Socially Dependent Interaction in Smart Spaces

How the Social Situation Influences the Interaction Style in Computer-Enhanced Environments

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***Abstract*—This paper reports on a cross-national user study exploring the influence of the social work situation on the preferred level of control over IT services in smart office environments. The acceptance of different control mechanisms was tested for representative functionalities with participants from Germany and the USA. The results of the questionnaire-based study show, that the social situation, in which a certain application is used, has a significant effect on the preferred level of user control.**

Keywords-Ambient Intelligence, Ubiquitous and Pervasive Computing, User Interface, Intelligent Environments, Human-Computer Interaction, User Study, Evaluation.

I. INTRODUCTION

With the amount of information technology constantly increasing and getting more and more ambient, future work environments are supposed to be intelligent, adaptive, and interactive [22]. Friedewald et al. [3] analyzed several smart office projects and scenarios addressing the design of future work environments, and found common characteristics, that all systems have in common. Based on similar studies, Gupta and Moitra [6] conclude, that the main objective of smart office environments is to provide distraction-free interaction between the user and the IT infrastructure, and to have the environment collaborate with the user in performing the tasks at hand more effectively.

Within the last years, several projects started to develop prototypes of smart office environments, which support office workers with a variety a different tasks, and dynamically adapt to the changing requirements of knowledge-based project work (see, e.g., [13] for an overview over state-of-the-art research activities). One of the first projects in this field was *i-LAND* [18], an interactive landscape for creativity and innovation, that provides a set of artifacts in combination with software for supporting individual as well as group work in meeting room scenarios. The *i-LAND* office environment consists of several so-called *Roomware* components, physical room elements with integrated information technology [19]. The corresponding software [23] provides new forms of interaction mechanisms, especially designed to support dynamic group work. Another early example is the *Oxygen* project [2], which envisions future environments as spaces of freely exchanged information and information services, similar to an information marketplace [24]. The consortium developed an integrated software system, which enables pervasive, human-centered computing through a combination of specific user and system technologies, developed for different usage situations [4]. In a similar fashion, the *Aura* project [5] aims at providing users with an 'invisible halo of computing and information services' in order to minimize the distractions experienced with traditional computational systems. The project implemented and tested a prototype system, which demonstrated the concept of a location-independent 'personal information aura' using various devices, like wearable, handheld, and desktop computers [17]. More recently, the *Ambient Agoras* project [11][20] implemented several examples of situated services and context-adapted applications for users in office environments [21]. This was done by using augmented physical artifacts, ambient displays as well as mobile devices in order to support collaboration, informal communication and social awareness within workspaces [16].

II. OVERALL RESEARCH GOAL

As the previous examples show, the interaction between users and the various services provide in smart office environments plays a crucial role in the design process of future systems. A review of state-of-the-art research systems [12] revealed, that there are three general approaches how services are provided in smart office environments, which show different degrees of user control:

- *Autonomous Action*
  Autonomous services provide the lowest degree of user control. Processes are fully automated and users are not able to control (e.g., acknowledge or reject) the functionality that is provided. In most cases, the service is automatically provided as soon as the user is identified by the system or a special event occurs (e.g., the user reaches a specific location).

- *User-Approved Action*
  Unlike autonomous services, user-approved services are not providing any functionality, unless the user approves it. Instead, the system fulfills an auxiliary role and acts in form of a digital assistant, which offers functionalities that might be helpful for the user in his current situation.

- *User-Controlled Action*
  In user-controlled services, users maintain full control over the service and can decide when and where a certain service is provided. In contrast to functionalities provided by traditional computer systems, the provided services are mostly personalized and adapted to the current context of the user.

While the automation of routine office tasks sounds promising at first sight, several evaluations, e.g., [15] showed, that users sometimes feel uneasy if they are not in control over a smart service. This is especially the case in multi-user situations, where the unintended disclosure of personal information could lead to serious privacy infringements [8][14]. This problem is of particular importance as a continuous trend towards higher local mobility is observable in most companies. Even if employees are within the office building, they spend considerable time away from their own desk, working in public or semi-public areas like meeting rooms, other offices or in the hallway [7][9]. According to estimations, white-collar workers spend between 25% and 70% of their daily working time in conferences or meetings with colleagues [3][10][25]. Bellotti and Bly [1] studied local mobility in a design company and observed an even higher level of mobility with people being away from their desk for around 90% of the time. This paper addresses these trends and explores the question how different social work situations influence the way users want to interact with future office systems.

III. Evaluation

A. Analysis of Existing Application Scenarios

In a first step, an analysis of existing literature was conducted in order to identify characteristic functionalities of future workplace systems as well as the social situations, in which they are expected to be used. The focus of this analysis was on work-related scenarios developed in Europe, Asia, and the United States. In the course of the scenario analysis, 430 different scenario elements were extracted from 63 scenario descriptions (see [12] for details). The scenario elements were assigned into 39 sub-groups, describing different types of functionalities. 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 reduced in order to avoid overloading participants in the study. Therefore, it was decided to test only the seven functionalities, most often addressed in existing scenario descriptions: (1) adaptation of content, (2) adaptation to enhance personal well-being, (3) support of personal encounters, (4) ambient displays, (5) personal reminders, (6) asynchronous communication, and (7) public activity histories. This set of scenario elements, include the functionalities of nearly half of all scenario elements, extracted from the various scenario descriptions. So, even if only the functionalities of seven sub-groups were tested, these functionalities seemed to be a good indication about applications and services that will become part of smart office environments.

B. Social Work Situations

The analysis of application scenarios and prototype systems also showed that smart office technologies could be used in a variety of different situations. In the context of this paper, we distinguish between two social surroundings in which a user could employ a certain service: private and public work situations.

- *Private Work Situation*
  In private situations the user is within a personal space (usually a private office) where all his activities could neither be heard nor seen by others. The complete interaction with the system, including data input and output, is therefore not perceivable by outsiders. The private nature of the interaction is restricted to the physical world and the time the user is interaction with the system. It does not include data security aspects, like the inspection of private information through security breaches at a later point in time. Private usage situations might also take place in public or semi-public spaces, if users have private devices, which enable them to interact with personal or confidential information in such a way, that others are not able to interpret these interactions.

- *Public Work Situation*
  Within office environments, public spaces describe locations, which are accessible by all members of a specific group. Depending on the size of the company, this could be the whole building or just an individual department. The members of this specific group are usually familiar with each other and jointly use the public spaces. Examples for public spaces include open plane offices, corridors or meeting rooms. Public situations comprise all interactions, where multiple users are present in a public area and which could (to a varying extend) be perceived by all people occupying this space.

C. Evaluation Scenario

In a second step, the key functionalities shown above were incorporate into a coherent evaluation scenario, which describes an ordinary working day of two co-workers in a future office environment. All functionalities and situations, described within the scenario, were taken from existing scenario elements, extracted during the analysis. For each functionality, it was aimed to choose a scenario element, which is representative for the whole group of elements and provides an understandable description of the functionality itself. In order to make the evaluation scenario as realistic as possible, the main activities, described in the course of the scenario, are standard office activities, which should be familiar to most test persons.

D. Questionnaire

The scenario was presented to a target user population using a paper-based questionnaire. The participants were asked to state their preferred level of control in two different social surroundings: a private work situation and a public work situation. To avoid any ambiguity in the assessment process, private and public work situations as well as the different degrees of control were explicitly described and potential consequences outlined.

E. Participants

In the course of a cross-cultural user study (see [12] for details), N=200 questionnaires were personally handed out to participants in Germany and the United States. For each country, N=100 questionnaires were given out to participants with work experience in office environments. 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.

IV. Results

The following sub-section show the results for each of the seven functionalities incorporated into the evaluation results, separately for the German and American sub-group as well as for the overall group.

A. Asynchronous Communication

With respect to asynchronous communication functionalities, the majority of participants, 45,8% in the German and 49,2% in the American group, prefer an autonomous system reaction in private work situations. This preference changes as the office space is shared with colleagues. Over half of the participants in both groups (53,1% of the Germans and 52,3% of the Americans) prefer to individually approve the services offered by the system in public work situations.

TABLE I. Results for Scenario Element Describing Asynchronous Communication

		UCA	UAA	AA
Private		**UCA**	**UAA**	**AA**
	Germany	9 (9,4%)	40 (41,7%)	44 (45,8%)
	USA	25 (38,5%)	8 (12,3%)	32 (49,2%)
	Overall	34 (21,2%)	48 (29,8%)	76 (47,2%)
Public		**UCA**	**UAA**	**AA**
	Germany	6 (6,3%)	51 (53,1%)	39 (40,6%)
	USA	3 (4,6%)	34 (52,3%)	27 (41,5%)
	Overall	9 (5,6%)	85 (52,8%)	66 (41,0%)

ACA = User-Controlled Action, UAA = User-Approved Action, AA = Autonomous Action

B. Public Activity Histories

Being asked about the preferred level of control in private work situations, the majority of German participants (47,9%) prefer an autonomous reaction by the system, while the majority of American participants (43,1%) prefer to approve potential actions personally. Nevertheless, in both groups the differences between autonomous system actions and user-approved system support is rather small. In public work situations, the preferred type of control is the same for both groups. Nearly half of the German participants (49,0%) prefer an autonomously acting system compared to 58,5% of the American participants favoring user-approved actions.

TABLE II. Results for Scenario Element Describing Public Activity Histories

		UCA	UAA	AA
Private		**UCA**	**UAA**	**AA**
	Germany	6 (6,3%)	43 (44,8%)	46 (47,9%)
	USA	11 (16,9%)	28 (43,1%)	26 (40,0%)
	Overall	17 (10,6%)	71 (44,1%)	72 (44,7%)
Public		**UCA**	**UAA**	**AA**
	Germany	5 (5,2%)	43 (44,8%)	47 (49,0%)
	USA	2 (3,1%)	38 (58,5%)	24 (36,9%)
	Overall	7 (4,3%)	81 (50,3%)	71 (44,1%)

ACA = User-Controlled Action, UAA = User-Approved Action, AA = Autonomous Action

C. Adaptation to Enhance Personal Well-Being

In private work situations, the preferred level of control is nearly evenly distributed over the three possible types of control in the German group, while American participants have a strong preference (76,9%) for user-controlled actions. In a public work situation, 47,9% of the German and 42,2% of the American participants prefer an autonomous action by the system.

TABLE III. Results for Scenario Element Describing Adaptation to Enhance Personal Well-Being

		UCA	UAA	AA
Private		**UCA**	**UAA**	**AA**
	Germany	36 (37,5%)	28 (29,2%)	30 (31,3%)
	USA	50 (76,9%)	10 (15,4%)	5 (7,7%)
	Overall	86 (53,4%)	38 (23,6%)	35 (21,7%)
Public		**UCA**	**UAA**	**AA**
	Germany	34 (35,4%)	15 (15,6%)	46 (47,9%)
	USA	26 (40,0%)	17 (26,2%)	22 (33,8%)
	Overall	60 (37,3%)	32 (19,9%)	68 (42,2%)

ACA = User-Controlled Action, UAA = User-Approved Action, AA = Autonomous Action

D. Personal Remiders

The preferred levels of control in both groups and social situations are autonomous system actions, with slightly more participants preferring this control option in a public work situation.

TABLE IV. Results for Scenario Element Describing Personal Reminders

		UCA	UAA	AA
Private		**UCA**	**UAA**	**AA**
	Germany	21 (21,9%)	34 (35,4%)	40 (41,7%)
	USA	19 (29,2%)	10 (15,4%)	35 (53,8%)
	Overall	40 (24,8%)	44 (27,3%)	75 (46,6%)
Public		**UCA**	**UAA**	**AA**
	Germany	9 (9,4%)	31 (32,3%)	53 (55,2%)
	USA	3 (4,6%)	22 (33,8%)	38 (58,5%)
	Overall	12 (7,5%)	53 (32,9%)	91 (56,5%)

ACA = User-Controlled Action, UAA = User-Approved Action, AA = Autonomous Action

E. *Ambient Displays*

Regarding the preferred level of control over ambient displays, there is no big variation between the different groups of users. While there is no clear preference for any of the control options in the German group, the group of American participants who prefer user-approved actions is slightly larger than the other two groups.

TABLE V. RESULTS FOR SCENARIO ELEMENT DESCRIBING AMBIENT DISPLAYS

		UCA	UAA	AA
Private		**UCA**	**UAA**	**AA**
	Germany	29 (30,2%)	37 (38,5%)	30 (31,3%)
	USA	44 (67,7%)	13 (20,0%)	8 (12,3%)
	Overall	73 (45,3%)	50 (31,1%)	38 (23,6%)
Public		**UCA**	**UAA**	**AA**
	Germany	34 (35,4%)	31 (32,3%)	30 (31,3%)
	USA	21 (32,3%)	25 (38,5%)	18 (27,7%)
	Overall	55 (34,2%)	56 (34,8%)	48 (29,8%)

ACA = User-Controlled Action, UAA = User-Approved Action, AA = Autonomous Action

F. *Support of Personal Encounters*

Nearly half of all participants in both groups would prefer an autonomous action by the system when they are in a private work situation. In public work situations, over 60% of the German participants would prefer an autonomous system reaction, while 52,3% of the American participants would favor to individually approve the action offered by the system.

TABLE VI. RESULTS FOR SCENARIO ELEMENT DESCRIBING THE SUPPORT OF PERSONAL ENCOUNTERS

Private		**UCA**	**UAA**	**AA**
	Germany	11 (11,5%)	41 (42,7%)	43 (44,8%)
	USA	18 (27,7%)	15 (23,1%)	32 (49,2%)
	Overall	29 (18,0%)	56 (34,8%)	75 (46,6%)
Public		**UCA**	**UAA**	**AA**
	Germany	5 (5,2%)	31 (32,3%)	58 (60,4%)
	USA	8 (12,3%)	34 (52,3%)	23 (35,4%)
	Overall	13 (88,1%)	65 (40,4%)	81 (50,3%)

ACA = User-Controlled Action, UAA = User-Approved Action, AA = Autonomous Action

G. *Adaptation of Content for Single User*

In a private work situation, over half of the German participants prefer an autonomous system action, while 43,1% of the American participants prefer to approve the action provided by the system. The preferences are nearly the same for public work situations with 52,1% of the German participants favoring an autonomous action by the system and 55,4% of the American participants preferring user-approved actions.

TABLE VII. RESULTS FOR SCENARIO ELEMENT DESCRIBING PERSONAL REMINDERS

Private		**UCA**	**UAA**	**AA**
	Germany	8 (8,3%)	38 (39,6%)	49 (51,0%)
	USA	22 (33,8%)	28 (43,1%)	14 (21,5%)
	Overall	30 (18,6%)	66 (41,0%)	63 (39,1%)
Public		**UCA**	**UAA**	**AA**
	Germany	7 (7,3%)	36 (37,5%)	50 (52,1%)
	USA	0 (0,0%)	36 (55,4%)	29 (44,6%)
	Overall	7 (4,3%)	72 (44,7%)	79 (49,1%)

ACA = User-Controlled Action, UAA = User-Approved Action, AA = Autonomous Action

V. CONCLUSION

The results of the study show that the social situation, in which a specific functionality is used, significantly influences the preferred level of control over the functionality. Table VIII gives an overview over the effects of the work situation on the preferred level of control.

TABLE VIII. OVERVIEW OVER THE INFLUENCES OF THE SOCIAL SITUATION ON THE PREFERRED LEVEL OF CONTROL

	Germany		**USA**		**Overall**	
	Pearson	**LR**	**Pearson**	**LR**	**Pearson**	**LR**
Asym. Communication	0,248	0,152	0,000	0,000	0,000	0,000
Activity Histories	0,992	0,992	0,032	0,020	0,160	0,151
Personal Well-Being	0,053	0,051	0,000	0,000	0,001	0,001
Personal Reminder	0,040	0,036	0,001	0,000	0,000	0,000
Ambient Display	0,614	0,534	0,001	0,001	0,087	0,061
Personal Encounters	0,102	0,099	0,002	0,002	0,062	0,058
Adaptation of Content	0,770	0,758	0,000	0,000	0,001	0,000
Summary						
items with $p \leq 0{,}05$	1	1	7	7	4	4
items with $p \leq 0{,}01$	0	0	6	6	4	4
items with $p \leq 0{,}001$	0	0	5	5	4	4

LR = Likelihood Ratio

In the overall group, the social situation has a highly significant influence on the preferred level of control for 4 out of the 7 tested functionalities. As the table shows, there are notable differences between the two national sub-groups. In the American group, the preferred level of control is significantly influenced by the social situation in all 7 cases. For over 70% of the questions the differences are even significant on a 0,1%-level. In the German sub-group, only the preferred level of control for personal reminder services is significantly effected by the social situation.

As illustrated above, there is an ongoing trend towards higher mobility in office environments. Based on the current developments, it has to be assumed that future office concepts will allow an even higher level of personal mobility than today's office concepts already do. Hence, the impact of the social situation on the preferred interaction style should motivate designer to re-think their implementation strategies and develop flexible interface concepts, that enable users to dynamically change among different input and output modalities.

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