User Preferences of Voice Controlled Smart Light Systems

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ABSTRACT

The use of smart home devices is widely spreading. Several ways exist to control such devices. Besides classical approaches such as buttons and remote controls, voice user interfaces (VUIs) are showcased as a primary input method in the context of smart home. Yet, few studies investigated the user's behaviour and experience with such newly offered input techniques. In this research, we carried out a field study to investigate the user preferences in using a VUIs for controlling a smart lighting system. The results indicate that the usage frequency drops after the first days and that users tend to use the system mainly once in the evening.

CCS CONCEPTS

• **Human-centered computing** → **Sound-based input / output**; **Empirical studies in ubiquitous and mobile computing**.

KEYWORDS

Voice User Interfaces; Smart Home; Smart Lighting.

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1 INTRODUCTION & BACKGROUND

Nowadays, the rapid technological growth has provided different interaction modalities that could be used to control interactive systems. One of this modalities is speech input. Speech controlled application provides hands-free and eyes-free [9, 19] ways of interaction. While this has a clear benefit for users not able to interact with classical graphical user interfaces (e.g., illiterate, visual impaired, and old-generation), it also has clear advantages for other users in certain situations (e.g., while both hands are occupied).

A novel group of systems that uses this input modality are the Intelligent Personal Agents (IPAs) such as Amazon Echo[1] or Google Home[2]. IPAs are also known as conversational interface, smart speaker, or as voice user interfaces in general. Although IPAs are being currently used in a lot of households to provide different features (e.g., check the weather, play music, etc.), an in-depth understanding of how and when these systems are being used still needs to be achieved.

In this paper, we investigate the user preferences in using speech to control smart home appliances. We use Amazon virtual assistant Alexa, by which we allowed the users to control a smart lighting system.We conducted a long term user study with 10 participants.

2 SMART HOMES

In an early definition of smart homes Briere and Hurely stated that *"A smart home is a harmonious home, a conglomeration of devices and capabilities working according to the Zen of Home Networking"* [4]. Later, Porter and Heppelmann [15] defined basic components for having a smart home. The first component is the physical one, which represents the hardware (i.e., basic electrical and mechanical components). The second component is the *"smart"* component, which depicts the sensing-related elements in the system (i.e., cameras and sensors). The last component is the connectivity component, which links all the component together with the system cloud allowing the user to control the devices even outside its functioning environment.

[1] https://www.amazon.com/echo
[2] https://store.google.com/product/google_home

Recent technological advancements have resulted in an more and more increased number of home appliances getting smart features (i.e., are controllable via network) which will be further increased in the future (e.g., through smart windows [2, 3]). For this, various interfaces modalities have been explored including classical graphical user interface [5], augmented reality interface [18], and voice interface [12, 19]. Particularly voice interfaces received considerable attention as it overcomes most of the challenges addressed to the form factor of the graphical user interfaces [19].

In a controlled study, Luria et al. [11] investigated the user experience of four smart home interface modalities (i.e., social robot commanded via tangible icons and expressive gestures for feedback communication, voice-controlled speaker, wall mounted touch-screen and mobile application). Their evaluation was based on the interface usability, participants distraction, and cognitive load. It came out that the mobile application scored the highest usability score, as the participants were most familiar with its' graphical user interface, yet it had the highest distraction scores. On the other side, the wall mounted screen interface was found to be the least distracting. It was also perceived as efficient, comfortable, and straightforward. However, it had the least enjoyment and the least perceived flow. For the social robot, the scores indicated high enjoyment, engagement levels as well as the situation awareness of the home state. Nonetheless, it did not go well with the usability and the sense of control. The last interface was the voice operated which was highly favored particularly since it offers hands-free and ubiquitous control. However, the users expressed their discomfort dealing with it because they lake the sense of control.

3 IMPLEMENTATION

We focus on evaluating the user experience and usage behaviour based on a real life smart home device usage. For that, we implemented a logging application that logs all speech commands that were used to operate a smart light bulbs. In our research, we used Amazon Echo dot, which is an Intelligent Personal Agent (IPA). One of its' benefits is the ease of implementing a customized property that is known also as *skill*. We implemented a skill that allows the user to control the light bulb using simple voice commands. We added to our skill a database to record the commands that the users used along with the timing when they were recorded. We worked with three main entities in our implementation, which are the speech skill, openHAB[3] to act as a bridge between the skill's back-end and the light bulb, and Milight to communicate with the bulb hardware.

As shown in Figure 1, the scenario starts with the user triggering Amazon Echo Dot with a command like *"Alexa, turn on the light"*. Alexa listens to the request and forwards it to be processed. Overall, we implemented three different commands: (1) turn on the light, (2) turn off the light, and (3) change the brightness to X percent (e.g., 20%, 70%) or dim the light. It then proceeds to our script on the lambda function that has three main roles which are triggering the database to record the request, sending the proper action to the openHAB server running on a Raspberry Pi, and a confirmation flag back to Amazon Echo Dot which responds with a confirmation message to the user. Meanwhile, the command is received by openHAB, which links it further to the targeted feature, along with the required change. The necessary action is then forwarded to the Milight smart bulb[4] which is controlled over Wifi. This Wifi connection is the gateway to communicate the targeted commands and changes to the bulb accordingly.

4 USER STUDY

We conducted a two-week study to explore the usage of voice-controlled IPAs (i.e., Amazon Echo) to control smart lighting systems in smart home environments. The study focuses on the speech interface and how people adapt to it as a control modality for their lights.

Participants and Procedure

We recruited 10 participants (6 male, 4 female) aged between 21 and 29 years ($M = 25.20$, $SD = 2.66$) from different nationalities (five Germans, 3 Egyptians, a Yemeni, and a Lebanese). None of the participants owned a smart home light system, an Amazon Echo, or used it prior to the study.

At the beginning of the first meeting with each participant, we handed the experiment description, along with an informed consent form that they signed upon agreeing to participate. Afterward, we asked them to fill in a pre-study questionnaire that we designed to reflect the participant expectation of the technology. Then, we handed them the smart light set (i.e., Milightbulb/s, Milight iBox, raspberry pi and an Amazon Echo) with an installation manual. Participants chose the language in which they could interact with the Echo. We asked each participant to place the smart bulb in any room of her/his choice in her/his house, where they were the only one using it. We handed them as many bulbs as they needed for the lamps of their choice. We informed them that they could not only switch on/off the light bulb, but also control its' brightness. Each participant had the bulb for two weeks, where they could use it in their normal daily life, without any further instructions.

[3] https://www.openhab.org/

[4] http://www.milight.com/

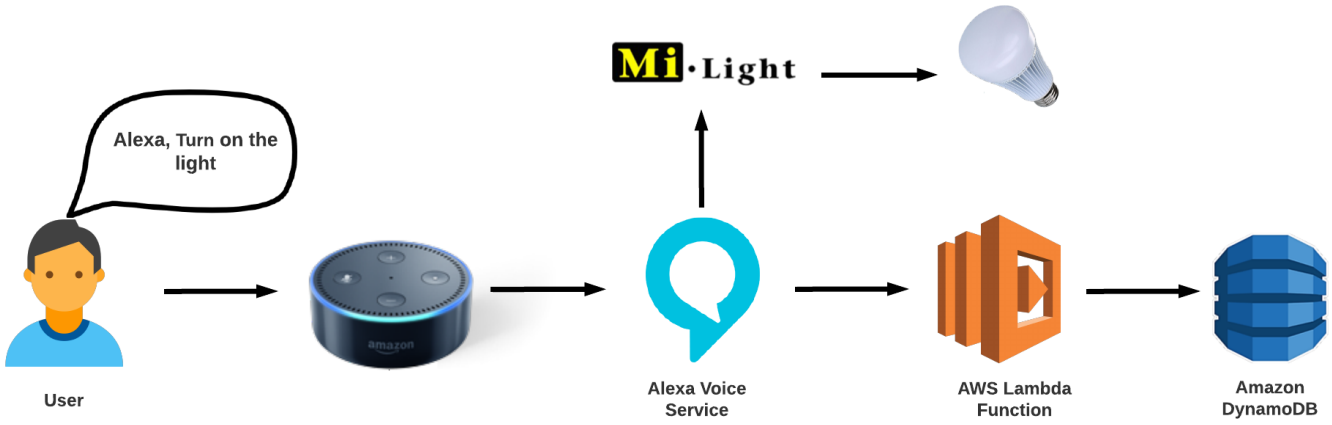

Figure 1: The system architecture, where the participant starts by saying a command as an triggering point to activate the system. Then, the command is then saved as an audio file and send to the Openhab for further processing.

At the end of the experiment, each participant answered, post-study questionnaire with similar questions to the pre-study questionnaire. Finally, we had a semi-structured interview with each participant, where each participant was generally asked about his experiences, his preferred controlling modality, and what is their future projection of such technology.

Results

In the following, we report on the results from the data logs, questionnaires, and interviews. We analyzed the Amazon echo usage frequency with respect to the time span (i.e., days, 1st week and 2nd week) and compared the usage frequency of each available command.

Quantitative Results. The logged data includes the command used (i.e., Alexa turn on/off the light, dim the light) in addition to the time-stamp, specifying the day and time.

Usage Frequency. In general, the overall mean of the number of times of which all the participants used the system is 42 times a day ($SD = 35.5$). The frequency of using the smart home light set significantly decreased from week one ($M = 59.20, SD = 41.88$) to week two ($M = 24.10, SD = 14.10$), $t(4) = -3.047, p = .038$ (see Figure 2).

Utilized Feature. We observed from the logged data which commands did the participants use most, as that would give us a better overview of the use cases. For that, we processed both the types of the logged commands and the distribution of the commands along the day. Our results show that the most commands were used between 21:00h and 23:00h (see Figure 3). With the highest number of commands throughout the day was the turn-off ($M = 34.3, SD = 20.7$), followed by

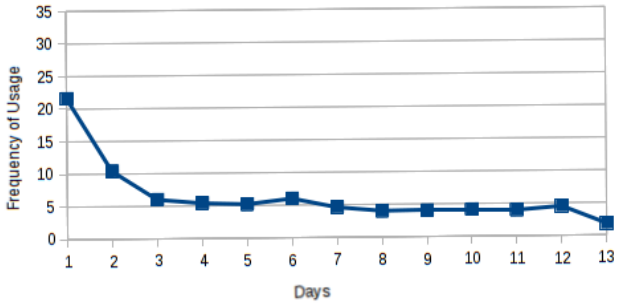

Figure 2: The mean value of the usage frequency across the two weeks testing duration.

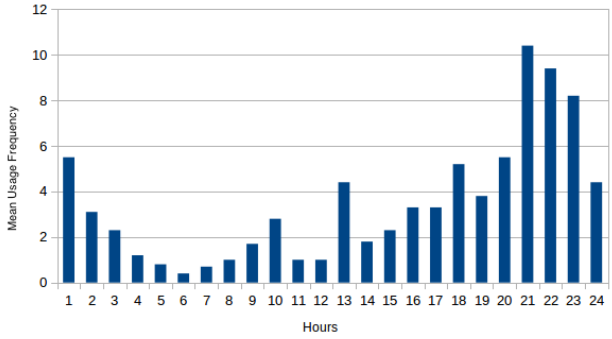

Figure 3: The mean value of the overall number of used commands, distributed across the 24-hrs day time. It shows that most of the commands were used between 21:00-23:00h.

turn on ($M = 29.2, SD = 20.7$) commands and the least used feature was the change of brightness ($M = 20.0, SD = 15.7$).

Qualitative Results. In the following, we present insights gathered during the interviews and through the questionnaires. In the pre- and post-study questionnaires, we asked the participants multiple questions about their opinion on smart home devices, whether they would like to have it,

and where they would use it most. Further, we asked which feature would they like to have for such a smart lighting system. Additionally, in the post-questionnaire, we added two questions comparing a switch with speech input.

With respect to obtaining smart home devices, the percentage dropped from 80% willing to have smart home devices in the pre-study questionnaire to 60% in the post-study questionnaire. However, regarding the Intelligent Personal Assistants (IPAs) such as Alexa, 50% slightly agreed to have it in the post questionnaire compared to 40% on borderline in the pre-questionnaire. Also, 10% increase was observed indicating speech as the way to go with controlling the smart light (i.e., 60% in the post questionnaire compared to 50% in the pre-questionnaire).

Regarding the expected usage and evaluation of our smart light system, the majority of our participants (i.e., 70%) used it in their bedrooms. As for the expected usage frequency, we noted 20% increase (i.e, 60% indicated several times a day usage in the pre-questionnaire and 80% in the post-questionnaire.). With respect to buying our smart light system, we obtained diverse answers in the pre-questionnaire with the highest percentage (i.e., 40%) indicating *slightly agree*. As for the post-questionnaire, the answers were divided into two main equal groups (i.e., 40% each) of *totally agree* and *slightly disagree*.

In the interviews, we asked the participants about our smart light system and the way they used it. The majority indicated (i.e., 70%) that it's optimum use is related to a high level of comfort-offering, as one participant explains: *"It is helpful whenever you don't want to go up and switch off the light, you wouldn't have to because you can just say it"*[P3].

With being more specific about the use case venue, 70% of the participants indicated that the best place for it is the bedroom when *"it is the most time I'm lazy"* [P1]. While others indicated different possible use cases for the speech across different appliances (i.e., sound systems, televisions, alarms, music, weather, and general daily information).

When we asked the participants about their overall impression on Alexa, 90% indicated that they liked it because it was *"helpful"*[P3], *"nice"*[P4], *"friendly and cool"*[9]. One of them further elaborated that *"even though my voice sometimes was sleepy it still understood me."*[P10]. While other related to it as a friendly human being as they elaborated *"It takes care of stuff for me, it is cool to have it in your daily life"*[P9] and even more as an entertaining companion *"I liked talking to it when I'm bored."*[P5].

Regarding obtaining Alexa, only half of the participants indicated that they would like to have it. Their main concern was security and privacy issues, as they further explained *"Although it is fun to have, it is kind of weird to have something listening to you all the time".*[P8] and in another comment *"I'm not fine with Amazon recording everything".* [P4].

5 DISCUSSION

Usage Timings and Conditions

Our results show that the usage is determined by the time, physical state and psychological mood. As most of the commands were recorded during the bedtime, where the users elaborated that they were *"too tired and sleepy to go and turn the light off using the switch."*[P3] as well as feeling *"lazy"*[P1]. The usage frequency of the different commands support this finding. Participants in the study used the '*"turn off"* command more often compared to *"turn on"* which indicates that they particularly prefer speech when they do not want to get out the bed anymore. Additionally, the fact that participants mainly chose the bedroom for setting up the system indicates a strong preference towards the usage when going to bed. Furthermore, examining the usage frequency across the two weeks, there was a significant drop in the second week compared to the first one. Where some of the participants mentioned their overwhelming first-impression of using such a device. This excitement partially faded away by time, which explains the noticeable decrease after the first 3 days of usage (see Figure 2).

Privacy and Security

Although that the majority of the users showed a high level of satisfaction using the system, only 40% of them showed interest in using IPAs for controlling their smart home in the future. When we further questioned them about why they would abstain from buying it, they cited their reasons to privacy and security issues. As one of them stated that it is *"weird"* to have something listening to you all the time. This goes in accordance with Parasuraman that people may refrain from using a technology if they don't trust it [13].

6 LIMITATIONS

We acknowledge the limitation that the testing environment was artificially set up. As the users were given the smart light set to use while knowing that it was part of an experimental study. This might have indirectly influenced their willingness to use such a system leading to an unrealistic behaviour.

7 CONCLUSION

A two-week in-the-wild study with 10 participants showed a high degree of satisfaction of using speech as a modality for controlling smart in home light. We found that users' are mainly interested in using speech input in situations in which they do not want to have the physical effort of using a wall switch (i.e., while being tired and going to bed).

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