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Ambient Timer – Unobtrusively Reminding Users of Upcoming Tasks with Ambient Light

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Abstract. Daily office work is often a mix of concentrated desktop work and scheduled meetings and appointments. However, constantly checking the clock and alarming popups interrupt the flow of creative work as they require the user's focused attention. We present *Ambient Timer*, an ambient light display designed to unobtrusively remind users of upcoming events. The light display - mounted around the monitor - is designed to slowly catch the user's attention and raise awareness for an upcoming event while not distracting her from the primary creative task such as writing a paper. Our experiment compared established reminder techniques such as checking the clock or using popups against *Ambient Timer* in two different designs. One of these designs produced a reminder in which the participants felt well informed on the progress of time and experienced a better "flow" of work than with traditional reminders.

Keywords: Ambient Light Display, Reminder, Interruptions, User Studies.

1 Introduction

In many of today's office jobs, we are expected to fulfil tasks that require concentration, creativity, and time. Yet, in many professions the day of an office worker is highly fragmented [15]. We arrive at 9 for a short briefing, have a meeting from 10-11, and leave at 12 to meet a colleague for lunch. Thus, we have to squeeze other work tasks into the free time slots and handle them one step at a time. In order to handle these tasks well and efficiently we need to focus our attention on them. Preferably we enter the state of *flow*, which means that we become fully immersed and focused on the task at hand [23].

adfa, p. 1, 2011.
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Fig. 1. Ambient Timer

However, when fully concentrated, we are less likely to pay attention to upcoming meetings and appointments [3,4]. We have observed two strategies to approach this problem: First, people that use electronic calendars have their devices create an alarm once the next meeting approaches [5]. This, however, can disrupt suddenly and unpleasantly and leave workers with unfinished tasks, and a mental state that is not ready to focus on the new topic of the upcoming meeting [1]. Second, many people keep watching the clock if a meeting is approaching soon. In this case, however, constantly switching between the primary task and watching the clock may be preventing the worker from focussing on the task at hand. In other cases, workers forget to check the time regularly and consequently do not show up in time for meetings.

What is missing is a solution that conveys the remaining time until the next meeting to workers, which allows them to focus on their primary task and enter a state of flow at the same time. Instead of sudden interruptions in form of alarms, we need a cue that gradually increases its saliency, moving slowly from subconscious into conscious perception, so that once the meeting arrives; workers have brought their primary task to a stable state and are ready to focus on the new topics.

We propose the concept of an *Ambient Timer*, which presents the time remaining for the current tasks in a way that slowly shifts from ambient to focal attention. As information display modality, we investigate the use of ambient light, which gradually increases obtrusiveness as the time for the current task runs out (**Fig. 1**). We envision the following usage scenario:

Alice is working on a report for the head of her department. At the same time, there is a meeting scheduled in thirty minutes, which she has to attend. The Ambient Timer is already emitting light in a low-attention state, so Alice feels confident that she will

be reminded of the meeting. A few minutes before the meeting, the status of the ambient light display has changed to a more salient, intense output. While she is still working on her report, she slowly becomes aware of the nearing deadline and starts finishing the paragraph she is currently working on. One minute before the meeting the light has become so salient that it is hard to ignore. Alice stores the document on the server, puts her computer into sleep mode, and arrives at the meeting on time.

In this paper, we investigate how to gradually increase the saliency of an ambient light display, so that it slowly catches the attention of a person that is focusing on another task. We report from a study in which we compared the *Ambient Timer* to keeping track of time with a clock and to using a popup alarm in a typical office task. The results provide evidence that Ambient Timer gives people confidence in being able to see the progress of time, make them experience fewer interruptions, and make it subjectively easier for them to enter the state of flow.

2 Related Work

Ambient information displays received greater attention ever since Weiser introduced his work on "calm technology". He pointed out that calm technology engages and switches back and forth between periphery and centre of attention [30]. Ishii et al. provided an insight into numerous possibilities for ambient displays in a work environment when creating their "ambientROOM" [13]. Pousman and Stasko elaborated numerous definitions of ambient displays [24]. In our understanding ambient information displays - such as the Ambient Timer - provide information which is important but not critical. They make a user aware of the information but do not require her to focus on the information display.

"Human interruption", is defined as "the process of coordinating abrupt changes in people's activities" [19]. Interruptions may have internal and external sources. An internal interruption may occur when e.g. throughout the process of writing a scientific paper new demand for literature arises. Thus the person will interrupt her work in order to find the required books. Examples for external interruptions are notification systems. McCrickard and Chewar describe notification systems as "interfaces specifically designed to support user access to additional digital information from sources secondary to current activities" [17]. While notification systems may often be distracting, this behaviour is usually tolerated by users [18]. Fogarty et al. report on the development of a sensor-based system to better automatically predict interruptability of human users [9]. Ambient Timer aims to notify its users on the progression of time without distracting them from their primary task.

In their work, Matthews et al. define multiple attention levels: inattention, divided attention and focused attention [16]. Inattention defines a state, in which information is not consciously observed, while divided attention means that information is consciously perceived but does not require the fully focused attention of the user yet. The existing reminding techniques clock and popup alarm both require focused attention, as one would either have to read and understand the digits or hands of the clock, or close the popup window in order to return to the task at hand. We aim to have the

Ambient Timer operate along inattention and divided attention transitioning from the first to the latter as time progresses. The orienting reflex as described by Sokolov [28] poses limitations on the possible design solutions. Müller et al. report on a study exploring the design space of an ambient reminding system [22].

Mankoff et al. report an ambient system, informing users on the approach of local busses at a faculty building [14]. While displaying information on an upcoming event (the arrival of the bus) the reported system does not increase obtrusiveness to make users aware of when the bus is near.

Dragicevic and Huot introduced the idea of continuously displaying the time until an event using an analogue clock metaphor on the computer screen [6]. This design aims at displaying information on time in an unobtrusive way. However, the information is displayed onscreen and not in the periphery.

Meyer et al. created a system for reminding elderly users of appointments and household events, utilising ambient light [21]. Their system however is more of an "ambient popup alarm", as it gives no information on the progression of time nor on the time remaining until the appointment starts.

Vastenburg et al. reported their work on the acceptability of notifications in home situations [29]. They found a correlation between user acceptability and intrusiveness and importance of the displayed message.

The above mentioned systems all address various aspects of ambient displays and conveying temporal information. However they do not address issues of gradual change in importance of temporal information and the need to notify the user on these changes without disrupting her.

On displaying information with increasing urgency in the periphery Birnholtz et al. report on a projected peripheral vision display [2]. Their results indicate that peripheral vision can be used to direct the user's attention. However, this system does not utilize an ambient light display, but rather projects graphical information.

What is missing is evidence that ambient light interfaces placed in the periphery allow to gradually shift the user's attention from inattention to focussed attention, without becoming disruptive.

In the following we report our experiment. We begin with a description of the apparatus.

3 Ambient Timer

As *Ambient Timer* we envision an ambient light display that notifies users unobtrusively of the progression of time in order to know when to finish the current task to be ready in time for the next appointment. *Ambient Timer* illuminates the periphery of a monitor, on which a user focuses her visual attention when working on the computer.

Focal and peripheral vision may be regarded as two separate perception channels [12]. As peripheral vision is more sensitive closer to the foveal point [20], we decided to place our ambient light display as close to the monitor as possible (**Fig. 2**). Placing the information in the periphery will allow the user keeping all monitor real estate for information that might not be suitable for display in the periphery.

To gradually grab the user's attention along the attention levels defined by Matthews et al. [16], the output of the *Ambient Timer* needs to gradually become more salient. In order to increase the saliency of the display to gain attention over time two forms of transition appear to be feasible: First, a sine wave change where the display alternates back and forth between two states with increasingly faster cycles. Second, we use an exponential change from the initial to the final state. Other forms of transition were ruled out after studying the related literature, e.g. linear change, which may not provide enough increased obtrusiveness due to human deficiencies in noticing slow changes [25], or cubic or saw tooth changes between initial and target state due to excessive obtrusiveness [28].

Müller et al. [22] explored the design space for displaying gradual changes with ambient light. Their results suggest that colour changes may be superior to change in brightness or saturation. While a sinusoid change may not require a sharp contrast from start to target colour, exponential changes - which appear to be more unobtrusive by design - require a sharp contrast of complementary colours such as green to red. As reported, the traffic light analogy was found helpful by participants. With regard to these results, we chose to introduce a sinusoid colour change with increasing frequency from green to orange as well as an exponential change from green to red as conditions for *Ambient Timer*, thus evaluating the patterns from each category that achieved best results overall against state-of-the-art reminding techniques.

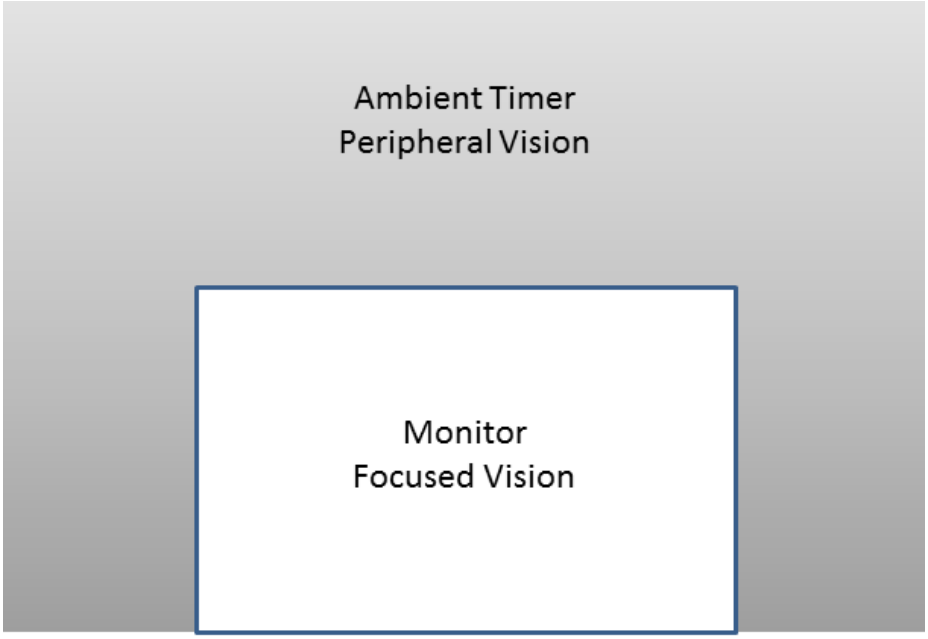

Fig. 2. Concept of Ambient Timer

Our apparatus is made of uniformly controlled LED-stripes which were fixed to a three-sided frame that had the same width and height as a 22 inch monitor used for

our studies (**Fig. 3**). This frame is mounted on the back of the monitor (**Fig. 4**). We placed frame and monitor on a desk close to a matt white wall. The gap between monitor and wall was about ten centimetres. This provided us with a surface to reflect the light emitted by the LEDs and illuminate the immediate periphery of the monitor. While the user focuses her view on the monitor, she can perceive the ambient light display in her peripheral vision.

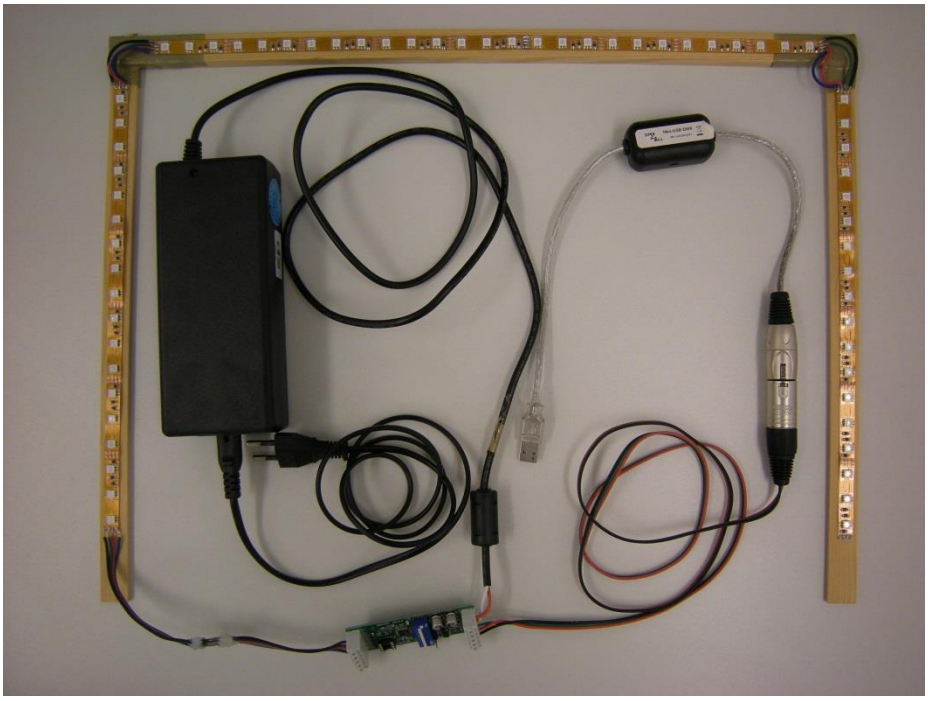

Fig. 3. LED-Frame

4 Methodology

In our experiment, we investigated if the *Ambient Timer* allows workers to work more concentrated and efficiently than when using state of the art reminders. Our general approach was to expose participants to a demanding primary task and evaluate the effectiveness of the *Ambient Timer* as reminding technique compared to state of the art baselines. As a primary task, we asked participants to copy (type) given texts and correct mistakes we placed in the original documents. Copying and correcting texts is a task requiring good concentration. Thus the impact of interruptions would be serious [10].

As secondary task, we asked the participants to be aware of the time and finish the primary task within ten minutes. We defined finishing as finalizing to copy and correct a full sentence once the participants thought that available time was running out.

Fig. 4. LED-Frame mounted on the backside of the monitor

Participants were instructed to inform the experimenter, when they thought that they had finished the primary task. Participants were discouraged from exceeding the time limit (overshoot), i.e. to take longer than ten minutes. If participants missed the end of the time period by more than 30 seconds a popup window informed them of the end of the trial. For staying aware about the remaining time, we experimentally compared two implementations of the Ambient Timer with using a clock, i.e. participants had to monitor the progress of time on a system clock with digits, and pop-ups, i.e. the only information given was a pop-up that was shown two minutes before the time expired. The two implementations of *Ambient Timer* were:

AT Expo: remaining time was conveyed via an exponential colour change from green to red.

AT Sinus: remaining time was conveyed via a sinusoid colour change between green and orange with increasingly faster cycles.

Our hypotheses were that:

H1: With the *Ambient Timer*, participants will be or feel less interrupted than with the clock.

H2: Participants will find/correct more and make less new mistakes when using the *Ambient Timer*.

H3: Participants feel confident and well informed on the progression of time when using *Ambient Timer*.

H4: Participants will find *Ambient Timer* as the favourable reminding technique.

4.1 Design

Type of Reminder, i.e. the way that participants were informed about the time that remained to complete the current task, served as independent variable. We compared four different techniques:

- In the *Popup* condition, the participants had no information about the remaining time. Instead a popup window appeared to inform them about the end of the task two minutes before the time expired. This condition reflects the common strategy of not checking the clock and only relying on popups by the calendar system to be reminded of appointments.
- In the *Clock* condition, we showed the system clock in the task bar at the bottom of the screen. The clock showed the current time with hours and minutes. No seconds were shown. By knowing when the task had to finish, the participants could calculate how much time is left. This condition reflects the other common strategy of keeping an eye on the clock when a meeting is approaching.
- In the *AT Expo* condition, the *Ambient Timer* was used to convey the remaining time via an exponential colour change from green to red.
- In the *AT Sinus* condition, the *Ambient Timer* was used to convey the remaining time via a sinusoid colour change between green and orange. With this condition, we aimed at testing a more obtrusive pattern, in case that the exponential change proves to be too unobtrusive when the user focusses on the primary task.

Except for in the *Clock* condition, no clock was available to the participants. During the experiment, the order of these conditions was counter-balanced to cancel out sequence effects. In order to assess the unobtrusiveness of these designs, and answer the hypotheses, we logged the following measures as dependent variables:

- *Interruptions*: The number of interruptions, i.e. any occurrence of a pause between keystrokes of more than one second.
- *Keystrokes*: the total number of keystrokes per task. We measured *keystrokes* to gain insights into how well participants were able to focus on the copying task in the various conditions.
- *Keystroke Time*: the average time between two keystrokes. This measure was taken to gain insight into the ratio of total keystrokes and interruptions. As not all participants stopped exactly at the ten minute mark and as the obtrusiveness of the displays was not evenly distributed across time we did not simply normalize our measures.
- *Corrected Mistakes*: the number of grammar and spelling mistakes corrected per task. We measured *Corrected Mistakes* to quantify how concentrated our participants can work with the compared reminding techniques.
- *Newly Introduced Mistakes*: the number of grammar and spelling mistakes that are newly introduced by the participant per task. *Newly Introduced Mistakes* was also measured to estimate the participants' level of concentration and flow.
- *Overshoots*: a Boolean value indicating whether the participant did not finish the task on time. If the participant continued to work on the task for more than 30 sec-

onds after the time ran out, we interrupted the task and counted this task as an over shoot. With this measure, we aimed at quantifying how well the different reminders helped the participants to stay aware of the remaining time.

In addition, for each of the conditions, we collected the participants' agreement (5-point Likert scale) to the following statements:

- *I think this technique is good.*
- *I felt distracted by the system.*
- *It was easy to monitor the progression of time.*
- *I felt sure about noticing the progression of time.*
- *I was able to complete the task in time.*
- *I entered the state of flow.*

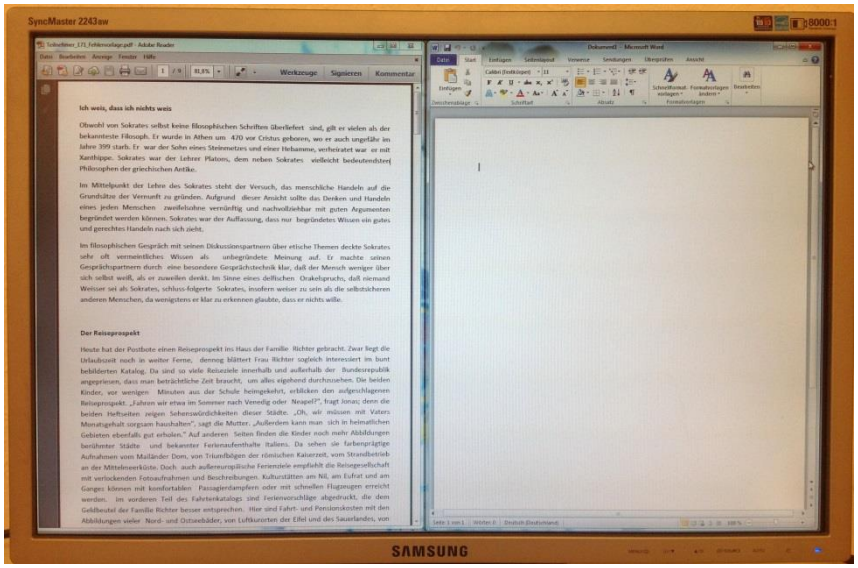

Fig. 5. Screen to copy and correct text

4.2 Apparatus

The texts to correct were taken from a collection of dictations for teachers working with tenth graders [27,7,26]. Each dictation had a special focus on certain words which we used as a guideline for placing mistakes into the text. For the copy and correct task, the screen was divided into two parallel text-fields, one containing the text, one used to copy the text into.

As work place, we used a standard desktop computer running Windows 7 with a 22-inch monitor on a standard working table. As shown in **Fig. 5**, the participants were provided with a text field to copy the text into. In the *Clock* Condition, we showed the current time, as shown in **Fig. 6**.

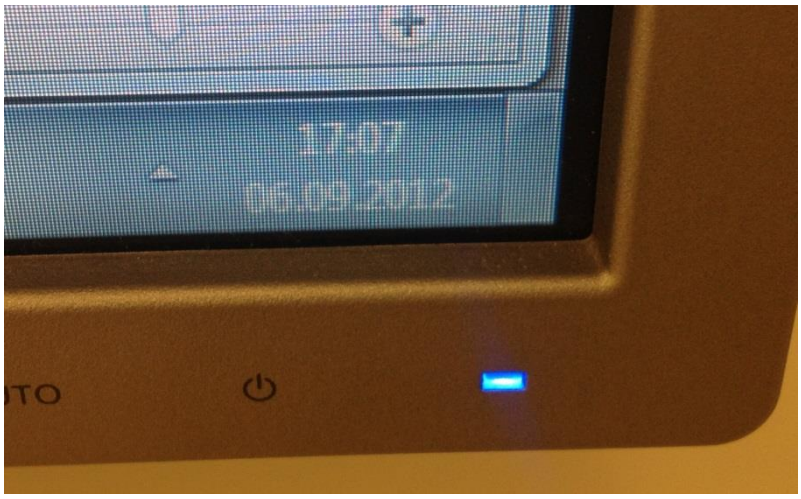

Fig. 6. On-screen system clock

We conducted our studies in a room with controlled light setting thus eliminating possible effects of changing surrounding light [8]. We kept the light level constant at 420 lux at the desktop which is in compliance with rules on office workspace settings.

For tracking interruptions, we used a key logger script that measured the time between individual keystrokes.

4.3 Participants

12 participants (4 female, 8 male) aged 17-45 *(M = 28.3, SD = 8.8)* took part in the experiment. None of the participants reported a case of colour blindness.

All participants were experienced in writing texts on computers. All participants rated their typing speed between fast and medium, two of them used 10-finger-typing.

Asked about their method of reminding themselves of appointments, participants either used a calendar with alarms on their computer (6) and/or on their phone (5) as well as regularly checked the clock (4). When using reminders, the lead time to appointments was stated to be any time from five to 60 minutes, or even one to two days in advance for full day events. All but one participant answered that they "sometimes" to "never" missed appointments. One participant said that missing appointments was a common occurrence. Participants received no compensation for their participation.

4.4 Procedure

Before the start of the experiment, participants were introduced to the scope of the study and familiarized with both light designs of the Ambient Timer. We then conducted four trials per participant, exposing them to the four conditions in randomized order.

After each trial, participants were asked to rate their agreement to the five statements regarding the used reminding technique. Upon completion of all four trials, we collected the participants' impressions in an open interview.

5 Results

5.1 Objective Measures

Figure 7 shows the descriptive statistical summary for the objective measures. We used repeated measures one-way ANOVA and Tukey HSD to test for significant effects.

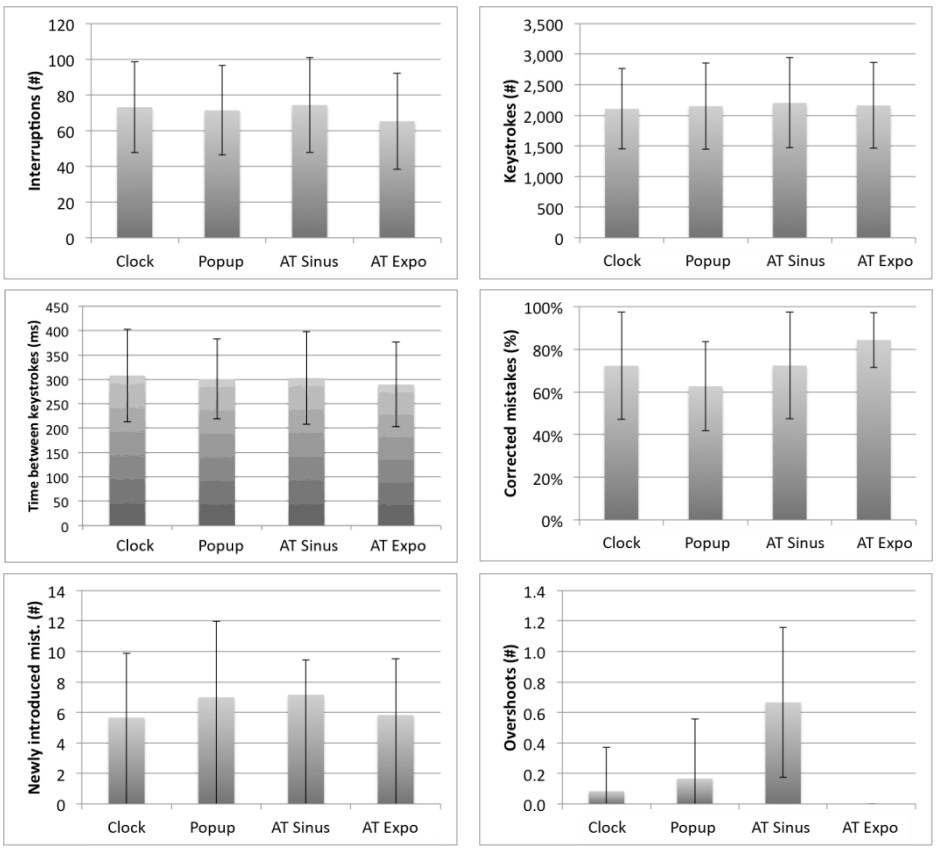

Fig. 7. Descriptive summary of objective measures (Bars show mean, error bars indicate standard deviation)

There was a significant effect on *Overshoots* $(F(3, 44) = 9.0, p < .001)$. The number of *Overshoots* was significantly higher in the *AT Sinus* condition, compared to the

Popup ($p < .001$), *Clock* ($p < .001$), and *AT Expo* ($p < .001$) conditions. Thus, participants had more difficulties to finish their tasks on time in the *AT Sinus* condition; participants did not finish their tasks on time as often as in the other tasks.

There were no significant effects on *Interruptions* ($F(3,44) = 0.29$, $p = .83$), *Keystrokes* ($F(3,44) = .04$, $p = .99$), *Keystroke Time* ($F(3,44) = .09$, $p = .97$), *Corrected Mistakes* ($F(3,44) = 2.03$, $p = .12$), and *Newly Introduced Mistakes* ($F(3,44) = .47$, $p = .7$). Hence, we cannot make any assumptions about the effect of *Type of Reminder* on the remaining dependent measures.

5.2 Subjective Measures

Fig. 8 shows the Median ratings of the participants' level of agreement with the six Likert-scale statements per condition. Assuming normally-distributed, interval scores, we analysed the data for significant effects by using repeated measures one-way ANOVA and post-hoc Tukey HSD tests.

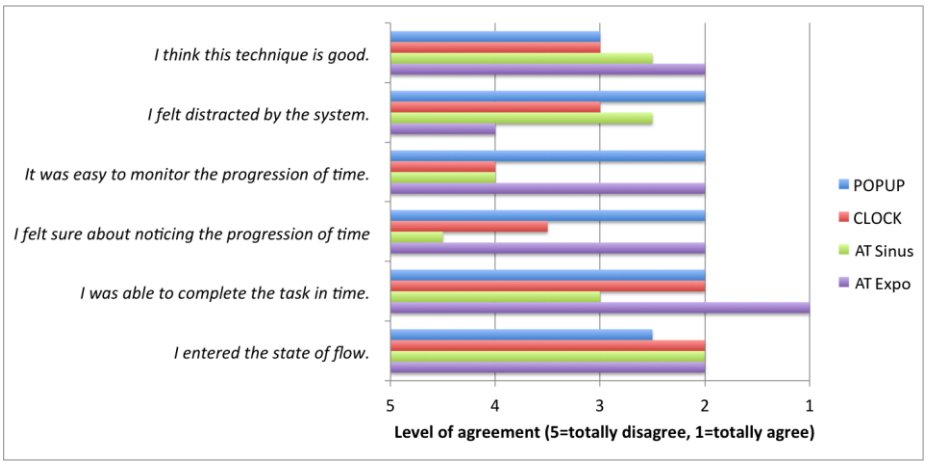

Fig. 8. Median level of agreement with the six statements per condition

There was a significant effect on the agreement to the statement *I think this technique is good* ($F(3, 44) = 4.5$, $p < .01$). The level of agreement in the *AT Expo* condition was significantly higher than in the *Popup* ($p < .05$) and in the *Clock* ($p < .05$) conditions. Thus, participants found *AT Expo* to be a better reminding technique than *Popup* and *Clock*.

There was a significant effect on the agreement to the statement *I felt distracted by the system* ($F(3, 44) = 4.8$, $p < .01$). The level of agreement in the *AT Expo* condition was significantly lower than in the *Popup* ($p < .05$), *Clock* ($p < .05$), and *AT Sinus* ($p = .06$) conditions. Thus, participants found *AT Expo* to be less distracting than the other reminding techniques.

There was a significant effect on the agreement to the statement *It was easy to monitor the progression of time* ($F(3, 44) = 8.7$, $p < .001$). The level of agreement in

the *Clock* condition was significantly higher than in the *Popup* ($p < .01$) and *AT Sinus* ($p < .01$) conditions. Likewise, the level of agreement in the *AT Expo* condition was significantly higher than in the *Popup* ($p < .001$) and *AT Sinus* ($p < .001$) conditions. Thus, in the *Clock* and *AT Expo* conditions, participants found it easier to monitor the progress of time than in the *Popup* and *AT Sinus* conditions.

There was a significant effect on the agreement to the statement *I felt sure about noticing the progression of time* ($F(3, 44) = 14.0$, $p < .001$). The results are analogue to the previous statement. The level of agreement in the *Clock* condition was significantly higher than in the *Popup* ($p < .001$) and *AT Sinus* ($p < .001$) conditions. Likewise, the level of agreement in the *AT Expo* condition was significantly higher than in the *Popup* ($p < .001$) and *AT Sinus* ($p < .001$) conditions. Thus, in the *Clock* and *AT Expo* conditions, participants were more confident that they would notice the progress of time than in the *Popup* and *AT Sinus* conditions.

There was a significant effect on the agreement to the statement *I was able to complete the task in time* ($F(3, 44) = 7.3$, $p < .001$). The level of agreement in the *AT Expo* condition was significantly higher than in the *Popup* ($p < .05$) and *AT Sinus* ($p < .05$) conditions. Thus, participants found it easier to complete the task in time in the *AT Expo* condition compared to the *Popup* and the *AT Sinus* conditions.

We could not find a significant effect on the agreement to the statement *I entered the state of flow* ($F(3, 44) = 2.6$, $p = .06$, marginally significant).

In summary, the clock and the *Ambient Timer* in the *AT Expo* condition were found to make it easy to monitor the progress of time and finish the task in time. In addition, the *Ambient Timer* in the *AT Expo* condition was found to be the better reminding technique and was rated to be least distracting.

5.3 Comments and Observations

For *Clock*, six participants answered that as keeping an eye on the clock was very common, it should not pose a problem. They felt it was reliable and that they were "in control". On the other hand ten participants answered when asked what had distracted them that switching focus from text to clock and back posed some problems in finding the correct line in the text again.

Concerning *Popup*, five participants were unhappy with the way the popup interrupted their work. Three participants commented that they liked how the system was hidden in the background until it popped up and that they could work relaxed until then.

On *AT Expo*, one participant said it was difficult to see the end of time, while another argued that it was like a clock only better. The calm exponential change was well accepted.

AT Sinus was found to be obtrusive by six participants. They felt unsure on how much time had already passed and said that they were somewhat distracted by the constant change of colours. While two participants said that the colour change was too subtle to notice without looking, one participant answered that he liked the subtle

changes best. Three participants mentioned that they might be able to get used to *AT Sinus* but that it needed more time to familiarize.

Ten participants said that they can imagine using the *Ambient Timer*, while two answered that they would not want to use it. Of the ten positive answers, one participant would use the *Ambient Timer* stand-alone, while the others preferred a combination of techniques (+ Popup (6), + Clock (3)) for better control of when the time ran out.

Concerning acceptability of an ambient light display placed at the user's desks 11 participants considered using the *Ambient Timer* in a work environment as being unproblematic. Out of the positive answers, some participants argued that the system could signal other colleagues that the user is about to leave for a meeting and that a discussion should be postponed to a later time, thus adding extra value to the information of an upcoming task. However, when engaged in group meetings or talks with customers or other outsiders, participants would like an option to temporarily disable the system as they felt the use of such a system inappropriate in these situations. Only one participant could imagine using *Ambient Timer* solely in a private setting.

Asked about the display time of *Ambient Timer*, most participants would prefer a lead time of 10-15 minutes to be able to bring their current work into a stable state before having to leave for the appointment.

We asked participants if they could think of other light patterns or colours to use in *Ambient Timer*. Five participants liked the *AT Expo* the way it was, especially as they liked the green = "go", red = "stop" traffic light analogy. A couple users suggested using blue as a starting colour, arguing that blue was a calming colour. Two participants suggested an exponential pattern with a flashing part at the end of the time period so that it would be easier to see.

5.4 Discussion

The experiment compared two designs of *Ambient Timer*, one with an exponential change of colour from green to red (*AT Expo*), and one with a sinusoidal change between green and orange with increasingly faster cycles (*AT Sinus*), a clock, and pop ups as means to monitor the remaining time. Our results show that participants experience fewer interruptions when using *Ambient Timer* with an exponential change from green to red, compared to all other reminder techniques in our experiment. Their average typing speed was faster when in this condition. Participants ranked this design best, felt most confident using it and preferred it over all other techniques.

Discussing results in relation to our hypotheses, we find that we have a split between the two *Ambient Timer* designs. While the exponential change from green to red performed very well, users experienced no benefits over state-of-the-art reminding techniques from the sinusoid change between green and orange. On the other hand it is worth to mention, that the sinusoid design was by no means a dropout.

H1: Participants will experience fewer interruptions when using the Ambient Timer

No significant effects could be found in a one-way ANOVA test of key-logging data to support this hypothesis. However, our participants' answers to the question of being in the "flow" received marginally significant better results for the exponential *Ambi-*

ent Timer design than when participants were in the *Clock* condition. *Ambient Timer*'s idea of reminding users without interrupting them works well in the exponential *Ambient Timer* design.

H2: Participants will make fewer mistakes when using the Ambient Timer

Even though participants found more mistakes we had prepared in the texts when using both *Ambient Timer* designs, we could not reveal any statistical significance for these findings from the key logging data. Hence, there is no evidence to support this hypothesis.

H3: Participants feel confident and well informed on the progression of time when using Ambient Timer

This hypothesis can be confirmed for the *Ambient Timer* with the exponential design and falsified for *Ambient Timer* in the sinusoid design. The exponential design scored roughly the same results as when participants used the clock, while state-of-the-art reminding technique *Popup* and the *Ambient Timer* with the sinusoid design scored results worse than average. The data revealed significantly better results for the exponential *Ambient Timer* design compared to state-of-the-art technique *Popup* and the sinusoid *Ambient Timer* design, as well as significantly better results for *Clock* compared to *Popup* and the *Ambient Timer* with the sinusoid design. We have no statistical evidence that the *Ambient Timer* with the exponential design performed better than *Clock*. Considering the significantly better results of exponential *Ambient Timer* design over *Clock* and *Popup* concerning the statement "This pattern is good" we conclude that *Ambient Timer* when in the exponential design makes a good alternative to state-of-the-art reminding techniques.

H4: Participants will find Ambient Timer as the favourable reminding technique

This can be verified for *Ambient Timer* in the exponential design and falsified for the sinusoid *Ambient Timer* design. The exponential *Ambient Timer* design ranked best together with *Clock*, while the sinusoid design ranked last.

Overall, H1 (less interruptions) was supported for the exponential *Ambient Timer* design and *Clock*, H2 (less mistakes) was not supported, and H3 (well informed) and H4 (favourable) were supported for *Ambient Timer* in the exponential design but not for the sinusoid design.

We have recorded split results suggesting that the benefits of using ambient light for reminding users of upcoming events depends on how the design increases its saliency to grab the user's attention. In our experiment, the exponential *Ambient Timer* design receives better scores on all questions we have asked our participants and is ranked best in the order of participants' preference. Participants' feedback in our questionnaires and interviews suggest that they like the way *Ambient Timer* in the exponential design keeps them updated on the time progress without them having to take their eyes off the primary task or being interrupted unexpectedly. With the exponential *Ambient Timer* design we have introduced a true alternative to the state-of-the-art reminding techniques *Clock* and *Popup*.

Concerning acceptability, the majority of participants had no concerns about the visibility of the system in an office environment. They saw benefits such as co-workers being more aware of the individual schedules. However, some would prefer to "mute" the system in group-work situations and when meeting with customers.

One of the limitations of our experiment is the type of setting. Evaluating ambient displays in a lab condition is always difficult, as the expected benefit of blending into the environment can hardly be achieved in a lab setting [11]. When using the *Ambient Timer*, participants were using a system that was already "on", which it would not normally be in a regular office setting. Therefore we cannot make any statements on how users will react to a "warm-up/turn-on"-phase. While we aimed at creating a challenging task that could be solved by the participants, we cannot simulate tasks that are truly relevant for our participants, which would then have enabled them even further to experience flow and immerse themselves in the tasks.

6 Conclusion

We presented *Ambient Timer*, a way of unobtrusively reminding users of upcoming events and appointments using ambient light. In an experiment, we compared the exponential change of colour from green to red, a sinusoidal change between green and orange with increasingly faster cycles, a clock, and pop ups as means to monitor the remaining time. The results show that ambient light can successfully convey remaining time. In particular, the exponential change from green to red was preferred over all other approaches. The participants found it to be a non-distracting way of monitoring the remaining time, in order to know when to wrap up the primary task.

The main contribution of the work is to provide evidence that ambient light displays are a good solution for extending the information space in an office environment by displaying information outside the user's monitor. Ambient light displays can help adding important information (such as reminders on upcoming tasks) without adding clutter or interruptions to the user's workflow by requiring focused vision. In a work environment that is increasingly exposed to interruptions, such approaches may help information workers to structure their days and focus on their primary tasks.

Future directions for this work will be a long-term test in an office environment evaluating ambient light "in the wild", giving participants a chance to evaluate the system against their usually used reminder technique over the course of a week. Participants will design their “own” light patterns, thus avoiding possible pitfalls such as colour vision deficiencies. This would give insights into how it blends into the periphery and becomes noticeable when appointments are due. Further we are reworking the prototype to make it more flexible in use by adding a semi-transparent cover. This will allow users, who do not have their computer monitor against a wall, to be able to see the light display.

Another possibility for further research is on novel light patterns for, using both uniform illumination of all LEDs as well as patterns controlling LEDs individually thus creating opportunities for evaluating "moving" patterns as well.

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