Learning Directly From Screen? Oh-No, I Must Print It! Metacognitive Analysis of Digitally Presented Text Learning

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Abstract

Most people, including our survey participants, believe that they learn less efficiently when reading from a computer screen than when reading from paper. We investigated the validity of this belief within a metacognitive framework for self-regulated learning. In three experiments, participants studied expository texts presented on paper or on screen, either in a self-regulated manner, or according to a fixed study-time schedule. They predicted their performance on memory and comprehension questions before being tested. Objective performance, subjective metacognitive monitoring, and control of study time were measured. The interrelationships between these variables and the learning media were analyzed within an adapted discrepancy-reduction framework (Dunlosky & Hertzog, 1998). On-screen learners performed worse than on-paper learners under self-regulated study, but not under a fixed study-time schedule. They also exhibited less calibrated (more overconfident) monitoring and a weaker relationship between monitoring and control of study time than did on-paper learners. Hence, an on-screen learning deficit was in fact observed, which appears to derive from less efficient metacognitive regulatory processes rather than from ergonomic factors per se. This study highlights the potential of the metacognitive approach for clarifying the source of differences in learning processes, and for pointing toward appropriate means of improving these processes.

Keywords: Metacognition, self regulation, e-learning, text learning, monitoring and control.

Introduction

Even though adult readers of today have been using computers extensively for many years, when thorough study of a topic is needed, most of us prefer printing the digitally available article rather than studying it directly from the computer screen. By doing so, the learner returns to the “secure ground” of on-paper learning (OPL), which provides a subjective feeling of enhanced learning. A great deal of research has focused on the ergonomics of software design and hardware usability, thereby improving the ease of reading directly from computer screens (e.g., Dillon, 1994; Muter, 1996). This research has contributed substantially to reducing the discomfort of on-screen learning (OSL), but the problem is far from being solved (e.g., Dillon, 1992; Sellen & Harper, 2002). Taking a different, *metacognitive* approach, our current research takes a step back and asks what does the subjective feeling of difficulty accompanying OSL indicate? Several options are considered: (a) the encoding of information into memory may be impaired in OSL relative to OPL, (b) strategic study processes, in particular, those related to the allocation of study time, may be less effective for OSL, or (c) the subjective feeling of difficulty accompanying OSL may be illusory, unrelated to objective learning indices and/or having no actual learning consequences.

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We focused on the learning of continuous text materials that could be presented in a similar manner on screen and on paper. The objective and subjective differences between OSL and OPL of continuous text have been analyzed before. For example, Dillon, McKnight, and Richardson (1988) found that compared to OPL, OSL was slower, less accurate, more fatiguing, less conducive to comprehension, and received lower subjective ratings (see also O'Hara & Sellen, 1997). Those differences were assumed to stem from ergonomic factors, but others found that reading speed and comprehension are unaffected by presentation medium (e.g., Muter & Maurutto, 1991).

Metacognitive Approach

In the current research, we adopted a metacognitive approach that provides concepts and methodological tools for examining the learning process and isolating multiple components, any of which might be responsible for differences between the two learning media, OSL and OPL. Nelson and Narens (1990) presented a theoretical framework for metamemory based on the now widely accepted distinction between *monitoring* and *control*. Monitoring involves people's subjective evaluations of their level of knowledge as the learning process progresses. Control involves the decisions that are made and the actions that are taken, based on the monitoring judgments. Dunlosky and Hertzog (1998) put forward the Discrepancy Reduction Theoretical Framework (DRTF) to describe the relation between monitoring and control in learning (see also Dunlosky & Connor, 1997). According to this model, the learning process actually starts before one begins to study the to-be-learned materials, by setting a desired degree of mastery, or *norm-of-study* (Le Ny, Denhiere, & Le Taillanter, 1972). During study, the judged level of mastery (monitoring) is compared with this norm-of-study. When the target level is reached, the person terminates the study (control).

This metacognitive framework and related literature deals mainly with the allocation of study-time for memorizing itemized materials, like lists of word-pairs. Text learning is much more complex (Kintsch, 1998). Yet, the monitoring and control processes involved in the regulation of text learning can be paralleled to those involved in memorizing word lists (e.g., Maki, 1998) and can be analyzed in light of the DRTF (e.g., Thiede, Anderson, & Therriault, 2003). In applying the DRTF to text learning, we assume that the study of a particular text will continue until the discrepancy between one's overall perceived state of learning and the adopted norm-of-study reaches zero.[1]

According to the DRTF, the control of study-time is a primary factor that can affect performance beyond more objective learning difficulties. Because the control of study-time is based on the learner's subjective evaluation rather than on the objective state of learning, the efficiency of control depends, among other things, on the accuracy of the learner's monitoring (Thiede et al., 2003). Two separate aspects of monitoring accuracy must be distinguished (Nelson, 1996): *resolution* (relative accuracy) and *calibration* (absolute accuracy). In the context of text learning, resolution reflects the extent to which one's monitoring judgments discriminate between more well learned and less well learned texts (e.g., Thiede et al., 2003). Calibration, in contrast, reflects the extent to which one's monitoring judgments overshoot or undershoot the actual level of one's learning, that is, over- or underconfidence (e.g., Pressley & Ghatala, 1988). Overconfident learners might believe that they have reached the target level whereas in fact they have not.

[1] It should be noted that there are other competing metacognitive theories regarding the control of study-time. A prominent example is Metcalfe and Kornell's (2005) Region of Proximal Learning model, by which learners use judgments of the rate of learning (jROLs) in deciding when to stop, rather than a predefined norm-of-study. We chose to cast our research in terms of the DRTF, but similar studies could be envisioned, guided by alternative metacognitive frameworks as well.

Conversely, learners that are underconfident about their state of learning for a given text might invest more time than is needed – time that might be invested more efficiently on other texts.

Koriat and Goldsmith (1996; see also Goldsmith & Koriat, in press) showed that monitoring accuracy alone is not enough for achieving optimal performance if not well implemented by efficient control operations. They proposed two additional control indices: *control policy* and *control sensitivity*. In the context of text learning, the control policy corresponds to the level of the norm-of-study – how strict or liberal it is. Control sensitivity is the extent to which the decision to stop/continue learning is in fact based on one's subjective monitoring, rather than, for instance, being erratic. Thus, when analyzed within this adapted metacognitive framework, text-learning performance depends on several cognitive and metacognitive components: Beyond the objective difficulty of the learning material and further difficulties imposed by the learning environment, ultimate performance should also depend on monitoring accuracy – both relative and absolute, on the control policy that is adopted, and on the sensitivity of the control operation to the monitoring output. Any or all of these components could differ between presentation media.

Experimental Design and Results

Guided by this framework, we compared the cognitive and metacognitive aspects of OSL and OPL in a survey and three experiments.

Survey

Method

We conducted a survey (N=126) to verify our intuition that people subjectively prefer OPL to OSL in real-life learning contexts. Participants included several age groups (including high-school youth) and a variety of occupations (including extensive computer users).

Results

Survey respondents at all ages (17-61) reported that they usually print digitalized texts before studying them and that they believe they remember and comprehend better when the materials are presented on paper (Figure 1, Panels A and B; F<1 for both).

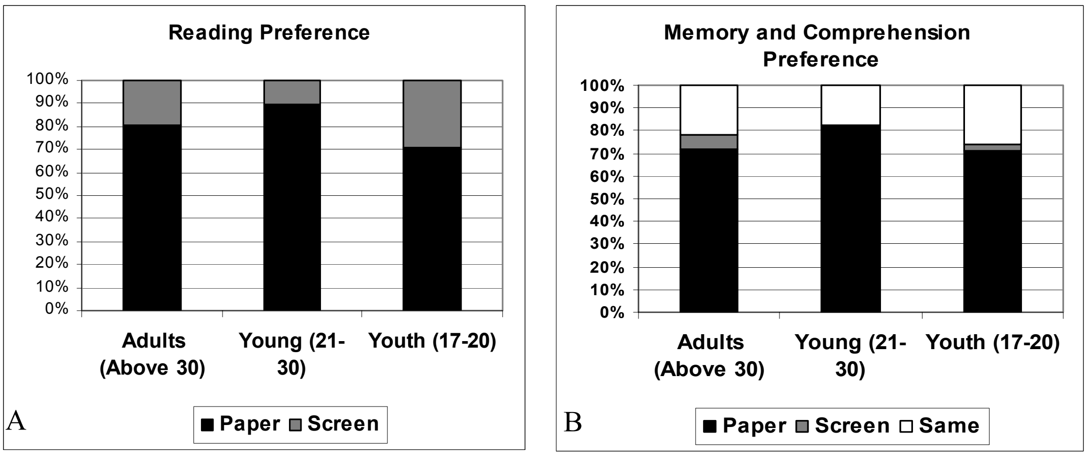

Figure 1. Age distribution in answers to the two target questions in the survey
Panel A – 1st question: Do people prefer to learn a paper printed or on screen?
Panel B – 2nd question: On which of the media do people think they comprehend and remember better: paper, screen or the same?

In light of the survey results, one would expect to find an objective deficit in OSL compared to OPL, in accordance with people's subjective feelings, or perhaps that the subjective feeling reflects a monitoring deficit with respect to OSL (underconfidence), while actual performance is unaffected by the presentation media.
Experiments 1-3 examined such possibilities.

Experiment 1

Monitoring can only affect learning if learners are free to regulate their study (Dunlosky & Thiede, 1998; Hacker, 1998). In Experiment 1, self regulation was prevented by setting a relatively short, fixed study time for each text. This was designed to reveal the purely cognitive aspects of memory and comprehension in the two media.

Method

Learning materials were six exploratory texts of about 1000 words each, taken from web sites intended for reading on screen. Half of the participants studied the materials on screen and half studied on paper. Monitoring was elicited by having the participants make predictions of performance (POP) at the end of studying each text, just before they took a multiple-choice exam in the same media as was used for learning. All participants (university undergraduates) were allowed to take notes and use marking tools while studying.

Results

No difference in test performance was found $t(32)=.68$, n.s. With regard to monitoring, significant overconfidence was exhibited under OSL, $t(16)=2.48$, $p<.05$, but not under OPL, $t(16)=.40$, n.s. (Figure 2, Panel A). This finding is opposite to what one would expect based on the survey results. Monitoring resolution, as measured by the within-individual gamma correlation between POP and performance, was unaffected by presentation media, $t(32)=.03$, n.s.

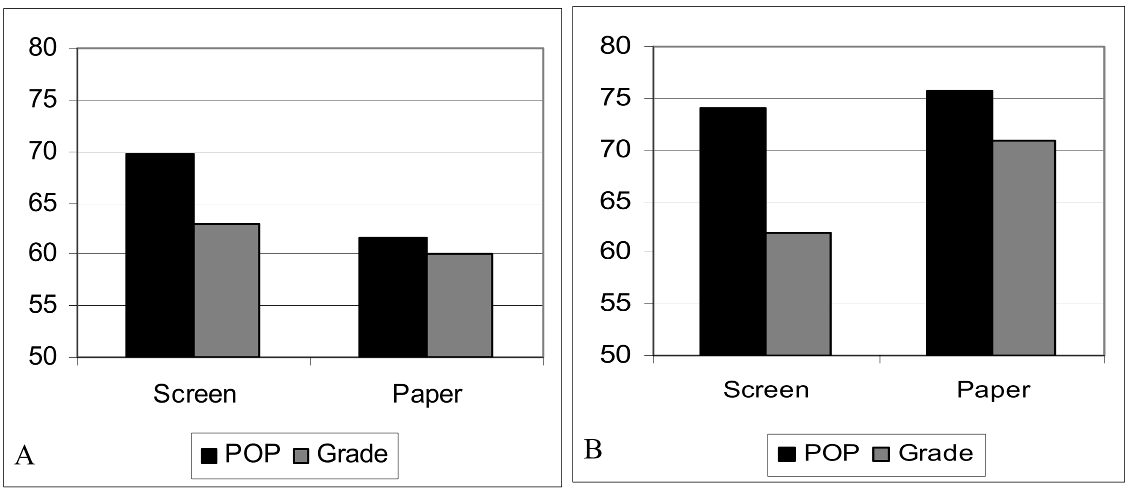

Figure 2. Mean Prediction of Performance (POP) and test grade (percent correct) for on-paper vs. on-screen learning, under a fixed study-time schedule (Experiment 1, Panel A) and under self-regulated study time (Experiment 2, Panel B).

Experiment 2

In order to examine the possible consequences of media differences in monitoring and control processes, self paced study was allowed in Experiment 2.

Method
The procedure was identical to Experiment 1, but this time participants could decide for themselves how much time to allocate to each text. They did have an overall time limit of 90 minutes, which is substantially longer than in Experiment 1.

Results
Total study time exploited by participants (M=76 minutes) was shorter than the 90-minute allotment. Again, the OSL participants were overconfident $t(18)=3.83$, $p<.001$ and the OPL participants well calibrated $t(18)=1.79$, n.s. Now, however, with self- regulation of study time, OSL test performance was lower than OPL (Figure 2, Panel B; $t(36)=2.50$, $p<.05$). As can be seen in Figure 2 by comparing the two panels, giving participants free control over study-time improved performance significantly for OPL $t(34)=2.65$, $p<.05$ but not for OSL $t(34)=.26$, n.s.

Experiment 3
Why did OSL not benefit from additional study-time, whereas OPL did benefit from it? What factors were operating under self regulation of study time that were not operating when study time was fixed? First, in accordance with the overconfidence found for OSL participants but not for OPL participants, the overall amount of invested study time was somewhat less for OSL compared to OPL. However, this is not the only candidate factor. Additional possibilities are control policy and control sensitivity. Experiment 3 examined these aspects of the learning process.

Now participants were asked to provide “online” POP judgments, up to five times during the course of studying each text. This change allowed us to examine the subjective learning curve, estimate the norm-of-study for each participant, and measure control sensitivity in terms of the relationship between POP level and the decision to continue/stop learning.

Method
The method was identical to Experiment 2: Participants were given free control over study time, but now they were also asked to stop every 3 minutes and provide POP judgments.

Results
The main findings of Experiment 2 were replicated. In addition, the norm-of-study was found to be similar for the two media $t(34)=.01$, n.s., indicating that participants stopped studying at a similar subjective knowledge level for both presentation media. Interestingly, however, the relationship between POP and time progress, as well as between POP and the decision to continue/stop learning (both measured by the respective within-individual gamma correlations), were significantly weaker for OSL relative to OPL, $t(34)=2.96$, $p<.01$ and $t(34)=2.16$, $p<.05$ respectively. These findings suggest that subjective monitoring is “noisier” for OSL than for OPL, and perhaps as a consequence, control of study time is less sensitive to one’s monitoring output under OSL than under OPL.

Discussion
We began this research with three possible explanations for the subjective inferiority of OSL relative to OPL. Apparently, this subjective inferiority is not illusory, since actual test performance was indeed inferior for OSL compared to OPL under self-regulation conditions. The finding that this inferiority was eliminated under a fixed study schedule counts against a purely ergonomic explanation. Instead, our adapted metacognitive framework and its associated methodological tools allowed us to isolate and examine factors that might not otherwise have been considered. Our results implicate overconfidence and decreased control sensitivity as, at

least, partly responsible for the OSL performance deficit. An interesting question for further study is whether OSL learners are in fact consistently overconfident at a specific-text level (our experimental results), but less confident at a more global level (our survey results), and if so, why? More generally, this initial study highlights the potential of the metacognitive approach for clarifying the source of differences in learning processes between different learning media, and for pointing us toward additional means of improving these processes.

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