Perceived Usefulness and Perceived Ease-of-Use of Ambient Intelligence Applications in Office Environments

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Abstract. This paper describes a multi-national study evaluating the perceived usefulness and perceived ease of use of Ambient Intelligence (AmI) applications in office environments. In a first step, existing usage scenarios were analyzed to identify characteristic functionalities and application domains. The identified core functionalities were integrated into a representative and coherent evaluation scenario, which was presented to a target user population in a questionnaire-based study. The results of the study indicate, that the participants regard the described Ambient Intelligence functionalities as rather useful and easy to use. Nevertheless, moderate overall ratings for both factors show, that the acceptance of AmI technologies is not as high as often argued.

Keywords: Ambient Intelligence, Ubiquitous Computing, Pervasive Computing, Technology Acceptance, Study, Perceived Usefulness, Perceived Ease-of-Use.

1 Introduction

Over the last few years, companies started to show increased interest in deploying Ambient Intelligence technologies in office environments. From an economical point of view, high innovation pressure forces companies to adopt emerging technologies in an early stage in order to be competitive [18]. However, the integration of new technologies in existing business processes and work environments is always associated with high financial investments. When companies invest in new technologies and spend great amounts of resources into its integration, they usually expect a considerable increase in productivity, efficiency, and long-term benefits [3]. But in order for these benefits to occur, it is necessary, that the technology is used and also incorporated into the daily routines of the employees [29]. Empirical evidence shows, that one of the main reasons for low returns of investment is the poor usage of the installed applications (see, e.g., [6], [7] or [15]). In most cases, the potential of the implemented applications is not fully realized, due to the unwillingness of users to accept and use the systems [5]. Hence, it is important to evaluate the acceptance of future applications in an early stage of the design process in order to identify potential problems and implement appropriate countermeasures.

M. Kurosu (Ed.): Human Centered Design, HCII 2009, LNCS 5619, pp. 1052–1061, 2009.

2 Technology Adoption

Predicting the adoption and use of information technology has been a key interest since the early days of information systems research [8]. The main goal of technology acceptance theory is, to explore the factors that influence the adoption and diffusion of new technologies throughout a social system [4]. Over the years, several independent theories for the acceptance as well as adoption of information technology have been developed. One of the best-established models of IT adoption and use is the Technology Acceptance Model (TAM) developed by Davis [13]. TAM is a further adaptation of the Theory of Reasoned Action (TRA) [16]. But while the Theory of Reasoned Action is a general theory of human behavior, TAM was specifically designed to model user acceptance in information systems [27]. Similar to most technology acceptance theories, it is assumed, that users could choose to employ a specific technology based on individual cost-benefit considerations (see [12]). The Technology Acceptance Model presupposes, that two particular constructs determine the user's acceptance of a technology: perceived ease-of-use (PEOU) and perceived usefulness (PU). According to the original definitions of Davis et al. [14], PEOU refers to "the degree, to which the [...] user expects the target system to be free of effort", while PU describes the individual's "subjective probability, that using a specific application system, will increase his or her job performance within an organizational context".

As shown in Figure, the Technology Acceptance Model suggests, that the user's decision to use a particular system evolves over four stages. Davis el al. [14] believe, that external variables (like individual abilities or situational constraints) indirectly influence technology usage through their impact on the perceived usefulness and perceived ease-of-use. Both factors affect a user's attitude towards the technology, which in turn influences the intention to use the technology [27]. As shown in the diagram, there is also a direct impact of perceived usefulness on the user's behavioral intention to use the technology. This is due to the fact, that even if individuals have a negative attitude towards a specific technology, this could be outweighed by a positive belief about the system's usefulness, which should finally lead to a positive usage intention.

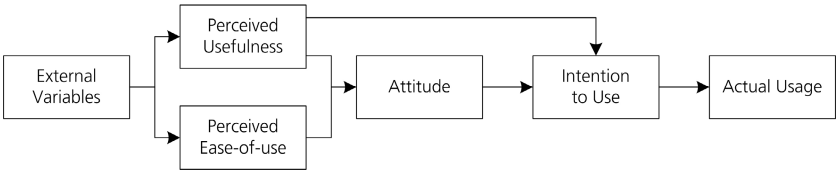

Fig. 1. Original Technology Acceptance Model [14]

The model has been tested by numerous authors, including Adams et al. [1], Chin and Todd [11], Hendrickson et al. [19], Igbaria et al. [20], Riemenschneider et al. [30], Subramanian [33], and Szajna [34]. In most of these studies, the TAM model was able to explain a reasonable amount of variance in the actual use of the technology [3]. An up-to-date review of existing TAM studies and meta analyses can be found in [25] or [26].

3 Goal and Approach

3.1 Research Goal

The majority of technology acceptance studies conducted so far analyze the adoption process of existing systems and applications, mostly with the goal of identifying the determinates that lead to the adoption. Instead of studying a real-world adoption process, the goal of this paper is to test, whether the core functionalities provided by Ambient Intelligence applications are accepted by potential users, and therefore are likely to be used in future office settings. This will be done by determining the perceived usefulness (PU) and the perceived ease-of-use (PEOU) of representative Ambient Intelligence functionalities.

Over the last decades, several studies showed, that the perceived usefulness of a system or application is a reliable predictor for its future usage. For example, Davis [13] found, that the perceived usefulness was significantly correlated with self-reported current usage (r=0,63) and self-predicted future usage (r=0,85). Similar to the perceived usefulness of a system, also the system's perceived ease-of-use proved to be a reliable indicator in numerous studies. Nevertheless, the perceived ease-of-use strongly depends on the actual implementation of the functionality and less on the functionality itself. As mentioned above, this paper aims to explore the acceptance of representative Ambient Intelligence functionalities, and therefore deliberately abstracts from concrete system implementations. In general, autonomous services are likely to receive rather high ratings regarding the perceived ease-of-use, as users are usually not required to perform any specific actions in order to benefit from a particular service. But experiences gained in previous studies (see, e.g., [31]) suggest, that users are willing to accept higher behavioral cost, in terms of additional user input, in order to gain more control over the provided services. Nonetheless, Ambient Intelligence applications are expected to be considerably easier to use than existing office applications, which greatly rely on manual user input. This means, that from the perspective of reduced behavioral costs, smart office applications will bring significant advantages over existing systems, and are therefore likely to be adopted by potential users. As it is not possible to assess the perceived ease-of-use in the traditional sense, this paper concentrates on the comparison of Ambient Intelligence functionality with traditional means, which are available in today's office environments and can be employed to achieve comparable results.

3.2 Conceptual Approach

Over the last two decades, numerous studies about technological acceptance have been conducted in different fields. The technologies and applications being tested include e-mail programs [13], internet banking [10], electronic commerce applications [28], word processors [9], electronic meeting systems [17], and tools for computer-aided software engineering [21]. Although the overall goal of this paper is quite similar to the intention of most technology adoption studies, there are two important differences that have to be taken into account. First, traditional studies investigate only the adoption of one specific technology. And second, the tested technologies exist either in form of functional prototypes or commercially available products. These two aspects do not

only allow a comparably high number of different questions, but also enable participants to provide feedback on more specific aspects, as they usually gained considerable experience with the specific technology in the pre-phase of the actual evaluation. In contrast, this paper aims to explore a variety of different functionalities, which are not yet implemented in form of concrete technologies.

Therefore, it was decided to evaluate the acceptance of generic Ambient Intelligence functionalities based on a systematically constructed usage scenario. The usage of a fictive scenario provides several advantages over technical prototypes. Scenarios allow describing complicated and rich situations in meaningful and accessible terms, and thereby help to analyze and communicate the core ideas of Ambient Intelligence [22]. Especially functionalities provided by smart environments are complicated to prototype in a realistic way, and poorly implemented prototypes might significantly influence the users' perception of a functionality and its potential impact on everyday life. In addition, several technological trends may be extrapolated and combined into a single scenario to analyze the bundled effects, that these technologies could induce on users [23].

Nevertheless, it is important to note that a scenario-based evaluation approach does not allow testing the actual acceptance of functionalities, based on their concrete usage in office environments. Instead, it is only possible to explore the intended usage behavior, based on the answers gained from participants. Hence, the feedback only reflects the intention of the participants to use a specific functionality, but not the actual adoption of the functionality. But a variety of studies showed, that there is a strong correlation between the intention to use a technology and its actual usage. According to Ajzen [2] the intention of users to employ a technology defines whether they will actually use it. This assumption was also confirmed in several technology adoption studies (see, e.g., [24]). Thus, it is assumed that the stated preference of users to employ a specific functionality is a good predictor of their future adoption behavior.

4 Evaluation

4.1 Identification of Representative Functionalities

In a first step, an analysis of existing Ambient Intelligence literature was conducted to identify representative usage scenarios and application domains. The focus of this analysis was on work-related scenarios developed in Europe and the United States. In the course of the scenario analysis, 430 beneficial scenario elements were extracted from 63 scenario descriptions. In the end, 39 functional groups were identified, which described different types of Ambient Intelligence functionalities (see [32] for details).

4.2 Usage Scenario

In order to assess the usefulness and ease-of-use of the different types of functionalities, the core functionalities, identified during the scenario analysis, were integrated into a representative and coherent evaluation scenario. While it would be helpful to get feedback on all different types of functionalities, the number of scenario elements to be used in the evaluation, had to be significantly reduced in order to avoid

overloading participants in the study. Therefore, it was decided to test only the functionalities, most often addressed in existing scenario descriptions. The final test scenario consisted of eight scenario elements, each illustrating an individual functionality within a smart office environment (see Table 1 and 2). The scenario incorporated the functionalities of nearly half of all the scenario elements identified during the analysis. So, even if only the functionalities of eight sub-groups were tested, these functionalities seem to be good indication about applications and services, that are likely to become part of future Ambient Intelligence environments.

4.3 Questionnaire

The scenario was presented to a target user population using a paper-based questionnaire. The participants were asked to rate each scenario element regarding the perceived usefulness and the perceived ease-of-use. Prior to the assessment of the each functionality, the corresponding scenario element was presented again in order to avoid any ambiguities. In order to capture user feedback, 10-point rating scales were used. For questions referring to the usefulness of the functionality, the endpoints were labelled 'not useful at all' and 'very useful'. Correspondingly, the endpoints of the rating scale for questions addressing the perceived ease-of-use were labelled 'more complicated' and 'easier'.

4.4 Participants

In total, 200 questionnaires were distributed to participants in Germany and the United States. For each country, 100 questionnaires were personally given out to persons with work experience in office environments. If possible, the participants were asked to hand on additional questionnaires to persons, who they regard as suitable for this study.. In total, N=161 persons returned their questionnaire, which resembles a return rate of 80,5%. Out of this group, N=96 came from Germany and N=65 from the United States. The overall population was nearly evenly distributed over male (49,1%) and female participants (50,9%), with slightly more males (52,1%) in Germany and slightly more female participants (55,4%) in the United States.

5 Results

5.1 Usefulness

In the first question for each scenario element the participants were asked to assess the general usefulness of the illustrated functionality. As explained above, a rating of '0' means, that a participant regards a specific functionality as not useful at all, while a '10' indicates, that this functionality is regarded to be very useful. Table 1 provides an overview over the perceived usefulness of the various scenario elements.

As shown in the table, the average rating over all scenario elements is M=6,55 on a 10-point scale. The average rating is slightly lower in the German group (M=6,44) and a little higher in the American (M=6,73). In all three groups, the average rating for each scenario element is higher than 5, which means, that all functionalities are regarded as rather useful than useless. Especially personal reminder services received

relatively high ratings, which might be due to the fact, that such applications are very practical and understandable in the office context. But they are also less innovative, as similar functionalities are already implemented in existing office applications and are supported by most state-of-the-art mobile devices. Hence, the perceived usefulness could be attributed to the practicality of the application itself, or its similarity to existing office applications, which are already accepted by users as part of their daily work life. Based on the existing data, it is not possible to clearly identify the factor(s), which influence the participants' perception regarding the usefulness of personal reminders. The adaptation of the physical surrounding to enhance personal well-being is another service, receiving comparable high rating regarding its usefulness. Other prominent functionalities, which are often described in existing application scenarios, like, e.g., the adaptation of content, get rather low ratings. In the American sub-group this functionality was even rated as the least useful of all illustrated services.

Table 1. Overview over the assessment of scenario elements regarding their usefulness

	Germany		**USA**		**Overall**	
Functionality	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
1. Adaptation of Content	6,91	3.	5,82	8.	6,47	4.
2. Personal Well-Being	6,95	2.	7,82	1.	7,30	2.
3. Personal Encounters	6,12	6.	6,71	4.	6,36	6.
4. Speech Input	5,18	8.	6,23	7.	5,60	8.
5. Ambient Displays	6,75	4.	6,98	3.	6,84	3.
6. Personal Reminder	7,61	1.	7,57	2.	7,60	1.
7. Asynchronous Communication	5,46	7.	6,27	6.	5,78	7.
8. Public Activity Histories	6,50	5.	6,40	5.	6,46	5.
Average Usefulness	**6,44**		**6,73**		**6,55**	

5.2 Ease-of-Use

In the second question, each functionality was assessed regarding the perceived ease-of-use. Like for the previous example, a 10-point scale was used, where a rating of '0' means, that this functionality appears to be more complicated to use than existing office practices, while a '10' would represent a functionality, that is easier to use.

As shown in Table 2, the scenario elements received an average rating of M=6,18 regarding their ease-of-use. In contrast to the previous question, the average rating was higher in the German group (M=6,39) and lower in the American (M=5,87). As the participants were asked to compare the illustrated functionalities to existing office practices, the ratings indicate, that one advantage of Ambient Intelligence technologies seems to be their increased ease-of-use and user-friendliness over traditional office applications. In the overall group, all functionalities received a rating higher than 5. This means that the described functionalities are at least as easy to use as existing office technologies, even if the ratings are not as high as one might have expected. As in the previous question, the two scenario elements, describing personal reminder

services and the adaptation of the physical surrounding to enhance personal well-being, received the highest ratings of all elements. While the scenario element describing speech input was rated the least useful, it received similarly low ratings regarding its ease-of-use. At least in office environments, participants from Germany as well as the United States do not seem to favor such interfaces over traditional interaction techniques. In the American sub-group, two functionalities were rated as more complicated to use than existing office technologies. The one, receiving the lowest rating regarding its ease-of-use are adaptation services, which are often seen as the key advantage of Ambient Intelligence technologies. These findings stand in a strong contrast to the development efforts that are currently put forth in the computer and telecommunication industry, to promote and establish such interaction and adaptation mechanisms.

Table 2. Overview over the assessment of scenario elements regarding their ease-of-use

	Germany		**USA**		**Overall**	
Functionality	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**
1. Adaptation of Content	6,71	3.	4,84	8.	5,96	6.
2. Personal Well-Being	7,08	2.	7,16	1.	7,11	1.
3. Personal Encounters	6,31	6.	6,26	3.	6,29	4.
4. Speech Input	5,28	8.	5,30	6.	5,29	7.
5. Ambient Displays	6,62	4.	6,87	2.	6,72	3.
6. Personal Reminder	7,23	1.	6,21	4.	6,82	2.
7. Asynchronous Communication	5,40	7.	4,98	7.	5,23	8.
8. Public Activity Histories	6,45	5.	5,34	5.	6,00	5.
Average Ease-of-Use	**6,39**		**5,87**		**6,18**	

6 Conclusion

The results of the study indicate, that the participants regard the described Ambient Intelligence technologies as rather useful and easy to use. Nevertheless, the moderate overall ratings for both factors show, that the acceptance of Ambient Intelligence technologies is not as high as often argued. The usefulness and ease-of-use ratings of most scenario elements range between 60% and 70% of the maximal possible scores. As Table 1 and 2 show, the average overall rating regarding the usefulness is M=6,55 and the average overall rating regarding the ease-of-use is M=6,18. Those scores are not remarkable high for technologies that are often said to revolutionize the nature of office environments. Nevertheless, the results of the study also show, that there is still a considerable potential to increase the usefulness and ease-of-use of Ambient Intelligence applications. With the knowledge about general user requirements and the acceptance of specific functionalities, the next step is to identify the reasons, which

caused the rather low ratings regarding the usefulness and ease-of-use of the illustrated functionalities. Only if those reasons are clearly identified, it becomes possible to revise the functionalities and application scenarios and thereby achieve higher acceptance rates.

Acknowledgments. The work presented in this paper was funded by the German Science Foundation (DFG).

References

1. Adams, D.A., Nelson, R.R., Todd, P.A.: Perceived Usefulness, Ease of Use, and Usage of Information Technology: A Replication. MIS Quarterly 16, 227–247 (1992)
2. Ajzen, I.: Residual Effects of Past on Later Behavior: Habituation and Reasoned Action Perspectives. Personality and Social Psychology Review 6(2), 107–122 (2002)
3. Alshare, K., Grandon, E., Miller, D.: Antecedents of Computer Technology Usage: Considerations of the Technology Acceptance Model in the Academic Environment. Journal of Computing Sciences in Colleges 19(4), 164–180 (2004)
4. Barnes, S.J., Huff, S.L.: Rising Sun: iMode and The Wireless Internet. Communications of the ACM 46(11), 78–84 (2003)
5. Benham, H.C., Raymond, B.C.: Information Technology Adoption: Evidence from a Voice Mail Introduction. ACM SIGCPR Computer Personnel 17(1), 3–25 (1996)
6. Brynjolfsson, E.: The Productivity Paradox of Information Technology. Communications of the ACM 36(12), 66–77 (1993)
7. Brynjolfsson, E., Hitt, L.: Paradox Lost? Firm-Level Evidence on the Returns to Information Systems Spending. Management Science 42(4), 541–558 (1996)
8. Burton-Jones, A., Hubona, G.S.: Individual Differences and Usage Behavior: Revisiting a Technology Acceptance Model Assumption. ACM SIGMIS Database 36(2), 58–77 (2005)
9. Chau, P.Y.K.: An Empirical Assessment of a Modified Technology Acceptance Model. Journal of Management Information Systems 13(2), 185–204 (1996)
10. Chau, P.Y.K., Lai, V.S.K.: An Empirical Investigation of the Determinants of User Acceptance of Internet Banking. Journal of Organizational Computing and Electronic Commerce 13(2), 123–145 (2003)
11. Chin, W.W., Todd, P.A.: On the Use, Usefulness, and Ease of Use of Structural Equation Modeling in MIS Research: A Note of Caution. MIS Quarterly 19(2), 237–246 (1995)
12. Compeau, D.R., Higgins, C.A., Huff, S.: Social Cognitive Theory and Individual Reactions to Computing Technology: A Longitudinal Study. MIS Quarterly 23(2), 145–158 (1999)
13. Davis, F.: Perceived Usefulness, Perceived Ease of Use, and End User Acceptance of Information Technology. MIS Quarterly 13(3), 318–339 (1989)
14. Davis, R.D., Bagozzi, R.R., Warshaw, P.R.: User Acceptance of Computer Technology: Comparison of Two Theoretical Models. Management Science 35(8), 982–1003 (1989)
15. Dewan, S., Min, C.: The Substitution of Information Technology for Other Factors of Production: A Firm Level Analysis. Management Science 43(12), 1660–1675 (1997)
16. Fishbein, M., Ajzen, I.: Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research. Addison-Wesley, Reading (1975)
17. George, J., Nunamaker, J.F., Valacich, J.S.: Electronic Meeting Systems as Innovation: A Study of the Innovation Process. Information and Management 22(3), 187–195 (1992)

18. Görisch, F., Hennig, F.: Ambient Business - Ubiquitous Computing im wirtschaftlichen Kontext. Seminar on Novel Forms of Human Computer Interaction: Smart Artifacts and Ambient Intelligence. Department of Computer Science, Technical University of Darmstadt (2006)
19. Hendrickson, A.R., Massey, P.D., Cronan, T.P.: On the Test-Retest Reliability of Perceived Usefulness and Perceived Ease of Use Scales. MIS Quarterly 17(2), 227–230 (1993)
20. Igbaria, M., Zinatelli, N., Cragg, P., Cavaye, A.L.M.: Personal Computing Acceptance Factors in Small Firms: A Structural Equation Model. MIS Quarterly 21(3), 279–305 (1997)
21. Iivari, J.: From a Macro Innovation Theory of IS Diffusion to a Micro Innovation Theory of IS Adoption: An Application to CASE Adoption. In: Avison, D., Kendall, J.E., DeGross, J.I. (eds.) Human, Organizational, and Social Dimensions of Information Systems Development, pp. 295–315. Elsevier Science Publishers, Amsterdam (1993)
22. Kaasinen, E., Rentto, K., Ikonen, V., Välkkynen, P.: MIMOSA Initial Usage Scenarios. Deliverable D1.1 of the Project Microsystems Platform for Mobile Services and Applications (MIMOSA), IST-2002- 507045 (2004)
23. Langheinrich, M., Coroama, V., Bohn, J., Mattern, F.: Living in a Smart Environment – Implications for the Coming Ubiquitous Information Society. Telecommunications Review 15(1), 132–143 (2005)
24. Lee, Y., Lee, J., Lee, Z.: Social Influence on Technology Acceptance Behavior: Self-Identity Theory Perspective. ACM SIGMIS Database 37(2-3), 60–75 (2006)
25. Legris, P., Ingham, J., Collerette, P.: Why Do People Use Information Technology? A Critical Review of the Technology Acceptance Model. Information and Management 40, 191–204 (2003)
26. Ma, Q., Liu, L.: The Technology Acceptance Model: A Meta-Analysis of Empirical Findings. Journal of End User Computing 16, 59–72 (2004)
27. Mathieson, K., Peacock, E., Chin, W.W.: Extending the Technology Acceptance Model: The Influence of Perceived User Resources. The DATA BASE for Advances in Information Systems 32(3), 86–112 (2001)
28. McCloskey, D.: Evaluating Electronic Commerce Acceptance with the Technology Acceptance Model. Journal of Computer Information Systems 4(2), 49–57 (2003)
29. Pearson, J.M., Crosby, L., Bahmanziari, T., Conrad, E.: An Empirical Investigation into the Relationship between Organizational Culture and Computer Efficacy as Moderated by Age and Gender. Journal of Computer Information Systems 43(2), 58–70 (2002)
30. Riemenschneider, C.K., Harrison, D.A., Mykytyn, P.P.: Understanding IT Adoption Decisions in Small Business: Integrating Current Theories. Information & Management (40), 269–285 (2003)
31. Röcker, C., Janse, M., Portolan, N., Streitz, N.A.: User Requirements for Intelligent Home Environments: A Scenario-Driven Approach and Empirical Cross-Cultural Study. In: Proceedings of the Intern. Conference on Smart Objects & Ambient Intelligence (sOc-EUSAI 2005), pp. 111–116 (2005)
32. Röcker, C.: Design Requirements for Future and Emerging Business Technologies: An Empirical Cross-Cultural Study Analyzing the Requirements for Ambient Intelligence Applications in Work Environments. Verlag Dr. Driesen, Taunusstein, Germany (2009)
33. Subramanian, G.H.: A Replication of Perceived Usefulness and Perceived Ease of Use Measurement. Decision Science 25(5-6), 863–874 (1994)

34. Szajna, B.: Software Evaluation and Choice: Predictive Validation of the Technology Acceptance Instrument. MIS Quarterly 18(3), 319–324 (1994)
35. Taylor, S., Todd, P.A.: Understanding Information Technology Usage: A Test of Competing Models. Information Systems Research (6), 144–176 (1995)
36. Karahanna, E., Straub, D.W., Chervany, N.L.: Information Technology Adoption Across Time: A Cross-Sectional Comparison of Pre-Adoption and Post-Adoption Beliefs. MIS Quarterly 23(2), 183–213 (1999)