What Can Hypertext Re-Reading Tell Us about the Design of Adaptive (Metacognitive) Help Functions?

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Abstract
A well-documented finding in the help-seeking literature is that especially those learners who need it the most do not seek help (appropriately). In this exploratory study, we investigated re-reading as a unique window into elementary help-seeking processes. Students had to learn the content of multiple hypertext pages of different complexity for a subsequent knowledge test. After this learning phase we randomly assigned learners to two experimental groups: The memory control group (MG, \( n = 14 \)) directly answered the knowledge test and the experimental help-seeking group (HSG, \( n = 15 \)) had the option to re-read the hypertext pages before answering. Results show that HSG students outperformed MG students and that HSG students strongly adapted the extent and frequency of their re-reading to task complexity and the complexity of the hypertext pages. However, more re-reading or more adaptivity did not automatically enhance performance on the knowledge test. The implications of these findings for the design of adaptive (metacognitive) help functions in computer-based learning environments will be discussed.

Help-Seeking and Re-Reading
Given learners’ difficulties in adequately using help-functions in computer-based learning environments (CBLEs), it is paramount to study the help-seeking process in detail in order to design adequate help functions. We argue that re-reading of written material provided in CBLEs, is a rudimentary process of help seeking. Thus re-reading provides a window into elementary processes involved in help-seeking, namely how students adapt their seeking for additional information to the task at hand and under which conditions they decide to seek help.

Help-Seeking in CBLEs
According to Aleven, Stahl, Schworm, Fischer, and Wallace (2003) an increasing number of studies provides evidence that learners often do not use help functions in CBLEs very effectively or even ignore them totally. However, some studies also show that the adequate use of help-functions is beneficial for performance. For example, Bartholomé, Stahl, Pieschl, and Bromme (2006) showed that the use of context-sensitive help within a CBLE was positively related to better performance. Also Renkl and colleagues (Renkl 2002, Schworm, and Renkl 2002) demonstrated a causal relation between the availability of help functions in a CBLE and better learning results.

In traditional classroom settings as well as in CBLEs help-seeking is conceptualized as a metacognitively guided self-regulated learning activity (Nelson-LeGall 1981; Newman, 1994). It is assumed to be a micro-level indicator of the macro-level self-regulated learning process of managing “task difficulties and demands” (Greene and Azevedo 2009). Help-seeking involves multiple complex phases (Nelson-LeGall 1981; Aleven et al. 2001): (1) Learners have to become aware of their need for help, for example by assessing task difficulty, monitoring progress, and evaluating one’s own comprehension. (2) Learners have to decide to seek help. In some contexts, learners may consciously decide not to seek help even though they recognize their own needs, for example, if they do not believe in the utility of the offered help functions. (3) Learners have to identify potential helper(s). CBLEs facilitate this step because they often offer easily accessible help functions. (4) Learners have to use strategies to elicit help, in CBLEs they can, for example, click on the selected help feature. (5) Learners can evaluate the effectiveness of the help-seeking episode. If the received help is not helpful, a learner may decide to select another kind of help. In CBLEs, help functions can take many forms (Aleven et al. 2003), for example they can be on-demand versus system-initiated or they can be process-oriented vs. function-oriented. In all cases, however, they provide additional information.

In contrast, we suggest to conceive re-reading as help seeking with regard to information which has been available from the beginning, but which might subjectively include new information for the reader because she or he has skipped parts of the content during initial reading or
has not developed an appropriate, comprehensive and accessible (relatively to the respective learning task) mental representation.

**Re-Reading**

Re-reading is a comprehension strategy of skilled readers (Brown and Pressley 1994) which can be as effective as other comprehension strategies (Anderson 1980; Haenggi and Perfetti 1992). Re-reading is often studied during first (initial) reading, for example by presenting text on the computer where back and forth navigation can be tracked (Goldman and Saul 1990). Empirical results show that in these cases more re-reading is related to better memory of facts (Hyönä and Nurminen 2006) and that poor readers are less inclined to re-read text (Johnson-Glenberg, 2005). Similar results are obtained when readers are explicitly instructed to re-read a whole text. In this context re-reading is associated with better memory of facts (Amlund, Kardash, and Kulhavy 1986) and better metacomprehension (Rawson, Dunlosky, and Thiede 2000), especially for better readers (Millis and King 2001).

Just as help-seeking, re-reading is assumed to be a metacognitively guided self-regulated learning activity (Greene and Azevedo 2009). All phases of help-seeking can also be found in their elementary form in re-reading: (1) Learners have to become aware of their comprehension problems. Poor readers’ lack of re-reading is often attributed to their inadequate comprehension monitoring (Baker 1984) just as inadequate help-seeking is often attributed to learners’ lack of awareness of their own needs (Aleven et al. 2003). Without any comprehension problems good readers most likely read a text only once (once through / linear approach; Goldman and Saul 1990). The decision to re-read (2) may be facilitated, for example because learners know about the utility of the offered “help”. Identifying potential helpers (3) may also be facilitated because the already-processed text is readily available. Regarding strategies to elicit help (4), good readers use different re-reading strategies adaptively: If they notice severe comprehension problems they may choose to re-read the full text once again (review approach), if they notice fragmentary understanding they may re-read selected passages (regress approach).

Based on these arguments we assume that re-reading offers access to students’ elementary processes of help-seeking because the involved cognitive processes are analogous although they may be partly facilitated.

**Research Questions**

The following research questions are based on our conceptual analysis above; however, they are also driven by a practical and applied interest in the design of adequate help functions in CBLEs: (1) Do students (effectively) use re-reading? To explore this research question, we compare an experimental group with the option to re-read hypertext pages when answering a corresponding knowledge test with a control group without this option. (2) Do students adapt their re-reading? According to the theoretically assumed phases of help-seeking and re-reading, learners should use re-reading adaptively only in those cases where they experience comprehension problems. However, it is an open issue also relevant for the design of adequate help functions which cues learners use for this kind of adaptation. Therefore, we explore a number of potentially relevant cues in the experimental group, for example task difficulty and text complexity. (3) Which re-reading parameters are predictive of performance? According to our conceptual analysis and previous research on help-seeking, we expect that more re-reading should be associated with better performance and that more adaptive students should perform better.

**Method**

**Participants**

Twenty-nine students of psychology participated in this exploratory study (27 females, 2 males). These students were on average 23 years old ($SD = .40$) and possessed little prior knowledge in molecular genetics (self-rated prior domain knowledge on a 5-point scale from $1 = $ very little to $5 = $ very much: $M = 1.72, SD = 0.73$).

![Structure of the hypertext on genetic fingerprinting.](image)

*Figure 1. Structure of the hypertext on genetic fingerprinting. The squares and ellipses symbolize hypertext pages and the lines symbolize the hierarchical structure. The hypertext pages that were randomly selected for this study are colored black.*
Material

Hypertext. The learning material was taken from a hypertext about genetic fingerprinting. The hypertext consists of an introduction to genetic fingerprinting, the main part with three chapters about different DNA analyses methods (sequencing of the mitochondrial genome (mtDNA analysis), short tandem repeat (STR) analysis, and Y-STR analysis (STR analysis on the male Y chromosome)), and three appendices with additional information (about biological background, case examples, and problems). All pages in the three chapters of the main part are linked in a hierarchical structure according to text complexity: simple introductory pages (level 1), moderately complex pages (level 2), and complex pages for experts (level 3). We randomly selected 13 hypertext pages for this study (colored black in Figure 1). More specifically, we selected three level 1 pages from the chapters about STR and Y-STR analyses (STR 1-1, Y 1-1, Y 1-2), four level 2 pages (STR 2-1, STR 2-2, STR 2-3, Y 2-1), and two level 3 pages (STR 3-1, Y 3-1). Furthermore, we selected pages from the appendices, one about biological background (BI 1), one example (EX 1), and two problems (PR 1, PR 2).

Subjective Judgments. During initial reading, students evaluated each hypertext page by judging the complexity of the text, the pictures, and the overall hypertext pages (each on a scale from 1 = simple to 7 = complex).

Performance. After initial reading of all hypertext pages, students answered a knowledge test with 13 multiple-choice questions, each specific to one previously read hypertext page. This is a sample question: “Which of these problems is not a typical artifact of STR analysis? (1) stutter-bands, (2) pull-ups, (3) spikes, (4) background noise, or (5) valleys (correct answer in italics)”.

Procedure

The study was run in group sessions that lasted approximately 1 hour. In the first part, all students were directed to access the 13 selected hypertext pages (see Figure 1) and were told to learn their content in order to answer knowledge questions later on. During or shortly after reading each hypertext page they judged the complexity of the text, picture, and total page. This learning phase was self-paced. Afterwards students had to answer the knowledge test. We randomly assigned students to one of two experimental conditions; before this test phase they were blind to these conditions: 14 students had to answer the knowledge test by relying on their memory alone (MG = memory group) and 15 students had the option to re-read the hypertext pages corresponding to the multiple-choice questions during the knowledge test (HSG = help-seeking group). We automatically logged students’ number of re-readings (NRR) and the duration of their re-readings (DRR) in the help seeking group (HSG).

Results

Because of the explorative nature of this study, we define \( p < .05 \) as significant, but also interpret effects with \( p < .10 \) as marginally significant.

The two experimental groups did not differ in initial reading. For none of the hypertext pages we found significant differences between HSG and MG students in initial reading time or judged complexity of texts, pictures, or whole hypertext pages.

Do Students (Effectively) Use Re-Reading?

Students in the HSG used the option to re-read extensively (NRR: \( M = 6.20; SD = 3.12 \)) and this amount of re-reading significantly differs from zero (\( t(14) = 8.94, p < .001 \)). Furthermore, they also spent a significant amount of time on re-reading if summed up across all questions (DRR: \( M = 3.02 \) minutes; \( SD = 1.18; t(14) = 7.69, p < .001 \)).

Regarding effectiveness, we compared the overall performance on the knowledge test between HSG and MG students. HSG students significantly outperformed MG students (HSG: \( M = 10.60; SD = 2.18; \) MG: \( M = 7.50, SD = 2.10; t(27) = -3.91, p = .001 \)). On a more detailed level, we computed Chi-square tests for each multiple-choice question separately. HSG students outperformed MG students (marginally) significantly on five questions about the hypertext pages STR 2-3 (\( X^2(1) = 10.64, p = .002 \)), STR 3-1 (\( X^2(1) = 4.14, p = .048 \)), STR 2-1 (\( X^2(1) = 9.95, p = .002 \)), Y 2-1 (\( X^2(1) = 2.89, p = .095 \)), and Y 3-1 (\( X^2(1) = 3.13, p = .082 \)). All these questions showed high task difficulty (solved by fewer than 50 % in the MG group) and pertained to hypertext pages on complex hierarchical levels (level 2 and level 3) (see Figure 2).

Figure 2. Graph depicting the percentage of correct answers as a function of experimental groups and hypertext pages

Do Students Adapt Their Re-Reading?

We explored a number of cues pertaining to each hypertext page or multiple-choice question that HSG students might use to become aware of comprehension problems and decide to re-read: (1) objective task difficulty (percentage of correct solutions in the MG condition), (2) objective text complexity (hierarchical hypertext levels 1-3), (3) initial
reading time, and students’ own subjective evaluations of complexity regarding (4) texts, (5) pictures, (6) and overall hypertext pages. In order to quantify students’ adaptations to these cues, we computed intra-individual Goodman-Kruskal Gamma correlations ($G; n = 13$, for 13 multiple-choice questions) between each of these cues and each of students’ indicators of re-reading (NRR and DRR). Furthermore, we tested the size of each of these mean correlations for significance in comparison to zero.

Results indicate that students significantly adapted their re-reading to most cues (see Table 1). For example, the negative mean correlation of $G = -.70$ between NRR and task difficulty indicates that the more students in the MG condition solved a task correctly (easy task) the fewer students in the HSG condition re-read the corresponding hypertext page. For example, the positive mean $G = .71$ between NRR and text complexity (levels) indicates that hypertext pages on more complex hierarchical levels were re-read more frequently.

Table 1. Mean Gamma correlations between cues (columns) and number (NRR) and duration of re-reading (DRR). Standard deviations in brackets.

<table>
<thead>
<tr>
<th></th>
<th>(1) task difficulty</th>
<th>(2) text complexity</th>
<th>(3) reading time</th>
<th>(4) subjective text complexity</th>
<th>(5) subjective picture complexity</th>
<th>(6) subjective page complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRR</td>
<td>-.70*** (.32)</td>
<td>.71*** (.36)</td>
<td>-.07 (.41)</td>
<td>.32*** (.36)</td>
<td>.33*** (.24)</td>
<td>.39*** (.28)</td>
</tr>
<tr>
<td>DRR</td>
<td>-.65*** (.23)</td>
<td>.62*** (.20)</td>
<td>.03 (.31)</td>
<td>.21** (.37)</td>
<td>.24*** (.28)</td>
<td>.32*** (.32)</td>
</tr>
</tbody>
</table>

Significantly different from zero with * $p < .10$, ** $p < .05$, or *** $p < .01$

Predictors of Performance?

We already demonstrated that HSG students outperformed MG students on a group level (see above). But which parameters of re-reading exactly predict performance? To answer this question, we explored the correlations between measures of re-reading (NRR and DRR) and adaptivity (to all cues) on the one hand and overall knowledge test performance on the other hand.

Results indicate that the relationship between re-reading and performance within the HSG condition is not straightforward: Performance on the knowledge test was neither significantly related to the total number of re-readings (NRR: $r = .03$, $p = .91$, $n = 15$) nor to the total duration of re-readings (DRR: $r = -.30$, $p = .28$, $n = 15$). Additionally, none of the adaptation measures proved to be a significant predictor of performance.

Discussion

Do Students (Effectively) Use Re-Reading?

Results indicate significant use of the option to re-read, which led to a significantly better performance of the HSG students than of the MG Students. Thus, these results are consistent with studies within the help-seeking literature that demonstrate a positive relationship between the availability of help functions and performance (Renkl 2002; Schworm and Renkl 2002). Furthermore, students seem to use this re-reading option more often than they use many other help-seeking functions in CBLEs (Aleven et al. 2003). This is not surprising, because re-reading in this study was directly relevant for answering knowledge test questions whereas most help-seeking functions in CBLEs are used within the learning phase. However, it is noteworthy that even under these conditions HSG students did not perform perfectly. It is an open issue if these less-than-perfect results are due to monitoring deficits (students thought they knew the correct answer), production deficits (students did not know how to extract the correct answer from the hypertext page, for example because they may lack cognitive or intellectual abilities), or motivational deficits (students were not motivated enough to spend the necessary effort).

Do Students Adapt their Re-Reading?

As a group, HSG students adapted their number (NRR) and duration (DRR) of re-reading significantly to almost all investigated cues. For the more objective cues such as task difficulty and text complexity defined by hypertext levels the Gamma correlations are of large effect size indicating strong adaptation while for the more subjective cues, namely learners’ own judgments regarding the complexity of texts, pictures, and hypertext pages, the Gamma correlations are of small or medium effect size indicating moderate adaptation. This kind of adaptation is consistent with theoretical assumptions. According to the outlined process model of help-seeking, help should only be accessed if the learner diagnoses a need for help. This is more likely for difficult tasks and for complex texts. These results are also consistent with other research areas: For example, Reynolds (1992) advocated adaptivity with regard to selective reading and Bromme and colleagues analyzed adaptivity with regard to complexity (Pieschl, Stahl, and Bromme 2008; Stahl, Pieschl, and Bromme 2006). However, it is surprising that students seem to adapt more strongly to objective cues than to their own subjective judgments. One potential explanation may be the quality of subjective judgments. Some learners’ subjective judgments may be very accurate while other learners’ judgments may be inaccurate. Additionally, learners’ reaction to all cues might not be a rational decision but rather an unconscious reaction without much awareness. Contrary to the high adaptation to most cues, on average students did not adapt their re-reading significantly to their initial reading time. It might be that
initial reading time is a more superficial indicator of text length rather than of conceptual text complexity and thus it might not have been beneficial to consider this cue for assessing comprehension problems.

Predictors of Performance?

Contrary to theoretical assumptions, neither students re-reading per se (NRR or DRR) nor students’ adaptivity was related significantly to their performance on the knowledge test. These findings are at odds with results from the help-seeking literature demonstrating that more help-seeking is related to better performance (Bartholomé, Stahl, Pieschl, and Bromme 2006). However, several explanations are feasible:

First, the kind of accessed information differs between re-reading and help-seeking. For example, in the study of Bartholomé et al. (2006) additional context-sensitive information supporting specific decisions was helpful while reading additional glossary definitions was not related to performance. In this study, the re-read hypertext pages were specific to the multiple-choice questions and thus conceptually related to context-sensitive help but not supportive in the sense that they directly referred to all multiple-choice options. Instead the majority of the hypertext page’s content was redundant for the question and no additional new information was presented.

Second, students’ relationships between re-reading and performance might be mediated by differences in initial reading. For example, Johnson-Glenberg (2005) compared re-reading defined as scroll-backs within an electronic text between a control group and an experimental group where re-reading was negatively related to better performance (Bartholomé, Stahl, Pieschl, and Bromme 2006). However, several explanations are feasible:

First, the kind of accessed information differs between re-reading and help-seeking. For example, in the study of Bartholomé et al. (2006) additional context-sensitive information supporting specific decisions was helpful while reading additional glossary definitions was not related to performance. In this study, the re-read hypertext pages were specific to the multiple-choice questions and thus conceptually related to context-sensitive help but not supportive in the sense that they directly referred to all multiple-choice options. Instead the majority of the hypertext page’s content was redundant for the question and no additional new information was presented.

Second, students’ relationships between re-reading and performance might be mediated by differences in initial reading. For example, Johnson-Glenberg (2005) compared re-reading defined as scroll-backs within an electronic text between a control group and an experimental group where students were prompted to use elaborate verbal and visual comprehension strategies. Even though students in the experimental condition used significantly more re-reading, the use of this re-reading was negatively related to indicators of comprehension. In the control condition on the other hand, re-reading was positively related to comprehension. The availability of other comprehension strategies thus might also have mediated the relationship between re-reading and performance. This implies that the relation between re-reading and performance strongly depends on initial reading strategies. In this study, University students might have used a diverse set of elaboration comprehension strategies during initial reading.

Third, students’ differences in learner characteristics might have overshadowed potential relationships. For example, Wood and Wood (1999) demonstrated that prior knowledge played an important role in help-seeking: Students with less prior domain knowledge sought help more often but performed worse than students with more prior domain knowledge, presumably because these students were less adapt at accurately judging their own needs. Other learner characteristics might also be relevant, for example goal orientation, epistemic beliefs (Aleven et al. 2003), need for closure, confidence, or persistence.

To summarize, re-reading seems not – at least not for the majority of learners – based on a thoroughly rational decision process. Contrary to theoretical assumptions, there is no logical pattern in re-reading. Instead we found ample inter-individual variance between learners on all performance levels. More research is needed to explore the complex interrelations between initial reading, re-reading, and moderating variables such as learner characteristics. We assume that this finding can also be transferred to help-seeking. Help-seeking also is no thoroughly rational decision process that can be easily predicted.

Implications

This explorative study demonstrates that a high quantity of help-seeking can be triggered by these specific conditions of re-reading in order to answer related knowledge questions. Furthermore, learners use re-reading adaptively, especially for more difficult tasks and for more complex learning material. This has implications for how to elicit quantitatively more help-seeking behavior in CBLEs. Learners might be more likely to seek help under the following conditions: If they are tested for their acquired knowledge (cf. multiple choice questions). If help functions are directly relevant for answering test questions (cf. hypertext pages that corresponded to multiple-choice questions). If test questions are at least moderately difficult (cf. task difficulty as relevant cue), if learning material is at least moderately complex (cf. task levels as relevant cue), and if learners judge the learning material to be at least moderately complex (cf. subjective judgments regarding text complexity). For the design of adaptive (metacognitive) help functions this implies that learners should be lead adaptively through the learning material in order to keep it challenging. Furthermore, if learners do not use help functions voluntarily, it might be effective to present system-initiated knowledge test questions and reflection prompts to elicit more help seeking.

However, this study also demonstrates ample inter-individual variance in quantity and adaptivity of re-reading and shows that neither of these factors directly predicts performance. This also has implications for help-seeking in CBLEs. Foremost, it shows that quantity of help-seeking or adaptivity of help-seeking does not guarantee better learning. Instead, the quality or efficiency of help-seeking might be mediated by other factors such understanding of the basic material (analogous to initial reading) or learner characteristics. Further research is needed to explore these complex interrelations. We can still draw tentative conclusions for the design of adaptive (metacognitive) help functions: In order to provide help adapted to learning processes these learning processes need to be automatically tracked, for example by a software such as nStudy (Winne, Hadwin, and Gress in press), and if possible compared to models of successful and unsuccessful learners. Only if learners’ initial learning processes seem insufficient system-initiated help should be offered. Additionally, it would be beneficial if the provision of help functions could be adaptive with regard to learner characteristics, not only in quantity but also in kind and content of provided help. We can only speculate about which of help would be adequate for what kind of learner: For example, system-
initiated help might be good for a novice learner with only little prior knowledge while learners with more prior knowledge might do better with on-demand help functions. Regarding content, a student lacking awareness of comprehension problems might need knowledge test questions or metacognitive monitoring prompts and a student with naïve epistemic beliefs might need a help function explaining the epistemic nature of the task and topic. Existing tools such as the Cognitive Tutor (Koedinger, Anderson, Hadley, and Mark 1997) that provide multiple levels of on-demand help in CBLEs are a good starting point. These could be further developed to automatically provide adequate quantity, kind of access (e.g., on-demand vs. system-initiated), and content of help (e.g., motivation, metacognition, epistemic cognition, or cognition) depending on previous learning processes and learner characteristics. However, we acknowledge that this suggestion might be more an impossible dream than a feasible proposition.

References


