Are Ambient Intelligent Applications Universally Accessible?

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ABSTRACT

The emergent HCI literature shows universal accessibility and ambient intelligence as growth hot spots. If so, it is important to ask if the latter can contribute to the former. One approach, taken here, is to evaluate the accessibility of ambient intelligent systems. To answer this question a sample of 200 papers were generated from the ACM Digital Library and six papers were selected for in-depth evaluation. Surprisingly, the data showed that, whilst they were rated well for accessibility, they were significantly less so for system smartness or user satisfaction. Usability was also rated more highly than user satisfaction and smartness.

Keywords

Universal accessibility, ambient intelligence, usability, system smartness, evaluation.

INTRODUCTION

The twin concepts of universal access (1) (2) and ambient intelligence (3) are emerging strongly in today's computing science research and development. If so, it is important to look at the potential for synergistic and antagonistic interactions between

them. In principle there are some interesting parallels. Both focus on the removal of barriers between the users and the resources that they need, both are user sensitive and both profoundly change the interaction between user and system. There are some apparent differences too. Universal access (UA) involves the conscious involvement of users, whilst ambient intelligence (AmI) may impact users in ways of which they are totally unaware. UA may actively involve users in system design but AmI may bypass them. Conversely, UA may not manage to capture the full extent of the diversity of the intended users, whilst AmI may be focused on the identification of the individual through technologies like RFID and beyond. This is not to support one concept over another but to acknowledge that they both may have strengths and weaknesses. If so, then an investigation of their potential overlap may enhance both. There are many ways to explore the relationship between the two concepts. One approach, taken here, is to evaluate the accessibility of a sample of ambient intelligent systems.

Methods

A quasi-random sample of six ambient intelligent system profiles were selected from the ACM Digital Library, from "journals" using the search terms "ambient" "intelligence" and "medical". This generated a list of 200 journal references. Items were selected from the list in order of relevance, sufficient information and interest i.e. each possible selection was rated on a ten-point scale for "relevance to ambient intelligence", "sufficient information to support evaluation" and "interest value" Seventeen relevant papers were identified initially and papers were selected at random (using the online facility supplied by Random.org (http://random.org/) on a continuous basis until four were identified that provided sufficient evidence for an accessibility assessment, reapplying the above three criteria of relevance, informative and interesting. An expert assessment was conducted on the basis of an inspection of each system and then the completion of four questionnaire, covering system user-interaction satisfaction, accessibility, usability and smartness. The questionnaires are appended to this paper. (5), (6), (7), (8).

Results

Surprisingly, an analysis of the accessibility of ambient intelligence systems proved to be more complex than anticipated i.e. Whilst the systems were rated highly overall for accessibility, there were a number of hidden complications. Surprisingly, the data showed that, whilst they were rated well for accessibility, all six were significantly less so for system smartness (Wilcoxon test, $T = 0$, $p<0.05$) or user satisfaction (Wilcoxon test, $T = 0$, $p<0.05$. Usability was also rated more highly than user satisfaction (Wilcoxon test, $T = 0$, $p<0.05$) and system smartness (Wilcoxon test, $T = 0$, $p<0.05$). However, accessibility and usability did not differ significantly form each other. The lower ratings for system smartness were due, in part, to the relatively unintelligent appreciation of human information but less so on the apparent smart and interactive responses that could be made to specific users and their requirements. In addition, some questions of the questionnaires were not easy to relate to AmI systems. The role of the user in the computer-human interaction in an AmI system tended to be much more passive and qualitatively different from an interaction with a user-sensitively designed system. The conscious awareness of the users was of less central focus in AmI. The use has much more control in a UA system than an AmI system. The design approaches to UA and AmI seem fundamentally different.

Identified emerging principles help to clarify some of these apparent differences. Privacy and security emerges as a major issue for AmI. Current work is looking at privacy principles and user preferences. If the users are not in control or, in some cases, are unaware of an ambient system operating, then it becomes difficult to see how users can be confident about security and privacy. Another big question is the option of opt-in versus opt-out approaches. In the former case, the user is asked to

choose to link to an ambient system. In the opt-out approach, it is assumed that the users are willing to participate unless they indicate to the contrary. If so, then users must posses the necessary perceptual, cognitive and psychomotor skills to do so. This seems unlikely in many cases where people have disabilities. The fundamental way that the users interact with the ambient system has been changed dramatically.

Table one: overview of sample

project	Description	AmI?	Accessibility?	Disabled users?	
1. MIMOSA	AmI applications on mobile devices	√	quick access	NS	
2. Active Surfaces	Swimming pool rehabilitation / position aware floating tiles	√	YES	Psychomotor / cognitive	
3. WaterCalls	Call queue coordination	√	YES / novel interface	No	
4. M/ORIS	Medical / Operating – real time monitoring of surgeon's behavior, gestures etc	√	YES / novel feedback	No, surgeons	
5. Smart clothes	Smart textiles; multi output / input	√	YES / novel inputs and outputs	Generic users	
6. ASPICE	Brain computer interface / robotics / demotics	√	YES / novel inputs and outputs	Psychomotor	

Table Two: ratings of sample

project	Accessibility /10	Smartness /10	Usability /10	User satisfaction / 10	
1. MIMOSA	7.3	6.78	7.72	6.71	
2. Active Surfaces	8.17	5.0	8.61	6.00	
3. WaterCalls	9.22	6.34	8.72	6.71	
4. M/ORIS	9.58	5.84	8.46	6.64	
5. Smart clothes	8.17	6.47	8.13	6.64	
6. ASPICE	8.39	6.25	8.13	6.64	

Discussion

AmI systems support enhanced accessibility substantially but, to do so, significant changes are made is user control, awareness and risk of loss of privacy. On the other hand, AmI systems can support a modern lifestyle in a non-invasive way. There are clearly trade-offs to be made, but alternatively, innovative design principles including guidelines for privacy, security, user awareness and user control. If that can be achieved, tomorrow's information society technology could be offering greater inclusivity through ambience, intelligence and universal accessibility.

It is also becoming clear that the equation of "artificial intelligence" and "ambient intelligence" could be problematic. The present systems all presented attractive, interactive interfaces and / or the ability to respond to specific users in a proactive and interactive manner. However, there were(perhaps unrealistic) concerns about their abilities to understand and respond intelligently to human knowledge and its interpretation. Perhaps ambient intelligence embodiments are merely "smart" and not truly "intelligent" when the latter is defined as responding like an intelligent human. Perhaps Penrose was correct when he argued that computer systems simply implement mathematical rules but do not understand the information that they are manipulating (Penrose, 1994).

Most surprising of all, all six example were rated highly for accessibility, but were significantly less so for system smartness or user satisfaction. Usability was also rated more highly than user satisfaction or system smartness. At the simplest level, these results demonstrate that the four concepts (as measured here by different questionnaires), except that there was a significant overlap between accessibility and usability. There are several possible explanations for this pattern of results. First, the usability and accessibility questionnaires may not have been defined clearly enough to avoid an apparent overlap. Second, usability and accessibility may be more familiar concepts than user satisfaction and system smartness, thus introducing a familiarity effect. However, one of the most important conclusions is that ambient intelligence, combined with good usability and accessibility scores, is not sufficient to generate high levels of user satisfaction. Perhaps there is a paradox here. Ambient intelligence may often be a background resource that is not always brought to the foreground and, if so, not always appreciated as much as it should (3). But, whatever the explanation, these results show that user satisfaction cannot be taken for granted by developers and other practitioners.

Finally, an inspection of the literatures of ambient intelligence and universal access provokes the conclusion that the synergy between these two related areas has yet to be developed to realize its potential. We now know how to evaluate AmI prototypes (9) and there are active steps to deploy user modeling (10) to create smart and accessible ubiquitous knowledge environments (11) to build upon the solid foundation of universal accessibility (12).

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APPENDIX: QUESTIONNAIRES

A questionnaire for user-interaction satisfaction

In addition to evaluating "hard" measures like time to complete a task and error rates, it is extremely useful to investigate the less observable aspects of interface design that cumulatively contribute to a user's subjective feelings of satisfaction or frustration. Questions in the questionnaire for user satisfaction are formulated according to the ones from the literature (cf. *QUIS* [Harper and Norman, 1993], *IBM Computer Usability Satisfaction Questionnaires* [Shneiderman, 1998], *SUMI* [HFRG, 1993], WAMMI [WAMMI consortium, 2002]).

Furthermore, two important facts were also taken into account – it is a design of a Web-based interface and, what is more important, it is an interface of a Web-based educational system that is under evaluation. The most intelligent system in the world does no good if users avoid it because they find it annoying. The *usability questionnaire* supports testing and determination of user subjective satisfaction with the shell's interface, as well as her/his satisfaction with its ease of use, efficiency, likeability, as well as with the attitude the system induces in users during its usage. Participants indicate level of their agreement with a questionnaire statement on a seven-point Likert scale. From the standpoint of the single participant the responses represent her/his subjective opinion, but as an average value taken from all participants they indicate an objective value of Web-based AS pleasantness.

Subjective satisfaction was determined from participants' answers to a paper-and-

pencil questionnaire; some questions asked specific aspects of working with the site/shell, while others asked for an assessment of how well certain adjectives described the site (anchored by arrange between "*disagree*" and "*agree*"); all questions used a seven-point Likert scale and some of them were inversely coded; for each question the items were averaged so that the possible range was from 1 to 7; the subjective satisfaction was the mean score of the following four aspects (each comprised five items from the questionnaire):

- *ease of use* of the site/shell; an example of a questionnaire item: "*Everything on this site is easy to understand.*",
- *efficiency* of the site/shell; an example of a questionnaire item: "*This site is too slow.*" (this item was inversely coded),
- *likeability* of the site/shell; an example of a questionnaire item: "*Overall, I am quite satisfied with the site.*", as well as
- *user feelings* while working with the site/shell; an example of a questionnaire items: "*frustrating*" and "*confusing*".

For each word below, please indicate how well it describes the site:

1	annoying	Disagree • • • • • • •	Agree
2	Confusing	Disagree • • • • • • •	Agree
3	Frustrating	Disagree • • • • • • •	Agree
4	interesting	Disagree • • • • • • •	Agree
5	stimulating	Disagree • • • • • • •	Agree
6	tiresome	Disagree • • • • • • •	Agree
7	useable	Disagree • • • • • • •	Agree
8	unpleasant	Disagree • • • • • • •	Agree
9	I feel in control when I am using this site.	Disagree • • • • • • •	Agree
10	This site uses terms understandable and familiar to me.	Disagree • • • • • • •	Agree
11	This site needs more introductory explanations.	Disagree • • • • • • •	Agree
12	I find this site useful.	Disagree • • • • • • •	Agree
13	Everything on this site is easy to understand.	Disagree • • • • • • •	Agree
14	This site is too slow.	Disagree • • • • • • •	Agree
15	I get what I expect when I click on objects on the site.	Disagree • • • • • • •	Agree
16	It is difficult to move around this site.	Disagree • • • • • • •	Agree
17	I feel efficient when using this site.	Disagree • • • • • • •	Agree
18	Compared to what I expected, the tasks did go really quickly.	Disagree • • • • • • •	Agree
19	I will characterize this site as an innovative one.	Disagree • • • • • • •	Agree
20	Overall, I am quite satisfied with this site.	Disagree • • • • • • •	Agree

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EVALUATION QUESTIONNAIRE ONE. To what extent does the website or application do well in the following areas? Give your rating by circling a number between 1 and 10, where 1 is the worst rating and 10 is the best rating. Please use the full range of ratings.

1.	The system overloads you with information.	1	2	3	4	5	6	7	8	9	10
2.	The system requires you to do tasks that are too complicated.	1	2	3	4	5	6	7	8	9	10
3.	The design makes it easy to track your current progress in tasks.	1	2	3	4	5	6	7	8	9	10
4.	It is easy to organize your use of this system.	1	2	3	4	5	6	7	8	9	10
5.	The system provides you with clear visual and auditory information.	1	2	3	4	5	6	7	8	9	10
6.	The system does not provide too much information to retain.	1	2	3	4	5	6	7	8	9	10
7.	The system provides information that can be seen or heard clearly.	1	2	3	4	5	6	7	8	9	10
8.	This system caters for people with visual or hearing problems.	1	2	3	4	5	6	7	8	9	10
9.	The system provides adequate feedback when you use it.	1	2	3	4	5	6	7	8	9	10
10.	The feedback is clear.	1	2	3	4	5	6	7	8	9	10
11.	The system feedback can be seen or heard clearly	1	2	3	4	5	6	7	8	9	10
12.	The amount of feedback is right.	1	2	3	4	5	6	7	8	9	10
13.	You have to hold too much in your mind when using this system.	1	2	3	4	5	6	7	8	9	10
14.	Important aspects of the system are easy to remember.	1	2	3	4	5	6	7	8	9	10
15.	Locations within the system are easy to remember.	1	2	3	4	5	6	7	8	9	10
16.	The instructions are easy to recall.	1	2	3	4	5	6	7	8	9	10
17.	The system is enjoyable to use.	1	2	3	4	5	6	7	8	9	10
18.	The system is frustrating to use.	1	2	3	4	5	6	7	8	9	10
19.	The system is pleasant to use.	1	2	3	4	5	6	7	8	9	10
20.	The system is rewarding to use.	1	2	3	4	5	6	7	8	9	10
21.	Using the system requires me to acquire a lot of knowledge	1	2	3	4	5	6	7	8	9	10
22.	The system structure is easy to learn	1	2	3	4	5	6	7	8	9	10
23.	There is too much to learn.	1	2	3	4	5	6	7	8	9	10
24.	The system methods are too complex to learn	1	2	3	4	5	6	7	8	9	10
25.	The system is based upon a cohesive model structure.	1	2	3	4	5	6	7	8	9	10
26.	The system structure is easy to imagine.	1	2	3	4	5	6	7	8	9	10
27.	The system is based upon an understandable	1	2	3	4	5	6	7	8	9	10

	model structure.										
28.	**The system structure is presented well**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
29.	**The system requires reasonable responses.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
30.	**The correct responses are easy to remember**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
31.	**The system provide adequate response support**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
32.	**The skills required to respond correctly are not difficult.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
33.	**It is easy to learn become skilled with this system.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
34.	**The skill requirements are acceptable.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
35.	**Complex responses are learnable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
36.	**The system supports complex response sequences.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

EVALUATION QUESTIONNAIRE 2. To what extent does the website or application do well in the following areas? Give your rating by circling a number between 1 and 10, where 1 is the worst rating and 10 is the best rating. Please use the full range of ratings.

		WORST									**BEST**
1.	**System recognizes my ID**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2.	**System recognizes my profile**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
3.	**Responds to simple searches well**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
4.	**Answers questions**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
5.	**Clarifies questions before answering**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
6.	**Understands that I have specific interests**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
7.	**Understands that I have specific expertise**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
8.	**Offers more information than that requested**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
9.	**Recognizes finer categories of people**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
10.	**Needs only limited amount of input from the user**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
11.	**Provides error free messages**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
12.	**Can identify the meaning of received data**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
13.	**Users knowledge to answer questions**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
14.	**Users commonsense to answer questions**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
15.	**Can provide search results in order of relevance**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

16.	**Provides useful feedback**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
17.	**Useful help system provided**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
18.	**Takes account of my interests when answering questions.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
19.	**Takes account of my expertise when answering questions.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
20.	**Responds to my emotional state**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
21.	**Recognizes humor**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
22.	**Recognizes irony**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
23.	**Has good manners**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
24.	**Can use numbers to make calculations**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
25.	**Can use logic**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
26.	**Uses hunches**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
27.	**Uses good judgment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
28.	**Responds to subtle details**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
29.	**Understands the structure of knowledge areas**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
30.	**Can solve problems**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
31.	**Can recognize patterns in data**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
32.	**Recognizes important changes**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**