Robots Versus Speakers: What Type of Central Smart Home Interface Consumers Prefer? *

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Abstract— In smart home environments, central interfaces that take commands from users and give orders to each relevant device appropriately are increasingly important. We investigated the type of central interface that consumers are more willing to adopt and whether these interfaces enhance the evaluation of services provided by smart home devices. This study confirms that speaker interfaces are preferred over social robots, speaker interfaces are perceived by users as more persuasive, and the adoption of central interfaces increases the overall service evaluation.

I. INTRODUCTION

"In a great establishment, the butler works very much with his head, and with his hands not at all." [1]

Modern households contain more smart devices than ever before. With the emergence of innovative social robots such as Temi and Elliq [2], [3], [4], the Consumer Electronics Show 2020 - one of the largest consumer electronics exhibition in the world - clearly showed that, even in traditional households, ordinary bedroom, kitchen, and bathroom products are now being equipped with smart technologies [5]. These smart devices are the modern version of servants in a home environment, providing a various array of services. With such an increasing number of smart devices, the importance of giving orders to each of them in an efficient and coherent way cannot be overstated [6], [7], [8], [9]. That is, a universal method to command these devices from the modern user's account is required. Companies such as Amazon and Google are providing central interfacing functions with their corresponding personal assistant applications, commonly installed in smartphones. In home environments, smart speakers and social robots are the prominent devices that can be equipped with these assistants, becoming the central hub of communication between the user and the household smart devices. In this article, we evaluate two types of central interfaces, speakers and social robots, and the consumers' preferences between them as central interfaces. In addition, we investigate whether the adoption of central interfaces

improves the users' evaluation of the services provided by smart devices.

This article is organized as follows. First, we provide definitions for terms used in this study. Second, we propose hypotheses regarding the types of central interfaces the consumers will prefer between smart speakers and social robots and the effect of interface type on the users' perception on the persuasiveness of the central interfaces. Third, we provide hypotheses regarding whether the adoption of central interfaces in home environments will lead to the improvement of the users' service evaluation. Fourth, we present the study conducted to test our hypotheses. Lastly, we discuss the theoretical and managerial implications and future research directions.

II. STUDY BACKGROUND

A. Smart Homes and Robotic Service Devices

Smart home environments utilize various technologies to enhance people's living conditions in the household. Kris et al. [10] divided domestic robots into seven categories, including cleaning, entertainment and toys, educational, companion, home security and disability assistive. They also separated smart home electronics into six categories: architectural, home automation, home health and activity monitoring, home security and assistive technologies. This study includes, beside robots and smart home products, all the devices that provide any type of service to household users. Therefore, we denote *robotic service devices* any products that deliver services to users through fulfilling their needs and wants [11] by robotic technologies such as manipulation, navigation, mobility, autonomy, or any other kind of artificial intelligence (AI) [12]. Thus, the internet of things (IoT) devices, household robotic appliances such as Roomba, smart speakers and social robots such as Jibo and Pepper are all robotic service devices here. Our definition is related to the description of robots by Britannica, *"any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a humanlike manner"* [13], in the sense that they are not required to have specific appearances or physical movements.

We divide robotic service devices into information service and physical service groups, in accordance with the nature of the service they deliver. That is, the information service devices deliver services that do not require their physical movements, such as providing weather conditions or dinner recipes. In contrast, the physical service devices require physical movement, such as robotic vacuum cleaners that provide service by autonomously moving to sweep the floor.

B. Central Interfaces in Smart Home Environment

Robotic service devices such as autonomous vacuum cleaners [14], lawnmowers [15], and window cleaner [16], are designed to serve users by relieving them of chores and related dangers. However, these benefits should come without the disadvantage of the complexity involved in controlling the device [7]. Leitner [17] argues that the increase in the number of smart home devices used resulted in a significant level of complexity of the human-device interfaces. Beccue [18] suggested that the fragmentation of smart home platforms and the absence of a unified, convenient way of controlling the devices hinder the adoption of smart home devices. Thus, a central interface providing methods to control the devices in a coherent and coordinated manner may improve the complex communication between users and devices, helping the users to effectively utilize the functions that the devices provide.

Companies and researchers are eager to produce such central interfaces. Leitner [17] suggested that AI-enabled assistants may reduce the complexity of interfacing, making the environment "smarter." In accordance with this, tech companies such as Amazon and Google are providing natural language processing-based assistants [19] with which the users can control robotic devices via voice commands [12], [20], [21], [22], [23]. This kind of central interfacing functionality needs to be assigned to one of the robotic service devices.

Besides smartphones, two types of devices are prominent in a smart home environment: smart speakers and social robots. For example, Amazon's Alexa, equipped with various IoT connections and home control functions, is loaded into Echo smart speakers [20] whereas another representative smart speaker, Google Home, is run by the Google Assistant [21]. Social robots such as Aido provide similar functionality for monitoring and controlling home devices [24], similar to Jibo [25] and Cloi [26]. In addition, Luria et al. [6] developed a robot called "Vyo," which is a personal assistant with the role to centralize the interface for smart homes. In this article, we name all the devices equipped with the functions of a central interface, "*mediators*." Although these robotic service devices provide various other functions, the mediation is more pronounced and could be a central functionality that these speakers or social robots provide.

In this context, we investigate what types of mediators the consumers prefer. Also, we explore whether the adoption of a mediator helps to enhance the users' service evaluation.

III. HYPOTHESIS

A. Mediator Types and Consumer Mediator Adoption

At present, commercial robotic service devices that include the functions of a central interface can be categorized into two groups: smart speakers and social robots. As speaker type mediators, Amazon's Alexa and Google Home are provided with functions to control IoT devices such as lights and vacuum cleaners via voice commands [20], [21]. Although they provide various other functionalities, such as search, music play, and user schedule management, one of their main purposes intended by the product developers is the control and management of all the household IoT devices and robotic service devices. That is, developers plan to make the smart speakers central hubs that monitor and control the

devices in the household, enabling the users to interact with them through the smart speakers instead of separately controlling each device. The second type of mediators is the social robots with humanlike features such as gestures and faces. Central interfaces are becoming core functions of these home personal assistant robots. For example, Aido can control connected devices in a home [24], and Jibo and Cloi provide similar functions [25], [26]. Few studies have investigated which mediators are preferred by consumers between speakers and social robots. For example, a previous study by Luria et al. [9] revealed that the users' response to the four different types of smart home control interfaces is different, depending on familiarity, flow and usability. However, this study does not reveal which, between the speaker and social robot, type of mediators the consumers are more willing to accept.

We consider that mediators are controlled basically via voice, because this is the activation method most robot assistants are equipped with [19]. Thus, we presume that one of the main differences between the speaker and robot types of mediators is their appearance. Oliver suggested that consumers tend to be satisfied with the product when their actual performance meets the expected performance [27]. The appearance of the product, which differs across the mediator types, affects consumers' expectations toward the product's functions [28]. That is, encountered with speaker type mediators, consumers expect information services and no movement, whereas, in the case of social robot type mediators, consumers expect physical services arising from the actuators and movements of the devices. When consumers experience mediating services - basically information-based functionalities - the performance of the device their expectation may match in the case of the speaker type mediators, whereas a mismatch occurs in the case of the social robot mediators, leading to dissatisfaction. Hence, we predict that the speaker type will be preferred over the social robot type mediators. This prediction is formally described as the following.

H1 : *Consumers will have higher purchase intention for speaker type mediators than social robot type mediators.*

B. Mediator Types and Persuasiveness

Gabbot and Hogg [29] asserted that the essential part of customers' satisfaction with the service is connected to aspects of personal relationships. As mediators act as an intermediary communicator between the user and the robotic service devices, whether they are perceived as persuasive, is important from the perspective of human-robot interaction (HRI) [30]. Previous HRI studies mostly investigated avenues to enhance the persuasive capacities of humanoid robots via changing various factors such as gender, gestures, and gaze. For example, Siegal et al. [31] showed that female robots were perceived as more persuasive than male robots by men. Ham et al. [32] showed that gazing increased persuasiveness, whether accompanied by gestures or not. Ghazali et al. [33] also showed that facial expressions helped increase the perceived persuasiveness. In contrast to previous approaches, we investigate which type of mediators will be perceived as more persuasive between the speaker and social robot interfaces.

The media equation by Reeves and Nass [34] asserts that people tend to perceive dedicated service providers as more

professional and intelligent than multi-service providers. Their study showed that a dedicated TV channel was perceived as more professional than a channel providing various topics. We predict that, due to their appearance, users will be inclined to expect more functions and services from social robot type mediators than from speaker type mediators. That is, the users may expect the social robot type mediator to provide more functions, beside communicating and issuing orders to household devices. However, the speaker type mediators may not generate false expectations regarding the services that they can provide. In summary, we expect that the loudspeakers with microphones that understand the users' commands via natural language processing and an internet connection and give commands to the devices will be perceived as more professional and, therefore, more persuasive. Thus, we predict that consumers will perceive the speaker type mediators as being more persuasive than the social robot type mediators.

H2: *Consumers will perceive the speaker type mediators more persuasive than social robot type mediators.*

C. Effects of Mediators on Service Evaluation

We investigate first the effect of adopting mediators in smart home environments on the service evaluation of robotic service devices. Although the field of HRI investigates various human responses regarding their experience with robotic service devices, there's only a few studies that investigated factors affecting the evaluation of services provided by the devices. For example, Lee et al. [35] investigated how strategies to mitigate the unexpected breakdowns of the devices affect the satisfaction of the users, including expectancy-setting and recovery. Researchers in the field of marketing, who traditionally have been investigating the factors which affect service evaluation, have recently focused on the services provided by robotic service devices. For example, Mende et al. [36] showed that consumers elicit discomfort when serviced by humanoid robots in restaurants, leading to their compensatory responses such as increased food intake. However, to our knowledge, the effect of interfacing intermediaries on the service evaluation of robotic devices has not been investigated until now.

In the field of service marketing, Zeithaml [37] suggested that factors that affect the service evaluation include tangibles, reliability, responsiveness, credibility, courtesy, competence, access, communication, security, and understanding the customer. We presume that adopting a mediator in a home environment equipped with various robotic service devices might affect each of the above ten dimensions. We predict that some of these factors - courtesy, communication, and understanding the customer - may be positively affected, leading to superior service evaluations. That is, having a single and dedicated communicator between the user and various devices may make the users feel that they are better treated and more respected in the deliverance of the service. That is, the adoption of a mediator may provide the users with the feeling of having a universal butler lead various robotic home servants. Further, having a mediator may increase the feeling of credibility. A uniform, central commander of a smart home environment, may give users the feeling that services are delivered in a better-managed fashion than when each device provides its services following direct user orders. In addition,

we presume that the access factor, which is related to how easily the consumer can have contact with the service provider, could be positively affected because the adoption of mediators relieves the users from the effort to find each device they need to command. However, with respect to responsiveness, users may feel a delay in service delivery because of mediated communication. We assume that other dimensions, such as tangibles, which is related with the appearances of the service provider, competency and security, are dependent on the intrinsic functionalities of the robotic service devices and independent on the presence of the mediator. Overall, we predict that the adoption of a mediator will positively affect service evaluation. We expect that the positive effect will not differ between the speaker and social robot interfaces. Thus, we predict that for both speaker and social robot type mediators, the adoption of mediators will improve the users' evaluation of services provided by robotic service devices.

H3-1 : *Consumers will evaluate the service provided by robotic service devices higher with social robot type mediators than without them.*

H3-2 : *Consumers will evaluate the service provided by robotic service devices higher with speaker type mediators than without them.*

IV. STUDY AND RESULTS

In order to explore what type of mediators is preferred by consumers and investigate the effect of mediators on the service evaluation, we conducted a within-participant study with the three conditions (control vs. social robot type mediator vs. speaker type mediator). Twenty-four people between the ages of 20 and 50 participated in the experiment, out of which eleven were males, and thirteen were females.

A. Stimuli

To test the hypotheses, we simulated in-house service environments provided by robotic service devices. We developed service scenarios that involved users and various robotic service devices. For each scenario, video clips to be shown to the participants were generated [38]. The scenarios were showing the user asking for various services from the devices, such as vacuuming and cleaning a room, and the robotic service devices delivering the services requested.

Prototype robotic service devices were developed specifically for this study. First, we developed a social robot prototype, called 'HuBot,' which we intentionally designed to be controlled by the experimenters in the scenarios. The design purpose of HuBot was to present it more humanlike than the smart speakers to the participants. This robot was composed of three parts: head, neck, and base. As the head, a small tablet computer was employed to show facial expressions such as gaze. Functioning as the neck, a Kubi telepresence robot by Revolve Robotics [39] controlled and tilted the screen-based head. The base consisted of a TurtleBot platform by ROBOTIS, which provided the movements of the robot [40] (see Fig. 1(a)). HuBot was used in the control and the social robot type mediator conditions. We employed the smart speaker "Wave" developed by Naver Corp. [41], shown in Fig. 1(b), as the speaker type mediator used in the experiment.
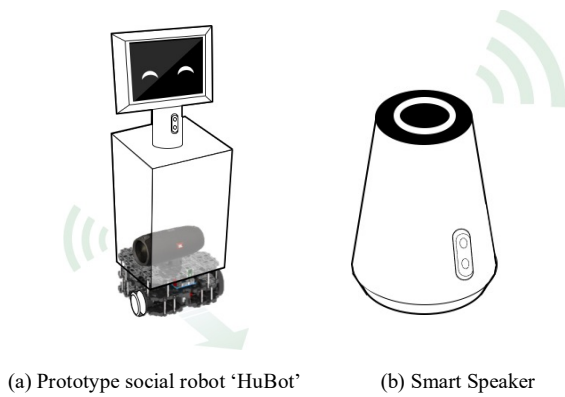
(a) Prototype social robot 'HuBot' (b) Smart Speaker

Figure 1.   Mediator Stimuli.

(a) Vacuum Cleaning Robot (b) Robotic Toy Box

Figure 2.   Robotic Service Devices Stimuli.

A vacuum cleaning robot and a robotic toy box were used as robotic service devices for the study. The vacuum cleaning robot employed was an iClebo by Yujin Robot [42] (Fig. 2(a)). We developed in-house the prototype robotic toy box, specifically to carry children's toys to and from the room they belonged to. The robotic toy box was composed of a box in which the toys could be transported and another TuttleBot base (Fig. 2(b)).

B. Scenarios

The robotic home service scenarios were developed according to the experimental conditions (See Table 1). In the case of the control condition, when the user requested a service the HuBot provided the service by itself, i.e., it either vacuumed the floor or carried the box full of toys from the living room to the kids' room. In these scenarios, the user first asked the robot to clean the floor, and the HuBot complied. Similarly, the user requested HuBot to organize the toys and the robot moved to the spot where the toys were scattered on the floor and then asked the user to put the toys into the box. After the user finished the task, the robot carried the toys to the kids' room. In the case of the mediator conditions, when the user requested a service the mediators - either the HuBot or the smart speaker, according to the conditions - gave orders to each robotic service product, including the vacuum cleaning robot and the robotic toy box. In this scenario, first, the user asked the mediator to clean the floor. Then, the vacuum cleaning robot received the command from the mediator and started cleaning the living room. Second, the user requested the mediator to organize the toys. When the robotic toy box received the command from the mediator, it moved near the user, who put the toys in the box. Then, the robotic toy box carried the toys away. Because adding mediators to home environments with robotic service devices such as the vacuum cleaning robot and the robotic toy box seems clearly advantageous to the user, we intentionally let HuBot provide services by itself in the control condition rather than adopting the vacuum cleaning robot and the robotic toy box. That is, the same HuBot was used as a mediator in the social robot mediator condition and as a robotic service device in the control condition. During the scenarios, all the devices were controlled by the Wizard of Oz technique.
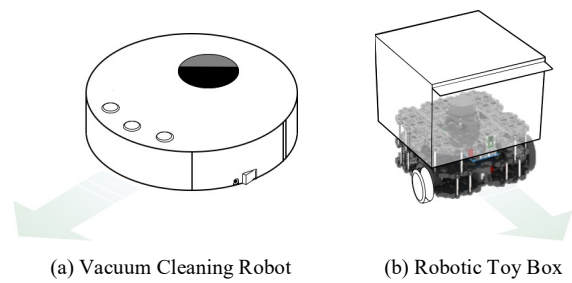
C. Measures

Participants' adoption of the mediators was measured by gauging their intention to purchase the product [43]. Purchase intention was measured by asking them, "To what extent do you intend to purchase the product?" and "To what extent are you willing to purchase the product?" Participants answered by "not at all/very much," and the purchase intention scale was shown to be reliable (Cronbach's Alpha = 0.98). Persuasiveness was measured by asking the participants three questions [30] : "To what extent the robot's suggestion convinced me?," "To what extent do you think the robot was similar to a good butler?" and "To what extent are you willing to use the robot's suggestion in the future?" Participants rated all three items by "not at all/very much," and the persuasiveness scale was shown to be reliable (Cronbach's Alpha = 0.90).

The service evaluation was determined from the scores the participants provided to three questions [35] : "To what extent the robots provide the user with a good or poor service?" (score from 1= very poor to 7 = very good), "To what extent would the user be satisfied with the service?" (1 = completely dissatisfied, 7 = completely satisfied), and "How likely do you find that the user would use this service again?" (1 = would avoid using the service, 7 = would want very much to use the service). The service evaluation scale was shown to be reliable (Cronbach's Alpha = 0.95).

TABLE I.   SCENARIOS FOR EACH CONDITION

Experimental Conditions	Scenarios
Control	
Social Robot Type Mediator	
Speaker Type Mediator	

To summarize, after the participant completed a written consent form, he or she watched each video clip according to the experimental conditions and then responded to the questionnaires online. The scenarios were provided to the participants in random order. The participants were also answered demographic questions after completing the questionnaire. Each of them was compensated with $9 after the experiment.

D. Study Results

Several *t*-tests were conducted to test the hypotheses mentioned in Section 3. To verify the effect of mediator types on their consumers' adoption, we compared the social robot type mediator vs. the speaker type mediator conditions. Participants in the speaker type mediator condition showed higher intention to purchase the mediator than the ones in the social robot type mediator condition ($M_{speaker\ type\ mediator}$ = 3.85, SD = 1.68 vs. $M_{social\ robot\ type\ mediator}$ = 3.29, SD = 1.60; $t(23)$ = 1.90; p = 0.036, one-tailed). Thus, H1 was supported. Second, participants in the speaker type mediator condition perceived the mediator as being more persuasive than the ones in the social robot type mediator condition ($M_{speaker\ type\ mediator}$ = 4.46, SD = 1.34 vs. $M_{social\ robot\ type\ mediator}$ = 3.39, SD = 1.40; $t(23)$ = 2.16; p = 0.021, one-tailed). Thus, H2 was supported (Fig. 3).

Further, to test the effect of adopting mediators on service evaluation, we compared the control and social robot type mediator conditions. Participants' evaluation of the service in the social robot type mediator condition was higher than that of the service in the control condition ($M_{social\ robot\ mediator}$ = 4.08, SD = 1.48 vs. $M_{control}$ = 3.58, SD = 1.47; $t(23)$ = 1.85 ; p = 0.039, one-tailed). Thus, H3-1 was supported by the experiment. Participants' evaluation of the service in the speaker type mediator condition was higher than that in the control condition ($M_{speaker\ mediator}$ = 4.39, SD = 1.29 vs. $M_{control}$ = 3.58, SD = 1.47; $t(23)$ = 1.85 ; p = 0.007, one-tailed). Thus, H3-2 was also supported (Fig. 4).
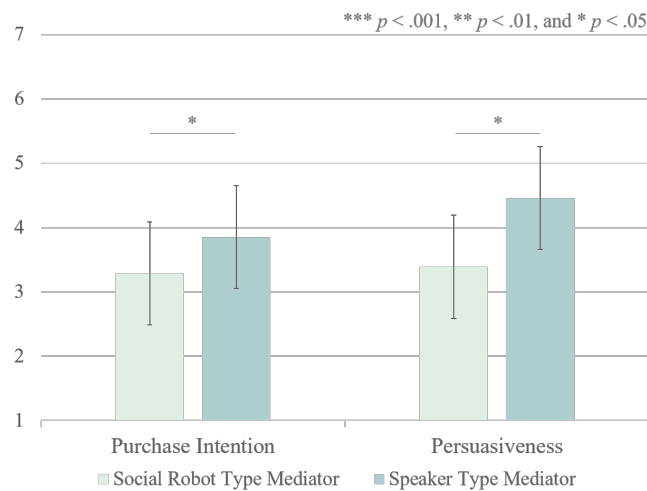

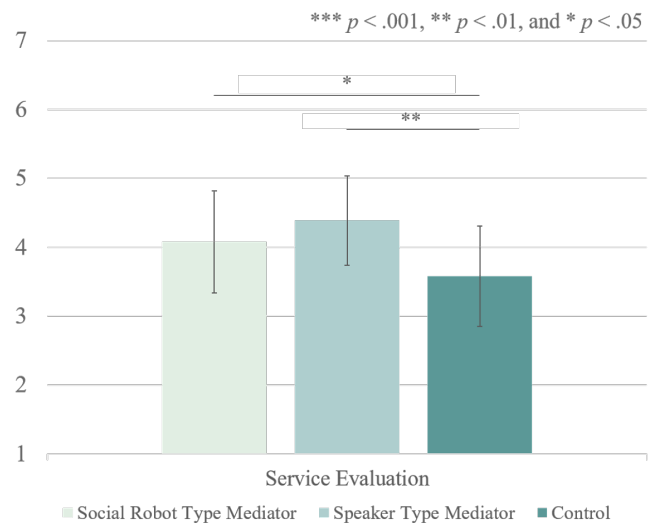Figure 3.   Purchase Intention and Perceived Persuasiveness on Mediator Types.

Figure 4.   Service Evaluation across Experimental Conditions.

V.   DISCUSSIONS

As the number of smart devices is increasing, functions to integrate these devices in households are becoming more important. Huijnen et al. [44] emphasized the social robot's role as a central assistant managing all the devices in a household. For the purposes of this study we defined *mediators* as robotic service devices with the function of interfacing intermediaries that connect the user with the various devices of the household. We investigated what type of mediator, i.e., speaker versus social robot, is preferred by consumers, and we explored which mediator is more effective in creating the perception of persuasiveness. In addition, we investigated the effects of adopting mediators on the service evaluation of robotic products. The results of the study revealed that the speaker type mediator was preferred by consumers to the social robot type mediator, also providing more perceived persuasiveness and that mediators improve the service evaluation.

A. Theoretical Implications

This study shows that consumers are inclined toward the adoption of speaker type mediators rather than social robot type mediators. That is, they show higher purchase intention for the speaker type mediators than for the social robot type mediators. We suspect that the appearance of the speaker type mediator prevented the participants from having expectations that could not be met by the mediator, which is, however, set only as an information service to connect users with robotic service devices. These results are in agreement with the study by Kwak et al. [45]. They showed that robots which resemble the objects suitable for their dedicated functions were shown to be more favored than humanlike robots for cleaning, education, and entertainment. It was also shown that consumers prefer the former rather than the latter, because it may mistakenly provide consumers over-expectations that cannot be met by their actual functions.

The results of this study also show that consumers perceive the mediators of the speaker type to be more persuasive than the social robot type. Based on the theory of media equation, we suspected that the simple appearances of the speaker type mediators, in comparison to the appearance

of the social robot mediators, will make consumers perceive them as possessing more competence regarding the intermediating function. It appears that our results coincide with the form follows function principle by Sullivan [46]. He asserted that the appearance of products should be based on their intended functions. Because central interfacing is one of the information services that do not involve physical movement of the devices, a simple appearance may be enough for voice recognition-based mediators such as Echo.

The results of this study contribute to the HRI research by showing the effect of mediators on the evaluation of the service provided by robotic devices. Although the importance of mediators in the modern smart home household is clear [6], [7], [8], [9], to our surprise we found scarce empirical evidence regarding the effect of mediators on service evaluation. Our study provides the experimental results to settle this matter. In addition, we provide a unique contribution to marketing literature. Previously, the field of service marketing focused on the customer evaluation of human service providers. However, as new robotic products are launched and the services they provide are increasing, more research is needed to evaluate the services provided by these devices. This study investigated the services provided in a home environment by robotic service devices.

B. Practical Implications

The results of this study suggest that the developers of mediators might consider developing their products as speaker type devices. Although these results cannot be generalized because common smart speakers and social robots have more functionalities besides mediating, it might be possible that mediators provided in smart speakers may be favored over mediators in social robots such as Jibo and Pepper. Further, this study provides implications for the development of personal assistants from Amazon and Google. That is, it might be advantageous to equip these assistants to speaker type devices, rather than social type devices, given that most of these assistants' functions are information-based.

As for the physical service device manufacturers, ensuring their easy connectivity to the mediators may enhance their service evaluation. For example, more companies are providing device connectivity to smart speakers. If their products can be controlled via these smart speakers effectively, their service evaluation may improve in comparison to the direct service provision (direct user activation of each device).

Further, in the case of the design of the smart home environment, the results of the study suggest that the integration of robotic service devices may be the key to the market success of smart homes. Concepts such as robot-as-a-service [47] and ubiquitous robotics [48] also deepen the need for coherence of smart home environments. The U.S. smart speaker consumer adoption report for 2019 [23] highlights the increase in smart speaker use for smart home control and finds that a large amount of existing smart speaker users will lead to the increase of the consumer adoption of more smart home devices. Further, smart speakers equipped with far-field microphones for voice recognition will allow for complete hand-free operations with various purposes, including playing music, information retrieval and, most importantly, environmental control [22].

C. Future Work

The next step is the verification of the underlying mechanisms of each of the results obtained in this study. Regarding the effect of the mediator types on the consumers' adoption and the perception of persuasiveness, the verification of the consumers' expectations with respect to the mediators' capabilities may provide valuable insights on the effect of the types of mediators. Further, regarding the effect of adopting mediators on the service evaluation, the effect of adoption on each of the factors affecting the service evaluation enumerated by Zeithaml [37] must be thoroughly studied.

Moreover, this study focused only on the speaker and social robot types of mediators. However, other types of mediators are emerging. For example, Samsung recently revealed its homecare robot Ballie [49], which monitors the home environment through a built-in camera and controls various household devices such as smart curtains, TVs, and vacuum cleaners. It does not possess the usual social robot features such as facial expressions or actuators but, unlike speakers, it is able to move around the house. Studies on this third type of mediators will be very useful.

Further, the results of this study should be verified in a variety of home environments. The scenarios in our study were limited to the physical services of floor cleaning and toy transporting. However, services providing information such as weather forecasts or recipes should be studied in the future. In some situations, the adoption of mediators may impact the service evaluation negatively because the users' order is delivered to end service devices via mediators, and the chain of service-order-delivery becomes indirect. When immediate service delivery is needed, direct control of the robotic service device might be more appropriate. Verifying these situations and the specific services that require direct control of robotic devices may help smart device developers to improve their design. Investigating the effects of individual characteristics such as expertise on robotics, gender, and age is also promising future research avenue.

D. Limitations

Although this study provided valuable results and implications, there are remaining factors that should be addressed in the future. The scenario-based video clips approach we adopted may have prevented the participants from correctly evaluating the services because they did not directly experience them. In the future, laboratory or home environment studies in which participants directly receive services need to be conducted. Further, it is possible that the overall quality of the appearance of the stimuli affected the results as well. That is, although we adopted a commercial smart speaker in the speaker type mediator condition, we employed a prototype robot for the social robot mediator condition. In the future, services that involve more than two devices need to be studied. For example, in the realization of the Internet of Robotics Things, various devices are utilized with an integrated service and the adoption of a mediator may prove more useful here.

In conclusion, we agree with Huijinen et al. [44], that the semantic integration of ambient devices within a smart environment is a necessity. That is, both the smart home and

the robot need to be fully integrated and, thus, both aware of the status and needs of the users and the service environment. The results of the study show that the mediators can be the center of the smart home services, serving as a modern butler.

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