Towards Time Design: Pacing of Hypertext Navigation by System Response Times

Herbert A. Meyer
artop - Institute
Humboldt-University of Berlin
Christburger Str. 4, 10405 Berlin, Germany
meyer@artop.de

Michael Hildebrandt
Department of Computer Science
University of York
York YO10 5DD, UK
hilde@cs.york.ac.uk

ABSTRACT
Two experiments investigated the effects of system response time (SRT) on hypertext navigation. Dependent variables were residence time, emotional strain and memory performance. A synchronization between human and computer response time was observed.

Keywords
Time design, system response time, usability, hypertext

INTRODUCTION
As long SRT is generally assumed to impede the user's progress, "the faster, the better" has become the credo of most Web developers. However, research in software engineering suggests that very short SRT might have equally detrimental effects on users' productivity and satisfaction [1, 3].

It is not surprising that work efficiency decreases when SRT becomes exceedingly long, as the flow of cognitive operations is disrupted by having to wait for the computer's response. However, Shneiderman [4] suggested that an agitated work style might be induced at very short SRT as the user tries to keep up with the computer's rapid work speed. In closely coupled systems the user might be paced by the machine, resulting in a scrambled control mode [2]. This idea is in contrast with the assumption of most hypertext concepts that the user's navigational decisions, including residence time (the time spent on a page), are largely autonomous. Our study assessed if pacing does occur in hypertext navigation and explored cognitive and emotional correlates of this effect. While previous studies demonstrated SRT effects in complex problem solving situations such as programming, we investigated if low-demand situations such as browsing a hypertext catalogue are also subject to the subtle influence of the computer's work speed. If pacing is not restricted to high-level cognition, consideration of SRT should become an essential part of usability assessment and Time Design should be explored as a method for optimizing the flow of interaction.

EXPERIMENT 1

Method
The hypertext database consisted of 2604 fashion photographs. The control structure supported navigation on three levels. The index level gave a choice of 12 designers. Choosing a designer led to the preview level showing eight thumbnails from the collection. There was a navigation panel consisting of three buttons for "previous eight pictures", "up to index level", "next eight pictures". Clicking any thumbnail led to the full-size level where a large version of the photo was shown. There were again three navigation buttons for "previous", "up" (to the preview level), and "next". When a link was activated, the page unloaded and an empty white background remained visible until the SRT (0.5s, 1.5s, 2.5s, 3,5s, manipulated between-subjects) had elapsed and the chosen page was displayed.

Participants were instructed to navigate the site freely until the program ended the session. They were told they participated in an experiment on time perception and should afterwards report how long the session had lasted, and give their impression of the site on a questionnaire. No mentioning was made of the SRT manipulation. The program terminated the session after 60 clicks. Mood ratings were obtained before and after the session. 44 volunteers (23 female, 21 male; mean age 25.3) were randomly assigned to the four experimental groups.

The dependent variable "residence time" was divided into two separate measures for *horizontal navigation* (progressing through a sequence of either thumbnails or pictures, i.e. clicking "next"-"next") and *vertical navigation* (terminating a sequence, changing direction, e.g. "next"-"up"). To test for SRT effects on emotional strain we computed post-pre-differences in *annoyance* from the mood scale ratings. Sex was entered as a factor in all analyses of variance (ANOVA) to control for differences in attitudes towards fashion, but no significant effects were found.

Results and Discussion
The upper part of Fig. 1 plots residence times for both horizontal and vertical navigation against SRT levels. The curves run almost in parallel and ANOVA confirmed a main effect in each case [$F(3,36)=4.45$, $p<.01$, resp. $F(3,36)=8.29$, $p<.01$]. In addition, SRT duration had a significant effect on

emotional strain [$F(3,36)=3.47$, $p<.05$]. The lower part of Fig. 1 shows that beyond three seconds, SRT increased annoyance.

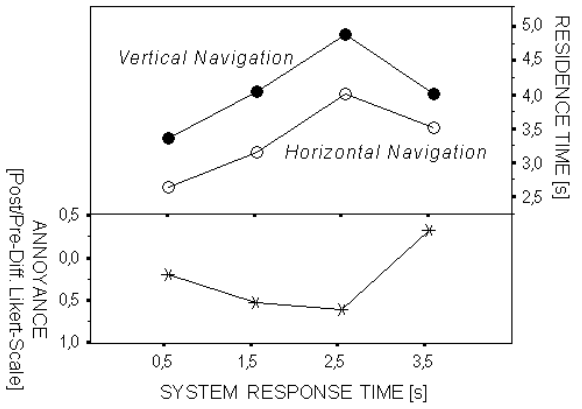

Figure 1. *Results of Experiment 1 (N=44)*

As predicted, the computer's speed paced the user's speed. The linear relationship broke down only when SRT was long enough to causes strong annoyance. A second experiment was carried out to investigate the cognitive correlates of the pacing effect.

EXPERIMENT 2

Method

Materials and procedure were the same as in Experiment 1. SRT levels were set to 0.75s, 1.25s, 1.75s, 2.25s, 2.75s, 3.25s, and 3.75s. An unannounced memory test was administered after the second mood rating. Participants were given 12 previously seen pictures (*old*), mixed with 12 distractor pictures (*new*). They had to decide if a picture was old or new. As a measure of recognition, discrimination indices *Pr* were computed [5]. 140 students (80 women, 60 men; mean age 24.8 years) volunteered for the experiment.

Results and Discussion

The influence of SRT on annoyance could not be confirmed ($F<1$), while the main effects for both residence time measures (vertical and horizontal) was replicated [$F(6,126)=5.57$, $p<.01$, resp. $F(6,124)=4.71$, $p<.01$]. The uppermost diagram of Fig. 2 reports peak recognition performance at a SRT of 1.75s [nearly significant; $F(6,89)=2.14$, $p=.06$]. At both longer and shorter SRT, performance was worse.

Importantly, there was again evidence for the pacing effect, indicated by the linear trend in the SRT/residence time plot (middle diagram of Fig. 1). Both experiments are consistent in their results on the relationship between SRT and mood: Experiment 1 showed a drop in residence time only when SRT caused significant annoyance. There was no drop in residence time in Experiment 2, but no increased annoyance was observed either. The data concerning memory performance agrees well with findings in software engineering: very short SRT induces an agitated, careless work style, resulting in low accuracy. Long SRT impedes or disrupts the work flow by generating cognitive overhead.

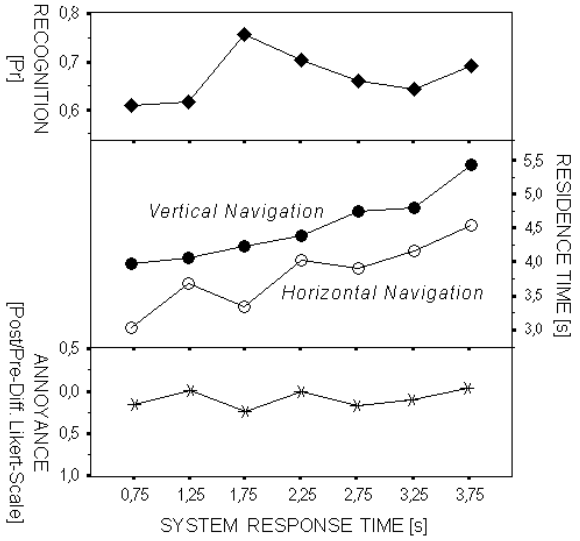

Figure 2. *Results of Experiment 2 (N=140)*

CONCLUSION

Our results clearly confirm that the computer's response speed is an important characteristic of hypertext applications. We showed effects of experimentally varied SRT on emotional strain and memory performance, and especially on residence time. In a subtle way, the computer acted as a "pacemaker" for the user's hypertext exploration. Our results also indicate that SRT should not *always* be reduced as much as technically possible, as its duration can be optimized to support cognitive processing. Time Design should be explored as a method for inducing a concentrated work style by introducing cognitive "costs" for erroneous decisions via SRT adjustment. A current field study collects a large-scale sample of SRT/performance data from an educational Website to investigate the effect of pacing on problem solving in an ecologically valid environment. Future research will apply Time Design to ubiquitous and mobile computing and the design of safety-critical systems.

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