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.*

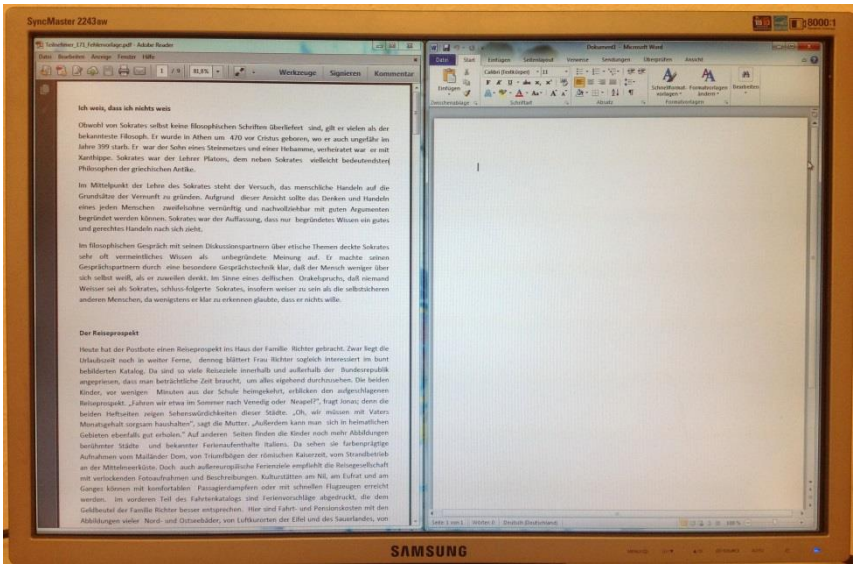

Fig. 5. Screen to copy and correct text

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**.

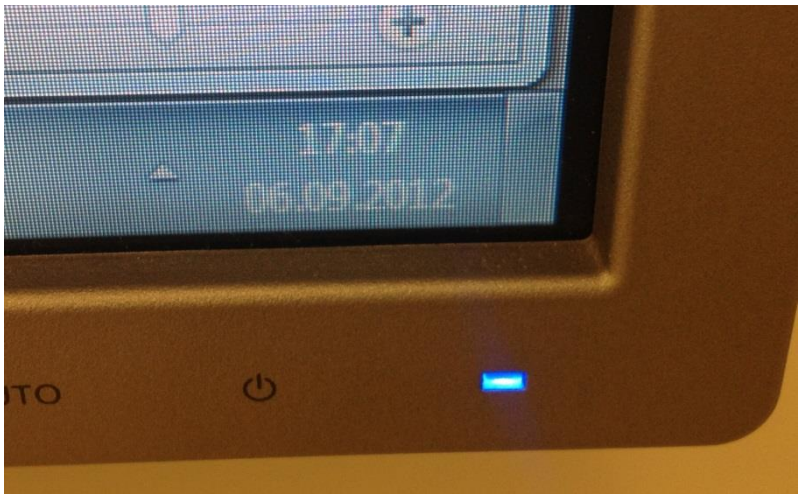

Fig. 6. On-screen system clock

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.

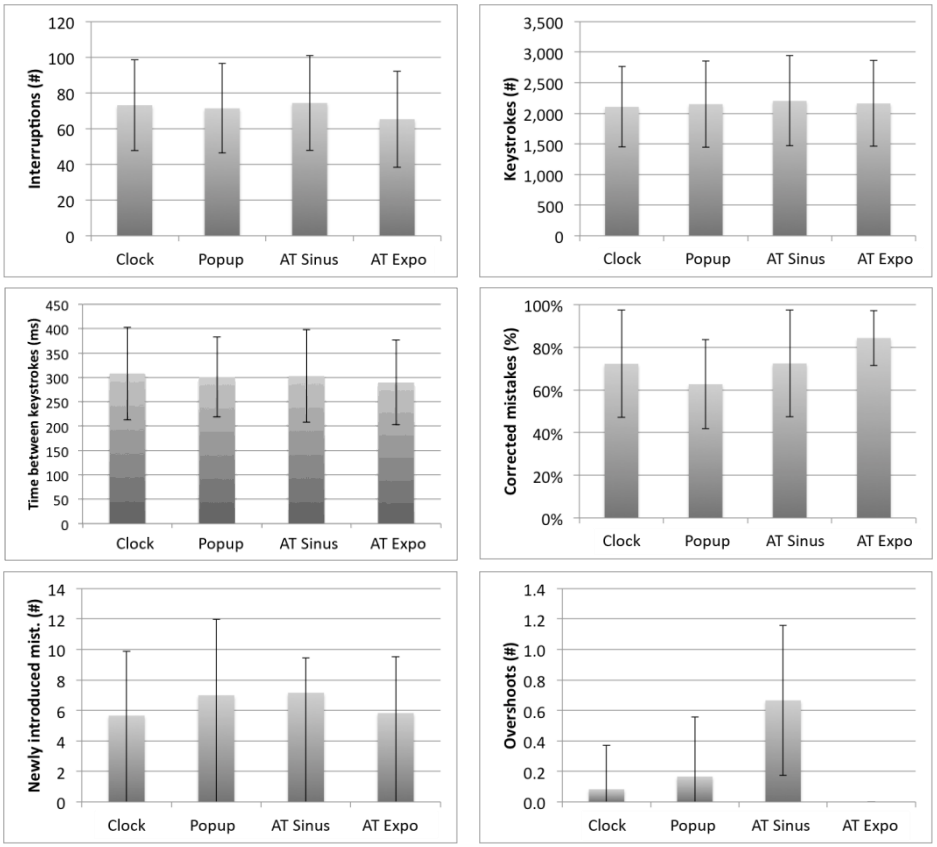

Fig. 7. Descriptive summary of objective measures (Bars show mean, error bars indicate standard deviation)

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.

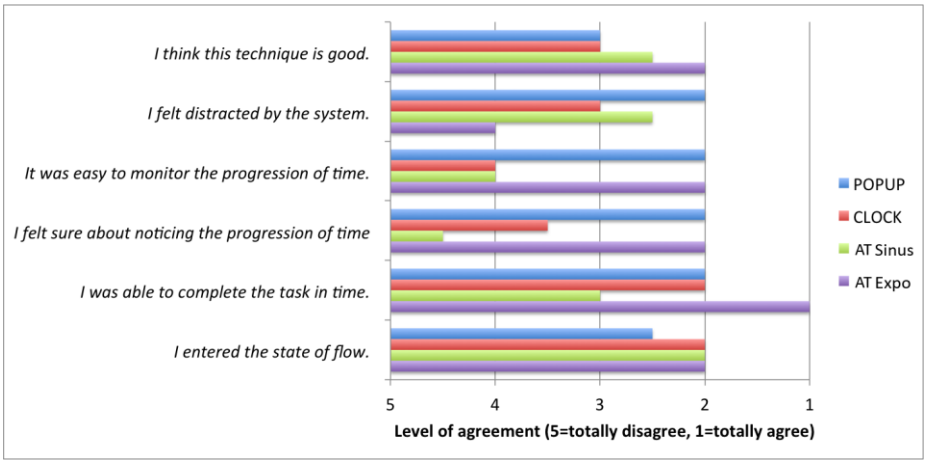

Fig. 8. Median level of agreement with the six statements per condition

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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