Towards Compromise User Experience Design in Ambient Intelligent Environment

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Abstract

Building, testing and evaluating UX for applications for Agricultural Ambient Intelligence Environments can be a difficult and time-consuming job. It can be an even longer and more challenging process due to their complexity and area of scope for complex intelligent systems. Many studies address the issue of UX design and evaluation of website user interface, mobiles, tangible equipment, wearable equipment and other, but it is necessary to look for UX deficiencies in all possible functions, every possible task. Depending on the structure of expert teams, experts' opinions can vary broadly vary or may even contradict. This paper presents possibilities of use the Best-Compromise-Mean (BeCoMe) method for evaluation UX design. BeCoMe was not used for UX evaluation yet. Verification of whether the BeCoMe method is suitable for UX evaluation is carried out on a tablet using two prototypes of control panels of an intelligent environment.

Keywords

User experience, interaction design, user interface, eye-tracking, BeCoMe, usability.

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Introduction

One of the main goals of the user-controlled software should be always a high user usability. Due to the diversity and different user experiences user interface design is a complex and often time and money consuming discipline. In the field of ambient intelligent systems, the demands on the user interface increase even more, because the systems can be controlled in various ways: by voice, movement, touch or keyboard.

The use of Ambient Intelligent Environment in agriculture or as a support for life in the countryside is actual and current topic. After Smart Cities, Intelligent Landscape, ie Agricultural Ambient Intelligence, is one of the next evolutionary steps. Fully autonomous or semi-automatic agricultural technology is now a common feature of agricultural companies. With the development of IoT devices and other sensor technologies, a large amount of data is available that can be used to support decision-making, forecasting or safety in agriculture or planning within municipalities. With the amount of this data and the demands on the simplicity and intuitiveness of the interface through which users communicate with ambient systems increase. In this case, the communication is two-way, ie not only from the user to the system, but the ambient systems actively communicate with the user. An important aspect that needs to be considered is the different experiences of the users who interact with the given systems. Communication and reaction in every direction must be clear enough. In the field of agriculture, the harsh environment (eg dust, dirt, moisture) in which communication terminals can be located is also an aspect.

Users make decisions based on previous experience when communicating with smart environments. These decisions are the first step in user interaction with the system. Interaction with a contemporary technological system goes far beyond usability, extending to one's emotions before, during, and after using the system, and cannot only be understood through research into the fundamental usability, attributes of efficiency, effectiveness, and satisfaction (Ntoa et al., 2021). Researchers in their endeavor are trying to answer what makes technology usable and user-friendly with a positive effect in intelligent environment (Augusto et al., 2010; Rymarczyk, 2020, Norman, 2013; Bibri, 2015; Ntoa et al., 2019). The growing possibilities of digital technologies allow using their advantages successfully both in business and private purposes (Kovacs & Vamosi Zarandne, 2022; Roshchyk et al., 2022). The objective of intelligent environments is to support users; as such, a main thrust of research should emphasize whether and how this goal is achieved, while in this context it is important to consider the implications of user evaluation (Augusto et al., 2010). Interface in intelligent environment needs to react in a way that feels logical, natural, helpful, and most importantly focuses on one´s individuality.

When the interaction target is not merely a technological system or application, but a whole intelligent environment, the measurement of UX becomes difficult (Hartson et al., 2012; Ntoa et al., 2021). It is appropriate to use a multimethod evaluation approach to evaluate user experience in intelligent environments, as it is not simply a matter of adhering to specific guidelines by individuals, but about the functioning of the whole intelligent system about identifying potential problems and solving them (Ntoa et al., 2021). The limitations of current evaluation methods are that they are target only on one application or web site, but intelligent environments are big cooperating systems. There is a need to search for UX flaws in all possible features every possible task, every possible screen etc. and it is not an easy task. Systems are also affected by many circumstances that make planning and decision making in the system difficult. Decision-making procedures are therefore often based on the options of experts who express their views, each from their own perspectives (Vrana et al., 2020). Using the BeCoMe method (Best-Compromise-Mean method), it is possible to find the optimal decision in group decision-making that corresponds to the best agreements (conformity) of all experts. The optimal decision is the result of a computationally complex fuzzy mathematical model (Vrana et al., 2020). The BeCoMe method was demonstrated in a case study about decision making COVID-19 (Vrana et al., 2020). It also has applicability in various other fields where a problem needs to be decided as agriculture economics and management, decision making in field rural development, drought/flood measures, energy self-sufficiency issues, IT contracts and etc.

Krug (2010) stated that users do not read but view, therefore the first impression is often the most important thing, and we agree. What users view can be tracked using the Eye-Tracking method. Eye-Tracking is a method used for evaluation UX design to record the participant´s eyes movement during an experiment while solving a given scenario. Recording is performed using a special device (eye-tracker). It determines which places on the screen the participant focuses on the most and for how long (Berger, 2019; Holmqvist et al., 2015). It is assumed that human works cognitively with what they see. The main advantages of using Eye-Tracking are the possibility of obtaining data in real time, where fixations directly correlate with how a person works with information cognitively (Orquin and Mueller Loose, 2013). In particular, in research on decision-making processes, it is considered as useful tool for examining various aspects (Brunyé and Gardony, 2017; Zuschke, 2019). To better understand cognitive decision-making processes, it is therefore necessary to combine Eye-Tracking with other methods that will help to understand the broader context of the participant's actions and allow validation of the data obtained by Eye-Tracking (Gidlöf et al., 2013; Berger, 2019). Eye-Tracking can be combined with the questionnaire for example.

The purpose of this paper is to verify whether the BeCoMe method can be used for UX evaluation.

Related work

Rapid development of new technologies in all areas of living; from applications, facility management, smart homes to smart cities or smart rural areas is reflected in high demand on the quality of user interfaces used to control devices. Methods for usability research and UX, the level and integrity of the collected metrics also constantly growing, leading to the possibility of an even more detailed understanding of user behavior (Çakar et al., 2017; Oguego et al., 2019).

The evaluation of user interface quality is an integral part of the design process (Johnson, 2010; Preece et al., 2011). Existing testing and evaluation methods of UX are for example: User Testing, Cognitive Walkthrough, Feature Inspection, Heuristic Evaluation, Split–Run Testing, Card Sorting, Eye-Tracking, Co-Discovery Learning, Performance Measurement, Question-Asking Protocol, Retrospective Testing, Thinking-Aloud, Focus Group, Field Observation, Interviews, Logging Actual Use, Questionnaires, Surveys, A/B Testing, Personas, Prototype, Standards Inspections etc. (Hartson et al., 2012). Depending on the circumstances, it is important to choose the appropriate method of testing and evaluation.

Nielsen (1993) wrote that Thinking-Aloud method may be the single most valuable usability engineering method. With this method, users can explain their intentions, what they are doing or are intent on doing, and their motivations, the reasons why they are performing any particular action, with this method. Additionally, the think-aloud technique can be used to assess emotional impact since an individual's feelings are internalized and this is what the technique allows access to.

Xu et al. (2007) focused on evaluating of tangible user interfaces for children using Think Aloud method, Peer Tutoring. Evaluating of UX by children must be approached differently than by adult participants. They found it crucial in what environment the evaluation takes place. They use a new method called Drawing Intervention, which helps them to get more information from children who could not find out by classical methods. The method is based on the fact that children draw anything related to what they have done and learnt so the evaluators involve the children in discussions about previous activities.

Schall (2015) focused on Eye-Tracking evaluation of UX on large-scale displays. He studied layout of elements on the screen of financial television networks, such as a main content, a dedicated box for news stories and stock information on one large-scale display.

Rim et al. (2013; 2017a) presented a usability evaluation of adaptive web interface which focuses on how users can learn to achieve their goals. They present adaptive web interface using a Bayesian networks approach to make inferences about the preferences of users. They found that Bayesian networks can be used to represent uncertainty in user modeling (Nguyen, 2009) and can be effective in diagnosing a user´s preferences. Later on, Rim et al (2017b) used a GOMS model approach to evaluate their adaptive web interface. A similar approach is developed by Lamminen et al. (2021) in their D-TEO method to analyze the information about the performance of users and diagnose problems and deficiencies in Web page designs.

The GOMS model approach proposed by Card et al. (1983) is widely used among usability specialists for computer system designers because it provides quantitative and qualitative predictions about how people will interact with the system. It is composed of methods that are used to achieve specific goals. A user performs specific steps (goals), which are assigned a specific execution time. It consists of four constructs: goals, operators, methods, and selection-rules (Card et al., 1983; John et al., 1999, Rim et al., 2017). When there is more than one way to achieve a goal – i.e., alternative methods are available – a selection rule must be used to decide between them (Card et al., 1983). The GOMS is not only specified for human behavior but can be used to specify the behavior of animals or smart devices (Freed et al., 2000).

Many approaches seek to define how a smart environment should be designed and evaluated. The nature of interaction in intelligent environments shifts from explicit to implicit, encompasses new methods of interaction, and extends from one-to-one interactions to many-to-many interactions (Stephanidis et al., 2019).

Vegas-Barbas et al. (2017) defined a set of interaction patterns, which were validated by end users through an informal discussion and concluded that patterns were adequate to cover the needs of the design of intelligent environments. Interaction in intelligent environments also include thing-to-thing interactions, which introduce additional concerns regarding conflicts resolution, interoperability, and consistency of interactions (Andrade et al., 2017).

Pavlovic et al. (2020) suggested using storytelling videos to communicate user values and design scenarios to stakeholders, and to generate proposals based on five factors (context of interaction, required system data, sensor input, user input, and desired output). De Carolis et al. (2012) propose a framework for recognizing user´s social attitudes in multimodal interaction in smart environments.

Ntoa et al. (2021) suggested a framework called UXIE which foresees the evaluation of seven fundamental attributes, namely intuitiveness, unobtrusiveness, adaptability and adaptivity, usability, appeal and emotions, safety and privacy, as well as technology acceptance and adoption.

User interfaces are available for different purposes and have different target groups. Every kind of UI should be designed according to the specific design conventions and knowledge of the users (Johnson, 2010). Pastushenko et al. (2019) wrote that the design guidelines might not be applicable in a general way, that UI elements should be adjusted according to the requirements of the chosen UI type and those of its users.

No existing evaluation method can serve every purpose and each has its own strengths and weaknesses (Hartson et al., 2012).

Materials and methods

Design of prototype of control panel

Before designing user interface, the following was considered:

Question	Recommendation
How will users interact with an intelligent environment when voice control doesn´t work?	Touch control via tablet.
What functionality user wants?	Easy to use, usable, understandable, accessible.
Which features and behaviors of the user interface will the user expect?	The user interface must respond promptly, without long animations or visual effects
What size is an adequate size for UI elements for interaction?	Size of icons and text should be changeable.
What fonts are easy to read in this UI?	Sans-serif fonts are recommended.
What uniform terminology will be used?	All titles of elements should be consistent across the whole application.
What information will be provided to let a user know what will happen before they perform an action?	The application must communicate clearly and intelligibly with the user and all important actions must be confirmed.
What feedback will get a user when an action is performed? And for how long?	All action must have a visual response on the screen.

Source: author

Table 1: Questions before designing UI.

A well-chosen arrangement of central control components should improve the user's rapid perception and processing of data (Vegas-Barbas et al., 2017).

Two prototypes of user interface designs for control panel of an intelligent environment applicable for a tablet were created (Figure 1, Figure 2). The layout, shape, order and text location of components in each UI is different. The background of prototype B is darker than prototype A. The design and placement of main control elements is different on each prototype. As a background for each prototype a neutral and positive background was selected.

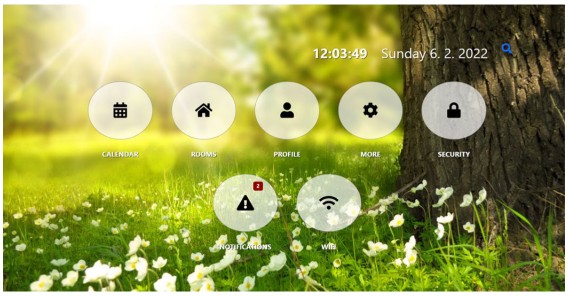

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Figure 1: Prototype A.

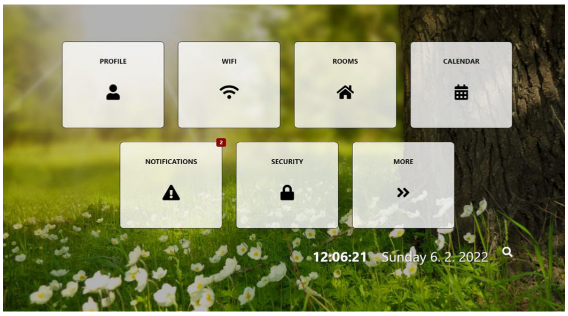

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Figure 2: Prototype B.

Participants

Fourteen participants were divided into two groups according to previous evaluation experience (Table 2). Seven of them have experience with evaluation. Therefore, both groups had seven participants. In each group was one woman. Age of participants was 26-48 years. Participants were testing the two designs of prototypes. All had good previous experience with information technology.

Evaluation used in prototype testing

A small-scale study was conducted to evaluate the prototypes of UI of a smart environment. The following methods were used to evaluate which layout is better: a) Eye-Tracking method with additional discussion about prototypes after testing. Testing was performed in the Usability laboratory in HUBRU (Human Behavior Research unit) at Czech University of Life Sciences in Prague; b) on-line questionnaire with twelve questions using the Likert scale which was evaluated by BeCoMe. The BeCoMe method has not been used for evaluating UX design by researchers yet.

Existing questionnaires were modified for this

Group	Experience with evaluation	Evaluation method
1	Possible users of systems - no	Eye-Tracking + discussion about prototypes
2	Experts for UX - yes	BeCoMe (questionnaire using of the Likert´s scale)

Source: author

Table 2: Division of groups.

evaluation (see Appendix 1). The questionnaire was inspired by SUS - System Usability Scale (Brooke, 1995) and QUIS - Questionnaire for User Interface Satisfaction (Shneiderman, 1987). Modified questionnaire with Likert´s scale was used in both methods.

Results and discussion

Our approach attempts to determine whether it is possible to use the decision-making method BeCoMe in the UX evaluation to support the choosing the best layout of components in the design of the control panel for an intelligent environment.

Each participant tested three scenarios. The results were evaluated by the Eye-Tracking method and the BeCoMe method.

Participants imagined a situation in which they came home and saw a red light, i.e., there is a problem with the control of intelligent system by speech. They had to control it through a control unit (in our case a tablet).

Results of Eye-Tracking testing

The participants had a goal to find out what happened to the system (find the error).

The participants easily found where the notification informing them about the system problem was in both prototypes (Figure 3 and Figure 4). Eye-Tracking results for prototype A show, that two participants first looked at a calendar, but they could not explain why.

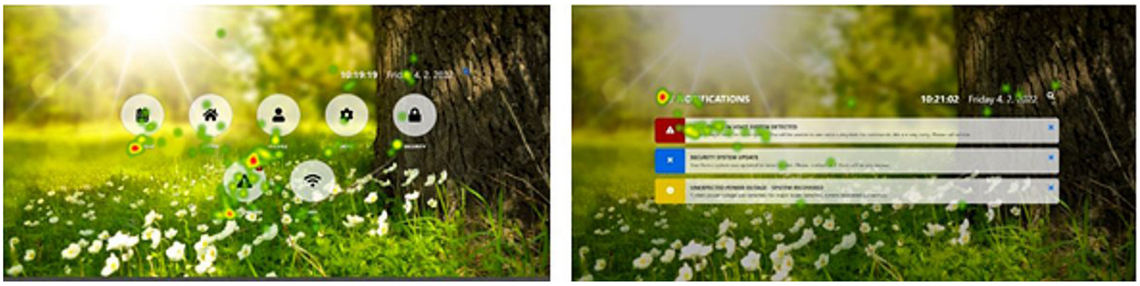
The participants were to look at the calendar and enter a new event.

Participants went through the scenario without any problems in both prototypes (Figure 5, Figure 6).

The participants were to set the temperature in room no. 2 to 22 °C

Participants managed the scenario without any problems (Figure 7, Figure 8). A participant did not immediately notice where the room selector was.

After Eye-Tracking testing, each participant discussed their experience with the prototypes. Both prototypes were easy to use by the participants, but they liked prototype A more. Also, seven out of seven participants expressed that the design of components in prototype A is more attractive. They confirmed Krug´s claim (2010) that they didn´t read, but only looked at the icons. They thought those were well chosen because they understood what the system would do. They didn´t have a problem either with the font size or with the terminology used or with the orientation of elements. All of them completed given scenarios.



Source: author

Figure 3: Test scenario no. 1, prototype A.

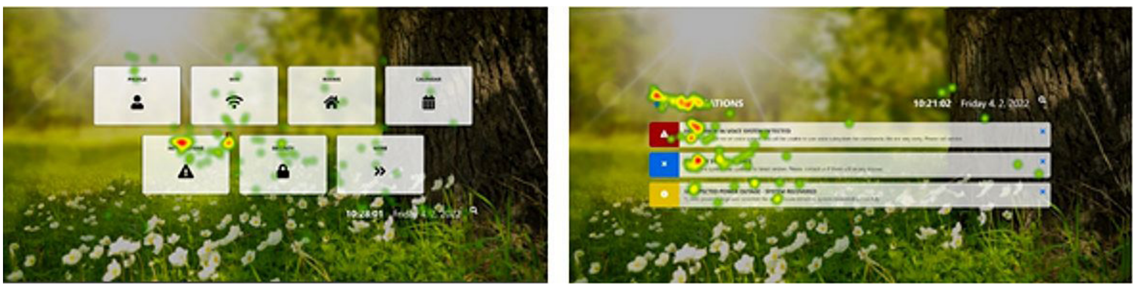


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Figure 4: Test scenario no. 1, prototype B.

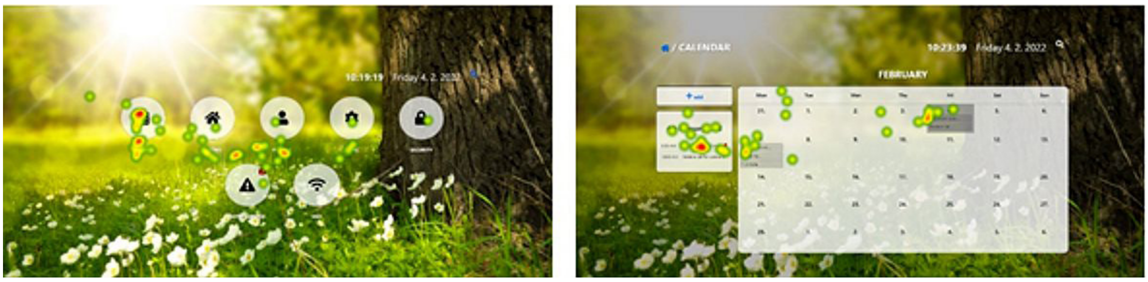

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Figure 5: Test scenario no. 2, prototype A.

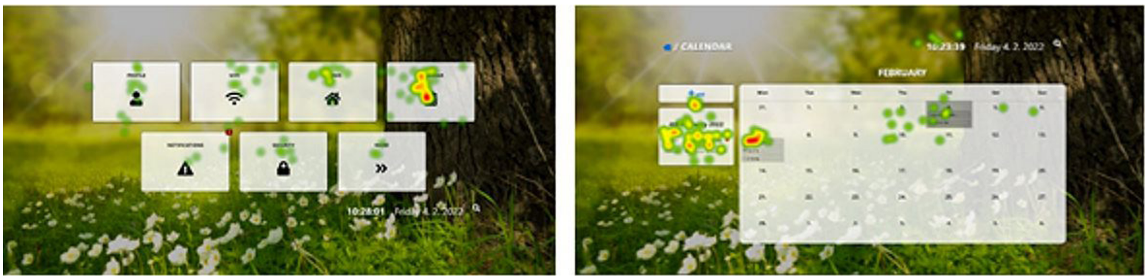

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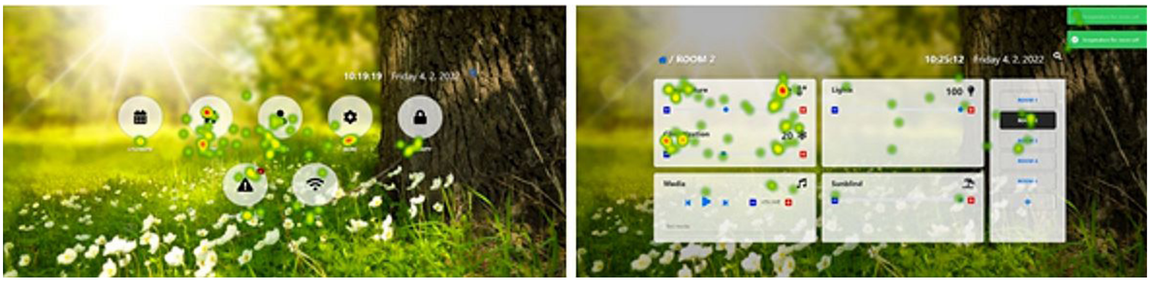
Figure 6: Test scenario no. 2, prototype B.



Source: author

Figure 7: Test scenario no. 3, prototype A.

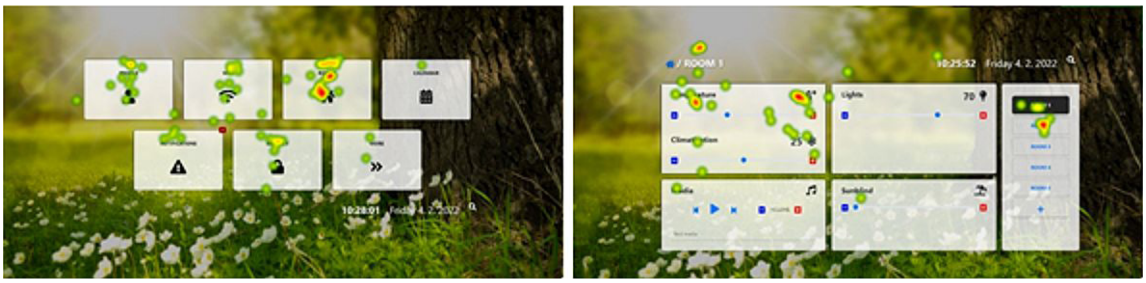


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Figure 8: Test scenario no. 3, prototype B.

Result of BeCoMe evaluation

Participants filled in questionnaires with twelve questions using the Likert scale for each prototype. For evaluation of questionnaires was used the BeCoMe method tool. Results of questionnaire for prototype A were better than for prototype B (Table 3). Both prototypes contained answers only in values not sure, rather yes, definitely yes. Negative values participants didn´t use.

The result of both methods Eye-Tracking and BeCoMe came out the same – prototype A is better. Therefore, it can be concluded that the using of the BeCoMe method in UX evaluation is possible. In the Table 4 we made a quick comparison of both methods.

Question	Prototype A		Prototype B	
1	76.79		98.21	1
2	94.64	1	71.43	
3	94.64	1	96.43	
4	76.79	1	73.21	
5	80.36	1	55.36	
6	92.86	1	78.57	
7	75.00		80.36	1
8	92.86	1	80.36	
9	92.86		94.64	1
10	100.00	1	94.64	
11	98.21	1	94.64	
12	98.21	1	78.57	
Sum of better result		9		3

Source: author

Table 3: Results of using the BeCoMe method tool.

	Eye-Tracking method with discussion	Questionnaires with Likert scale evaluated by **BeCoMe method**
When use?	In the planning phase. In the development phase. When redesign UI.	In the planning phase. In the development phase. When redesigning UI.When a decision is needed.
Place of evaluation	Lab with equipment for Eye-Tracking	Real environment – PC with Excel
Output data	Qualitative	Qualitative
Number of users/experts in our experiment	7 (6 men, 1 woman)	7 (6 men, 1 woman)

Source: author

Table 4: Comparison of both methods.

Conclusion

In the article, we presented if the BeCoMe method can be used to evaluate UX design. A common way of evaluating of an interface is to let users try out the interface and analyze how well they are able to perform selected scenarios. User testing can provide useful feedback, but mostly it is quite expensive in time and effort and financially if it is done in specialized laboratories. According to this small-scale study, it seems that the BeCoMe method can be used to evaluate UX design. In order to be able to state that the BeCoMe method can 100% replace the proven methods used to evaluate UX design, more extensive testing needs to be performed. Based on the information obtained within this study, we conclude that the BeCoMe method can be used as a complementary method to support the results of another evaluation method and can reduce costly laboratory testing.

Another finding which came from Eye-Tracking testing in the first scenario was that two participants looked at the calendar icon first instead of the notification icon. They couldn't explain why. We assume it could be because of the order of the icons on the screen of the prototype or it was just coincidence. Further testing is needed to verify why this occurred.

Although findings in this work are generally applicable the main goal was to prove that the BeCoMe method is usable as an effective method for UX evaluation in Agricultural Ambient Intelligence Environments. The main issue of those systems is the wide audience of users with different experience that can interact with those systems. Also, the main factor is a harsh agricultural environment which can limit commonly usable ways of communication. All those factors have impact on time and money spend to develop proper UX. Cost and time effective UX evaluation of those systems by experts with BeCoMe support is very promising.

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Appendix 1

QUESTIONAIRE USED IN BeCoMe METHOD

Evaluation criteria (Likert scales): 1 = definitely not, 2 = rather not, 3 = not sure, 4 = rather yes, 5 = definitely yes.

1. The system has a logical arrangement of components.
2. The system is consistent.
3. Overall, I am satisfied with how easy it is to use this system.
4. The visual design is attractive e.g., colors, shapes, layout.
5. I like the graphic elements of the system.
6. The font size is right for me.
7. I understand all the functions of the system.
8. Orientation in navigation is intuitive for me.
9. I simply find the required system functionality.
10. I am able to complete my tasks using the system.
11. It is easy to find the information I need.
12. Terminology is understandable.