# Information Ergonomics Guidelines for Multi-User Readability on Semi-Public Large Interactive Screens

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## ABSTRACT
Contemporary knowledge work environments are increasingly based on ubiquitous information access beyond classic single user desktop workplaces. Especially in enterprise contexts personal mobile devices and stationary interactive large screens gain more and more importance for information discovery. In contrast to former PC-based user interfaces these new digitally embedded ubiquitous workspaces raise a demand for new visualizations and socio-technically integrated interaction paradigms to allow simultaneous co-located multi-user interaction. Based on the findings during different field studies within the last five years, our focus in this paper lies on multi-user walk-up-and-use information discovery scenarios in semi-public corporate spaces like coffee corners or beside the elevator. For these settings we present a work-in-progress concept for information ergonomic guidelines that can facilitate the deployment of large interactive screens as additional ubiquitous user interfaces for information discovery.

## Categories and Subject Descriptors
H.5.2 [User Interfaces]: Style Guides, Standardization, User-centered Design

## General Terms
Design, Human Factors

## Keywords
Semi-Public Displays, Information Discovery, Multi-User, Large Screen, Information Ergonomics, Readability, Interaction Zones, CommunityMirrors, Socio-technical Integration

## 1. INTRODUCTION
Beside the triumphal procession of mobile devices in the field of personal knowledge discovery during the last couple of years, the success of multi-touch technology has also contributed to the general availability of stationary large interactive screen environments. Current large screen deployments in corporate contexts are nevertheless still mostly used for video conferencing or single-user presentation purposes in meeting rooms while the "normal" knowledge work is done on local PCs at the individual offices (cf. Fig. 1)

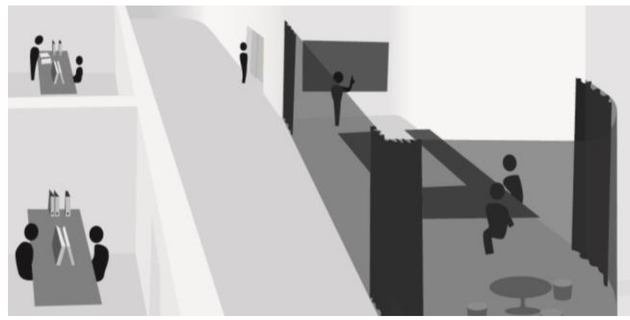

**Fig. 1: Current usage of single user large screen environments in meeting rooms along with traditional desktop workspaces**

Driven by the success of other ubiquitous devices, large screens are meanwhile incrementally installed at different semi-public spaces like coffee-corners, gangways or beside elevators allowing peripheral information consumption while passing by. In contrast to the former usage in closed meeting room settings these new types of installations are much more open, and allow immediate direct simultaneous interaction from multiple users at the same time (cf. Fig. 2)

**Fig. 2: Natural Open Collaboration Spaces (NOCS) with socio-technically integrated ubiquitous interactive large screens.**

During the last couple of years we have developed, accompanied and evaluated different settings in various corporate contexts where large interactive screens have been deployed under the label "CommunityMirrors" [14–16, 20–24]. Our goal within this paper is to generalize our key findings during the field studies regarding the different requirements of large screen multi-user information ergonomics in contrast to existing desktop systems. Within that context our main focus lies on the generation of a first set of simple guidelines that can help developers to guarantee a high level of usability and a good user experience while building their own large screen user interfaces for ubiquitous large screen


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information discovery. In addition to these recommended actions, we present a brief overview of our current work-in-progress implementation of the guidelines in the next generation CommunityMirror Framework (CMF).

# 2. COMMUNITYMIRRORS

In a nutshell CommunityMirrors can be seen as peripherally recognizable interactive "windows" that take information objects (IO) out of the IT systems that they are usually stored in. CommunityMirrors present IOs in semi-public spaces (like e.g. hallways of organizations) enabling interactive ubiquitous information discovery (cf. Fig. 2). In this context we also speak of "information radiators". The term has first been coined by Alistair Cockburn for frequently updated posters showing the current state in software development processes in a high traffic hallway. Cockburn described an information radiator simply as "information in a place where passersby can see it." [5], p.114. The radiators provide pieces of information or in other words concrete visual representations of IOs stored in the underlying data sources in a way that makes them consumable peripherally (see Section 2.2.2). In contrast to most other IT systems which only "provide" information after a certain user interaction (e.g. a particular search) these information radiators proactively distribute their "info particles" independently from any user in order to generate appreciation for the contributors and thereby motivate them for further participation and sharing.

## 2.1 Field studies

The name "CommunityMirrors" reflects the fact that the ubiquitous interface "mirrors" virtual activities of IT systems in physical spaces and thereby blends between digital and non-digital contexts.

**Fig. 3: Different CommunityMirror installations in action**

Based on the CommuntyMirror Framework (CMF), a flexible toolkit that helps to create specific CommunityMirror applications for different deployment scenarios, the concept has been implemented e.g. as MeetingMirror™ [13], LibraryMirror™ [12], IdeaMirror™ [15] and SocialNetworkingMirror™ [24] as exemplarily shown in Fig. 3.

In addition to these short term evaluations we also accompanied the development of a large scale installation in the US headquarter of 3M [19]. During that development parts of the concepts shown in Fig. 2 found their persistent way into a real corporate environment including complete architectural integration into the knowledge workers workplaces as shown in Fig. 4:

**Fig. 4: „Blue Collaboration Hub" a multi-touch multi-device multi-user space at 3M headquarter in St. Paul** [32]

## 2.2 Key concepts of CommunityMirrors

After the overall introduction and description of the field studies the three subsections of this chapter give a brief overview over the key concepts behind CommunityMirrors as foundation of our argumentation for the large screen information ergonomics presented in the following chapter 3.

### *2.2.1 Awareness through ubiquitous Activity Streams*

Awareness information have gained more and more importance for collaborative knowledge processes – especially in form of activity streams from (Enterprise) Social Software (e.g. [1, 9, 17]). By the extension of user interfaces for Social Software beyond the desktop this potential can be transferred to social situations allowing not only individuals to separately consume the awareness information, but also groups of people to jointly watch and talk about activities of others. This in turn can help to foster "mutual knowledge" [25, 28] through "consequential communication"[1] as indicated in Fig. 5. Furthermore the semi-public presentation of contributions to a certain information space can help to simultaneously generate more appreciation for the contributors. As amendments to classic desktops (not replacements!) the interfaces can help to create visibility about what is going on in the organization ("awareness"[2]) and facilitate the accidental discovery of relevant information without having to explicitly look for it ("serendipity", [11, 27])).

[1] „In addition to explicit communication, people also pick up considerable information that is unintentionally "given off" by others as they go about their activities. This is called consequential communication […]." [10], p. 99.

[2] "understanding of the activities of others, which provides a context for your own activities", [7].

**Fig. 5: Establishing of mutual knowledge and a better common ground**

The re-integration of IOs into their social surrounding enables people to directly talk about the discovered information without computer mediation. Thereby, the additional interfaces can help to efficiently generate a better "common ground" (cf. [4]) for successful collaboration.

### *2.2.2 Peripheral Information Perception*

Awareness information with their rather short half-life period profit a lot from being consumable peripherally, e.g. while walking from one office to another or while standing around talking with others during the coffee break (cf. Fig. 2). Beyond-desktop user interfaces for awareness information therefore need to use special visualizations fitting these particular requirements. Making information peripherally recognizable for people passing by is of course not a completely new requirement. It is rather something that is currently simply not present in most enterprises because most of the (knowledge) work is done at the personal desktop. Concerning required visualizations we can learn a lot from existing public use cases like information displays at the airport where current arrivals and departures are shown to passengers passing by like in Fig. 6.


**Fig. 6: Peripherally recognizable displays at the airport**

Not only for proactively looking users, but also as "eye catcher" for passers-by CommunityMirrors require visualizations that highly differ from well-known single-user desktop reading contexts in order to allow peripheral information perception. The selected visualizations should contribute to discoverability of information while approaching the respective display. Therefore, they need to display IOs in different sizes to be simultaneously attractive to users standing right in front of the screens as well as to people only passing by. Depending on the particular deployment scenario e.g. the optimal font-size highly depends on influencing factors like screen size and resolution, illumination of the surrounding, medium view distance of users, or speed of the visitor stream. These circumstances are of particular importance for our information ergonomics concept in the following chapter.

### *2.2.3 Multi-User Interaction*

The typical CommunityMirror scenario targets co-located synchronous multi-user interaction with the different users viewing the large screen(s) from different distances. In contrast to single user desktop interaction or interaction with personal mobile devices the most important difference is the presence of multiple users in front of one (large) user interface at the same time. Existing large screen settings are in most of the cases based on one mainly interacting user, e.g. a presenter in a meeting who is in control of the respective PowerPoint slides. The interaction itself thereby takes place mediated by an additional presentation device like e.g. a personal notebook as shown in Fig. 7 on the left. When transferring these interaction mechanisms without any changes to a touchscreen interface, the pointing device as well as the notebook are not needed anymore, but the interaction paradigms themselves are still only working for one user at the same time. This is also a learning from the field of mobile touchscreen development [2]. Furthermore, with growing display sizes there is not only a simplification of certain user interaction possibilities [18], but also a more important social component of the overall socio-technical system, as users in front of the screens are not only interacting with the system, but also with each other. This relevant design facet of inter-human-interaction is currently often neglected and is also a key influencing factor for our information ergonomics concept in the next chapter.

Based on this argumentation we need completely new interaction paradigms and visualizations for real multi-user interaction on large screens. Today's typical master-slave situations that are based on only one dedicated presenter that is able to use of potential "presentation space" on the wall-sized displays does not work anymore. Instead screens need to already show some existing content allowing joint interactive browsing and information discovery along with other personal devices like shown in Fig. 7 on the right.

**Fig. 7: Classic single-user interaction vs. real multi-user multi-touch interaction on a large display**

Independent from the technical interaction challenge which is meanwhile rather "solved" by multi-touch technology with sufficient touch points, this setting raises completely new demands on multi-user capable information visualizations and interaction paradigms like e.g.:

- **Workspaces**: as there are no "windows", how are individual territories defined in order to visually separate users from another but also allow multi-user interactions like content sharing while preventing "world manipulations" where one user can disturb the interaction of another user with the same visualization.

- **Menus / navigations**: with the absence of toolbars or menu bars known from classic desktop applications, how can users simultaneously access important system functionality without interrupting each other's information discovery.
- **Multi-Distance information presentation**: as users can be in different distance to the screens, how can interfaces specifically target different classes of potential user-view port distances with e.g. different font-sizes

The last point in that list will be the main focus of the following suggestions based on our already conducted field studies (see Section 2.1).

# 3. LARGE SCREEN INFORMATION ERGONOMICS

Derived from the presented learnings within our various field studies we now suggest a first set of large screen information ergonomics guidelines for multi-user readability. As already outlined above, many established ergonomic standards for desktop interfaces cannot be applied directly to multi-user large screen applications. Instead all considerations, e.g. for font-size calculations, need to involve different interaction zones and user attention levels.

## 3.1 Interaction Zones and Attention Levels

As a basis for our concept we therefore developed a social integration model for ubiquitous Natural User Interfaces in organizational contexts, which is visualized in Fig. 8. The theory of the interaction zones is mainly derived from [26, 31], and was adapted to the given context. We identified the following interesting cyclic areas:

1. The **Interaction Zone**, where physical interaction with the device occurs,
2. the **Communication Zone**, in which users actively monitor other people and partly talk to them while they are interacting with the system,
3. the **Notification Zone** without direct involvement, in which users' attention can quickly be caught by certain attractors on the screen and
4. the **Ambient Zone**, which mainly supports the submission of peripherally recognizable awareness information.

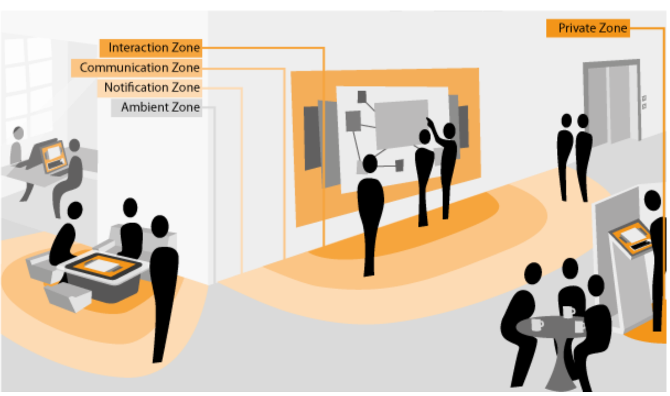


**Fig. 8: Different interaction zones of CommunityMirrors**

The different zones distinguish themselves by different levels of attention the respective users pay to the application. The attention can also be visualized with regard to the viewing direction of the corresponding users as shown in Fig. 9.

With the emergent use of activity streams from Social Software as additional data source for CommunityMirrors we are confronted with an additional level of intensity: the intensity of user interaction with the shown content.

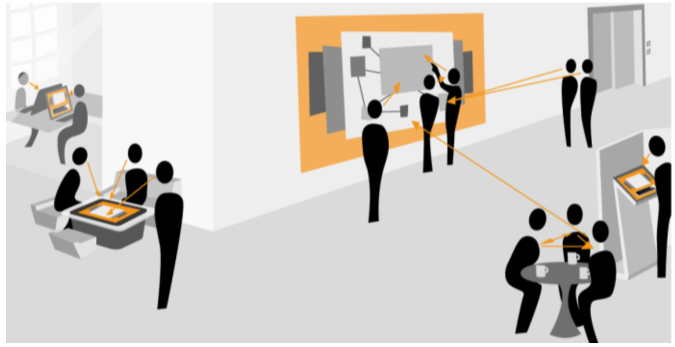

**Fig. 9: View directions of the different users in the social surrounding**

As known e.g. from research on facebook Social Software users can be distinguished very clearly by their behavior [17]. There are certain users with a very strong presence that frequently comment on posts. In contrast to that there are many users that don't interact at all and just watch what is happening in the stream. This spectrum is also valid for semi-public interaction with Social Software beyond the desktop. Accordingly we differentiate the following interaction levels beside the ground level "not involved":

**Awareness**: The lowest level; users of this level are in most cases just passing by consuming the IOs peripherally in the Ambient or Notification Zone of Fig. 8. In addition to that, the awareness level is also very present in the Communication Zone, here even twice, once as awareness of what is shown on the screen and once as awareness of what other users are talking about while using the system. Users that have reached this first level can be attracted very easily to further interaction when they see something they are interested in personally (cf. serendipity in Section 2.2.1).

**Discovery**: The second interaction level is reached as soon as a user is somehow active in the Interaction Zone of Fig. 8, e.g. in order to display more details about a seen info particle. The typical behavior in this level is browsing around for a while in the information space. The duration of the discovery phase depends very much on whether the user can easily find more information that he is personally interested in as well as of his personal involvement in the information he sees.

**Engagement**: This third level is very specific for Social Software and depends much on the personal identification of the user with the content he has discovered. Depending on the individual involvement he will show his appreciation for some of the displayed info particles. The best-known mechanism Social Software offers for that is the facebook Like-Button. But also other engagement mechanisms like e.g. a star ranking can be offered.

**Collaboration**: This last and highest interaction level is reached as soon as a user decides not only to consume information or engage with it, but to really contribute to the joint information space. The easiest way of doing that is e.g. adding a comment to a certain IO.

The size and boundaries of the different interaction zones are of course depending on the particular environment the screens are installed in. But with sufficient knowledge of the architectural surroundings they can be measured and defined as radiuses (R) which is one of the influencing factors for the rest of our concept.

### 3.2 Screen Size, Resolution and Readability

Multi-touch screens with sizes between 55” and 65” are meanwhile “standard”. Larger screens are today in most of the cases built as cascades of smaller displays as shown e.g. in Fig. 4 at the wall or the table (in that case 3x2x32” cascades). Nevertheless display sizes are still growing. One of the main challenges with larger displays is the “low” resolution. With competitive technologies like e.g. Apple’s retina displays users get more and more used to very clear and sharp font renderings. As 4k displays are currently very unusual for large screens and in addition to that very expensive, the existing full-hd resolutions (1080p) can be seen as one of the key challenges for information visualizations for displays beyond 24”. Looking at practical values and taking one of our large interactive screens, the MT550W7 MultiTaction Cell 55" as an example, the screen has a resolution of 1920x1080 which makes it 44 DPI. For comparison an iPhone 5 has 326 DPI (factor 7.4).

In some preliminary tests on a 55” screen we observed that font sizes smaller than 12px cannot be read, because they appear completely blurred. But also font-sizes larger than 12px appeared blurred and could only be read with higher concentration and additional efforts. These observations were made from distances between close-up to the screen (10cm) up to 2.5m.

In this context also font-types had a perceptible influence on the readability. In our preliminary tests under Windows the Windows font-types Calibri and Cambria appeared slightly better readable than other fonts. Regarding serif vs. non-serif font-types, previous studies found no objective difference but a subjective preference for non-serif fonts for reading on digital surfaces [3]. Therefore we will continue to include both variants in further experiments.

Another factor influencing readability is the text wrapping, i.e. the width of a line of text. Studies found that 55 characters per line (CPL) are optimal for reading on screens but longer lines facilitate faster reading and skimming of text [8]. To our knowledge previous studies have not yet evaluated whether this value can be applied directly to large screens as well. Regarding these influencing factors we are planning more detailed user studies in the future (cf. Section 4).

### 3.3 Device Dependent Base Font-Size (BFS)

Based on our findings above a minimum font-size is more or less determined by the hardware specifications of the used screen(s), in particular by the height and width of the display(s) in millimeters in combination with their optical resolution (today full-hd in most of the cases). Independent from additional font smoothing technologies for LCD displays (like e.g. Microsoft ClearType or Apple FontSmooting) we found 9px to be sufficient for the active zone (< 0.5m) for 24” displays and 12px to be sufficient for 55” displays. Nevertheless, further tests are required to evaluate the exact functional dependency of the base-font size from the screen height and width.

### 3.4 Lighting conditions and Contrast

Very typical for semi-public spaces are architectural and environmental influencing factors like e.g. differing lighting conditions. A screen situated at a corridor with artificial lighting only is much easier to handle than a screen near a window where daylight and weather conditions can change the lighting conditions almost constantly. In case the screen is affected by daylight a high contrast (C) is particularly important for achieving high readability [30]. To ensure information ergonomics during intensive external lighting influences the BFS and the font-weight as well as the contrast between text and background can be automatically increased (e.g. by lighting up the background color and darkening the foreground / text color).

### 3.5 Device Independent Interaction Zone Dependent Font Sizes (IZDFS)

Considering the described multi-user aspect of semi-public large screens the displayed information objects have to be readable for all users in different interaction zones in the best case. Based on that assumption there cannot be one single running text / headline font-size throughout the whole application as known from most websites on the Internet. Instead, we need different scaling factors for the different interaction zones depending on their individual distances (R). In [29] content was continuously zoomed to adjust to different distances of the users but no interaction zones were used. In combination with the device specific base font-size described in the section before this brings much complexity into the development process as designers / developers need to calculate different font-sizes depending on different roughly anticipated user distances. Although there are already font-size-distance calculation algorithms based on standards (e.g. [6]), there is a need for an interaction zone dependent font-size model that facilitates the information visualization process by automatically providing the best font-sizes depending on the number of recognized users in the respective target interaction zone of a displayed IO. This can for example be achieved by user tracking with Microsoft Kinect or similar technology.

### 3.6 Maximum Number of Displayed Information Objects (MDIO)

As suggested in the previous section, in the ideal case, content is readable for all users in different distances. This can be achieved by internally assigning information objects to individually tracked users. Unfortunately this approach cannot be scaled infinitely as the maximum number of displayed IOs is limited by the screen-size. Too many information objects will clutter the screen. In the worst case content might even be occluded by other contents. As alternative a system like suggested in [29] could be used, where content may overlap but smaller content is displayed on top of larger content. The effects on readability and information perception of this approach have not yet been evaluated in detail. In any case, a reasonable Maximum Number of Displayed Information Objects (MDIO) has to be calculated. Taking the different interaction zones and therefore different content sizes into account a dynamic maximum number of information objects for each zone would be the ideal case. Considering the number of users in each zone we refer to this value as Maximum Number of Displayed Information Objects for a specific Interaction Zone (MDIO4IZ). The calculation of the MDIO4IZ needs to be based on the sum of screen occlusion of all displayed information objects.

### 3.7 Passerby-Effect

In general two different readability situations have to be considered for semi-public display settings: readability while **passing**-by (walking) and readability while **standing** in front of the screens. Most of the afore mentioned metrics apply to both scenarios. Nevertheless, it seems that the IZDFS in the respective interaction zone needs to be slightly higher to ensure readability for passers-by than for users standing. Although there is further research required (as we also found bold fonts to be recognized better by passers-by than fonts with normal font-weight), we assume that there is an additional readability dependency when text is being moved along with the users walking direction / speed. This needs more intensive user tracking and a lot of interpolations to prevent “hopping” of information on the screen. A recent study [29] found that passers-by just skim the text while continuing with the same pace as before and therefore only remember a few words of the displayed content. Because of that, the content itself has to be adjusted to the presented scenario, e.g. short and concise text for the passing-by setting. Thus, we plan various user studies to evaluate the different effects depending on e.g. walking speed (see Section 4).

## 4. Information Ergonomics Guidelines

Summing up, we identified different influencing factors that are much more important for the development of semi-public multi-user large screen applications than for classic single-user desktop application. The following table gives a summarizing overview of these factors:

| # | Influencing factor | Required measures | Influences |
|---|---|---|---|
| 3.1<br>3.4 | interaction zone size | - Rx = radius distance of interaction zone x in inch<br>- BFS | IZDFS |
| 3.2 | screen size | height (H) and width (W) in inch | BFS, MDIO |
| 3.2 | screen resolution | dots per inch (DPI) | BFS |
| 3.2 | font type | * | * |
| 3.4 | lighting conditions | external light intensity | - BFS<br>- contrast (C) |
| 3.5 | number of users in each interaction zone | body / face tracking | MDIO4IZx |
| 3.7 | motion of users | body tracking | - IZDFS<br>- font-weight*<br>- text speed (TS)* |
| * further research required | | | |

**Fig. 10: Influencing factors, required measures and dependent variables of semi-public large screen information ergonomics**

Based on this collection we propose the following optimization order as guideline to ensure high information ergonomics in terms of readability for semi-public multi-user large screen interfaces:

1. Calculation of BFS and MDIO based on H, W and DPI of display.
2. Definition of R1-R4 depending of the context-specific interaction zone radiuses.
3. Calculation of IZDFS based on BFS and R1-R4.[3]
4. Automatic adaptation of C for the whole application in reaction to the lighting conditions.
5. Automatic adaptation of MDIO4IZx depending on the number of users in the respective zone 1-4.
6. Automatic adaptation of the IZDFS based on the motion of users in the corresponding interaction zone, maybe also additional text movement and more font-weight*.

[3] Developers thereby only need to make definitions like setFontSize (“Notification Zone”), which would then automatically adapt to the specific context of the application once defined.

## 5. Conclusion and further Research

After a general description of the special requirements of semi-public large screen multi-user interfaces, we described some of our key findings from different field studies during the last five years. Ubiquitous stationary devices are becoming more and more important for the socio-technically integrated access to corporate information spaces. To enable real multi-user information consumption in semi-public spaces using large screens as information radiators the requirements are completely different from single-user desktop applications. The collected influencing factors shown in Fig. 10, as well as our optimization strategy, can be seen as a first important step towards semi-public multi-user information ergonomics. Nevertheless most of the presented facts have been directly observed within the different evaluated settings and need to be proven within additional experiments. So, the current status of the presented research can be seen as work-in-progress. Currently, we are working on the incorporation of these metrics into the next generation of our CommunityMirror Framework in order to be able to prove our assumptions in additional laboratory experiments.

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