Attitudes Towards Vertical Farming at Home: A User Study

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Abstract
Vertical farming is a promising new technology for increasing crop yields per square meter. However, little research has been done so far in people's perception of this technology. The aim of this project was to gain a better understanding of consumers' attitude on small scale vertical farming at home. This was achieved by developing a prototype that uses sensor and LED technology for growing food at home and deploying it in a user study. The prototype was built to give users a genuine feeling of what it would be like to use a small scale vertical farming system. The user study showed that the attitudes towards the system were mostly positive. However, a fully autonomous system is not desirable and there are concerns regarding food safety.

Author Keywords
Ambient Intelligence; Intelligent Environments; Autonomy and Control; Vertical Farming; Technology Acceptance; Sustainability

ACM Classification Keywords
H.5.m. Information interfaces and presentation. HCI, Miscellaneous.

Introduction
The world's population has been growing enormously from two and a half billion in 1950 to seven billion in

2014. According to the United Nations, this growth is to continue, reaching over 8.3 billion (low variant) in 2050 [1]. One of the major challenges of this rapid growth is how to feed this ever growing population. The amount of arable land – land that can be used for agricultural purposes – does not increase in step with the population. While the population is expected to grow with another 29% by 2050, the amount of arable land is expected to increase with less than 5% over the same period [2].

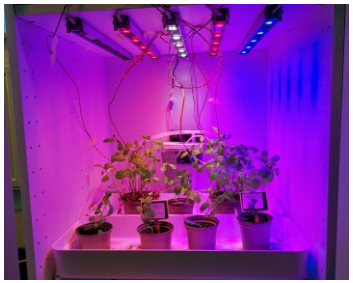
In search of solutions to sustain the earth's rapid population growth, the agricultural sector is exploring innovative food production methods to increase yields per m^2. One possible way to do this is by using vertical farming [3]. Vertical farms use sensor and LED technology to enable crops to grow in closed intelligent environments, independently from the sun and the climate. The LED light acts as an artificial sun, while sensors keep a close watch on the plants and adjust the system when needed. Because the sun is no longer needed, artificial arable surfaces can be created on top of each other or in areas normally unsuitable for food production due to lack of sunlight or unsuitable climate.

Vertical farming is a relatively new method and the amount of research is therefor limited. Current studies look towards large scale implementations [3][4]. However, little is known about small scale vertical farming. It is possible to use vertical farming technology on a smaller scale, for example at home. When vertical farming is used at home, consumers can contribute in a small way through creating more arable land and the production of sustainable food.

However, small scale vertical farming at home brings challenges. Firstly, there is little known about the attitude of consumers towards acceptance of vertical farming compared to technology-based food innovations, which are generally received with a lot of skepticism [5][6][7]. Technology-based food innovations create new products, for example by genetically manipulating organisms [5]. One of the major concerns of the new products is food safety. Although it is not the only determinant of a product's quality, consumers tend to apply certain safety considerations to specific technologies. These considerations could severely delay the adoption of the technology in question [8][9].

Despommier suggests that vertical farming would not have to suffer from these safety considerations. All the food grown by using vertical farming can be grown organically and will greatly decrease the risk of infectious diseases for plants [10]. This is how vertical farming differs from most technology-based food innovations, like genetically modified foods or food irradiation, which actually alter the food [7] and create new products. Tenbült et al. suggest that if a product becomes perceived as less natural after genetic modification, the less it will be accepted [11].

Secondly, there are challenges in determining the conditions for acceptance of an intelligent environment for small scale vertical farming at home [12]. This second challenge formed the basis of this paper, in which we aim to investigate consumers' attitude towards using small scale vertical farming systems at home.



Figures 1 & 2 : The prototype deployed in the user study

For this purpose, a user study was conducted. The study's first focus was on consumer attitudes towards using the technology of vertical farming for the natural process of growing plants for produce. The study's second focus was the interaction between the user and such a vertical farming system.

Before presenting the methodology and results of the study, we will first elaborate on the process and methods used. In the last part of the paper, the results of the user study will be discussed.

Related Work

Utilizing a small scale vertical farming system at home means using an intelligent environment. Over the years, a lot of research has been conducted on the acceptance of such context-aware systems. Kaasinen et al. [12] list several factors, which play a key role in achieving acceptance. The most notable factors for this user study are trust, the sense of being in control and usefulness, which is confirmed by Davis [13].

According to Misker, Linderberg and Neerincx, users are willing to invest more time in exchange for control over a system [14]. Friedewald et al. [15] confirm that the ideal application of ambient intelligence is a delicate mix between autonomy and self-control. They conclude that: "*It is certainly not desirable to aim at a full automation of the home with ambient-intelligence applications*" (p. 236). Full automation is perhaps something that is impossible to achieve. In fact the more we try to get systems to act on our behalf, the more we have to watch every move they make, according to Belotti and Edwards [16]. They continue by stating: "*Effective control is not simply about whether the user is intimately involved in execution . . . it is more a matter of how easily the user attains the desired outcome*" (p. 208).

In an essay titled "Questioning Ubiquitous Computing" Araya points out that the marginality of the enhancement plays a critical role in acceptance; if the relevance of a product compared to the necessary investment is too low even the most wealthy will not buy your product [17].

These investigations mentioned above provide guidelines for designing an intelligent environment. The challenge appears to lie in the fact that a user should trust the system to be intelligent enough to take care of your plants – and therefore be considered useful – yet still give the user a sense of being in control. The prototype should help in defining this fine line between desired control and automation in case of a small scale vertical farming system.

System Overview

The basic prototype used for study was provided by the Urban Technology research program of the Amsterdam University of Applied Sciences contained five Philips GreenPower LED research modules – two deep red, one red, one blue, and one white – mounted inside an IKEA kitchen cabinet. While the red and blue lights are essential for plant growth, the white light predominantly provides better vision for the user. A water pump for automatic irrigation was present as well as an electric fan for ventilation of the system. The prototype was then transformed into an intelligent environment. The conversion towards an intelligent environment was achieved by adding sensors and an Arduino microcontroller.

To know whether a plant is in need of water, a set of soil humidity sensors were installed. Two light dependent resistors were added as a control to see if the lights are on or off. An ultrasonic sensor measures the amount of water in the water reservoir, while a series of graphite based sensors measure the presence of water in the plant trays. These pins provide a check to see if there is still water available for the plants to soak up before turning on the pump to add water to the trays. The temperature and humidity were being monitored, when these reach a certain threshold the fan is turned on automatically. The various data was collected and sent via a Wi-Fi module to a database.

Method

In order to address the question of *what the consumer attitude is towards using small-scale vertical farming systems at home*, twenty-one interviews were held around the university area and at an event on the topic of sustainability. At the university, the participants consisted out of students and teachers, while at the sustainability event the participants were of a more diverse background. The mean age of the participants was thirty years and the gender distribution was fourteen male and seven female.

The interviews, consisting of nine questions, provided a deeper understanding of the user's attitude towards using an intelligent environment for vertical farming intended for home usage. Each interview could be divided in two different segments, the first consisted of a series of questions aimed at getting a better idea of the interviewee's interest and experience with both technology and growing plants for produce. The second segment was aimed at the user's perception of the prototype. During the second segment of the interviews, participants were asked to interact with the prototype and perform certain tasks, for example placing a humidity sensor in the soil. These questions focused on the need of being in control and how the user perceived the product compared to more traditional ways of growing plants for produce.

Results

Of the twenty-one people that participated in the interviews, four said they simply did not want to take care of plants. These four people have been excluded from the results because they do not form part of the target audience, leaving a total of seventeen participants. From the seventeen remaining participants thirteen had experience, in various degrees, with growing plants for produce.

When asked about the main issues, three participants answered that they sometimes feel to lack the knowledge to properly take care of their plants. A bigger problem though, seemed to be lack of time, which was mentioned by nine of the participants. Two out of these nine participants indicated that, as a direct result of this lack of time, they sometimes forgot to take care of their plants. From the four participants who never grew plants for produce, three said their main reason was the lack of time.

Even though time was a major issue, a majority would still prefer to perform the tasks in taking care of a plant themselves, instead of letting the system completely take care of it. The results suggest that the more experienced a participant considered himself, the less likely the system was allowed to take care of their plants. A reason a number of participants gave was that they like being a part of the cultivation process; it

gives them a sense of fulfillment and achievement when it is time to harvest. They are afraid that a fully automated small-scale vertical farming system might lower their involvement in the process. However, several participants suggested they would like to use the system as a backup, should there be a time when they would be unable to take care of the plants themselves. Twelve of the seventeen participants indicated that they would get plants for produce sooner if they had a backup system for their plants.

The presence of the sensors did not feel unnatural for the participants. Only five out of seventeen indicated it felt strange to be working with sensors and plants. The most common explanation given was that technology has become more prominent over the last few years. Out of the five participants who replied that they found the experience with the prototype unnatural, the majority indicated that this was largely caused by the fact that the plants were inside a small closed cabinet. The sensors were not the main reason, though the sensors did enhance the unnatural feeling. These participants said they felt the plants had to be more visible and felt plants needed to 'breathe in the open'. Only four out of seventeen participants said they had the idea they were mainly working with technology instead of plants. Four participants indicated that for them it was hard to determine whether they were working with technology or plants.

When asked whether the participants would be interested in having a product similar to the prototype at home the response was mostly positive, but almost all of the participants who showed interest had demands or conditions that had to be met before actual purchase would happen. Only two out of seventeen said they would buy it without a doubt, while most others mentioned the price as an obstacle. At the moment, participants feel the benefits they gain by growing their own plants for produce does not justify the costs. The quality and in some cases safety of the food was also a factor of uncertainty for many. In the end, for six out of seventeen participants the main reason of using a vertical farming system at home was to try out a new technology.

Discussion

Even though no generalizations based on the current research are possible, this user study showed that consumers are not afraid to let smart urban farming technology into their homes. The use of technology in the everyday environment seemed to be perceived as normal within the group of participants. During the cultivation process the presence of technology did not seem to be an issue.

The sensors did not lead to an increased unnatural feeling when working with plants. The design of the prototype appeared to be a more important factor. Closing off plants inside a system and removing them from sight created a feeling of disengagement between the user and the plants. Clear visibility of the plants should be maintained in order for the user to have the feeling that the plants are still natural. More research should be done on how to develop a prototype that provides a more natural feeling to increase acceptance.

The fact that a slight majority indicated that they would still prefer to perform the tasks in caring for a plant themselves, underlines the importance of a sense of control. In order to maintain such a level of control, a small-scale vertical farming systems should mainly

work as a control mechanism. A fully autonomous system did not offer the desired sense of control for many of the participants, which corresponds with Friedewald et al. that full automation is not desirable [15].

The interviews were focused on technology and interaction and did not contain questions on food quality, however the topic repeatedly came up when people were asked if they were interested in similar systems as the prototype. Participants showed to have concerns about food safety and nutrition values, comparable to the concerns mentioned in the Eurobarometer survey [18]. Even though vertical farming does not alter the food itself, the results of this user study suggest that it shares the same skepticism as with technology-based food innovations.

One of the main questions that can be derived from this study is whether a system such as the prototype deployed in this user study, is a viable product in the long run. While the overall attitude was positive and participants seemed interested in the concept, they also had many conditions that need to be met before they would actually consider buying a vertical farming product for usage at home. Even more, people seem to be interested in the technological phenomenon of vertical farming, rather than actually using it as an alternative to buying food. The question so arises: Do people view the small-scale vertical farming system purely as a gadget, which can be easily discarded as soon as a new, more interesting product arrives?

Also, more research needs to be done to uncover whether combining a variety of plants inside one generalized climate will affect the plants in any way. As all plants have their own specific needs, it remains to be seen if using one climate proves sufficient for high crop yields. If yields are not high enough, it could have an effect on the marginality of the enhancement as described by Araya [17].

Conclusion and Future work

The focus of this user study was to gain a better understanding of consumer attitudes towards using small-scale vertical farming systems at home. The study has shown that consumers are not likely to have an issue with the technology involved in vertical farming on a small scale. Yet, it appears that there are concerns around food safety and costs for obtaining a small-scale vertical farming system. The next steps are to conduct more research on the acceptance of vertical farming on a larger scale, and a follow up user study with a larger population. Furthermore, the results published in the paper provide sufficient ground for more research on making improvements in small-scale vertical farming systems and studying the issue of automated systems and control.

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