Time Aura: Interfaces for Pacing

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ABSTRACT
Historically one of the visions for human-computer symbiosis has been to augment human intelligence and extend people's cognitive abilities. In this paper, we present two visually-based systems to enhance a person's ability to flexibly control their pace while engaged in a cognitively demanding activity. In these investigations, we explore pacing interfaces that minimize the cognitive demands for assessing a current pace, provide ambient cues that can be quickly interpreted without incurring significant interruption from the current task, and place knowledge in the world to flexibly support different pacing strategies. Evaluation of our pacing interfaces shows that technology can successfully support pacing.

KEYWORDS:
Pacing, ubiquitous computing, visual interfaces.

INTRODUCTION
Time awareness and pacing are among the most important and common tasks in our daily lives: we keep a schedule, give public presentations, take tests, and perform other time-constrained tasks that require adequate pacing for their successful completion. To aid in keeping proper pace, people employ a number of ubiquitous devices that support time management: watches, alarm clocks, and paper or computer-based organizers. Yet these devices have their limitations; their methods of providing time awareness are often distracting and disruptive, and the schedules, once entered, are static and cannot compensate for changes that occur as the schedule is executed.

As computing devices become truly ubiquitous, the opportunity exists to devise ways to support people's pacing ability in a variety of tasks. In this research, we explore interfaces that extend people's pacing abilities in some well known tasks that require appropriate pacing skills for success.

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Pacing has been studied considerably in the domain of psychology, especially in the domains of human perception, cognition, and behavior. We know, for example, that when faced with a cognitively demanding task, people's pacing skills decline rapidly. What has not been examined is how human-computer interfaces can enhance people's pacing abilities in authentic task situations. This form of *intelligence augmentation* harkens back to some of the original visions for human-computer symbiosis [2][7].

Though a number of interfaces currently exist to support pacing, they suffer from some notable drawbacks. Watches provide a real time display, but the user must often undertake many internal calculations to make use of the information it presents. For example, when giving a presentation, the user may mentally mark the beginning of the presentation and note when it should end. However, during the presentation, the user must take the time to retrieve this information, and make mental calculations to determine the elapsed time and time remaining. A stopwatch is an improvement in that it can display either elapsed time or time remaining. However, its display is not designed for quick readability, and still requires that the user proactively monitor the time and perform many of the same internal calculations as with a watch. What is lacking in both of these interfaces is the support for fast perception of pacing information that minimizes cognitive demands for the processing of that information.

People also employ strategies for calculating and maintaining their pace. One such strategy is checkpoints, whereby the user monitors elapsed time at predetermined points and compares it to an *a priori* plan. Based on this comparison, the user may opt to speed up, slow down, or maintain the current pace. Another strategy is to incorporate pacing cues within the task to influence the pace. For example, the number of bullet points in a slide presentation influences the amount of time the speaker spends on that slide. Coupled with rehearsal, these strategies can help the user learn the ideal pace for the task at hand. These strategies point to mechanisms for minimizing the cognitive demands of pacing during a task. However, one obvious limitation of these strategies is that they only work with an undisturbed, *a priori* plan. An early interruption and discussion during a presentation can easily undermine the usefulness of later checkpoints and previous rehearsals. As we will see, one of the greatest challenges in creating interfaces for pacing is allowing the user to adopt multiple strategies for completing a timed task.

In this paper, we discuss our efforts in designing visual cues to provide cognitive support for people performing a timed task that requires pacing. In these investigations, we explore pacing interfaces that minimize the cognitive demands for assessing a current pace, provide ambient cues that can be quickly read without incurring significant interruption from the current task, and place knowledge in the world to flexibly support different strategies for managing the pace of a timed task. To ground these investigations, we evaluated pacing interfaces for two common time-oriented tasks: taking a computerized test, and giving an oral presentation. Anticipating large individual differences in performance for both of these tasks, we did not set our goal to perform large-scale experiments to minimize these differences. In this work we hope to illustrate what factors would merit such future research by reporting simple quantitative results, pointing to apparent trends in the data, and discussing qualitative reactions to our interfaces. To close, we discuss lessons learned from our designs, and implications for future research.

BACKGROUND

Pacing

People are often faced with the need to pace themselves while simultaneously performing a cognitively demanding task. In such cases, pacing is conceptualized as a secondary task that nonetheless requires appropriate cognitive resources. However, a significant body of psychological research indicates that accurate time estimation suffers when individuals must tend to both a cognitively demanding task and a time estimation task [1][3][12][13][15][18]. Additionally, when the difficulty of the cognitive non-temporal task increases, the accuracy of the time estimation becomes worse, with individuals under-estimating time intervals. Casini and Macar [3] as well as Zakay and Block [18] explain that these phenomena arise from a competition between temporal and non-temporal processors for limited attention resources.

Carefully designed and presented pacing cues can help people keep and re-adjust their internal pace. Moreover, with training the need for constantly present external pacing cues lessens [6].

Cognitive Aids

Historically, interface designers have leveraged knowledge about human capabilities to inform the design of usable computer interfaces. For example, the constraints of short-term memory can guide menu and dialogue design. Others have sought to design computer interfaces that extend basic human capabilities. Douglas Engelbart [7] proposed the concept of *intelligence augmentation* - extending people's cognitive abilities by scaffolding cognitive activities with appropriate models and visualizations of information. This human-machine symbiosis was also championed by other early visionaries such as Licklider and Bush [2]. In *Cognition in the Wild*, Hutchins [9] also describes cognition as a partnership between human thought and the external world. Kirsh [11] provides many examples of people manipulating their physical environment to minimize the complexities of internal mental calculations.

Current research in ubiquitous and wearable computing has resurrected Engelbart's vision. Rhodes demonstrated multiple remembrance agents that extend a person's long-term memory, as actions implicitly trigger retrieval from an ever-growing store of information [14]. Lamming [10] describes a human memory prosthesis in his design of "Forget-Me-Not." In this research, our goal is to extend another basic human capability – pacing – to enable people to more accurately regulate their pace in a time-dependent task.

Ambient Displays

Another important aspect of providing cognitive support for people is the form in which this support is presented. Ambient displays take advantage of our ability to perceive information on a background level while performing a foreground task. While theories of attention are hotly contested, ambient displays seek to present information in the appropriate modality and form that can be interpreted with minimal cognitive effort. In this research, we examine the use of simple color cues as an ambient pacing display in increasingly demanding tasks. We contrast, and then combine, the color display with another peripheral display that provides more information related to pacing the entire task, yet requires greater attention and cognitive resources.

Dynamic Interfaces

Much of the existing research exploring temporal cognitive aids can be found in the field of ergonomics of dynamic interfaces. Dynamic interfaces represent a class of interfaces for users who perform time-dependent tasks on a regular basis, such as pilots or power plant workers. In most cases the operator is faced with a dynamic situation and has to carry out a regulatory task that consists of monitoring the process, detecting any anomaly and intervening, if necessary, in order to bring the process back to normal. De Keyser [4] identifies the following requirements for dynamic interfaces:

- Minimize cognitive cost related to the regulation of the dynamic situation;
- Enable the operator to perceive any change in the situation;
- Keep a record of, and regularly reassess, its development;
- Lead to an optimal management of temporal constraints linked to the succession and duration of the task, and facilitate synchronization;
- Be compatible with temporal reasoning;

- Be able to learn the temporal structure of the situation, whether implicitly or explicitly (from *Time and Dynamic Control of Behavior*, p.192)

INTERFACES FOR PACING

Pilots and operators of power plants are not the only people who deal with dynamic situations. We live in a dynamic environment, and time management is a necessary and essential part of many tasks and activities. The objective of this research is to extend the concepts of dynamic interfaces to the design of cognitive aids in the form of pacing interfaces that support our everyday activities.

Suchman's Situated Action [17] and Gibson's ecological approach to perception [8] claim that information required to carry out a task can be dynamically induced from the environment without the necessity to infer it cognitively. Using these theories as guides, our goal is to provide our users with the information necessary to follow a pre-determined pace by presenting a clear and comprehensive indication of the difference between their current pace and the pre-determined pace.

Based on these theories of cognition, attention and pacing, our design goals for pacing interfaces are:

- Minimize the cognitive load for regulating a dynamic task
- Provide information on the progress of the task
- Clearly indicate any discrepancy between the planned pace and the current pace
- Lead to an optimal recovery strategy
- Do not require the same or more effort than the task they are designed to augment

TRANSLATING THEORY INTO DESIGN

To research and evaluate the design of pacing interfaces, we chose two cognitively demanding tasks with tight time constraints: taking a computer-based test, and giving a presentation using PowerPoint™ slides.

First Design – Computerized Tests

Design Considerations

We start our investigations with a task as simple as taking a computer-based test like the Graduate Record Examination (GRE). For the sake of this research, we simplify the task by removing the option to jump between questions, or to return to the previous ones.

Following GRE suggestions, we calculate the optimal pace for the test based on the type and difficulty of questions. We also track the pace that our users keep while answering questions, and compare it to the optimal pace. Our goal is to provide the users with a clear indication of the difference between their real pace, and the suggested optimal pace, so that they can adjust accordingly.

To explore the design of pacing cues, we created and tested three different pacing interfaces, all of which utilize visual cues to provide pacing information.

Color-Scheme The first implementation is designed according to our understanding of "optimal" pacing cues. These cues should be the least obtrusive, and require the least amount of mental calculations. The background color of this interface gradually and continuously changes according to the difference between the user's pace and the recommended pace using linear gradients. Blue color indicates being ahead of time, white indicates full correspondence to the predefined pace, and red indicates falling behind.

Time-Line The second design presents the users with more pacing information, namely a time-line indicating their progress in time, compared with the entire time-period dedicated to the task. The time-line indicates the beginning and end points of the test, and reference marks for every quarter. A sliding bar along the time-line indicates how much time has passed since the beginning of the test. Because we provide more information in this interface, we expect that this information requires more mental calculations, and hence introduces more interruption.

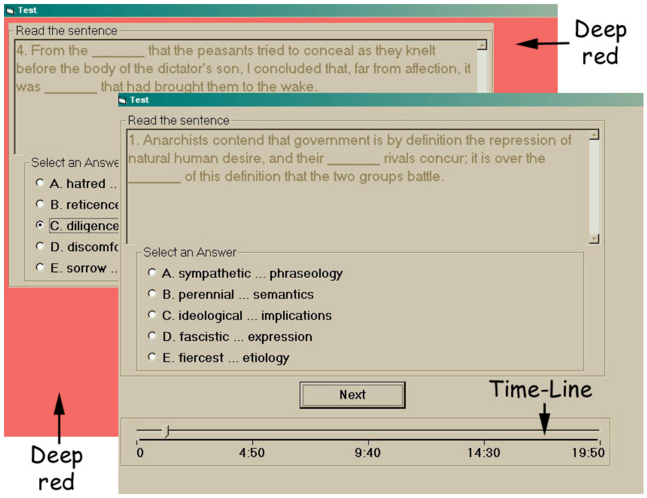


Figure 1. Color-Scheme and Time-Line Interfaces

Digital Watch The third design serves two purposes: to create a control condition that requires maximum mental calculations, and to provide the most common ways that people use to pace themselves – a digital watch interface.

Evaluation with Users

To evaluate the effect of the visual pacing cues, we created a mock GRE exam, and recruited subjects to take the exam using one of our three designs. Again, our goal was not to create an extensive experimental setting, controlling all the factors that contribute to the overall performance of users, such as individual expertise and experience, anxiety level, and individual styles and strategies. Instead, we wanted to perform a simple quantitative analysis, in conjunction with obtaining a qualitative impression of our design, to inform our future work.

We recruited 21 graduate students in the College of Computing who recently took the general GRE. All of them were native English speakers. Following an introduction to the task, the subjects had a training session to familiarize themselves with the structure of the test and the pacing software. The test consisted of 30 sentence-completion questions of the verbal part of GRE test. The subjects were given 20 minutes to complete the test, with a suggested pace of 40 seconds per question. During the test, the subjects could only move forward, without skipping questions, or returning to the previous ones. At the end of the test, the subjects completed an oral and written debriefing, providing their impressions of the pacing cues and suggestions for improvements.

Results

Time Management Subjects in both experimental conditions, Color-Scheme and Time-Line, demonstrated a better ability to pace themselves through the task, while two subjects in a control condition did not have enough time to finish the test.

Performance As we anticipated, we discovered large individual differences in performance, measured by the number of correctly answered questions as well as in pacing – time spent per question for different questions. We found an insignificant difference in performance for different conditions with users in Color-Scheme condition having the highest number of correctly answered questions and users in Time-Line condition the lowest (see Figure 2).

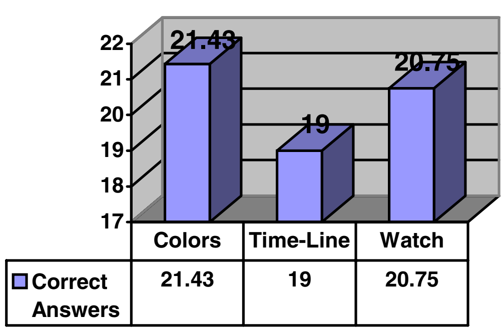


Figure 2: Performance on the test.

Users' Evaluation The results of the questionnaire with the users' evaluation of their performance and our pacing cues are presented in Fig. 3

Benefit of the pacing cues The users in Color-Scheme group reported benefiting most from the pacing cues. This result was significantly different from other conditions. The users in the Time-Line condition also reported benefiting from the cues, but mentioned that they had to keep in mind a lot of information to take a full advantage of the cues. They needed to remember how many questions there were in the test, mentally visualize their progress in the test, and compare this information with their progress in time. A general comment was that they would prefer to have visual representations of this information so that they could make faster decisions.

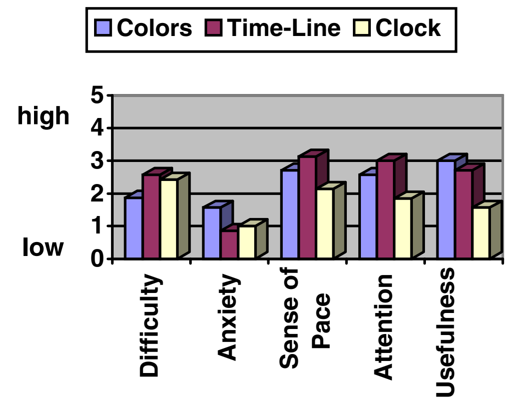


Figure 3. In the questionnaire the users evaluated their performance on a Lickert Scale.

Attention to Cues Because we provided our subjects in the Time-Line condition with more information, we expected the additional information would require more mental effort, and thus create more interruption. The users in Time-Line condition supported our expectations, reporting the highest level of perceived control over their pace, and also the highest level of attention to pacing cues.

Anxiety level The users in the Color-Scheme condition reported the highest anxiety level during the test, likely a direct consequence of the presence of visual pacing cues that constantly reminded them of the time limitations. This correlation between high anxiety levels and good performance, given the presence of visual pacing cues, is an intriguing result warranting further investigation.

Discussion and Lessons Learned

The evaluation of the visual pacing cues for the computer-based tests provide positive and encouraging results. Our pacing cues help users to better manage their time, and to pace themselves during the test, though individual differences in performance and pacing strategies prevent us from achieving more quantitative and exact results. A more tightly controlled experimental setting would be beneficial in obtaining more quantitative results.

One noteworthy behavior that we observed was that individuals did not blindly follow the predefined pace. Rather, subjects used the cues creatively and devised with their own time-management strategies. For example, some subjects proactively created a safe time-buffer by quickly answering the first several questions until the interface displayed a deep shade of blue. At that point, they felt that they did not need to worry about running out of time, and concentrated on maintaining the time-buffer while answering questions.

Additionally, we found that providing a high-level task overview that allows for planning of resource allocation may be equally as important as continuous pacing suggestions. This feature becomes even more critical for more complex tasks where the pacing is dependent on a plurality of factors. In our system, the Color-Scheme interface lacks this high-level overview, and would benefit from this addition.

Presentation Pacing

In the next phase of the research we turned to the more complex task of giving a presentation in a predetermined amount of time.

Design Considerations

Though qualitatively different from taking a computer-based test, we nonetheless decided to base our design on the same visual pacing cues algorithm. However, we did expand the design of our system to include lessons learned from the previous experiment, and to accommodate the increased complexity of the task.

To further inform our design, we conducted a series of interviews and observations of our colleagues as they prepared and gave presentations. From these data, we identified the following factors deemed important for a pacing interface:

1. Task overview. A task overview provides a summary of the entire presentation, providing such information as the number of slides, the slides' names, total time for the presentation, and the amount of time per slide.
2. Progress report. A progress report indicates the current location within the task: elapsed time, remaining time, number of slides presented, number of slides left to present, preferably with a correspondence between the two.
3. Pacing cues dependent on the task and current progress. As with the previous interface, the pacing cues should help answer pacing questions, such as, "Should I speed up, slow down or continue with the current pace?"
4. Control over the task. In addition to providing our users with pacing information, they should be able to control the presentation as they see fit, e.g. skipping slides as necessary, or jumping directly to a desired slide. Though these features already exist in existing presentation software, the challenge is integrating these features with our pacing cues.

In this design, we wanted to combine the best features from our two pacing interfaces described in the previous section: minute-by-minute pacing using the color-scheme, and a more general task overview that would allow for planning based on the idea of time-line. The implementation of these requirements in the new pacing interface is presented in Figure 4.

To test our design, we implemented a pacing interface and integrated it with Microsoft PowerPoint™ 97. The system uses a feature of PowerPoint™ that allows one to connect two computers together, with one machine presenting slides to the audience, and the other machine providing our custom pacing information to the presenter.

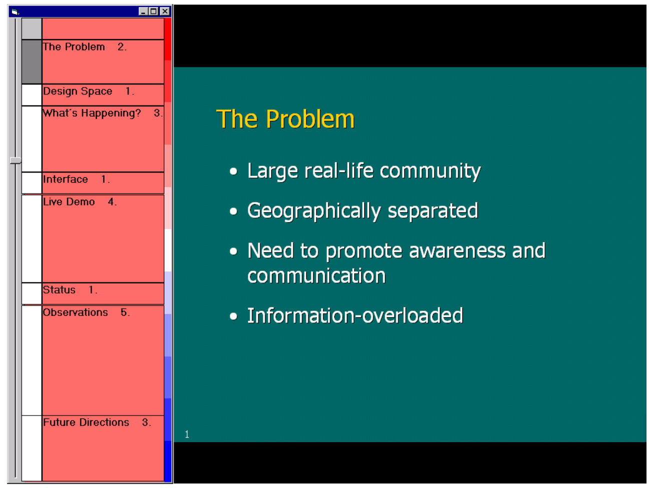


Figure 4: PowerPoint Pacing Interface

The presentation pacing interface we developed aims to help users keep a pace determined in advance of the presentation. The pacing interface allows one to equally distribute time across slides, or to change the time distribution on a per-slide basis. Users can also use our pacing interface in concert with the rehearsal feature of PowerPoint™, which records the time spent on each slide during a presentation.

To meet the design requirements listed above, our interface implements the following features:

- **Overview of the task**. Slides are visually represented as rectangles with their height corresponding to the amount of time dedicated for a particular slide. Considering issues of scalability, the names of slides only appear for "major" points of the presentation. A vertical sliding bar on the left represents the total time for the presentation.
- **Progress report**. A color coding shows progress per slide: dark gray for the current slide, light gray for visited slides, and white for skipped slides or slides still to be visited. The time bar indicates the progress through the presentation.
- **Pacing cues** – The color scheme used in the previous design was applied for the Presentation Pacing interface as well (see above).

A considerable challenge in the design of this interface was providing pertinent pacing information in a way that did not overwhelm the user. Our strategy was to provide different levels of information to support different pacing needs:

- Color coding (dark blue to dark red) provides a rough estimate on the current pace without requiring significant attention from the user.
- Color coding of per-slide progress, and the position of the sliding time-bar provide more detailed information when needed, and also suggest recovery strategies, such as skipping a slide to catch up, but come at the cost of requiring more attention. We envisioned that users would rely first on the more general color coding cues, and refer to these more precise cues only when there was a large deviation from the planned pace.

Evaluation with Users

To evaluate our pacing interface we invited nine students from Georgia Tech's College of Computing to participate in an experiment. The background, age, and presentation skills and experience, varied greatly from one user to another. To minimize the effect of these differences, all users were given the same task of presenting a pre-made presentation based on a two-page article from a popular science magazine. Additionally, the pace for the presentation was determined by the experimenters.

After a brief introduction, the users were randomly assigned to one of the two conditions: half of them gave the presentation using our pacing software, while the other half used the standard PowerPoint software. The users were given 15 minutes to read the article and view the slides, and another 15 minutes to familiarize themselves with the pacing software and to rehearse the presentation. Users were also offered an opportunity to take notes and use them while presenting.

After the training session users gave a seven minute presentation to an audience of professors from the College of Computing. After the presentation, the users completed a questionnaire and had a debriefing session.

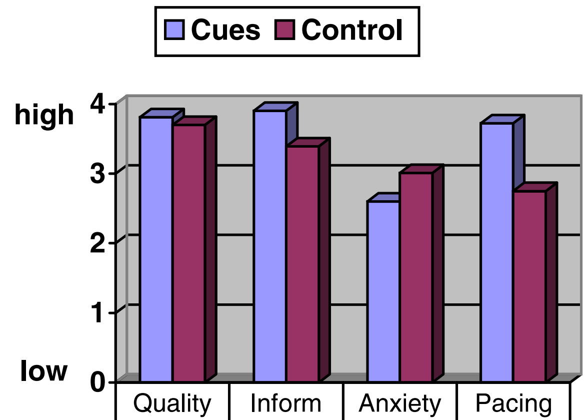
Results

The presenters were evaluated using the following criteria:

- Overall quality of the presentation
- How informative the presentation was, including the attention paid to details
- Apparent anxiety level of the presenter
- How well the presenters paced themselves through the presentation

The results of the experiment are presented in a Figure 5. We found that those who used the pacing interface were significantly better at pacing their presentation, even though the other parameters were not significantly different.

Presentation Styles During the evaluation we discovered that the pacing cues were used differently by people with different presentation styles. We identified two main presentation styles, and hence uses of the pacing cues. Some of our users tried to be as brief as possible in their presentations, giving only the essentials, and skipping all



	Quality	Inform	Anxiety	Pacing
Cues	3.81	3.9	2.6	3.72
Control	3.7	3.39	3.01	2.75

Figure 5. Evaluation Results

the details that they considered irrelevant or not important. These users found that they had more time for the presentation than they expected. Our pacing cues reminded them of the remaining time, and encouraged them to make their presentations more informative.

Another group of users tried to be as specific as possible in their presentations, and to give as many details as they could remember, or extract from their notes. Users in this group had a tendency to run over time, using pacing cues to keep within the time frame.

Notes Some of the users, while trying to make their presentations as informative as possible, often referred to their notes. Dividing their attention occasionally prevented them from taking full advantage of the cues. This finding led us to the question of whether visual cues are the best media for tasks with a heavy visual workload. Tangible or audio cues may be more beneficial for tasks of this sort.

Discussion and Lessons Learned

As with the GRE pacing experiment, we found the pacing cues to be beneficial for the users in helping them pace themselves through the presentation

This experiment highlighted the question of whether our interface is universally beneficial, or if the benefit depends on the particular pacing strategy the user is choosing. In this design, we did not distinguish between helping people who underestimate their time to give more informative presentations, versus people who overestimate time, and have a tendency of running over time. This interesting question will be further explored in our future investigations.

Although this brief testing introduced interesting issues, and provided insights into presentation and pacing styles we realize it was a rather unusual presentation task and environment. To gain deeper understanding, we plan to conduct a longitudinal study, and to offer our pacing software for use on a regular basis. We hope to find out whether pacing cues can be most beneficial during official presentations or while rehearsing, what features of the interface are used most frequently, and whether there is a need for personalization of the interface.

GENERAL DISCUSSION AND CONCLUSION

Both of our evaluations showed that computing technology can be used to help people pace themselves during the performance of a number of time-dependent tasks. External pacing cues alter users' performance and can be successfully used for rehearsing or performing those tasks.

Pacing interfaces

We found that people use different pacing and time management techniques, and this difference requires either flexible or customized designs, for example, for people who underestimate or overestimate time. We also found that people use pacing cues creatively, again pointing to the need for flexible or customizable pacing interfaces.

Another issue that appeared to be of most importance for the presentation task is the issue of compensatory strategies. In the experimental our users were limited to only a straightforward way of giving a presentation; they did not have time to revisit slides and were not familiar enough with the material to make significant adjustments to the presentation. In reality however, the pacing for the presentation is a highly complicated issue that only partially depends on time. In cases when the audience is losing interest in the subject, or multiple questions arise during the presentation, and it is impossible to keep pre-planned pace, what behavior should be exhibited by pacing cues? Simple notification of a permanently lost pace will only increase the anxiety level of the presenter. In cases like this, the interface should be intelligent enough to recover from the loss of pace and still provide the presenter with useful information, perhaps suggesting recovery strategies. Sensing technology could also help detect situations potentially dangerous for the pace of the presentation, like multiple questions from the audience, and warn the presenter of possible consequences.

In both of our designs, we use visual pacing cues that are appropriate for tasks where a computer display is available. However, this modality might prove limited for tasks that already exhibit a heavy visual workload. Tangible or audio cues may be more beneficial for such tasks.

To ensure consistency in our evaluations, the planning of the pace was done beforehand by the investigators. However, in the real world, users are rarely presented with an optimal pace – they must instead calculate it themselves. Our current prototypes offer only limited support for adjusting time management strategies before a task. In future designs, we will address this challenge by creating more opportunities for iterative design of the pace.

Managing Attention

As we expected, one of the most interesting challenges in the design process was providing information on different levels, allowing for better attention managing strategies. In the presentation pacing interface, we resolved this issue by providing minute by minute pacing using color coding of the background that could be noticed without requiring significant attention resources. More detailed information is provided in a different form, and can be interpreted by allocating more attention to the interface. This approach of multi-layered interfaces can be applied to ambient displays in general. Users can pay more attention to detailed information, or quickly glance at simpler peripheral cues.

Cognitive Aid

In this research we identified pacing as a common human activity that can be enhanced by a supporting technology. The interfaces presented here assist in pacing while performing cognitively demanding tasks. Our findings suggest future investigations of the pacing of everyday activities, like managing a daily schedule. We also plan to investigate pacing in a variety of other tasks or activities where time is a constraint, e.g. dancing, music instruction, sport training, playing video games, etc. Pacing issues for these activities were investigated in psychology [5][16]. However they present new challenges – keeping track of the actual pace requires advanced sensing technology.

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