Living and Working in Automated Environments

Evaluating the Concerns of End-Users in Technology-Enhanced Spaces

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Abstract— **This paper reports on a cross-cultural user study, which analyzes the perception of concerns commonly associated with technology-enhanced environments. The results of the study show that the concerns addressed in state-of-the-art literature do only partially reflect the concerns of potential users. The analysis also shows that the perception is significantly influenced by several factors. Especially the participants' cultural background has a significant influence on the perception of most concerns.**

Keywords-Ubiquitous and Pervasive Computing, Ambient Intelligence, Intelligent Environments, Smart Spaces, Technology Acceptance, User Study, Evaluation,

I. INTRODUCTION

Extrapolating the current developments in the area of information and communication technologies, we soon have to expect environments, where computers are ubiquitously available in different forms and sizes. The increasing miniaturization of computer technology is expected to result in processors and sensors being integrated into more and more everyday objects, leading to the disappearance of traditional desktop computers [15]. This coming 'post-PC' era will be characterized by automated environments, which recognize and respond to the needs of users in an almost invisible way. Such technology-enhanced environments will inevitably bring a variety of changes in different areas of life (see, e.g., [11], [13] or [17]). Although future applications are not clear yet, numerous authors foresee considerable negative consequences (see, e.g., [1], [3], [7] or [10]). In most cases, the predicted concerns represent worst-case scenarios of a completely computerized world. Nevertheless, it is important to be aware of potential concerns in order to counteract them in an early stage of the development process.

II. RESEARCH GOAL AND APPROACH

Empirical evidence shows, that the acceptance of new technologies is mostly influenced by individually perceived concerns, rather than actual technological risks. So even if the concerns, commonly associated with the usage of Ambient Intelligence technologies, are identified on a theoretical basis, it is still unclear whether the identified problems actually reflect the concerns of potential users. Therefore, this paper aims to analyze the perception of concerns commonly associated with the integration of computer and automation technologies in home and work environments. The potential concerns were identified by reviewing state-of-the-art literature from different research domains (see [12] for more details on the literature survey). Some of the identified concerns refer to long-term changes in individual or societal behavior and are therefore not immediately perceivable by users. As it is expected that the participants are unable to reliably evaluate the consequences of these technology-induced changes, some of the concerns identified during the literature analysis were excluded from the evaluation. Therefore, the study only addressed the following eight concerns, which are most often associated with technology-enhanced environments: (1) loss of control, (2) high dependency on technology, (3) misuse of data, (4) loss of privacy, (5) interruption of work processes, (6) changes in the organization of work, (7) effects on employment, and (8) effects on environment and health.

III. EVALUATION

A variety of technology acceptance studies conducted in the past showed significant variations between different groups of users (see, e.g., [2], [4], [5], [6], [8], [9] or [16]). Hence, it is likely that inter-personal differences also effect the perception of concerns associated with technology-enhanced environments. If this assumption is true, it is important to be aware of these differences in order to appropriately address them in the design process of future applications. In order to identify such inter-personal differences the influences of the following factors were individually analyzed: nationality, gender, age, computer usage, computer knowledge, and education level. The data were collected using a paper-based questionnaire consisting of two parts. In the first part, an introductory scenario was presented, which illustrated representative functionalities of technology-enhanced environments. The incorporated functionalities were extracted from 516 scenario elements coming from 68 different literature sources (see [14] for more details). In the second part, several statements were presented, each addressing a specific concern or negative consequence, which could arise through the usage of the described functionalities. In total, N=161 persons participated in the study, of which N=95 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.

IV. RESULTS

A. General Perception of Potential Concerns

For each of the previously identified concerns, the participants were asked whether they agree that the specific concern is a consequence of the emergence of technology-enhanced environments. To capture the level of agreement ten-point rating scales were used for all statements. A value of '0' means, that a participant does not agree at all with the statement, while a '10' indicates total agreement. Table 1 gives a general overview over all results and shows the mean value (M), standard deviation (SD) and mean difference (MD) for all concerns. The results are split down for German and American participants and are also shown for the entire group of participants. For German participants the mean values, representing the level of agreement, range from M=3,80 for the statement regarding potential changes in the organization of work to M=7,72 for the statement describing a potential loss of privacy. The statement illustrating negative effects on employment receives the least agreement in the group of American participants with a mean value of only M=1,86. The statement, with which American participants agree the strongest (M=6,77), is the one predicting a potential loss of control over smart applications and personal data, which are captured and stored by these applications. The results show that the loss of informational privacy and the misuse of personal data are seen as the biggest problems, while consequences for the environment and personal health are regarded as rather unlikely.

TABLE I. GENERAL PERCEPTION OF POTENTIAL CONCERNS.

		M	SD	MD
Loss of Control (Q1)				
1. It is likely that users lose control over a smart application or the personal data that is being captured and stored.	Germany	6,66	2,68	
	USA	6,77	2,12	
	Overall	6,70	2,47	
	Difference			-0,11
High Dependency on Technology (Q2)				
2. It is likely that users develop a high dependency on specific applications and their underlying technical infrastructure.	Germany	6,37	2,68	
	USA	6,51	2,32	
	Overall	6,43	2,54	
	Difference			-0,14
Misuse of Data (Q3)				
3. It is likely that personal information is illegally captured and stored by others.	Germany	7,48	2,61	
	USA	5,66	3,02	
	Overall	6,75	2,92	
	Difference			1,83
Loss of Privacy (Q4)				
4. It is likely that the described functionalities will lead to a decreased level of privacy in work environments.	Germany	7,72	2,50	
	USA	6,69	2,70	
	Overall	7,31	2,62	
	Difference			1,03
Interruption of Work Process (Q5)				
5. It is likely that the described functionalities will lead to additional interruptions of work processes and everyday office tasks.	Germany	5,58	2,60	
	USA	6,06	2,45	
	Overall	5,77	2,54	
	Difference			-0,47
Changes in the Organization of Work (Q6)				
6. It is likely that the described functionalities will negatively influence the way work is organized, distributed and performed.	Germany	3,80	2,72	
	USA	3,49	2,21	
	Overall	3,67	2,53	
	Difference			0,30
Effects on Employment (Q7)				
7. It is likely that the described functionalities will lead to higher unemployment due to the rationalization of business processes.	Germany	4,11	3,05	
	USA	1,86	1,89	
	Overall	3,21	2,86	
	Difference			2,25
Effects on Environment and Health (Q8)				
8. It is likely that the continuous usage of the described technologies will have negative effects on the environment and personal health.	Germany	4,29	2,96	
	USA	2,81	2,52	
	Overall	3,71	2,88	
	Difference			1,48

Table 2 provides a ranking of the potential concerns according to the participants' level of agreement. The loss of informational privacy and the misuse of personal data are seen as the biggest problems, while consequences for the environment and personal health are regarded as rather unlikely.

TABLE II. RANKING OF POTENTIAL CONCERNS COMMONLY ASSOCIATED WITH AMBIENT INTELLIGENCE TECHNOLOGIES.

Potential Concern	Germany	USA	Overall
Q1 Loss of Control	6,66 (3.)	6,77 (1.)	6,70 (3.)
Q2 High Dependency on Tech.	6,37 (4.)	6,51 (3.)	6,43 (4.)
Q3 Misuse of Data	7,48 (2.)	5,66 (5.)	6,75 (2.)
Q4 Loss of Privacy	7,72 (1.)	6,69 (2.)	7,31 (1.)
Q5 Inter. of Work Process	5,58 (5.)	6,06 (4.)	5,77 (5.)
Q6 Changes in Org. of Work	3,80 (8.)	3,49 (6.)	3,67 (7.)
Q7 Effects on Employment	4,11 (7.)	1,86 (8.)	3,21 (8.)
Q8 Effects on Env. and Health	4,29 (6.)	2,81 (7.)	3,71 (6.)
Average Perception	**5,75**	**4,98**	**5,44**

B. Inter-Personal Differences

In the following paragraphs the influences of inter-personal differences on the perception of concerns are investigated. The results are split down for each individual factor (nationality, gender, age, computer usage per day, computer knowledge, and education level) and are separately analyzed for significant differences. Due to the different characteristics of the factors, several statistical procedures were employed. Two-tailed t-tests were used to compare the mean values between German and American participants as well as between male and female participants. For the remaining four factors, one-way ANOVAs were used to identify potential mean differences among the groups. In all statistical analyses, the p-values were calculated up to three positions after the decimal point. P-values smaller than that are shown as '0,000', which means that the difference is significant on a level smaller than p=0,0005.

The influences of the participants' nationality on the assessment of potential concerns are shown in Table 3. For half of the identified concerns there are significant differences between German and American participants. In all cases, the mean differences are positive, which means that German participants consider the concerns as more serious than American participants. This is especially apparent in question 7, which addresses negative effects on employment. With a mean difference of MD=2,2495 the rating in the German group is over two scale points higher compared to the American group.

TABLE III. INFLUENCE OF THE PARTICIPANTS' NATIONALITY ON THE ASSESSMENT OF POTENTIAL CONCERNS.

Potential Concern	MD	Sig.
Q1 Loss of Control	-0,1135	0,777
Q2 High Dependency on Technology	-0,1422	0,730
Q3 Misuse of Data	1,8260	0,000
Q4 Loss of Privacy	1,0250	0,015
Q5 Interruption of Work Process	-0,4719	0,251
Q6 Changes in the Organization of Work	0,3036	0,458
Q7 Effects on Employment	2,2495	0,000
Q8 Effects on Environment and Health	1,4832	0,001

An overview over potential gender influences on the assessment of concerns (Q1 to Q8) is presented in Table 4. In the overall group only the answers to question 2 (high dependency on technology) and question 8 (effects on environments and health) are significantly different between male and female participants. This is also the case for the German sub-group. For both questions the ratings of female participants are significantly higher. This might lead to the conclusion, that female participants regard the potential concerns of Ambient Intelligence technologies as more serious compared to male participants. But due to the low number of significant mean differences, such conclusions have to be regarded with great care. Especially as less than 40% of all mean differences in the American and overall group are positive.

TABLE IV. INFLUENCE OF THE GENDER ON THE ASSESSMENT OF POTENTIAL CONCERNS.

	Germany		USA		Overall	
	MD	**Sig.**	**MD**	**Sig.**	**MD**	**Sig.**
Q1	0,0842	0,879	-0,4817	0,372	-0,1303	0,740
Q2	1,5751	0,004	0,0829	0,888	0,9881	0,013
Q3	0,0423	0,937	-1,5381	0,043	-0,7268	0,115
Q4	-0,2030	0,694	-0,7667	0,263	-0,5058	0,224
Q5	-0,0117	0,982	-0,8651	0,162	-0,3101	0,442
Q6	0,9054	0,103	0,3988	0,479	0,6755	0,091
Q7	0,0658	0,917	-1,3274	0,004	-0,6636	0,143
Q8	2,3556	0,000	0,6194	0,338	1,5308	0,001

Table 5 shows the results of the one-sided ANOVAs computed to analyze the influence of the age group on the assessment of potential concerns. In the overall group only the answers to question 2 (high dependency on technology) and question 8 (effects on environment and health) differ significantly. This is also the case in the German sub-group with similar p-values for both questions. In the American sub-group there are no significant differences regarding the perception of potential concerns.

TABLE V. INFLUENCE OF THE AGE GROUP ON THE ASSESSMENT OF POTENTIAL CONCERNS.

	Germany		USA		Overall	
	F	**Sig.**	**F**	**Sig.**	**F**	**Sig.**
Q1	1,438	0,243	1,695	0,192	2,404	0,094
Q2	6,910	0,002	0,136	0,873	3,409	0,036
Q3	0,396	0,674	0,487	0,617	1,172	0,312
Q4	1,304	0,276	1,110	0,336	1,392	0,252
Q5	0,232	0,794	0,293	0,747	0,178	0,837
Q6	0,005	0,995	0,018	0,982	0,044	0,957
Q7	1,884	0,158	3,053	0,055	2,882	0,059
Q8	3,988	0,022	2,322	0,107	4,750	0,010

Regarding the duration of computer usage per day, only the answers to two questions differ significantly in the American and overall group (see Table 6). In the German sub-group the number of questions, which show significant

differences, doubles to 50% of the addressed concerns. In three cases the differences are even significant on a 1%-level, while none of the answers differ significantly on this level in the American and overall group.

TABLE VI. INFLUENCE OF THE DURATION OF COMPUTER USAGE PER DAY ON THE ASSESSMENT OF POTENTIAL CONCERNS.

	Germany		USA		Overall	
	F	**Sig.**	**F**	**Sig.**	**F**	**Sig.**
Q1	1,944	0,128	0,999	0,399	1,274	0,285
Q2	4,230	0,008	1,412	0,248	3,103	0,028
Q3	4,407	0,006	2,919	0,041	3,826	0,011
Q4	0,328	0,805	1,891	0,141	1,073	0,362
Q5	4,613	0,005	0,792	0,503	1,973	0,120
Q6	3,305	0,024	2,316	0,085	1,824	0,145
Q7	0,326	0,807	2,852	0,045	0,951	0,417
Q8	1,299	0,279	1,289	0,287	1,125	0,341

In contrast, the perception of concerns among users with different levels of computer knowledge is only significantly different in the American sub-group. For both other groups the answers to none of the questions differ significantly. Hence, it seems legitimate to conclude that self-assessed computer knowledge does not influence the perception of concerns.

TABLE VII. INFLUENCE OF THE COMPUTER KNOWLEDGE ON THE ASSESSMENT OF POTENTIAL CONCERNS.

	Germany		USA		Overall	
	F	**Sig.**	**F**	**Sig.**	**F**	**Sig.**
Q1	0,932	0,482	0,482	0,749	1,048	0,384
Q2	0,214	3,411	3,411	0,014	0,665	0,617
Q3	0,204	4,041	4,041	0,006	0,759	0,553
Q4	1,107	3,201	3,201	0,019	2,076	0,087
Q5	0,324	0,853	0,853	0,497	0,806	0,523
Q6	0,081	1,431	1,431	0,235	0,407	0,804
Q7	0,712	1,109	1,109	0,361	1,994	0,098
Q8	0,827	1,799	1,799	0,141	1,308	0,270

Finally, Table 8 shows an overview over the influences of the education level. In the overall group the perception of three concerns (37,5%) differs significantly among user groups with different education levels. In the German as well as in the American sub-group only one ANOVA delivered a significant p-value.

TABLE VIII. INFLUENCE OF THE EDUCATION LEVEL ON THE ASSESSMENT OF POTENTIAL CONCERNS.

	Germany		USA		Overall	
	F	**Sig.**	**F**	**Sig.**	**F**	**Sig.**
Q1	0,969	0,003	0,528	0,468	0,609	0,008
Q2	1,873	0,429	2,737	0,716	0,900	0,657
Q3	0,176	0,122	0,952	0,037	0,655	0,466
Q4	1,512	0,950	0,572	0,441	2,517	0,625
Q5	1,848	0,205	0,740	0,684	1,081	0,044
Q6	0,284	0,126	0,552	0,569	0,453	0,368
Q7	1,703	0,888	1,942	0,699	2,907	0,770
Q8	0,637	0,156	0,685	0,115	0,479	0,024

V. CONCLUSION

At first sight, an average overall mean value of M=5,44 suggests, that the participants do not really regard the identified concerns as realistic consequences associated with the usage of Ambient Intelligence technologies. But a closer look at the results reveals that there are two types of concerns. While some concerns are immediate consequence of the usage of Ambient Intelligence technologies, others are not. Especially the effects on employment, environment and health as well as changes in the organization of work have to be seen as long-term problems without immediate consequences for the individual user. In addition, the personal usage behavior does not necessarily prevent a user from those consequences. When a critical mass of people uses a specific technology, a user might experience the consequences of this usage even if she chose not to employ the technology herself. For example, if co-workers use wireless communication devices within a shared office environment, all employees are exposed to the radiation in a nearly equal manner. As shown in Table 3, there are considerable differences between the ratings of the first five concerns and the last three, which refer to long-term consequences. When considering only concerns, that have direct consequences for the individual user, all ratings are higher than 5 with an average overall mean value of M=6,59. This means, that those concerns are perceived as rather realistic problems of Ambient Intelligence technologies.

The analysis of inter-personal differences showed, that the participants' nationality is the factor with the strongest influence on the perception of concerns. The answers to 50% of the questions are significantly different on a 5%-level and nearly 40% of the answers show significant differences on a 0,1%-level. The second factor, that seems to have an impact on the perception is the participants' degree of education. If compared on a 5%-level, the perception of over one third of the presented concerns differs significantly. Differences regarding the participants' gender, age and duration of computer usage per day effect the perception of some concerns, but the influences are comparably low. For all three factors only the answers to one forth of the questions differ significantly. With no significant difference in any of the questions, the participants' self-assessed computer

knowledge does not seem to have any influence on the perception of concerns.

VI. Future Work

As illustrated above, some concerns refer to immediate consequence, while others represent long-term problems without direct effects on the individual user. In order to adequately address these concerns in the design of new systems, further studies are necessary in order to explore, how the temporal scope of the consequence (immediate vs. long-term effects) influences the perception of users.

The evaluation results also indicate, that not all risks, which are currently discussed in literature, are actually perceived as such by users. Nevertheless, there seem to be serious concerns, like for example the loss of control or the misuse of personal information, which are likely to hinder the acceptance of technology-enhanced environments. Therefore, it is important to address and counteract those concerns in the design of future systems.

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