Design and evaluation of an ambient display to support time management during meetings

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Abstract. An explorative research to investigate the opportunities of using light as a communication medium to provide peripheral information is presented. An innovative ambient display, using dynamic light patterns on the walls of the meeting room to support time management during meetings has been developed. Designed according to the principles of calm technology and information decoration, the system seeks for a balance between aesthetical and informational quality. Two prototypes were created and qualitative research methods are used to evaluate the concept and the efficacy of light in conveying information. The results confirm the value of our concept by showing an appreciation of the usefulness and a good level of comprehension of the users towards the system. The project led to insightful considerations on design guidelines and recommendations for further development of ambient displays to use light to convey abstract information in a subtle, unobtrusive way.

Keywords: Adaptive Interfaces, Ambient Display, Information Decoration, Novel User Interfaces and Interaction Techniques, Aesthetic Design.

1 Introduction

Recent developments in modern lighting and control technologies allow the development of interactive intelligent lighting systems. Decentralized, solid state, energy efficient light sources are combined with new control and interaction technologies to enhance well-being, user experience, and increase efficiency in task support in contexts usually related to functional lighting only, such as home, hospitality, and working environments.

This project explores a new concept for the development of interactive lighting systems. We propose a novel application of lighting which combines its aesthetical and functional properties. Specifically, we aim to investigate whether lighting can be used as a communication medium to provide peripheral information within a working environment. Current trends in lighting solutions for professional environments include dynamic lighting solutions to enhance productivity and well-being (by affecting circadian rhythms), customizable lighting systems to create different atmospheres and moods, and light decorations used to aesthetically enhance working spaces [40]. An ambient display which uses light as a communication medium fits in these current trends, due to its potential aesthetic value. Such system would represent a novelty in comparison to existing lighting solutions, since it combines decorative and informative aspects, resulting both pleasant and helpful for the potential users.

A successful ambient display should provide relevant information in appropriate locations [17][25]. Although several work-related activities could be supported by our system, for this study we choose to focus on meeting situations. Meetings are essential activities within a working environment. Studies revealed that the number of meetings people attend and the time they spend on them dramatically increased in the past years. Although in an initial user study we found several issues (e.g. procedural issues, emotional issues, hierarchical issues, level of intimacy etc.) time management was indicated as a crucial issue within a meeting situation. One of the main causes of dissatisfaction among meetings' participants is the duration of the meeting, often too lengthy [27]. Meetings often take longer than planned due to prolonged discussions and little control on individual contributions. This frequently leads to an unequal distribution of time, with the first speakers using more time than expected, and the last ones hurrying up due to the end of the meeting approaching.

Moreover, different studies revealed that personal time estimation decreases in accuracy when individuals are simultaneously engaged in a cognitively demanding task [24][39]. This is often the case during meetings, when people are involved in presentations and discussions. Even when a moderator is in charge to guarantee the schedule is respected, effectively managing each transition is not effortless.

Technology can offer support for pacing and timing a meeting, by providing interfaces that extend human capabilities. In addition, Suchman's situated action [30] and Gibson's ecological approach to perception [9] has shown that contextual information can support individuals to carry out their task without the necessity to infer it cognitively.

Therefore, an ambient display that makes people aware of their time-consumption in respect of the overall time scheduled for a meeting, could rise meetings' efficiency in two ways: first, real-time indications would help each participant to better manage individual contributions, adjusting the speech to fit the schedule; second, being aware of consuming other's time would invite individuals to be more accountable on their use of common time. Also, time awareness information can support decision making and enhance group coordination by providing people with contextual cues that can be used to guide personal actions.

To be able to investigate this in context, we developed an adaptive ambient display [36] that uses dynamic light patterns to support time management during meetings. Our study relates to different research areas, since it combines principles from information decoration [6] and calm technology [34], with the insights provided by cognitive psychology and information visualization. Moreover, we followed an iterative user centered design cycle, involving end-users at all phases of the study.

The next sections provide detailed information on specific phases: section 2 presents earlier work and background knowledge on information decoration and ambient displays. Section 3 introduces the concept and design requirements, while section 4 describes two cycles of prototype implementation and the evaluation results. Finally, section 5 discusses the main outcomes and possible directions for the future development. The explorative nature of this project provided insightful considerations for possible interactions with ambient intelligent environments, and preliminary guidelines to use light as an information source in concrete user setups.

2 Information decoration, ambient displays, and related work

The main goal of Information Decoration [6] is to design awareness systems that provide contextual information to their users without overburdening them. These systems seamlessly merge with the physical environment and seek for a balance between informational and aesthetic quality. The information is presented by means of ambient displays [36], based on the principles of calm technology [34] and ubiquitous computing [35]. Although providing an exhaustive definition of ambient displays is difficult, these can be described as systems that display important, but not critical information; are embedded in the environment; exploit the ability of users to move their focus of attention from the periphery to the center and back; use subtle changes to reflect updates in information without distracting the user from his primary task; are aesthetically pleasing and environmentally appropriate [22]; and might use different modality (visual, sound, smell etc.) to portray the information [36].

Several attempts were made to provide guidelines for the design [17][22][31] and the evaluation [16][21] of ambient displays. Pousman and Stasko [22] compared several systems and developed a taxonomy based on four design dimensions:

- *Information Capacity* the number of discrete information sources that a system can represent.
- *Notification Level*: the degree to which system alerts are meant to interrupt a user.
- *Representational Fidelity*: level of abstraction used for the visualization of the information.
- *Aesthetic Emphasis*: importance given to aesthetics.

We used this taxonomy to set initial design requirements, and obtain a tradeoff between these dimensions. Literature provides a considerable number of examples of such systems, as well as similar approaches suggested by different disciplines, such as informative art [25]. Figure 1 shows the most relevant examples we found of ambient displays that use light as mean of communication: **Daylight Display** (2003) [17] consists of a floor lamp which changes its brightness according to the external light conditions. **Hello.Wall** (2003) [23] is a wall-size display which emits context-dependent information using light patterns to provide awareness information and atmospheres in organizational environments. The display reflects the identity and the distance of people passing by. **Power-aware cord** (2005) [10]is an electrical power strip that uses dynamic glowing patterns to display the amount of energy passing through it, in order to increase energy awareness among the users. **Ambient Orb** (2007) [1] is a commercial product consisting of a glass lamp that uses color to display information about weather forecasts, trends in the market, or the traffic.

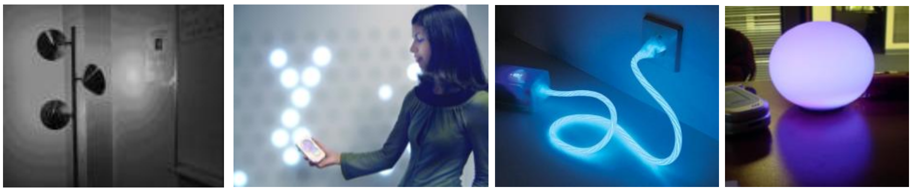

Fig. 1. From left to right: **Daylight Display; Hello.Wall; Power-aware cord; Ambient Orb**.

2.1 Related work on meeting rooms

Previous studies have touched upon pacing interfaces and ambient displays for meeting rooms. Although the described systems are meant for different situations and utilize more traditional implementation techniques, they relate to our research either for their purpose (enhancing pace ability for high cognitive demanding tasks; inviting to a more social acceptable behavior by providing feedback), or their characteristics (shared, adaptive displays). **Time aura** (2001) [15] is a desktop-based application that helps people to adjust their pacing while they give a presentation. It provides an overview of the presentation's structure, and real-time information and suggestions about the progress of the task and feedback on speaker's performance. **Second messenger** (2004) [4, 5] uses a shared display to visualize real-time how much each person has spoken during a meeting in relation to the others. Its aim is to influence groups' behavior towards a more balanced level of participation. **Meeting Mediator** (2008) [14] detects social interactions and provides persuasive feedback to enhance group collaboration in situations where balanced participation and high interactivity is desirable. Behavioral change is promoted by visualizing the interactivity level of the meeting (subjects' active participation to the meeting) and individual speaking time. The feedback is provided to each participant on a personal display. **Relational Cockpit** (2009) [29] is a system that generates unobtrusive feedback on the social dynamics of a meeting. The feedback is presented on the top of the table, each participant has an individual visualization showing the personal cumulative speaking time since the beginning of the meeting; the duration of the current turn; the cumulative visual attention he/she gave to other participants as a listener, and the cumulative and current visual attention he/she got from the listeners. **Conversation Clock** (2009) [12] is described as a "social mirror" that visualizes the level of participation of individuals engaged in a group conversation. The system provides a historical overview of turn-taking and participation within a group. Finally, Rienks [26] presented an overview of **agent-based systems** in order to understand how attendees of a meeting respond to the presence of a virtual assistant, and how such an "assistant" should act and manifests itself.

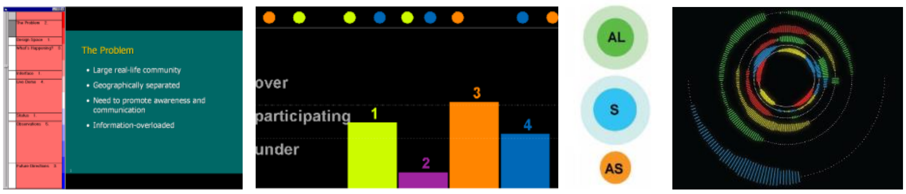

Fig. 2. Time aura; Second messenger; Relational Cockpit; Conversation clock.

All the presented studies found evidence that technology is able to support cognitively demanding tasks during a meeting situation as well as to influence meeting processes. Further research is still needed to understand to which extend this influence positively changes the actual meeting's outcomes. Also, the same studies highlighted some issues and concerns to take into account for the design and implementation of such systems. These issues will be further discussed in the next section, presenting a list of design goals and requirements.

3 Design of the ambient display

This section describes the system's development, the concept, the goals we want to achieve with our design, and the solutions we adopted to meet our initial requirements. We emphasize the explorative nature of our research: as the first step in a long-term project, the goal of our research is not to design an ultimate time management system, but to investigate the opportunities of light to communicate information in an unobtrusive way. This work fits in ongoing research projects on developing new, innovative, interaction styles for and with lighting in the context of the intelligent office. To be able to investigate this in context, we have selected meetings and time management as a specific case.

In the prototype iterations, we focus on issues related to the visualization of information by means of light and the impact such a system might have on users. We are aware that there are other interaction related issues: the design of an interface and interaction styles allowing potential users to interact with the system before and during the meeting. Before a system like this can actually be implemented also the software architecture to support the data processes and the specification of devices and techniques [3, 20] for the collection of real-time, contextual information need to be developed. Although these are important aspects they are not addressed here.

3.1 Concept description

We develop an adaptive ambient display which provides timing information inside a meeting room to support time management during meetings where several individual contributions are planned. Three representative scenarios were chosen for its further development: presentations, round table meeting, and discussion meeting. These scenarios are characterized by one-to-many, sequential many-to-one, and random many-to-many communication patterns respectively, as well as an alternation between roles: participants being in turn member of the audience or main speaker.

The system uses dynamic light patterns to provide a general overview of the meeting and its progress. The system also provides cognitive aid to the people who give an individual contribution to the meeting, for instance by displaying the time available for their presentation, or an indication of their elapsed and remaining time. Specifically, the system could display the following information:

- meeting duration (total time programmed for the meeting);
- meeting schedule (planned activities, such as agenda points, presentations etc.);
- activity duration
- progress of the meeting (overall time elapsed and time left to conclude);
- feedback on individual contribution time (time scheduled and elapsed time);
- notification of transitions between activities (the current activity is almost over and a new phase is starting).

As the meeting proceeds, the system tracks what it is going on in the room, and updates the schedule according to the duration of the previous activities. For example, if the first presentation last longer than planned, the system recalculates the optimal duration of the next ones, and it will allocate them in a shorter time-frame, to fit within the scheduled duration of the meeting.

3.2 Design goals and choices

Referring to the fundamental principles of information decoration [6] and calm technology [34], to earlier work, and to the selected scenarios we have set five requirements to be achieved with the design of the ambient display:

1. **Provide contextual information in an unobtrusive way**. The system should support an "on-demand" interaction. The users decide when they want to retrieve information from the ambient display, they are not required to use of the display the whole time. Information is embedded in the environment. Unobtrusiveness implies that people that need to be focused on primary tasks will not be distracted.
2. **Reduce cognitive load for pacing and time keeping.** The system should provide clear information, minimizing cognitive demands for the processing of that information. Therefore, the display should be always visible, easy to interpret and to recognize in a glance. Also conventional tools, such as clocks, provide time awareness. Yet, these devices might be experienced disruptive to participants who are performing a cognitively demanding activity. Ambient displays take advantage of our ability to quickly switch between focus of attention from center to the periphery and back, while performing different tasks [34]. Yet, the information capacity [22] and the complexity of the visualization are crucial factors for the interpretation and cognition.
3. The system should **support different roles and activities within a meeting**. Speakers need to be aware of their progress within presentations, while other participants might have different needs, according to the role they have in a particular moment; a rough indication of the progress within the meeting or activity might be sufficient to take decisions about their actions.
4. **Invite meeting participants to a more accountable use of common time.** The system should address individual's accountability by visualizing the impact of their individual use of time on the common schedule.
5. **Seek a balance between aesthetical and information quality.** In line with the information decoration [6] and visualization [33] principles and the general guidelines for the design of ambient displays [22], the system should portray information through a subtle visualization, pleasant for everybody exposed to it. Although aesthetic judgment is subjective, integration within the architectural properties of the actual location and its application context needs to be fulfilled.

According to these requirements some basic design choices for the actual design of the display can be made as guideline for the first implementations:

Shared display. We opt for (one or more) shared displays which will be visible at any time to everyone attending the meeting. We expect that individual participants will become more accountable on use of time when everybody knows how individual behavior affects the common schedule. This expectation is based on the concept of social translucence [7], defined as a property of systems which enhance mutual awareness and accountability by displaying socially significant information to their shared users. Social translucency is based on theories on the formation of group norms [11] and on the self-regulation of behavior [3]. Although Dimicco's study [5] indicates that some negative reactions might occur because of the public display of personal feedback, we consider timing information not sensitive enough to cause users' discomfort.

Low information capacity. Since in a meeting situation each possible user is already involved in different primary tasks, a low information capacity is preferable, in order to ensure an effective retrieval of information. Displays that encode large numbers of data might result more informative, but certainly they require more time to be read and understood.

Linear representation of time. Different visualizations can be proposed for the representation of time. A linear representation of time is preferable because of its similarity with a timeline. Following Yakura's definition [38], timelines are a graphical representation of a set of planned activities, organized over a time interval. Unlike clocks and calendars, which measure time, timelines represent time in a narrative way, providing a concrete basis to organize and coordinate work. A linear representation requires an orientation to be interpreted; cognitive psychology tells that scan patterns similar to reading (left-to-right, top-to-bottom) appear intuitively to users even when they have no relevance to the performed task [18].

Pre-attentive processing. The automatic detection of basic visual information without consciously focusing on the display is referred to as pre-attentive processing [32]. Thanks to this property, users who are engaged in another task can quickly catch elements in a visualization which differ in color, size, position, orientation, and other basic characteristics. We use pre-attentive processing to visualize crucial information, such as the progress within the meeting and the different activities.

Static status display, subtle transitions. We choose to visualize meeting "status" and "notifications" for changes in status. Status represents a specific condition or activity of the meeting, for instance agenda items or presentations. A status is displayed statically, i.e. the display does not change during the activity. Notifications indicate transitions between different activities (status), i.e. when the time allocated to a specific activity is about to elapse. Notifications are dynamically displayed. These dynamical effects can be designed with different degrees of subtlety, depending on the level of attention that is required.

Multiple visualization modes to support different roles of participants. To optimally support the different roles participants have during a meeting, we chose to combine two different modes for visualization. The "overview mode" displays all the planned activities, their expected duration and the overall progress within the meeting, allowing all the participants to have an overview of the meeting progress in a glance, including their possible upcoming personal contributions. When a specific activity is going on which requires more control, the system highlights the time slots allocated to that specific activity: "presentation mode".

Convenient location for higher cognitive demanding tasks. As the most convenient location for the display to ensure a good visibility of the display to every participant in all the possible scenarios, we decided to display the information on the meeting room's walls: multiple, identical displays could be used to allow an easy information access to all the attendees. In case of one display, it should be preferably placed opposite the presenter's position.

Light beams as information medium. Several light appliances and effects were considered for the actual implementation of the system. Eventually, our project aims to integrate timing displays into state-of-the-art intelligent (office) lighting systems.

However, for prototyping purposes we preferred using more traditional luminaries, such as (halogen) spots and indirect light because they do not resemble too much to ordinary graphical displays and because these fixtures are commonly used in public and professional environments. The prototypes are explorative research vehicles and not iterative designs of final systems. This is also the reason why the aesthetic quality of the displays (requirement 5) is not subject of our present evaluation.

3.3 Evaluation and Research questions

The evaluation of an ambient display might be complicated and costly, because of the difficulty to define its efficacy in measurable terms [16]. In order to reach our goal, i.e. to understand if light visualizations can effectively convey information to people engaged in a meeting, we design low-fidelity prototypes and set-up experiments with real users, taking into account our design goals and previous studies on similar systems [4][12][14][29]. We apply qualitative research methods (observations, questionnaires, interviews) to collect data. No quantitative data were collected on whether our system increases the efficiency of meetings. Our evaluation is formative, aimed at better understanding and informing the design process. The results are less formal than in summative evaluation.

We identified three clusters in our evaluation: *perception*, *interpretation* and *experience*. Each of these clusters has related research questions to be addressed, as shown in table 1.

Table 1. Research questions.

Perception
Pre-attentive processing: do people catch the information they are looking for at a glance? ***Notifications***: are the notifications noticeable? To which extent? ***Location and visibility***: is the display location comfortable for everyone to see it? ***Distraction***: does the ambient display distract people during the meeting?
Interpretation
Information clarity: do people quickly understand the information they catch at a glance? Is there any element of the visualization that creates confusion during its retrieval? ***Information capacity***: is the portrayed information enough to provide a satisfactory overview of the meeting progress? Are the participants able to remember the coding?
Experience
Participant's use of the ambient display: how do people actually use the ambient display? ***Perceived usefulness***: does the presenter find the system useful to pace his/her presentation? Do the other participants find the feedback useful to organize their actions? ***Stress level***: do the speakers feel more stressed because of the ambient display? ***Social dynamics*****:** does the presenter feel more accountable for his/her use of time? ***Reaction to the shared display*****:** how do people react to the public nature of the information displayed? Is the system too intrusive?

The questions in the *perception* cluster include cognitive aspects related to the identification of information from the display. The *interpretation* cluster relates to the comprehension of the portrayed information, while the questions in the *experience* cluster cover aspects associated with the users' reactions to the system, both as individuals and as a group. The research questions reflect issues that we expect to encounter during the implementation of our system. The main goal of this explorative study is to find out which of these topics are more relevant in relation to the design choices we made and how can we exploit them in the next iterations.

4 Implementation and Evaluation results

In two iterative design cycles, two prototypes of the system have been implemented and tested with actual users: first a low-fidelity graphical visualization, projected with a beamer on the wall. Second a full-scale mock-up using halogen lamps. The prototypes are implemented following the design choices described in the previous section and based on a specific presentation scenario: to support meetings consisting of a series of presentations and in between Q&A sessions.

4.1 First prototype: Low-fidelity graphical implementation

This initial prototype consists of a dynamic graphical pattern to be projected on one of the meeting room's walls. The low-fidelity visualization consists of several bars that differ in color hue, color lightness, and height (see Figure 3). Each bar represents a 5 minute timeframe, and the number of these bars indicates the total meeting duration (so 12 bars represent one hour meeting). To maintain a low information capacity, we considered a 5 minutes resolution to be enough to provide the users with a sufficient overview on the overall schedule. This scale also accommodates the duration of the different activities (often planned to last 5, 10 or 15 minutes), as well as the overall meeting duration, which is on average between 30 and 90 minutes [13][19]. In line with our general design choices, the pattern modifies to indicate meeting status, and to notify activity transitions. We coded the different information as follows:

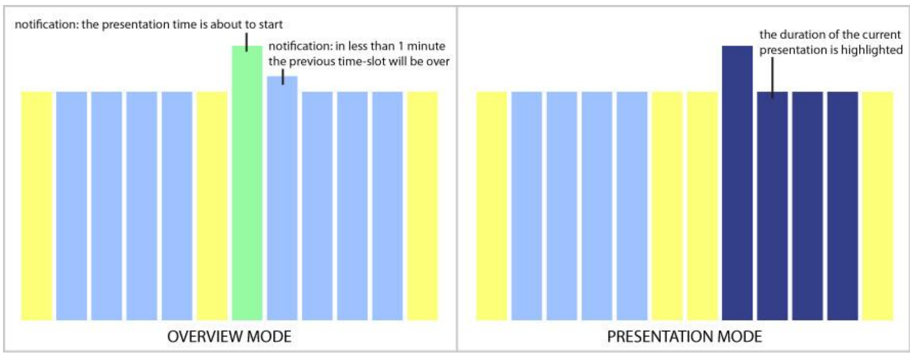

Fig. 3. Impression of the low-fidelity visualization prototype (for explanation see text).

Status: Three variables (size; color, and color intensity) are selected to represent system states to easily trigger pre-attentive processing in our users.

- Meeting progress – *size*: the highest bar, popping out the pattern, is the present time slot. Its position in the pattern is an immediate cue on overall progress.
- Meeting schedule – *color*: light blue bars represent presentations, while yellow bars represent the in between discussions. Primary colors were chosen to ensure high-contrast visualization also in difficult ambient lighting conditions.
- Presentation mode – *color intensity*: darker blue bars identify the current, ongoing, presentation slot. This visualization was preferred over other information visualization's techniques, such as fisheye's distortion techniques [28], to maintain a clear overview on the complete meeting.

Notifications: Subtle changes in bars' length and color indicate notifications that do not require a high level of attention from the users. Such slow modifications will not distract the subjects, but still add extra information: users can immediately notice that something is changing. More noticeable blinks are used for critical notifications.

- Time slot almost elapsed – *dynamic change in length*: during the last minutes of the active time slot, the next bar starts growing towards the height of the active one. Then the new slot becomes active and the expired one shrinks again.
- Upcoming change in activity – *color transition*: when 3 minutes are left for the next presentation to start, the yellow bar slowly turns into blue.
- Approaching end of presentation time – *blink*: when 3 minutes are left for the presentation to be over, the blue bar starts blinking at low-rate. When 1 minute is left, the blink becomes faster. Blinking is preferred over static cues as it can persistently attract users' attention: ensuring the information will be noticed and constantly reminding the presenter of the upcoming end of his personal time.

4.2 First prototype: In-field concept evaluation and results

During two meetings the prototype was evaluated with the same group. A total of 20 participants (18 students and 2 professors) took part in the study. During the first meeting (two hours) the results of four student projects were presented, each with a scheduled presentation time of 20 minutes, followed by a 10 minutes discussion. In the second meeting (one hour), four student projects were presented, all with a scheduled presentation time of 10 minutes, followed by a 5 minutes discussion. A beamer projection of the visualization was shown opposite to the presenter location, see figure 4 for the test set-up.

All notifications and the time-tracking features were preprogrammed for the test, allowing for manual real-time updates (when necessary) by the researcher. No specific instructions about how and when to use the system was given, only the information coding was explained to familiarize the students with the visualization.

The objective of this experiment is to gain qualitative data about the actual impact that our system would have on the participants (*experience* cluster). We choose an in-field evaluation (real presentation session) over a controlled study as we expected that testing our system in this context would provide more insights on the actual experience. Although the projection of the visualization does not use real light sources to convey information, also initial insights on the *perception* and the *interpretation* clusters–were collected and later used for the development of the second prototype. After each meeting all the participants filled-in an open-ended questionnaire on their experience as audience. The presenters were also asked to respond to a closed-ended-likert scale questionnaire followed by a 10 minutes, semi-structured interview with a researcher. The questionnaires and raw data are not included in this paper. The results are summarized below for the three evaluation clusters.

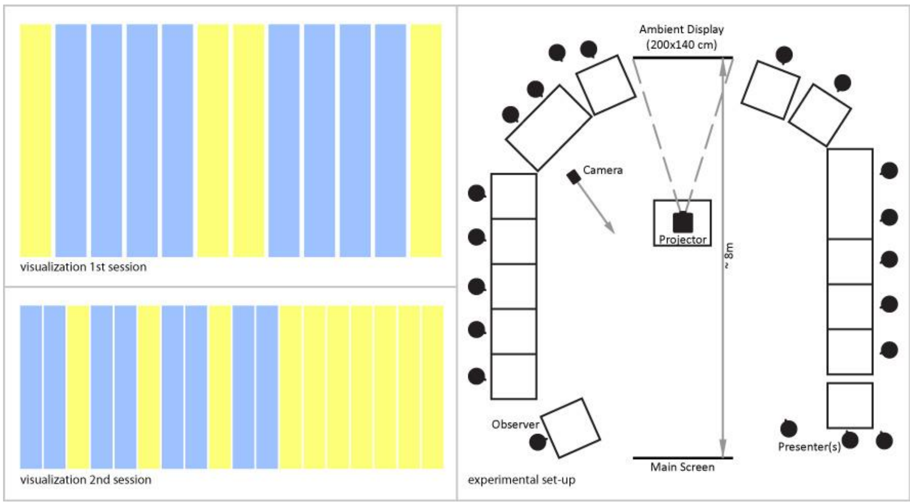

Fig. 4. Set up first evaluation.

The findings on the *experience* cluster show that the subjects comfortably **used the display** to be aware of the meeting's progress, as well as to manage their available time. All participants reported to have looked at the display. As members of the audience "out of curiosity", but mainly towards the end of the presentations to check whether the schedule was respected. Also the presenters reported they looked at display during their presentation time. Yet, few presenters used it while they were actually speaking. Most of the presenters checked the display before or right after their turn. Also, the system prompted some episodes of situated actions [30], (e.g. decide to ask a question; arrive late at the meeting and refer to the display to have an idea about the general progress of the meeting, etc.) confirming that increasing people's awareness towards the actual progress of the common activity leads to a more appropriate personal behavior. Although timing of the presentations appeared not a main issue during the sessions, most subjects recognized the feedback to be **helpful** (*"knowing how much time you speak, and how much you have left, that's really helpful"*) to improve their efficiency and to coordinate the whole group. No significant **stress** was reported in relation to the presence of the ambient display; instead, some participants appreciated its "calming" effect, and found it less stressful than being interrupted or notified by other people about their available time. Further research is needed to understand the system's impact on the meeting's **social dynamics**, especially to verify whether it increases the participants' feeling of their own accountability. Finally, the little concern created by the public nature of the display among the users, confirmed our expectations that timing information is not too sensitive to be visualized in a shared display.

The outcomes related to the *perception* questions illustrate that the system succeeded in providing peripheral information to the participants involved in a real meeting situation, without distracting or annoying them. The visualization successfully triggered **pre-attentive processing**, making it easy for people to spot the meeting's progress in a glance. Also, our choice of using subtle transitions as **notifications** to create an apparent static visualization was confirmed by the participants who found this helpful to have a better retrieval of the information. The more intrusive blink notifications at the end of the presentations could not be evaluated, since most of the contributions lasted shorter than planned. As expected, the display was considered "more natural" and less **distracting** than retrieving timing information from screen applications, personal devices or other people. The **location** of the display was found convenient for and by the presenters who could quickly glance at it while they were looking at the audience. However, the efficacy of a *single* display in supporting the audience is not verified: some of the listeners had to turn their head to actually see it. Good visibility might be a precondition for perception.

The results from the *interpretation* questions indicate that participants could correctly understand the **information** portrayed. "*I think the visualization is really insightful and helpful because it really shows information in terms of where you are and how much you have available*". As observed during previous studies [4] [36], the initial briefing and some experience with the display were necessary to help the participants in properly retrieve the information. Furthermore, like Sturm and Terken's experiment [29], the few users who did not comprehend the meaning of the visualization stopped using the display. Obviously longitudinal studies are preferred over one-session experiments for further evaluations because the consequent learning effect might solve the initial interpretation issues, and because multiple sessions might be also useful to overcome the novelty effects that usually accompany the introduction of a new technology. Finally, all the participants confirmed that the **information capacity** portrayed in the display was sufficient to support them in managing their time, and observed that adding more elements could compromise the display readability, making it more difficult to recognize the coding. Still, few participants found the 5 min slots not accurate enough for the presenter and demanded more specific time information.

Concluding, our users showed an appreciation for the way a tool like this could support time management during their meetings, without being too intrusive or distracting. This confirms our initial expectations towards the system. Furthermore, this evaluation provided useful insights to proceed with the next iteration cycle of implementation. Specifically, we decided to highlight the timing of the present activity (ongoing presentation) more. Second, we decided to change the notification indicating the transition from one time-slot to the next one (within an activity like a presentation), since several subjects reported to be confused by the fact that the next slot already starts moving while the current slot is still active. Moreover, also the increasing length of the bars was considered misleading in representing the elapsing time. In the next implementation this transition is notified by a single time-slot (the active one) which becomes slowly less visible, until it is completely diminished and the next one is active. This implementation also matches better with actual lighting.

4.3 Second prototype: Halogen spots implementation

Building upon the findings of our first evaluation a second prototype has been created and tested. In this prototype, eight halogen spots combined with color filters create the colorful bars. Only a part of the display was implemented, allowing to perform a single session of *presentation-Q&A* instead of a complete meeting schedule (see Figure 5). A combination of white and orange beams is chosen to indicate the different activities. The information is coded as follows:

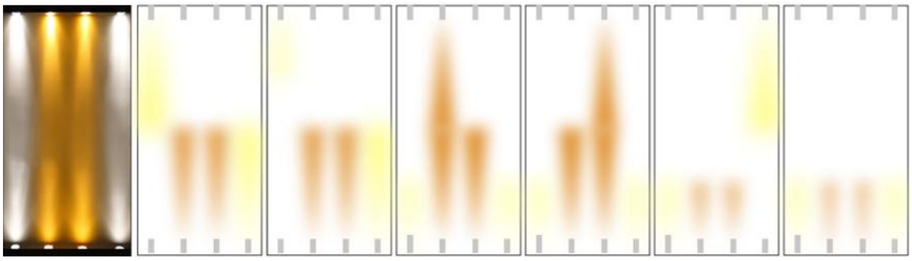

Fig. 5. Halogen spots prototype. Most left a picture of the real panel with all eight spots on. The other panels simulate from left to right a possible meeting scenario (see text for explanation).

Status: Direction (up/down), color, and intensity are selected to display status.

- Meeting progress – *direction*: the bottom-to-top beams visualize the overall schedule, while the top-to-bottom beams indicate the currently elapsing slot. The direction of beams replaces beams' length since beam length turned out to be hard to implement with the available light fixtures.
- Meeting schedule – *colors*: white beams represent the Q&A and preparation phases while the orange beams represent the actual presentation time.
- Presentation mode – *intensity*: during a presentation, the orange beams increase their intensity, while the white ones are dimmed.

Notifications: Again intensity and blink are used to indicate notifications.

- Time slot almost elapsed – *intensity*: when 1 minute is left the current upper starts dimming. When the time is totally over, the next beam switches on.
- Approaching end of presentation – *blink*: when 2 minutes are left for the presentation, the current time-slot starts blinking. When 1 minute is left, the blink becomes faster.

4.4 Second prototype: Controlled context evaluation and results

Goal of this second study was to verify the efficacy of our light visualization to convey clear information to the users. This relates to the questions in the *perception* and *interpretation* clusters. The collected data provided useful insights to better understand how to code information with light. So although the second prototype has a different purpose, we consider it a next design iteration because it takes into account the lessons learned from the first iteration and because it uses real light as a medium (indicating a higher fidelity).

The evaluation using the second prototype consisted of five experimental sessions carried out in a controlled condition in our lab, to ensure all the participants would use the display in similar ambient lighting conditions (illuminance level above 250 lux) and the display's visibility would not affect the visualization. Five pairs of participants (10 in total) recruited among master students and employees took part in the evaluation. Each experimental session consisted of two times 12 minutes, in which each participant had 3 minutes to organize a speech about a topic of their choice, 6 minute to present it, and 3 minutes of Q&A session with the other participant and the researcher/observer, who followed the presentation as audience. Then the participants swapped their places, and the second one became the speaker. This specific timing was preprogrammed in the display and participants were asked to coordinate their actions accordingly. A short explanation about the system's behavior and the information portrayed was given before the beginning of the actual test. The system behaved identically throughout the two sessions except for the notifications indicating the end of a presentation: in the first session the blinks were implemented as smooth brightness changes, while in the second session the blinks were implemented faster, the light smoothly dimming and suddenly becoming bright again. This difference was not explained to the participants. We expected the first notification to be less obtrusive, but also less noticeable by the peripheral view. After the experiment both participants had a semi-structured interview with the researcher to collect qualitative data about their experience with the display.

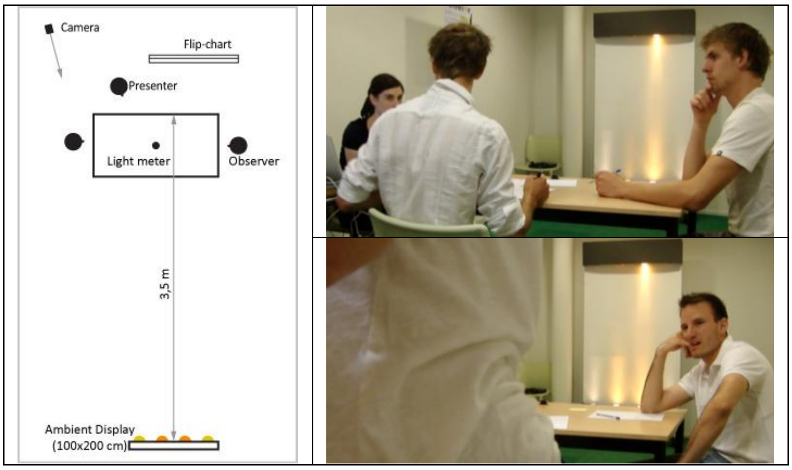

Fig. 6. Set up and impression of second evaluation.

The results collected on *perception* illustrate that both the orientation of the beams and their different colors were effective to trigger **pre-attentive processing**, making it easy for the participants to check their progress without losing track of their speech. Also, the **notifications** indicating the end of the presentation time were found helpful to retrieve information from the display without actively looking at the visualization. Since none of our participants had specific remarks related to the different notifications in first and the second iteration, we can conclude that neither the first blinks were too smooth to be noticed, nor the second ones were too obtrusive.

None of the speakers reported **distraction** from the presence of the ambient display, but several participants found it distracting for the audience. This could be related to the novelty of the display (several participants reported to often look at the display out of curiosity, to see how it would behave), we expect this effect will fade when users will get more familiar with the display; also, given the situation with only two people attending the presentation, any distraction from the listeners was very noticeable during the test.

The outcomes related to *interpretation* confirmed the efficacy of the general design of our visualization: again, all the participants found the display easy to interpret, and no particular difficulties were found in having an overview of the meeting progress. However, several subjects were slightly confused by the notifications, because the changes occurring in a single light beam were not sufficiently visible to have a precise indication of how much time they had left. This can be related to the lack of other reference elements in the visualization.

Finally, although the evaluation did not specifically address questions on *experience*, several positive comments were gained in relation to **perceived usefulness**. All subjects recognized the value of the system in increasing awareness towards time management issues, as well as group coordination within a meeting situation. Also, the way our ambient display provides information was found unobtrusive and, in some cases, even "relaxing".

Concluding, the results with the second prototype confirm the positive attitude of the potential users towards a lighting system that supports time management during meetings and indicate that it is indeed possible to use light to convey peripheral information to users engaged in different primary tasks. We observe, however, limitations associated to the controlled condition in which the study was carried out. In contrast to our in-context first evaluation, during this second experiment several subjects were more focused on following the display than giving their presentations. Also the same remarks on longitudinal use and novelty effect can be made. We conclude that for further development and evaluations, in-field studies provide more insightful outcomes to assess the overall value of the concept.

5 Conclusions and recommendations

This study investigated the opportunities of light as a communication medium to provide peripheral information in working environments. An innovative ambient display was proposed which supports time management during meetings by visualizing time awareness information on the walls of a meeting room using decorative light beams. Such an adaptive system fits in the current trends of intelligent lighting solutions for the professional environment, which will become context aware and exploit light to support activities carried out in the working space and at the same time aesthetically enhance that specific environment.

In an explorative research-through-design process, case-specific design goals and requirements were formulated and two different explorative prototypes were created. The outcomes from two experimental studies with these prototypes showed users recognized the display "useful" to support time management during group activities, both as a tool that assists the speakers for pacing their presentations, and as a system that increases audience's awareness and enhances coordination in the whole group. The level of comprehension of the information portrayed confirmed that it is indeed possible to use light to convey information in a subtle, unobtrusive way: the visualization was found easy to be read at a glance, and simple to interpret, although a certain level of familiarization with the system was required, as is often the case with ambient displays [36]. Also, the system succeeded in maintaining its peripheral nature, without distracting or annoying the users. Participants in the studies appreciated its "calming" visualization and found it "more natural" than traditional methods to retrieve timing information while engaged in their primary tasks. Finally, we did not reveal privacy issues if the aim of the feedback is to improve the overall efficiency rather than assessing individual's performance.

These results support the idea that light can be successfully used as a communication medium for the abstract visualization of peripheral information and that ambient displays which communicate through light are appropriate in meeting room contexts: they display important but not critical information, seamlessly merge with the surroundings, are useful when needed, but still pleasant and not disturbing for main activities that are going on in the same location. More in general, the project contributed to better understanding of interactions with ambient intelligent environments and of the impact that interactive technology might have on group activities.

The experience obtained during the explorative development provides new perspectives for the development of such systems. This encourages us to further develop the system, especially with respect to high fidelity visualizations, i.e. more beautiful, using real lighting equipment, embedded in a real environment, and longitudinal in-context studies. In particular, we individuated several important issues for further development: First, additional investigation is needed to better understand the level of information detail our display requires. The display aimed to give users an indication of their progress, and not about specific values. We assumed that over-detailed indications and notifications were not necessary and not desirable for the efficacy of our system and choose arbitrary time slots. Although our system succeeded in making users aware of the meeting progress, several participants felt discomfort because of the lack of specific, detailed information about the elapsing time. Second, special attention needs to be paid to users' expectations towards the system's behavior: should the display be more adaptive, and act as a mirror of the actual situation, or should it be more proactive, by indicating which action should be performed in order to respect the schedule? Third, the design of an interface and interaction styles allowing users to interact explicitly with such an information decoration system before and during the meeting, need to be developed. Finally, additional in-field evaluations are needed to better understand to which extent, and how, the system affects the participant's perception of their accountability. Specifically, it is interesting to investigate whether social translucency [7] alone is enough to make participants more accountable towards their own actions, or that explicit persuasive cues [8] are needed to trigger a more substantial behavioral effect. Although our initial results indicate that "transparency" is an important factor for the acceptance of the public nature of the feedback, subtle persuasive mechanisms will enhance the effectiveness of the display, without making people uncomfortable.

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