# Intelligent Privacy Support for Large Public Displays

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**Abstract.** This paper presents a novel concept for personalized privacy support on large public displays. In a first step, a formative evaluation was conducted in order to analyze the requirements of potential users regarding the protection of private information on large public displays. The insights gained in this evaluation were used to design a system, which automatically adapts the information visible on public displays according to the current social situation and the individual privacy preferences of the user working on the display. The developed system was evaluated regarding its appropriateness for daily usage and its usefulness to protect privacy.

**Keywords:** Large Public Displays, Intelligent Privacy Support, Smart Environments, Privacy-Enhancing Technologies, Context-Adapted Information Representation, Evaluation.

## 1 Introduction

The concept of Ambient Intelligence propagates a vision of future environments where people are supported and assisted in their everyday activities by information technologies that are very different from the computer as we know it today (Röcker at al., 2005). The envisioned technologies "will weave themselves into the fabric of everyday life until they are indistinguishable from it" (Weiser, 1991). By making numerous computers available throughout the physical environment, people are enabled and enticed to move around and interact with computers more naturally than they currently do. Instead of using traditional computers or personal mobile devices, users can access information using computational devices embedded into the environment.

As ubiquitously available displays are about to become an integral part of smart home environments, several projects aim at providing users with personalized services and information on large public displays. Many of these services are intended to provide walk-up-and-use functionality, like quickly accessing e-mails or the internet. When using such applications on large displays in public areas, the possibility of other people being able to see confidential information inevitably causes privacy concerns. Empirical evidence shows that these concerns are justified: exploring the influence of the display size on privacy infringements, Tan and Czerwinski (2003) found that, even given constant visual angles and similar legibility, individuals are more likely to read text on a large display than on a small one. In addition to that, several other studies reported similar results and emphasized the importance of informational privacy, both in the office and in the home domain. Nevertheless, most developers still rely on social protocols or do not address privacy questions at all, when designing applications for large public displays. Until today, there are very few approaches that support users in preserving their privacy while working on large displays in public places.

## 2 Formative Evaluation of User Requirements

In order to provide trusted mechanisms for privacy protection, it is most crucial to involve potential users right away from the beginning of the design process. Therefore, a formative evaluation was conducted to analyse the requirements of users regarding the protection of private information when using large public displays. The goal of this evaluation was to investigate how automated protection mechanisms influence the usage of large displays in public environments.

### 2.1 Materials and Methods

To elicit feedback from the target user population, a scenario-driven approach was chosen. During a questionnaire-based evaluation, different scenarios were presented to the participants in a three-step process. First, and prior to the presentation of the main scenarios, the participants were asked to assess the suitability of large displays in public areas. Therefore, examples of different applications and information types were presented to the participants, which had to be rated on a five-point scale.

In the second part of the evaluation, the participants were asked to visualize a scenario, where they are working on a large public display located in a hallway of an office building. Since the display (or, more explicitly, the computer it is connected to) is integrated in the company network, the display can be used as a desktop replacement (i.e., all standard application are running on it). The scenario describes a situation, where several application windows (for example, an internet browser, a document viewer, and an e-mail program) are displayed on the public display. At the end of the scenario, the participants were explicitly reminded that passers-by are likely to see what they are doing, but also that these passers-by are mostly colleagues (i.e., people they are familiar with). In the following questions, they were asked to assess their perceived privacy while working on the display, to specify applications they would use in such a situation, and to rate the suitability of large public displays for accessing public as well as private information.

Besides this general information, we aimed at gaining specific feedback on how automated privacy protection would influence the usage of large displays in public environments. Therefore, the initial scenario was extended with a fictitious system, which automatically protects the privacy of users working on the display. The described system protects individual user privacy by automatically hiding sensitive information when other people approach the display. The participants, however, were asked not to care *how* this is achieved, but focus on the fact that they can work on the display without being afraid of potential privacy infringements.

The questions presented in the previous part were adapted to the extended scenario and had to be answered under the light of a generic privacy protection system that unobtrusively works in the background. In addition to that, the participants were asked to assess the usefulness of the presented approach and to answer several questions concerning the interface requirements of automated privacy protection systems.

### 2.2 Participants

Altogether, N=55 people participated in the evaluation. The gender and age distribution are shown in Tab. 1.

**Tab. 1.** Gender and age distribution of the participants.

| **Gender Distribution** | | | **Age Distribution** | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Male** | **Female** | **Total** | **<25** | **25-34** | **35-44** | **45-54** | **>54** | **Total** |
| 36 | 19 | 55 | 16 | 22 | 4 | 9 | 4 | 55 |
| 65,45% | 34,55% | 100, 00% | 29,09% | 40,00% | 7,27% | 16,36% | 7,27% | 100,00% |

In addition to the standard demographical information, the participants were asked to assess their technical experience (see Tab. 2).

**Tab. 2.** Technical experience of the participants.

| Very Experienced | Experienced | Average | Not Very Experienced | No Experience | Total |
|---|---|---|---|---|---|
| 13 | 16 | 17 | 7 | 2 | 55 |
| 23,64% | 29,09% | 30,91% | 12,73% | 3,64% | 100,00% |

It is worth noticing that in most cases there were no or only slight differences between the demographical groups.

### 2.3 Results

Above all, we wanted the participants to provide us with information about how suitable they consider large displays in public areas in general (see Fig. 1). We listed six applications for large public displays that had to be rated on a scale ranging from 1 (very suitable) to 5 (totally unsuitable).
Over 80% of the participants considered large displays to be suitable or very suitable for displaying rather public or general content such as advertisements or traffic information. In the case of entertainment-related content or presentations, the majority (over 60%) still classified large public displays as suitable or very suitable.
The remaining two applications, namely desktop replacement and internet browsing, however, turned out to be rather unsuitable for being displayed on large public displays: more than half the interviewees considered them to be unsuitable or even absolutely unsuitable.

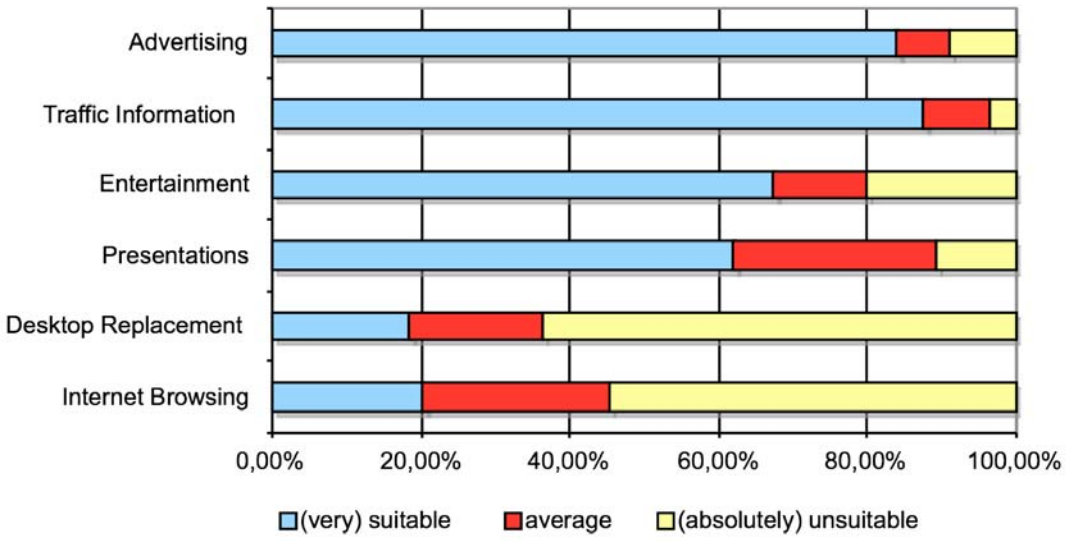


**Fig. 1.** Results to the answers "How suitable do you consider large displays for the following application: *app*" with *app* ∈ {advertising, traffic information, entertainment, presentations, desktop replacement, internet browsing}. The applications had to be rated on a scale from 1 (very suitable) to 5 (absolutely unsuitable).

Based on the aforementioned scenario, where the participants were asked to imagine the situation of being within a office hallway working on a large public display, we asked the participants how comfortable they would feel, using such a large display in the described situation. Less than 10% stated that they would feel comfortable or even very comfortable (see Tab. 3).

**Tab. 3.** Answers to the question "Would you feel comfortable using a large public display in an office hallway in general?", rated on a scale from 1 (very comfortable) to 5 (absolutely uncomfortable).

| 1 | 2 | 3 | 4 | 5 | Total | Mean | Variance | Std. Error |
|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 21 | 14 | 15 | 55 | 3,67 | 1,0929 | 1,0454 |
| 3,64% | 5,45% | 38,18% | 25,45% | 27,27% | 100,00% | | | |

We further asked them whether they would use the large display for viewing e-mails or documents of private content (e.g., an e-mail from a family member). The question had to be rated from 1 (yes, always) to 5 (no, never). The result was very distinct, but not yet surprising: almost all participants would rather not use a large public display for viewing private content.

**Tab. 4.** Answers to the question "Would you use the large display for viewing private content?", rated on a scale from 1 (yes, always) to 5 (no, never).

| 1 | 2 | 3 | 4 | 5 | Total | Mean | Variance | Std. Error |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 11 | 43 | 55 | 4,76 | 0,2169 | 0,4657 |
| 0,00% | 0,00% | 1,82% | 20,00% | 78,18% | 100,00% | | | |

Finally, we asked the participants to consider the case in which they have to immediately send an urgent e-mail of private nature. In the described scenario, the large display is right next to them, compared to their own office, which is a few minutes away. The question was, whether they would prefer to use the large public display or rather go back to their private desktop computer instead.

**Tab. 5.** Answers to the question "If you need to send an urgent e-mail, would you rather go back to your desktop computer or use the large display (that happens to be spatially close to you)?".

| Use Large Display | Go Back | Total |
|---|---|---|
| 12 | 43 | 55 |
| 21,82% | 78,18% | 100,00% |

Almost 80% would rather go all the way back to their desktop computer instead of using the public computer system directly next to them. The fact that a *private* e-Mail needs to be sent certainly is the main reason for this result. Furthermore, it is worth mentioning that the answer depended on the *technical experience*: while only less than 8% of the *very experienced* users would use the large display, more than 23% of the users that are *not very experienced* and 28% of the users that have *no experience* would use the large display.

**Tab. 6.** Answers to the question "How important is privacy to you in general?", rated on a scale from 1 (very important to 5 (not important at all).

| 1 | 2 | 3 | 4 | 5 | Total | Mean | Variance | Std. Error |
|---|---|---|---|---|---|---|---|---|
| 29 | 24 | 1 | 0 | 1 | 55 | 1,55 | 0,5025 | 0,7089 |
| 52,73% | 43,64% | 1,82% | 0,00% | 1,82% | 100,00% | | | |

In this context, we asked the participants how important privacy was to them in general. Similar to the scales before, the participants could express their preferences on a scale from 1 (very important) to 5 (not at all important). Again, the results were not really surprising as almost all participants considered privacy to be important or very important (see Tab. 6).
Summing up the results, the evaluation showed that users are largely concerned with their privacy and that they are rather reluctant to use large public displays, at least without proper protection against possible privacy infringements.
In the last part of the evaluation, we extended the initial scenario and asked the participants to imagine that there would be "some kind" of privacy protection system available that is able to protect their privacy by hiding private or sensitive content whenever other people approach the large public display. In the first part of this second questionnaire we explicitly requested them to disregard *how* the system works, but to rather be not afraid of privacy infringements. We then repeated the questions of whether they would feel generally comfortable with using the large public display (Fig. 2), and whether they would use the display for displaying public and private content (Fig. 3). The light bars stand for the answers if no privacy protection system is available while the dark bars represent the existence of such a system.
In case of public content, a system designed to prevent privacy infringement resulted in the frequency of participants willing to use a large public display to almost sextuple from 5,45% to 30,91% regarding answer 1 (yes, always).

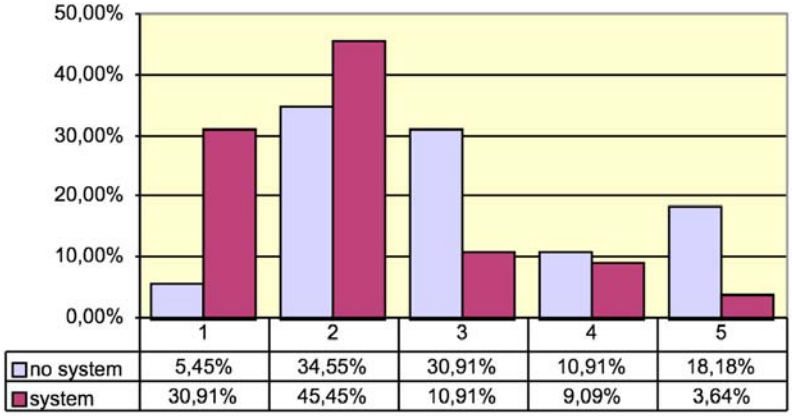


**Fig. 2.** Answers to the question "Would you use a large *public* display depending on whether a privacy protection system is available?", both rated on a scale from 1 (yes, always) to 5 (no, never).

In the case of private content, the result is even more obvious and distinct: while almost 80% of the participants answered that they would never (answer 5) use a large display for viewing private documents without a privacy protection system, this number shrunk to 20% given such a system. Summarizing all the listed and discussed results, it is evident that the provision of a privacy protection system can significantly increase the users' trust when using a large display in public environments.

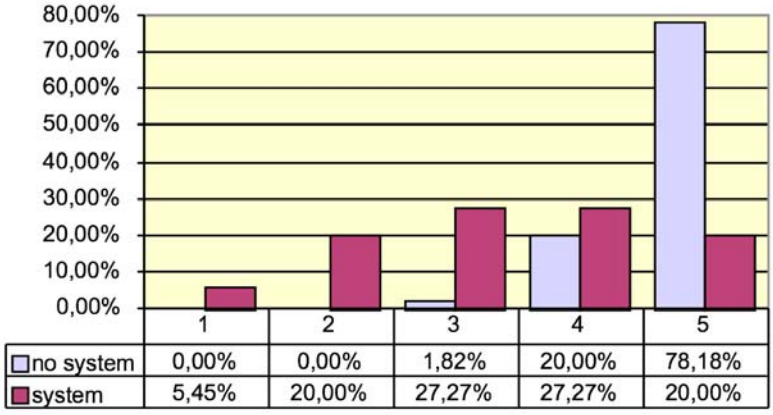


**Fig. 3.** Answers to the question "Would you use a large *private* display depending on whether a privacy protection system is available?", both rated on a scale from 1 (yes, always) to 5 (no, never)..

## 3 Active Privacy Support for Large Public Displays

The insights gained in the evaluation were used to design a system for automated privacy support on large public displays. The developed application called SPIROS (see Röcker at al., 2006) gives users the freedom to spontaneously work on large public displays, without the fear of privacy infringements through passers-by. The system automatically controls the information that is visible to others, without requiring users to employ any additional equipment. This is achieved by providing users with a 'private space' in front of large displays in a shared environment. Within that personal space, the information that is visible to others is automatically controlled according to the user's individual preferences. In order to adapt the information representation to the current context, people entering the private space around a public display are automatically detected and identified using infrared and RFID technology. Based on the identity of the person(s) entering the private space and the privacy preferences of the user working on the public display, the information currently visible is automatically adapted.

## 4 Evaluation of the Developed Prototype System

### 4.1 Materials, Methods and Participants

In a second evaluation, the developed system was presented to the same group of persons who already participated in the first study. This time, the participants were asked to rate the conceptual approach as well as the implemented protection mechanisms regarding their appropriateness for daily usage and their usefulness to protect privacy.

The first part of the questionnaire briefly described the developed system. It was explained that the system scans the environment and is able to detect people passing-by the display. It is further illustrated how users can classify documents and applications and assign special actions that will be executed by the system if other persons approach the display.

For a better understanding, a concrete situation was described in form of a scenario. The participants were asked to imagine a situation, were they are viewing a project-related document as well as a news page in an additional browser window. The project document contains information that only authorized people (in this case project members) are allowed to see. While they are browsing through the confidential project document, a person, who works in the same company, but is not a member of the project team, approaches the display. In this case, the

presented system would be able to minimize or hide the project-related document, but leave the browser window open. Thus, the approaching colleague would see the news website, but not the confidential project information.

### 4.2 Results

We first wanted to know, how comfortable the participants would feel using SPIROS compared to other approaches. Therefore, the participants were asked to rate the different approaches on a scale from 1 (very comfortable) to 5 (absolutely uncomfortable).

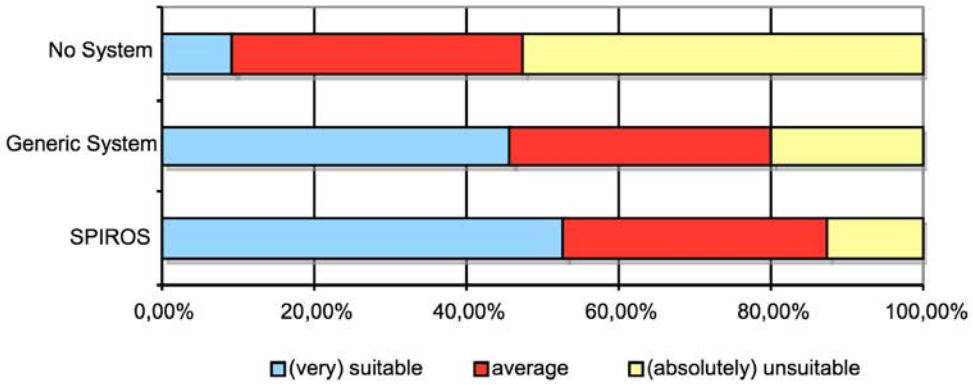


**Fig. 4.** Answers to the question "How comfortable would you feel working on a large display in a public environment?", rated on a scale from 1 (very comfortable) to 5 (absolutely uncomfortable).

Figure 4 basically discloses two things:

- There is a tremendous difference between having a privacy protection system or not, and
- Users are more comfortable with the idea of using SPIROS than using *any* system.

The first premise is rather obvious: while the majority of the users would feel rather uncomfortable if no system was installed (answers *4* and *5*), only 20% felt the same way if there is a system available. The second point is less obvious but still visible: comparing the statistic means and variances of each distribution, the observable differences demonstrate the supremacy of our approach (see Tab. 7).

**Tab. 7.** Mean and Variance of the question "How comfortable would you feel working on a large display in a public environment?", rated on a scale from 1 (very comfortable) to 5 (absolutely uncomfortable).

| Type of Privacy Protection | Mean | Variance |
|---|---|---|
| No System | 3,67 | 1,0929 |
| Generic System | 2,67 | 0,8747 |
| SPIROS | 2,42 | 0,8615 |

Thus, it is not surprising that the majority would use our system: more than two third (67%) are willing to protect their privacy with SPIROS when asked whether they would use our system (the participants could answer with "yes" and "no").
Very important was also the assessment of the possible measures that can be taken by our system. We proposed four possible actions (in the order of increasing privacy protection potential) that had to be rated from 1 (very good) to 5 (very poor):

- "Show Message" (a pop-up message saying "someone is approaching" is displayed),
- "Cover Window" (a cover window with harmless content pops us and covers private or sensitive information),
- "Minimize Window" (all windows that currently display private or sensitive content are minimized), and
- "Hide Window" (completely hides all windows displaying sensitive content, i.e., they are not even visible in the task bar).

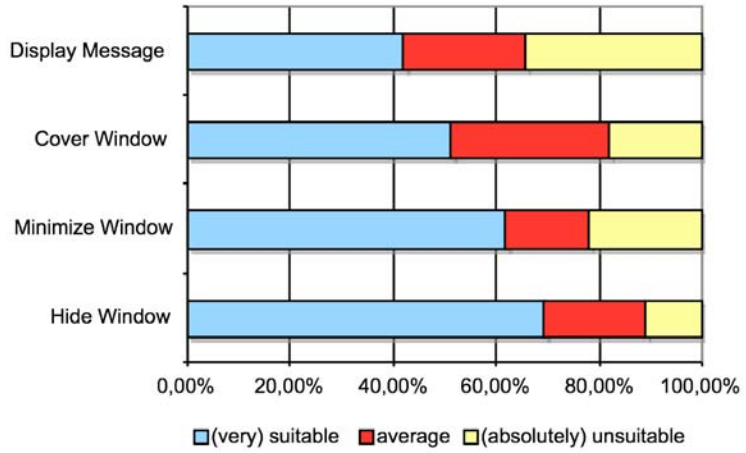


**Fig. 5.** Answers to the question "What do you think of each possible action?", rated on a scale from 1 (very good) to 5 (very poor).

We were rather curious to find out which action would be liked best. The feedback on displaying a message was relatively balanced: obviously, people see this action very differently. The other three actions received a better feedback: more than 50% considered the cover window to be very good or good, more than 60% thought the same of minimizing, and even approx. 70% found hiding to be very good or good. Apparently, the complete hiding of private or confidential information pleases the participants the most.
Finally, we wanted to know whether the participants would generally use SPIROS (see Tab. 8). Giving the previous findings, it is not surprising that the majority would use our system: more than two third (67%) are willing to protect their privacy with the system presented above.

**Tab. 8.** Answers to the question "Would you use such a system?".

| Yes | No | Total |
|---|---|---|
| 37 | 18 | 55 |
| 67,27% | 32,73% | 100,00% |

The evaluation disclosed that people are much more willing to use large displays in office hallways if a privacy protection system is available and even much more so if it is SPIROS. The high user acceptance is based on the good protection of their privacy: a well and unobtrusively installed solution (i.e., if the scanners and sensors well installed and adjusted) is able to provide privacy on a very high level. This fact builds the basis for gaining the users' trust and mostly takes away their fear of using large displays in public environments.

## 5 Conclusion

In this paper we presented a novel concept for personalized privacy support on large public displays. In a first step, a formative evaluation was conducted in order to analyze the requirements of potential users regarding the protection of private information on large public displays. The insights gained in this evaluation were used to design a system, which automatically adapts the information visible on public displays according to the current social situation and the individual privacy preferences of the user working at the display. In a second evaluation, the developed system was evaluated regarding its appropriateness for daily usage and its usefulness to protect privacy. The results of the evaluation showed, that users are in general willing to trust system-based protection mechanisms, provided that they are well implemented. The proposed combination of pre-defined privacy profiles and context-adapted information visualization proofed to be a good trade-off between usability and adequate privacy protection.

## 7 References


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