accordingly. Furthermore, for tasks that could not be resolved by the devices, collaboration was encouraged by the devices asking for the participants' help. In particular, for high outer social connectedness, we sought mutual



ISC: Inner Social Connectedness, OSC: Outer Social Connectedness, PSS: Perceived Social Support, PIS: Perceived Informational Support, PES: Perceived Emotional Support, CS: Companionship

Fig. 1. Full research model.

Table 1
Number of participants in each condition group.

	Unmediated Interaction		Mediated Interaction	
	High ISC	Low ISC	High ISC	Low ISC
High ESC	*A* $N = 14$	*B* $N = 14$	*E* $N = 15$	*F* $N = 14$
Low ESC	*C* $N = 13$	*D* (*Common Cell*) $N = 13$	*G* $N = 13$	*D* (*Common Cell*) $N = 13$

benefits through group purchases with parents and friends' smart home devices. We also ensured social connectedness through messages related to healthcare and content sharing.

With a high inner social connectedness condition, messages from smart home devices were displayed on the TV screen's bottom right side. With a high outer social connectedness condition, messages from smart home devices at parents and friends' homes were displayed on the TV screen's upper left side.

Lastly, when the two types of social connectedness were low, dummy messages, in the form of news −instead of messages from the devices-were displayed.

A summary of social connectedness experimental conditions is presented in Fig. 2.

4.4.2. Interaction type (mediated or unmediated)

Interactions are classified according to whether the controlling agent's presence is highlighted or not. In unmediated interaction, each smart home device sent messages to participants through a TV. We used thumbnail images of actual devices and showed their names at the bottom of the thumbnails (e.g., My Home TV, Friend's Home Refrigerator). Devices also sent direct messages to participants, revealing their presence (e.g., "Master, I'm a washing machine …").

In mediated interaction, participants and devices interacted only through the virtual smart home agent "Tivo." Thumbnail images and names at the bottom used only virtual agent images and the name Tivo rather than actual devices' images and names. Only the agent sent messages to participants revealing its presence (e.g., "Master, I'm a Tivo …"). However, when inner social connecteness and outer social connectedness were low, dummy messages were displayed instead of the smart home device or Tivo's messages, and therefore they were not classified according to the interaction type. A summary of the experimental conditions depending on the interaction type is presented in Fig. 2.

4.5. Experimental setting and apparatus

A studio apartment was set up for this study (Fig. 3). Some furniture—a desk, sofa, and carpet—was arranged to create a homey mood. Smart home devices included a television, washing machine, robot vacuum cleaner, refrigerator, body mass index (BMI) meter, desktop, and air-conditioner. Using the "Wizard-of-Oz" technique (i.e., without participants' knowledge), experimenters remotely controlled smart home devices.

Moreover, we developed a web page using the AXURE RP 8.0 prototype tool, and the web page was transmitted from a laptop to the TV screen in real time by Chromecast Screenmirroring. The web page included drama content and smart home messages. All the stimuli were delivered to participants through this application.

4.6. Procedure

The experiment was performed in adjoining rooms—a control and a main room—with a one-way mirror between them. In the main room, each participant was informed about the overall experimental procedure through a PowerPoint presentation displayed on a monitor and was asked to sign a consent form before the experimental session. It was imperative that participants understood the communication method with the machines because this form and style had not been previously experienced. After presenting the machines' positions with their names, participants were instructed on how they could interact with the machines. All

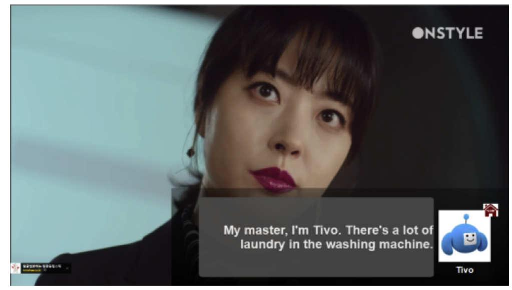
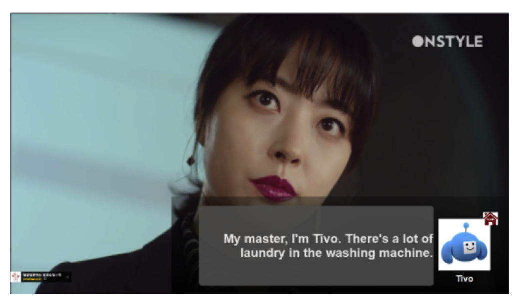
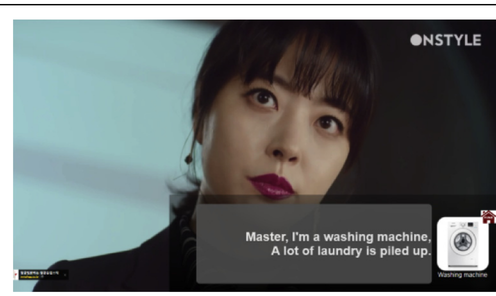
High Inner social connectedness (ISC)	Messages from smart home devices were displayed on the TV screen's bottom right side	
High Outer Social Connectedness (OSC)	Messages from smart home devices at parents and friends' homes were displayed on the TV screen's upper left side.	
Low Inner / Outer Social Connectedness	Dummy messages in the form of news –instead of messages from the devices- were displayed.	
Mediated interaction	Participants and devices interacted only through the virtual smart home agent "Tivo." Thumbnail images and names at the bottom used only virtual agent images and the name Tivo rather than actual devices' images and names.	
Unmediated interaction	Each smart home device sent messages to participants through a TV. We used thumbnail images of actual devices and showed their names at the bottom of the thumbnails (e.g., My Home TV, Friend's Home Refrigerator).	

Fig. 2. Manipulation of ISC, OSC, and interaction type.

participants were requested to imagine that the main room was their home. Participants with a high outer social connectedness condition were especially informed that their parents and friends' homes were also built as smart homes and included the same devices. After the introduction, participants experienced receiving a message from a device and responding to it, following the experimenter's guidance, so they could be familiar with how they could "voice-interact" with machines. The experimental session

Fig. 3. Experimental smart home setting.

began after the introduction and some practice.

4.7. Measurements

All questionnaire items were from prior validated studies (Barrera, Sandler, & Ramsay, 1981; Bhattacherjee & Hikmet, 2007; Buhrmester & Furman, 1987; Lee & Robbins, 1995; Marigold, Cavallo, Holmes, & Wood, 2014). They were translated into Korean and minimally revised to fit the current study's experimental smart home setting. To test the questionnaire items' validity and reliability, we conducted a pre-test and a pilot test with 4 and 15 participants, respectively. We also asked an HCI expert to review the questionnaire items. Some items were revised or removed as their original meaning could be lost when translated into Korean. A total of 22 questions were included in the final questionnaire, with all responses on a 7-point Likert scale from 1 (strongly disagree) to 7 (strongly agree). Questionnaire items are presented in Appendix A.

5. Results

5.1. Manipulation check

Using independent variables, we conducted a manipulation check to test whether the stimuli for the inner social connectedness (ISC) and outer social connectedness (OSC) conditions were properly implemented in the experiment. Inner and outer social connectedness levels were measured using the 7-point Likert scale questionnaire. All items were adapted from prior research and modified after the pre-test and pilot test sessions. For each experimental condition group, averages of responses were analyzed using a *t*-test.

A significantly higher inner social connectedness (ISC) value was reported from the high inner social connectedness condition group ($M = 4.39$, $SD = 1.42$), as compared with the low inner social connectedness group ($M = 3.58$, $SD = 1.50$). This result was statistically significant ($t(94) = 2.683$, $p < 0.01$). In terms of outer social connectedness (OSC), the high outer social connectedness condition group ($M = 4.31$, $SD = 1.43$) reported a significantly higher outer social connectedness value than the low condition group ($M = 2.64$, $SD = 1.36$). This result was also statistically significant ($t(94) = 5.752$, $p < 0.001$). A summary of statistical data is shown in Table 2.

5.2. Measurement validation

Smart PLS 3.0 was used to test the structural model proposed in Fig. 4. Before testing our research hypotheses, we conducted verification tests to determine the measurement model's validity using Smart PLS 3.0. Results are shown in Table 3. Results for testing the convergent validity demonstrated significant factor loadings for all measurement items (0.70, AVE > 0.50). All values satisfied the thresholds. Reliability in a measurement model can be identified by testing for composite reliability and determining the Cronbach's alpha value. Reliability was assured when both values exceeded 0.70 (Chin, 1998; Fornell & Larcker, 1981). Our composite reliability and Cronbach's alpha values both exceeded 0.70; thus, they were considered acceptable. We report each construct's means and standard deviations in Table 3. All items consequently demonstrated convergent validity for measuring concepts presented in our study (Bagozzi & Yi, 1988) (see Fig. 5).

Discriminant validity is confirmed when the square root of the AVE for each construct is larger than the inter-construct's correlation value (Fornell & Larcker, 1981). As presented in Table 4, the square root of AVE for each construct in our study has a higher value than the inter-construct correlations. Therefore, it satisfied the conditions for discriminant validity (Gefen, Straub, & Boudreau, 2000; Segars & Grover, 1998).

5.3. Hypotheses testing (structural equation model)

We collected survey data from 96 individuals in the experiment. Based on this data, structural equation modeling (SEM) was used to analyze the hypotheses using partial least squares (PLS) with Smart PLS 3.0. Due to this study's exploratory characteristics (Chin, Marcolin, & Newsted, 2003) and multi-level model (Barclay, Thompson, & Higgins, 1995; Chin, 1998), PLS was considered to be an appropriate method of analysis. Perceived social support (PSS) was measured in the second order. The two sub-constructs of perceived social support (PSS) are gathered into one first-order construct. This way, the second-order constructs are represented by the first-order construct.

Before we ran PLS-SEM, we conducted three analysis to ensure that our sample size of 96 is sufficient to test our hypothesis. The power analysis (Cohen, 1988) indicates the minimum sample size of 77 and the minimum R-square method (Hair et al., 2014) requires the minimum sample size of 59. Finally, the Inverse Square Root Method (Kock & Hadaya, 2016), the strictest one, recommends the minimum sample isze of 97.32, which means our sample size is one or two short. Therefore, we believe that our sample size meets average minimum sample size.

In order to test the hypotheses, path coefficients and statistics t (bootstrap sample N = 500) and R^2 were examined. The influence of inner social connectedness (ISC) on perceived social support (PSS) was 0.335(H1: $p < 0.001$), and the influence of outer social connectedness (OSC) on perceived social support (PSS) was 0.300 (H2: $p < 0.001$), whereas the t-values for each respective path were 3.180 and 3.167. These values exceed the minimum significant t-

Table 2
Summary of manipulation check results.

IVs	Mean (std. dev.)		Manipulation Checks		
	High	Low	Mean difference	*t* statistic	Significance level
ISC	4.39(1.42)	3.58(1.50)	0.81	$t(94) = 2.683$	$p = 0.009^{**}$
OSC	4.31(1.43)	2.64(1.36)	1.67	$t(94) = 5.752$	$p = 0.000^{***}$

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
IVs = Independent Variables.
ISC = Inner Social Connectedness, OSC = Outer Social Connectedness.

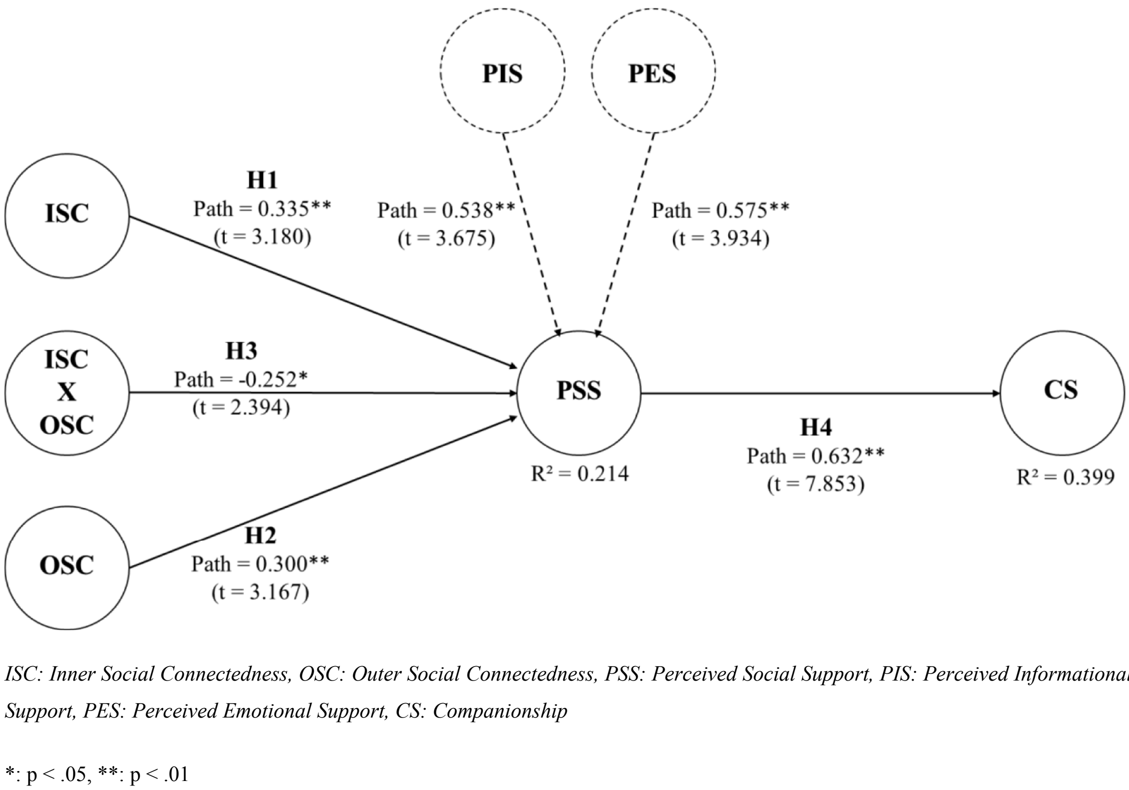


Fig. 4. Structural model.

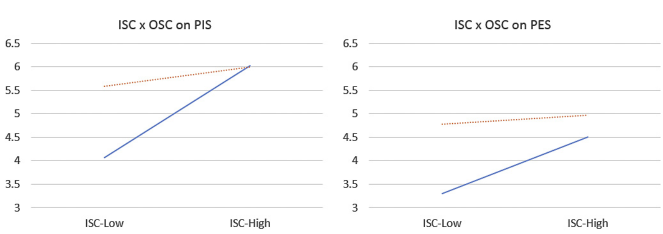


Fig. 5. Results of testing Hypotheses 3: Interaction effects between independent variables.

value of 1.96 and thus support Hypotheses 1 and 2. An interaction effect between inner social connectedness (ISC) and outer social connectedness (OSC) on perceived social support (PSS) was revealed to have a path coefficient of −0.252 (H3: $p < 0.05$) and a t-value of 2.394. Because the t-value exceeds 1.96, Hypothesis 3 was supported. This interaction effect reveals that the effect of inner social connectedness (ISC) on perceived social support (PSS) is reduced when outer social connectedness (OSC) is high as compared to when it is low. The influence of perceived social support (PSS) on companionship was 0.632 (H4: $p < 0.001$) with a t-value of 7.853, which exceeds the minimum t-value and thus supports Hypothesis 4. As confirmed by all the results, all hypotheses were supported. Table 5 illustrates all statistical results, and the structural equation model is shown in Fig. 4.

5.4. Hypotheses testing (ANOVA)

A three-way repeated measure analysis of variance (ANOVA) was conducted on three hypotheses (H1, H2, and H3) in more detailed testing, using SPSS 23 IBM. Results are displayed in Table 6.

As indicated in Table 6, regarding the effect of ISC (inner social connectedness) and OSC (outer social connectedness) on PIS(perceived informational support), the result of testing H1 is $F(1,92) = 29.877$, $p < 0.001$ and that of testing H2 is $F(1,92) = 10.420$, $p < 0.01$. Table 6 shows that the interaction effect of ISC (inner social connectedness) and OSC (outer social connectedness) on PIS (perceived informational support) (H3) is statistically significant ($F(1,92) = 11.445$ and $p < 0.01$). Table 6 illustrates the interaction effect between ISC (inner social connectedness) and OSC (outer social connectedness). From this table, we can infer that the positive effect of ISC (inner social connectedness) on PIS

Table 3
Convergent validity and reliability.

Construct	Item	Factor Loading	AVE	Composite Reliability	Cronbach's Alpha
ISC	ISC 1	0.880	0.838	0.963	0.952
	ISC 2	0.942			
	ISC 3	0.928			
	ISC 4	0.919			
	ISC 5	0.907			
OSC	OSC 1	0.921	0.872	0.971	0.964
	OSC 2	0.922			
	OSC 3	0.956			
	OSC 4	0.941			
	OSC 5	0.928			
PIS	PIS 1	0.896	0.839	0.954	0.936
	PIS 2	0.923			
	PIS 3	0.908			
	PIS 4	0.936			
PES	PES 1	0.870	0.764	0.928	0.896
	PES 2	0.891			
	PES 3	0.909			
	PES 4	0.823			
CS	CS 1	0.803	0.653	0.882	0.827
	CS 2	0.873			
	CS 3	0.726			
	CS 4	0.822			

ISC: Inner Social Connectedness, OSC: Outer Social Connectedness, PSS: Perceived Social Support, PIS: Perceived Informational Support, PES: Perceived Emotional Support, CS: Companionship.

Table 4
Discriminant validity.

Construct	ISC	OSC	PIS	PES	CS
ISC	**(0.916)**				
OSC	0.573	**(0.934)**			
PIS	0.364	0.272	**(0.916)**		
PES	0.466	0.433	0.616	**(0.874)**	
CS	0.426	0.454	0.550	0.597	**(0.808)**

ISC: Inner Social Connectedness, OSC: Outer Social Connectedness, PIS: Perceived Informational Support, PES: Perceived Emotional Support, CS: Companionship.

(perceived informational support) is smaller in the OSC (outer social connectedness) condition than in the non-OSC(outer social connectedness) condition.

Regarding the effect of ISC (inner social connectedness) and OSC (outer social connectedness) on PES (perceived emotional support), the result of testing H1 was $F(1,92) = 5.138$ ($p < 0.05$) and that of testing of H2 was $F(1,92) = 10.116$ ($p = 0.01$). Table 6 shows that the interaction effect of inner and outer social connectedness on perceived emotional support (PES)(H3) is not statistically significant ($F(1,92) = 2.445$ and $p > 0.10$).

Table 5
Results of testing the inter-construct.

IV	DV	Hypotheses	Path Coefficients	T-statistics	*p-value*	Results
ISC	PSS	H1	0.335	3.180	0.001^{**}	Supported
OSC	PSS	H2	0.300	3.167	0.001^{**}	Supported
ISC x OSC	PSS	H3	−0.252	2.394	0.012^{*}	Supported
PSS	CS	H4	0.632	7.853	0.0001^{***}	Supported

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
ISC: Inner Social Connectedness, OSC: Outer Social Connectedness, PSS: Perceived Social Support, PIS: Perceived Informational Support, PES: Perceived Emotional Support, CS: Companionship.

Table 6
Results on social support (ANOVA).

IV	DV	Mean (std. dev.)		Hypotheses testing			Hypotheses supported
		High	Low	*F* statistic	Significant level	Eta square	
ISC	PIS	6.01(0.82)	5.08(1.49)	$F(1,92) = 29.877$	$p = 0.000^{***}$	$\eta^2 = 0.224$	H1: Supported
	PES	4.29(1.67)	4.74(1.34)	$F(1,92) = 5.138$	$p = 0.026^{*}$	$\eta^2 = 0.053$	
OSC	PIS	5.80(1.04)	5.40(1.42)	$F(1,92) = 10.420$	$p = 0.002^{**}$	$\eta^2 = 0.102$	H2: Supported
	PES	4.89(1.42)	4.13(1.49)	$F(1,92) = 10.116$	$p = 0.002^{**}$	$\eta^2 = 0.099$	
ISCx OSC	PIS	–	–	$F(1,92) = 11.445$	$p = 0.001^{**}$	$\eta^2 = 0.111$	H3: Partially Supported
	PES	–	–	$F(1,92) = 2.775$	$p = 0.100$	$\eta^2 = 0.029$	

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
ISC = Inner Social Connectedness, OSC = Outer Social Connectedness, PIS: perceived Informational Support, PES: Perceived Emotional Support.
Levene's Test (PIS: $F(3,92) = 1.577$, $p = 0.200$, PES: $F(3,92) = 0.26177$, $p = 0.853$).

Table 7
Multi-group analysis between unmediated and mediated interaction.

Paths	tspooled	Unmediated Path Coefficient	Mediated Path Coefficient	Hypothesis Support
H5: ISC–>PSS	5.350	0.435	0.313	Supported
H6: OSC–>PSS	−6.572	0.242	0.390	Supported

Thus, hypotheses H1 and H2 are statistically supported, while H3 is partially supported.

5.5. Hypotheses testing (multi-group analysis)

To compare the research model across the two interaction types, a multi-group PLS (partial least squares) analysis was conducted by comparing the differences in coefficients of the corresponding structural paths for the two research sites (see Table 7) (Keil et al., 2000). The analysis revealed that the path coefficient of unmediated interaction from inner social connectedness (ISC) to perceived social support (PSS) is significantly stronger than the one of mediated interaction ($t_{spooled} = 5.35$; Unmediated path coeff. = 0.435; Mediated path coeff. = 0.313). Thus, H5 was supported. Moreover, as the path coefficient of mediated interaction from outer social connectedness (OSC) to perceived social support (PSS) is significantly stronger than that of unmediated interaction ($t_{spooled} = -6.572$; Unmediated path coeff. = 0.242; Mediated path coeff. = 0.390), H6 is also supported.

6. Discussion

So far, the smart home technology has been considered only in terms of convenience and operability and it has the limitation of not reflecting the characteristics of a “Home”, which is an important element of social interaction. This problem becomes even more important in a single-person family. To solve this problem, this study introduced the concept of social connectedness and interaction type between users and smart home devices, and also conducted an experimental study to investigate the effect of social connectedness and interaction type on social support and companionship.

This study makes several contributions. First, we confirm through the experimental study that social connectedness between users and devices can improve perceived social support for users in a smart home context. In addition, the social connectedness in a smart home can be divided into two types (inner/outer), and their specific effects are confirmed. The effect of inner social connectedness (ISC) on perceived social support (PSS) is reduced when outer social connectedness (OSC) is high as compared to when it is low. Second, the relationship between social support and companionship has been identified. Companionship is an important factor for establishing friendships with various objects. In a broad sense, perceived companionship best predicts happiness in life. In addition, companionship can lead to an individual experiencing positive feelings, and it can eventually affect satisfaction. Especially in the smart home context, companionship is an important factor as a life partner. We found that social support from smart home devices can enhance companionship. Lastly, interaction design has expanded its area in this study. In the HCI field, interaction design was studied usually in a one-to-one relationship between the user and a machine (especially the smart phone and robot). However, in a new research domain called the smart home system, we extended the user-machine relationship from one-to-one to one-to-many and examined the differences in the effect on social support. In particular, the important implication is that unmediated interaction can be more effective in inner social connectedness and that mediated interaction can be more effective in outer social connectedness. This result tells us that the devices' presence is more effective when the devices are close to the user and are used often. Furthermore, the user wants to interact with a close single agent that acts on behalf of the devices that are far from the user.

Given the increasing number of IoT smart things, this study has practical implications. In particular, as the smart home is emerging as a promising ICT (Information and Communication Technology) system, the approach taken to design efficient and stable communication between users and devices has suggested a direction for direct and diverse use in the future. From these results, we infer that interaction methods and social connectedness need to be considered as crucial factors when designing smart homes, where communication and interaction between a human being and smart home devices occur frequently. Especially, there is an important practical implication in design guide for smart home services. Enhancing the user's perceived companionship for new smart home devices increases the possibility for services to settle in the initial market. Although there may be various methods such as advertisement and marketing, it is expected that the provision of the companionship will play a significant role. Especially, the method presented in this study does not need any additional costs. Also, it is possible to provide a design guide according to the situation of the service provider for the smart home interaction. In a service that is based on single agent for interaction with the user, it may be efficient to extend connectivity with more devices outside home such as family or friends' houses. On the other hand, in a service that is based on multiple devices interacting with user directly, it is efficient to strengthen connectivity with devices inside home such as my TV and refrigerator.

This study has several limitations as well. First, the user's smart home experience was artificially designed in a controlled lab environment, therefore it might be unnatural. Moreover, intervals related to the operation of the smart home device were somewhat distant from an actual household situation as events that occurred during the experiment would have taken place at longer intervals in the actual home. Second, smart home device messages that occupy part of the television screen may be perceived as distracting when watching the content. Last, even though we assessed reliability and validity, the use of subjective measurements can be disputed. Thus, future studies should develop additional objective measures to improve the quality of the results.

In conclusion, the home is both a social place to build connections and a technical to perform individual roles. The smart home system provides opportunities to increase the potential of the home to fulfill the two purposes, as well as risks to deteriorate the raison d'etre of home. We hope that our research provides the initial step to increase the opportunity as well as decrease the risk of smart home system by revealing the effects of social connectedness between human occupants and multiple devices, upon perceived social support and companionship with devices.

Acknowledgments

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Appendix A. Measurement Items

Dependent Variables	Measurement Items	References
Inner Social Connectedness	I think I belong to the same group with the smart home device in my home. I feel a sense of belonging with smart home device in my home. I feel close to smart home device in my home. I feel like I'm with smart home device in my home. I feel socially connected with smart home device in my home.	Lee & Robbins, 1995
Outer Social Connectedness	I think I belong to the same group with the smart home device of other houses (mother or friend). I feel a sense of belonging with smart home device of other houses (mother or friend). I feel close to smart home device of other houses (mother or friend). I feel like I'm with smart home device of other houses (mother or friend). I feel socially connected with smart home device of other houses (mother or friend).	Lee & Robbins, 1995
Emotional Support	The smart home device seemed to feel close to me. The smart home device seemed to look after for me The smart home device seemed to be trying to make me feel good. The smart home device seemed to take care of me.	Marigold et al., 2014; Barrera et al., 1981
Informational Support	The smart home device seems to give me information on how I should behave. The smart home device seems to tell me what I need to do. The smart home device helped me understand the situation clearly and easily while I was at home. The smart home device seems to let me know if something is wrong.	Marigold et al., 2014; Barrera et al., 1981
Companionship	I had a good time with a smart home device. I thought I was with a smart home device. I think I spent my leisure time with a smart home device. I was interested in talking to a smart home device.	Buhrmester & Furman, 1987.

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