Acceptance of Autonomy and Cloud in the Smart Home and Concerns

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Abstract

This paper presents the results of an initial survey that examines the acceptance of autonomous behavior and cloud dependency in smarthomes. In addition, this paper presents concerns on both topics. Depending on whether someone already lives in a smarthome or not, the acceptance changes.

1 Smarthomes and Autonomy

In recent years, a wide range of smarthome technology (e.g. smart speakers with digital assistants, wireless lighting systems, wireless power plugs, door locks) has become commercially available and has found its way into more and more households. It is expected that this development will continue with an increasing tendency in the coming years (Statista, 2018). Most of these smarthomes have been made incrementally smarter by integrating more and more devices over time. However, users quickly discover that devices from different manufacturers cannot easily be combined. Combining different kinds of smart devices, however, enable novel and exciting application. Hence, advanced smarthomes usually integrate the many different devices by means of central automation software, such as (FHEM, 2018; OpenHAB 2018), which support the many different interfaces and protocols and allow the devices to be automated in combination by user-defined rules.

Currently, control and automation are primarily based on such rules, which have to be defined and created in advance by someone and remain active until they are adapted or replaced by new rules. The flexibility of such rules is limited and require manual intervention when new situations or changes occur in a household. For example, the lighting behavior or the time for automatically turning the blinds may vary depending on the time of year. Inhabitants' lives may change and new daily routines may arise or existing routines may change, making changes to the automation rulesets necessary. The flexibility and adaptability of such smarthomes can be improved by automatically learning the behavior and routines of inhabit-

Veröffentlicht durch die Gesellschaft für Informatik e. V. 2018 in
R. Dachselt, G. Weber (Hrsg.):
Mensch und Computer 2018 – Tagungsband, 02.–05. September 2018, Dresden.
 https://doi.org/10.18420/muc2018-mci-0402

ants and the environment (locally or by means of high-performance cloud services) and, if necessary, with the inhabitant's consent, adapting the rules or having new ones created. Such systems are called autonomous systems. However, autonomous smarthomes must be accepted and trusted by inhabitants in order to become successful. Previous research on this topic (Ball, 2011) showed that in intelligent environments different autonomy levels are accepted differently by different people for different situations and applications. In particular, at home, where privacy is much more important than at work or in public places, autonomous behavior and its acceptance must be considered more closely. On the other hand, a growing number of people are using smart speakers with digital assistants (e.g. Amazon Echo, Google Assistant) in their smarthome, which permanently listen to the environment and thus violate their privacy. Therefore, for many people, there seems to be a balance between the advantages (and in favor) of smart technology and their own privacy. According to (Statista, 2018), 600k-800k smarthomes in Germany were forecast for 2017. Hence, many people in Germany have already gained daily experiences with smarthome technology. Our aim was to query the overall acceptance of smarthome users towards autonomy as well as cloud dependency in the smarthome by means of an online survey. In contrast to previous works (Ball, 2018), we address respondents that already have daily experience with smarthomes and with smart devices that make use of cloud services. Furthermore, respondents commented on their concerns about the two topics. The goal is to use the results of the analysis for a larger study in more countries as future work.

2 Online Survey: Autonomy and Cloud

In order to reach German participants who already live in a smarthome, are familiar with smarthome technology, or have interest in smarthomes, we placed the online survey purposefully in appropriate specialized forums (fhem.de, smarthomeforum.de, innogy-smarthome-forum.com, roboter-forum.com, microcontroller.net, funkyhome.de) and groups on Facebook (FHEM, university pages). The survey first asked for acceptance levels by choosing from a given selection and then asked for concerns, which could be entered as free text for the topics autonomy and cloud dependency. We sorted all respondents' comments and derived superordinate categories, which covered all comments. By this way, the frequencies in the categories were determined depending on whether respondents already live in a smarthome or not. In the following, we list the most frequent categories across all identified categories.

Over a period of six weeks in Dec. 2017, we received 211 responses in total (73% male) of which 52% (66% male) live in a smarthome and 48% (34% male) do not. Figure 1 shows the distribution of age groups between respondents. There is a highly significant association between the age groups and whether respondents live in a smarthome $\chi^2(5)=72.77$, $p<.001$, $BF_{01}=35.89*10^{12}$. Considering Figure 1, there is a tendency for respondents to live more often in a smarthome with increasing age. The occupations of the respondents span a very broad range, for example developer, managing director, designer, police officer, motorcar mechanic, electrician, nurse, teacher, or pensioner. Respondents had to rate on a Likert-scale (1-5, 1 means "No") whether they were technically skilled.

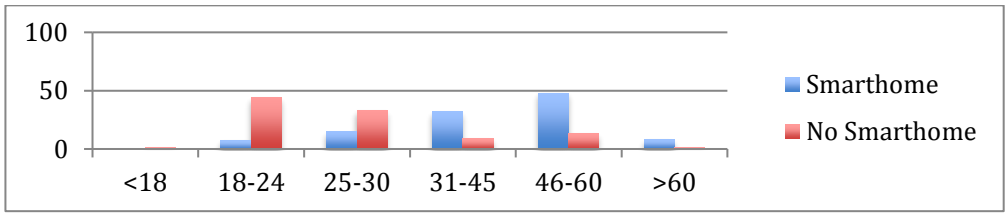

Figure 1: Ages of respondents and whether they live in a smarthome or not.

Respondents that live in a smarthome feel more technically skilled (*M=4.43, SE=0.08*) than the other group (*M=3.76, SE=0.1*). This difference, -0.665, BCa 95% CI [-0.92, -0.41], is significant, $t(191)$=-5.10, p=0.000, r=.346.

2.1 Acceptance of Autonomy

In order to measure the general acceptance of autonomy in the smarthome, the survey first described different levels of autonomy similar to those in (Ball, 2011). However, we used three instead of four levels due to two reasons. First, we believe that there are more than two levels of "semi-autonomous", which still need to be explored and determined from the daily experiences of smarthome users. Second, since we do not yet know the levels in between, the question is easier for a respondent to understand if only one "semi-autonomous" is presented to the respondent. The autonomy levels were: *Not autonomous* (fully end-user driven), *Semi-autonomous* (ruleset based, not learning), and *Fully autonomous* (system learns from inhabitants and adapts or creates rules by itself).

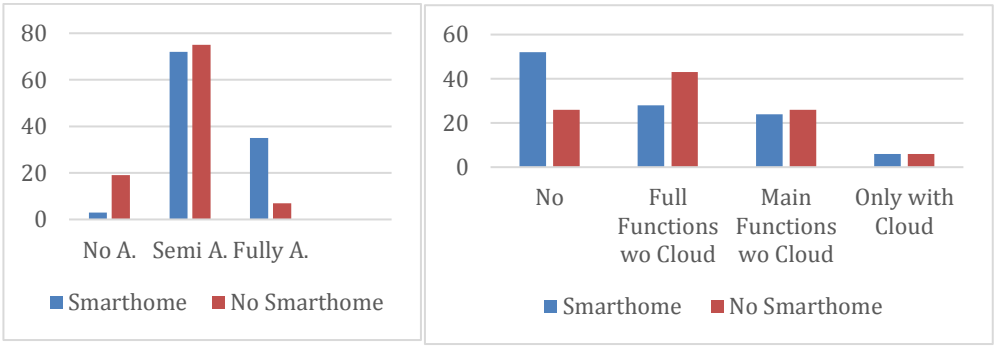

Figure 2: Acceptance of autonomous behavior (left) and cloud dependency (right).

Figure 2 (left) shows the distribution of acceptance of autonomy for the two groups of respondents. The statistics revealed a highly significant association between the autonomy levels and whether respondents live in a smarthome $\chi^2(2)=30.04$, p<.001, $BF_{01}=5*10^5$. Analysis of the comments revealed that respondents most frequently had concerns about the categories Malfunction (33.65%), Loss of control (30.33), Privacy of data (8.06%), Security (8.06%), and Flexibility (8.06%). Statistical analysis did not reveal any differences between

both groups across all categories. Respondents were also asked what kind of tasks or devices they would leave under the control of an autonomous smarthome. The most frequently mentioned categories were Heating/AC/Ventilation (53.08%), Lighting (33.65%), Window blinds (21.8%), (Vacuum) Cleaner (10.9%), Energy management/Power plugs (9.48%) and Security/Cameras/Observation (9%). Statistical analysis showed a significant association between the categories Window blinds ($\chi^2(1)=4.26$, $p<.05$), Security/Cameras/Observation ($\chi^2(1)=6.368$, $p<.05$) and whether respondents live in a smarthome.

2.2 Acceptance of Cloud

In terms of cloud dependency, the survey first explained that smart devices may work together with cloud services, for example for speech recognition, providing an overview or controlling devices when not at home. Then, the respondents had to rate on a Likert-scale (1-5, 1 means "No") whether they would accept that smart devices make use of cloud services. The statistics showed no significant differences for this rating. However, respondents also had to choose the highest cloud dependency level they would accept within four dependency levels: "No dependency" (device must not have a cloud dependency), "Full functions" (without a cloud, there are only local functions but no remote/advanced functions), "Main functions" (without a cloud, no control through network but a minimal functionality must work, e.g. switch on/off by physical buttons), "Only with cloud" (device works only with a cloud). Figure 2 (right) shows the distribution of acceptance of cloud dependency for the two groups. The statistics revealed a significant association between the acceptance of cloud dependency and whether respondents live in a smarthome $\chi^2(3)=11.55$, $p<.05$, $BF_{01}=6.7$. Analysis of the given comments showed that respondents most frequently had concerns about the categories Security (33.65%), Privacy of data (23.7%), Privacy (12.32%), Reliability (11.85%), Availability (8.53%), and Dependency on Internet (6.64%). Statistical analysis showed highly significant association between the categories Reliability ($\chi^2(1)=14.44$, $p<.001$), Availability ($\chi^2(1)=10.89$, $p=.001$) and whether respondents live in a smarthome.

3 Discussion and Conclusion

The results of our research so far show that respondents who already live in a smarthome are significantly more positive towards a fully autonomous smarthome, which learns and adapts the smarthome. This can be explained by the experience due to recurring adjustments of the smarthome. Respondents who do not live in a smarthome hardly had this experience. We also found that respondents who live in a smarthome are much more cautious about cloud dependency which is explained by the given concerns. The statistical analysis of the concerns about cloud dependency clearly shows that reliability (7.3x) and availability (8x) were mentioned significantly more often for respondents who live in a smarthome. This may be due to the stronger impact of negative experiences in a smarthome in the event of a cloud failure.

Acknowledgements: We want to thank the following students for their help with this work: Thomas Tasler, Nicolas Schwarz, Andreas Klamper, Fabio Hellmann.

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