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Empirical study

Does visualization affect monitoring accuracy, restudy choice, and comprehension scores of students in primary education?

Danny Kostons [a,*], Bjorn B. de Koning [b]

[a] University of Groningen, Groningen Institute for Educational Research, The Netherlands
[b] Department of Psychology, Education, and Child Studies, Erasmus School of Social and Behavioral Sciences, Erasmus University Rotterdam, The Netherlands

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ABSTRACT

In the present study, we investigated how 116 fourth and fifth grade students' monitoring skills were associated with restudy choices and explored whether drawing was a useful intervention to improve monitoring accuracy, restudy choice, and comprehension scores. During the first session, all students read a text, judged their learning of the information within that text, selected paragraphs to reread, reread those parts, and then made another judgment of learning (JOL) before doing a post-test. Several significant correlations were found between the various variables involved, such as higher JOLs before rereading related to fewer paragraphs being reread, and JOL-accuracy after rereading was positively correlated with the scores on the postreading questions. For the second session, students were split-up into three conditions: a control condition and two drawing conditions. In the long-drawing condition, students were allowed to draw throughout the whole second session, including post-test. In the brief-drawing condition participants only got to draw the first time they read the second text. We did not find significant differences on the postreading scores. The only differences we found were that the participants in the long drawing group were more accurate in their JOLs before rereading and selected more paragraphs to reread than the other two groups, and invested more mental effort in comparison to the other groups. Drawing more elements was positively correlated with the posttest scores and JOLs, whereas drawing more details was negatively correlated with posttest scores and did not correlate with JOLs. As students in the long drawing condition drew both more elements but also created more detail in those drawings compared to the short drawing condition, it is possible that the beneficial effects of creating drawings were cancelled out by the negative effects.

1. Introduction

Much of what students in primary education have to learn, is presented in written form and the ability for students to comprehend what they read is paramount to their academic development (Law, Chan, & Sachs, 2008; Savolainen, Ahonen, Aro, Tolvanen, & Holopainen, 2008; Spörer; Brunstein, & Kieschke, 2009). Due to a shift from teacher-centered to student-centered education, students have been increasingly required to appropriately monitor and control their reading (Cromley & Azevedo, 2007; Pressley & Wharton-McDonald, 1997; Schraw, 1998). Being capable of regulating one's own learning has therefore become an essential skill in education (e.g., Zimmerman, 1990). However, many students struggle with properly comprehending a text (Cromley & Azevedo, 2007; Garner & Taylor, 1982; Markman, 1977), particularly because they experience difficulties with effectively monitoring and controlling their reading process (Thiede, Anderson, & Therriault, 2003). The present study investigates how students' monitoring skills are associated with restudy choices and explores whether drawing is a useful intervention to improve comprehension monitoring accuracy, restudy choice, and postreading comprehension scores.

1.1. Text comprehension

According to Kintsch's (1986, 1998) seminal work on text comprehension, a text can be conceptually processed at three levels of analysis. First, there is the processing at the very surface level, dealing with the parsing of a text. Within the second level, readers deal with the text-base, where propositions and relations within the text are derived to represent the meaning of the text. The final level is where a situational model is created, or adjusted, and

* Corresponding author at: University of Groningen, GION, Grote Rozenstraat 3, 9712 TG Groningen, The Netherlands.
E-mail address: d.d.n.m.kostons@rug.nl (D. Kostons).

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involves the construction of a coherent mental representation of what the text is about by integrating text content with previously read information and/or with the reader's prior knowledge. In other words, at the situational level the mental representation of a text is not built up out of the literal words the reader processes, but is a non-verbal representation that is integrated with the prior knowledge of the reader. As such, reading does not only lead to the construction of new propositions for each text, but prior knowledge influences how these propositions are understood. Furthermore, new propositions activate existing schemata, which may in turn activate other propositions as well.

This implies that understanding a text requires students to make inferences. For propositions that have to be understood within the text base and/or situational level, these inferences are coherence inferences, as they deal with the coherence of propositions in the text and other propositions of that same text. For propositions that relate to prior knowledge (and propositions from other texts), these so-called elaborative inferences rely on extension of the text-base by using prior knowledge (Cain & Oakhill, 1990; Oakhill, 1982, 1984). Deficiencies in making inferences, will negatively affect text comprehension (Cain, Oakhill, Barnes, & Bryant, 2001). Importantly, unless activation of context irrelevant aspects are detected, propositions from the text and existing schemata are strengthened and the new propositions are integrated into the existing, now incorrect, schemata. The "unless" in the prior sentence is quite important; readers need to detect irregularities or conflicts in their understanding to improve comprehension. For many students in primary education, this monitoring for understanding is not an automatic process, but rather requires deliberate effort.

1.2. Self-regulated learning and monitoring accuracy

Self-regulated learning is an active, constructive process in which learners plan, monitor, and control their own learning process (e.g., Pintrich, 2000; Winne, 2001; Winne & Hadwin, 1998; Zimmerman & Schunk, 2001). Different elements stand out in this definition. First of all, students are actively involved and are to be engaged in learning. This component links directly to the second element which is the purposeful focus on the achievement of a goal. Students can achieve their goals through the regulation and control of cognition, referring to the use of learning strategies to enhance one's learning (Alexander, Graham, & Harris, 1998; Zimmerman, 1990). According to Alexander et al. (1998), a learning strategy is particularly relevant because it provides procedural knowledge to complete a task: the 'how to' knowledge. Consistent with this, learning strategies have been shown to facilitate self-regulated learning (Dignath, Buettner, & Lanfeldt, 2008) and enhance performance (Donker, De Boer, Kostons, Dignath van Ewijk, & Van der Werf, 2014); in other words, they are essential for academic development. Such strategic top-down activities are particularly necessary if the normal flow of information processing breaks down (Kintsch, 2005).

In order to deploy reading strategies effectively, students need to recognize when they need (and when they do not need) such strategies to enhance comprehension. Therefore, a critical step in the self-regulatory process is monitoring one's progress as not only the comprehension at the end of the reading task is important, but also the process by which it was obtained (see e.g., Segers, Dochy, & Cascallar, 2003). Accurate monitoring helps students to identify which information is well-learned and which information requires additional study. By monitoring one's own comprehension while working on a task, a student evaluates the mental representation of the reading process and his/her progress, which in the model by Kintsch (1998) translates to evaluations of the integrity of the propositional network and/or one's constructed situational model.

Whereas research on comprehension monitoring has identified different ways to determine monitoring accuracy (see Bjork, Dunlosky, & Kornell, 2013; Dunlosky & Lipko, 2007) for the purposes of our study we will focus on absolute monitoring accuracy. Absolute accuracy refers to judgments students make with regards to their actual performance, usually represented in terms of over- or underestimations of performance (Dunlosky & Rawson, 2012). These are the kinds of judgments related to assessing one's own performance on a comprehension or learning task, for example to determine a next learning task (i.e., Kostons, Van Gog, & Paas, 2012). In line with this, in the present study we are interested in how students judge their comprehension and contrast this with their actual performance on a reading assignment.

Over the years, research has shown that accurate monitoring seems to be fairly difficult for students. For example, typical intra-individual correlations between peoples' predictive Judgments of Learning (JOL; Koriat & Bjork, 2005) from text and their actual text comprehension performance (i.e., absolute monitoring accuracy) are below 0.30 (Dunlosky & Lipko, 2007; Thiede, Griffin, Wiley, & Redford, 2009). One reason for inaccurate monitoring may be that both reading and monitoring one's comprehension of that performance simultaneously compete for limited working memory resources; especially under conditions of high cognitive load, monitoring or reading may be negatively affected by a lack of cognitive resources (Van Gog, Kester, & Paas, 2011). Furthermore, research has investigated several factors that influence the accuracy of JOLs (Dunlosky & Nelson, 1992; Nelson & Dunlosky, 1991; Nelson, Narens, & Dunlosky, 2004) and subsequent selection for restudy (Metcalfe & Kornell, 2005; Thiede & Dunlosky, 1999; Van Loon, de Bruin, Van Gog, & Van Merrienboer, 2013). According to the cue-utilization model (Koriat, 1997), readers have access to many cues that they can use to make a judgment of learning when reading a text. In particular, there is evidence that if readers base their judgments on representation-based cues, which are cues that stem from trying to enhance the situation model while reading, these readers have higher monitoring accuracy (Thiede, Griffin, Wiley, & Anderson, 2010). Critically, however, Thiede et al. (2009) have shown that students often do not use such representation-based cues, because using these cues requires a considerable amount of effort. Moreover, it seems that cognitive biases can guide readers to the utilization of the wrong cues to assess their performance. For example, when people fail to solve a problem, and are subsequently provided with feedback on the correct solution, they are often inclined to overestimate the likelihood that they could have produced it themselves (i.e., hindsight bias), and when an answer comes to mind easily, it is not only more likely to be provided, but also more likely to be assumed correct (i.e., availability bias; for a review, see Bjork, 1999). Based on the above analysis, it seems that students need some support to make accurate judgments of their level of text comprehension.

1.3. Improving JOL in text comprehension

Several studies focusing on improving the accuracy of monitoring judgments have examined different manipulations that increase the accessibility of cues related to the situation model of a text (for an overview, see Thiede et al., 2009). Thiede et al. (2003), for example, showed that when more accurate judgments of text comprehension were induced, people restudied more strategically and performed better. Specifically, their results showed that summarizing or providing keywords after reading, but prior to judging comprehension, was an effective way to improve college students' judgments of text comprehension. Summaries or keywords generated after a short delay were more effective at improving JOLs than those made immediately after reading.

The authors argued that the delay between reading and judgment forced readers to rely on situation model cues, because the surface features of a text decay over time, which led to improved comprehension monitoring accuracy.

Similarly, Griffin, Wiley, and Thiede (2008) demonstrated that having readers self-explain the relations between the elements in a text is also an effective way to improve monitoring accuracy. When prompting readers to make sense of the text by, for example, trying to uncover the meaning of sentences and making connections between elements distributed over the text, those readers are more likely to construct a coherent mental representation of the text and to fill in missing information by drawing upon information from the text and prior knowledge from memory (Chi, De Leeuw, & Lavancher, 1994). Hence, readers have more representation-based cues available, which could help them in making more accurate judgments on their comprehension. Whether or not these cues need to remain explicitly available later or whether mental creation of such cues is sufficient, is one of two main foci of this particular study. Furthermore, students who expect an inference test instead of a memory test seem to generate more accurate monitoring judgment predictions for inference tests, suggesting that monitoring accuracy can also be improved if readers know what kind of test to expect (Thiede, Wiley, & Griffin, 2011).

1.4. Graphic strategies

A relatively recent approach for trying to improve monitoring accuracy is to ask students to visualize the learning content. As indicated by the work of Chang, Sung, and Chen (2002) and Leopold and Leutner (2015), visualization facilitates the organization and integration of information into the situation model. Rather than keeping this situation model as a purely mental construct, visualization provides a graphic representation of the text content that is analogous to the mental representation (i.e., situation model) of the readers (De Koning & Van der Schoot, 2013). This falls in line with Redford, Thiede, Wiley, and Griffin' (2012) suggestion that concept mapping is a good way to "help readers form an external representation of a situation model for a text" (p. 263). However, there seems to be a mismatch between the extent to which a situation model as described by Kintsch and concept mapping (as investigated by Redford et al., 2012) are visuospatial in nature. In their review paper of various visual representational strategies, De Koning and van der Schoot (2013; also see De Koning & van der Schoot, 2014) argued that whereas a situation model is a non-linguistic or visuospatial representation of the state of affairs described in a text, concept mapping only provides a (visually) structured representation of the words and sentences in a text (not what the text is about) and therefore does not necessarily move beyond the linguistic representation levels. From this perspective, concept mapping may not sufficiently focus readers on the situation model features of the text and is therefore less likely to make situation model cues accessible to readers leading to less accurate monitoring judgments. As such, drawings lead to the visualizations of the described situation and therefore may be more suitable for fostering the creation of situation models that form the basis for students' monitoring judgments, particularly when visual information of a text is salient and can be visualized concretely.

Asking readers to draw a picture that represents the elements and event(s) depicted in a story is a practical and popular way to visualize text content, particularly in the case of narratives focusing on situations with causality (Ainsworth, Prain, & Tytler, 2011). It is suggested that drawing helps readers to construct an external visual representation, which in turn facilitates the construction of a situation model (Van Meter, 2001). Engaging in a drawing activity tends to be especially helpful to promote deeper levels of comprehension (De Koning & Van der Schoot, 2013) and aids in the construction of inferences relevant to comprehending a text (Cain et al., 2001). The constructed situation model is likely to enhance monitoring, as incomplete or conflicting information in the situational model is explicitly depicted visually and therefore is more likely to be picked up by the learner (Rubman & Waters, 2000). As a consequence, the construction of a drawing increases the salience of cues related to the situation model representation when readers provide a judgment on their text comprehension and their subsequent selection of rereading activities through which they can adjust and refine their situational models.

It is important to note that the quality of the drawing likely determines the quality of the learners' situation model. That is, merely the act of drawing does not necessarily result in a coherent situation model, and thus may insufficiently improve monitoring and control aspects of self-regulated learning, as well as performance scores. This poses a serious risk in current education given that students in primary education are not very apt at making meaningful drawings (Van Meter, 2001), which might lead to additional activities that do require effort from students but do not promote learning. So, unless students are adequately supported, through instructions or other scaffolds, it is unlikely that young students will be able to construct drawings (or concept maps) that are well-organized and include all critical information and leave out irrelevant information such as decorating details (Redford et al., 2012; Van Meter, 2001).

1.5. The present study

The first aim of this study is to elucidate whether students' monitoring and controlling processes, and performance scores correlate. Most studies focus either on monitoring accuracy or choices made, but few studies investigated both of them simultaneously as well as the relationship between these two factors and performance scores (but see Kostons et al., 2012; Van Loon et al., 2013). As such, the present study asked students to read a text and make a judgment of learning, but also, based on this judgment of learning and several test questions after the first read of the text, required students to indicate which paragraphs they wanted to reread, do the rereading, again make judgments of learning before getting to the final questions about the text. This first aim is summarized in our first research question; to what extent do absolute monitoring accuracy, rereading choices, and reading comprehension scores correlate? We expect that a) students with high JOL accuracy have higher performance scores, b) that those with low JOLs, will select more paragraphs to restudy, and c) those who restudied more paragraphs will outperform students who restudied fewer paragraphs, although this relationship is mediated by their JOL.

The second aim of this study is to investigate whether an intervention targeted at visualizing the situation and events described in a text is effective at improving monitoring accuracy, restudy choices and reading comprehension. This study specifically investigates the monitoring abilities of younger students (4th and 5th grade) to see whether a drawing intervention could help them to improve their monitoring accuracy, restudy choices and reading comprehension. This second aim is reflected in our second research question; what is the effect of a drawing intervention during text comprehension on judgments of learning accuracy, rereading choices, and reading comprehension posttest scores?

Interestingly, most of the literature seems to lead to the suggestion that the *creation* of visualizations, instead of having the visualization available after it has been first created, should aid in developing better situational models (De Koning & Van der Schoot, 2013; Thiede et al., 2011). However, as this has not been investigated directly, we not only investigated whether drawings are more effective than not drawing, but also whether drawing is more effective when this is done (and available) only for a short time when reading the text for the first time (i.e., short drawing condition), or whether these drawings need to remain available throughout answering questions about the text and rereading as well (i.e., long drawing condition) to have a positive influence. Considering that additional drawing activities might also increase the required mental effort involved in the task, we also take a single mental effort measure, to not only look at effectiveness of long versus short drawing conditions, but also mental effort.

The effectiveness of drawing was tested in the second part of the study. The setup of this second part was similar to the first part, with some alterations. First, students read a different text. Second, there were two experimental groups who received instruction and material helping them to draw either through the first reading of the text (i.e., short-drawing group) or to draw continuously during reading and use that drawing throughout the whole procedure including the post-test (i.e., long drawing group). A control group read the text, provided judgements of learning, indicated paragraphs to reread, reread these paragraphs, and completed the test without engaging in drawing. Our hypothesis is that drawing should improve the accuracy of JOLs, leads to more appropriate rereading choices, and results in higher text comprehension posttest scores than not drawing. Moreover, we hypothesized that although having drawings available longer will result in higher posttest performance scores, this will also lead to higher mental effort with extended additional activities next to the learning task itself.

The third aim of this study was to investigate whether drawing quality relates to posttest performance and monitoring accuracy. We expected that, as indicated under the second aim, the mere act of making a drawing may have a positive effect, but we expect this to be influenced by the quality of the drawing. Specifically, we hypothesized that drawing more relevant elements and relations between elements should be positively related with text-comprehension performance, whereas more idiosyncratic or irrelevant elements/superfluous detailing of relevant elements, is likely negatively related to text comprehension performance.

2. Method

2.1. Participants

Participants were 116 students (49 boys; 67 girls) from primary education, from two classes from Grade 4 and two classes from Grade 5, with an average age of 11.18 years ($SD = 0.72$). Participants were predominantly native-born Dutch students, which is representative for schools in the region where the study took place (i.e., northern part of the Netherlands). The four teachers of the classes were not involved in the actual procedure of the study.

2.2. Materials

2.2.1. Booklet 1

Booklet 1 was used in the first session. The first page consisted of five multiple-choice questions about the text to measure prior knowledge (for example, "What is the main function of dreaming according to Freud?"). The next page contained a single text on the subject of dreaming, which was 443 words long divided into six paragraphs with subheadings. This text was created by Cito, the Dutch Institute for Educational Measurement, as part of their formal assessment of fourth graders. No statistics with regards to readability or difficulty were available.

Subsequently, students were asked (a) how well they thought they had understood each of the paragraphs, which they had to indicate for each paragraph separately on a five-point Likert-scale, with 1 being very little understood and 5 begin most of the information understood, and (b) how many of five questions about the text they were going to answer correctly. The next page presented these five multiple-choice questions (Cronbach's $\alpha = 0.76$; different from the first five prior knowledge questions). These questions were focused on recall of information in the text, and each item was specifically matched with information in a single paragraph.

A single item measured mental effort on a five-point Likert-scale ("How much effort was required to solve the task?", (1) very low effort, (2) low effort, (3) average effort, (4) high effort, and (5) very high effort; adapted from the cognitive load theory research paradigm; Paas & Van Merriënboer, 1994).

Subsequently, students got a list of the six subheadings and had to indicate whether or not they intended to re-read those paragraphs. Student got to re-read the text and again had to indicate how well they thought they had understood each paragraph, indicate how well they thought they would answer five subsequent new questions, and then answer the questions with a final cognitive load item.

2.2.2. Booklet 2

Booklet 2, used during the second session, was very similar to the first booklet. However, the text on the subject of geothermic energy was longer with 722 words, divided over two pages and seven paragraphs with subheadings. This text was created by Cito as part of their formal examination for fifth graders. No statistics with regards to readability or difficulty were available. Pre-, inter- and postreading questions consisted of eight multiple-choice items (Cronbach's $\alpha = 0.81$), rather than five. Finally, depending on the condition, this booklet had instructions about making a single drawing, either only during the first reading (brief-drawing condition) after which the drawing was taken away or throughout the session, even while answering on the posttest (long-drawing condition).

2.3. Procedure

The first session started with a brief explanation of the research procedure. Participants would proceed through Booklet 1 one page at a time, with the test-leader indicating when they could turn the page, which was timed and kept constant between conditions. Under no circumstances were participants allowed to go back to an earlier page in the booklet, which the test-leader checked. Every time participants had turned to the next page, the test-leader would explain what the participants needed to do on that page.

In-between the first and second session, which were twelve days apart, we divided participants from session one randomly into three groups; one group that would serve as a control and went through both booklets without making drawings ($n = 35$, 49% girls, mean age 11.00), a second group that would not only read a text, but also draw a picture of what they read during the first read of the text only ($n = 38$, 61% girls, mean age 10.97), and a third group that could keep the drawing while answering questions and during the second time reading as well ($n = 43$, 63% girls, mean age 11.51).

The second session was organized exactly as the first session, except for the division in three conditions. Time on task was kept constant. This means that, although the two drawing conditions spend more time on the Booklets overall because these also contained an explanation about the drawing activity, they spend an equal amount of time on the task of interest. To avoid interference with regards to instruction by the test-leader, participants within a condition were put in a separate room from participants of the other two conditions. Specific instructions were provided to each group, and these instructions were also put in writing in the booklet. For the two drawing-conditions, students were told that drawing served to make the text clearer and that the drawing could take any from, but that the main of focus lay on the understanding of the text and answering the multiple-choice questions correctly. They were told that they would have to draw the most important elements from the text and try to draw how these elements related to each other. Students in the long-drawing condition did not get any instructions how to use their drawings after reading the text, but were told that they could use the drawings as they saw fit. All participants were also told that the grading of this assignment was not part of their course work and would only be used for research purposes.

2.4. Data-analysis

In interpreting the qualitative aspects, we used the model posited by Kintsch (1998) to formulate our coding scheme. Although this framework has mostly been used in the context of propositional networks, of which examples were given in the introduction, the main focus of this framework is on situation models, and should therefore also match with our current goals here. First of all, at a base level, we would expect that a drawing should contain clear concepts, which in the case of a drawing are clearly defined elements within the drawing. If no such clear elements could be detected within the drawing, these were considered doodles without interpretable qualities (code 1). If such elements could be discerned, code 2 could be assigned (see Fig. 1 for an example).

In the propositional network model of Kintsch, the next step is construction of relations between elements. So if the drawing not only consisted of elements, but also with some sort of relationships between these elements, code 3 was assigned. Finally, in the case that the base cohesive system as with code 3 was in place, but superfluous additions to the internal network were made, such as additional relationships or beautification of the drawing, code 4 was assigned (see Fig. 2 for an example). Note that in none of the coding, we checked whether the drawings were correct or had missing elements.

Two researchers counted the number of elements that could be distinguished in twenty drawings. With an interrater reliability of Kappa = 0.87, one of the researchers counted the number of elements in the remaining drawings. This procedure was repeated for detail level of the drawing (Kappa = 0.80).

3. Results

3.1. Aim 1: Correlations

The first aim of this study was to elucidate whether students' monitoring and controlling processes as well as comprehension scores correlate. Descriptives with regards to the posttest scores, effort, judgment of learning, JOL accuracy and rereading choices are presented in Table 1. JOL-scores were determined by adding together the certainty with which student thought they had understood each paragraph (six paragraphs, rating 1–5). The JOL-accuracy was calculated as the absolute difference between the number of questions participants thought they had correct and

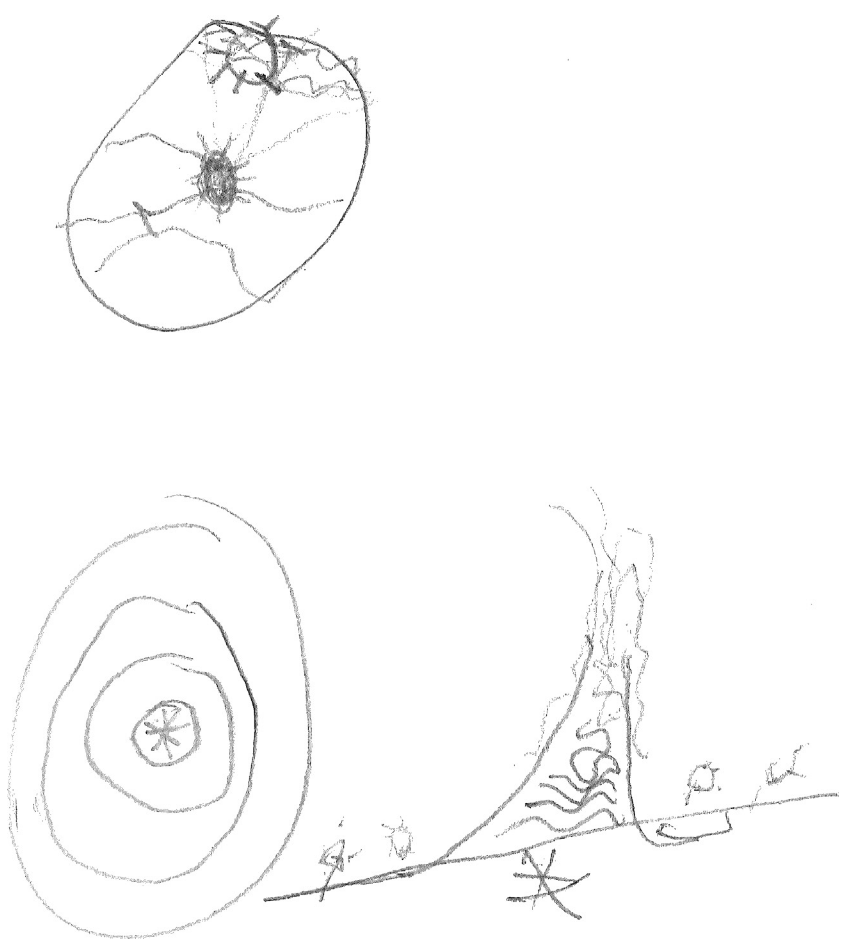

Fig. 1. Drawing with discernable elements (code 2).

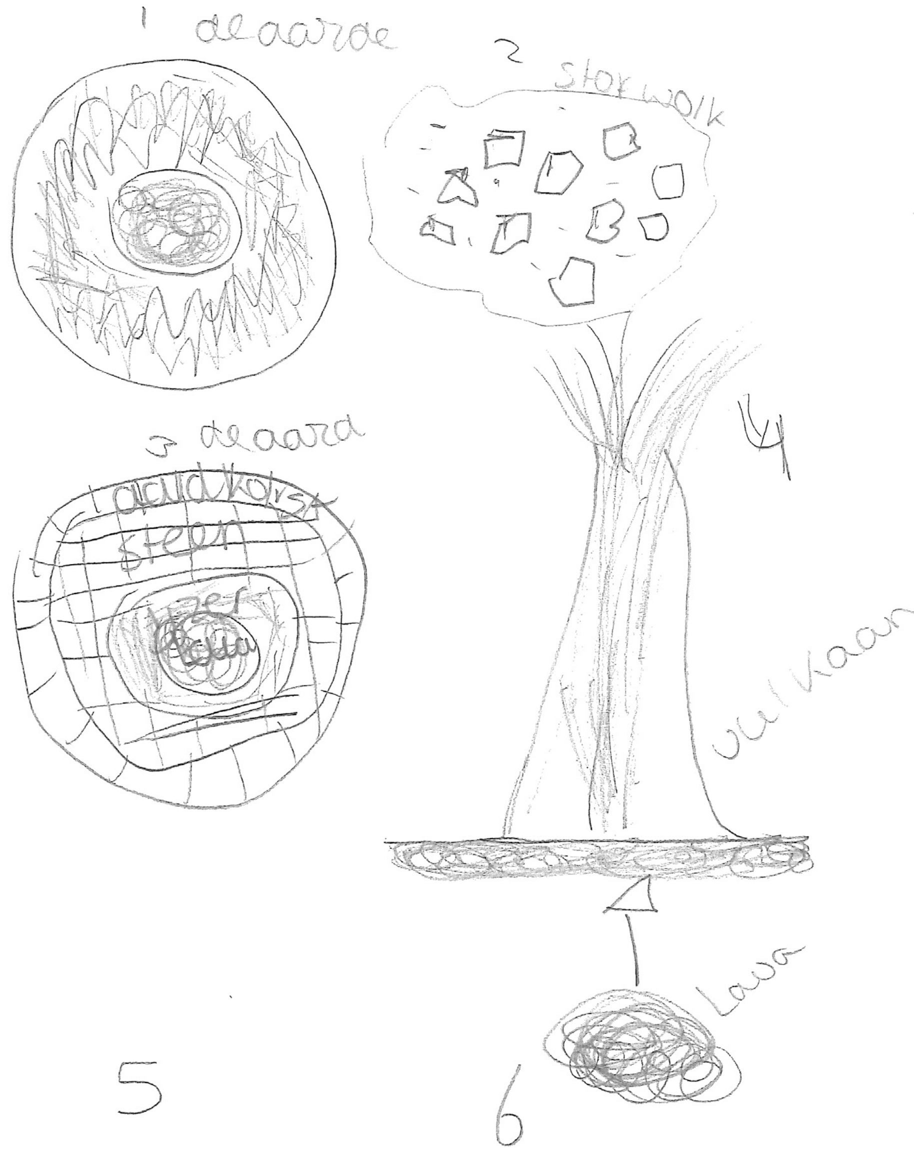

Fig. 2. Drawing with relationships (code 3).

Table 1
Descriptives Session 1.

	Min	Max	Mean	SD
Pre-reading	0	4	1.32	0.92
JOL1 (halfway)	0	5	2.98	0.89
JOL1 accuracy	0	4	1.32	1.07
Inter-reading	0	5	2.34	1.08
Reread	0	6	2.22	1.31
JOL2 (final)	1	5	3.43	0.93
JOL2 accuracy	0	4	0.97	0.82
Post-reading	0	5	2.97	0.98
Effort	1	5	2.34	0.95

the actual number of correct questions, thereby ranging from zero to five, with zero reflecting a perfectly accurate judgment. We took the absolute of these measures, as otherwise, groups of students might seem more accurate due to averaging of over- and underestimating participants.

A correlational analysis was run (see Table 2) to get insight into the correlation between various steps in the decision making process from performing a task to selecting a new task and the final post-test scores. Specifically, we looked at (1) the first JOL, as this JOL should influence the rereading activities, (2) the JOL-accuracy of that first JOL, to determine whether the first JOL was on target or not, (3) the number of paragraphs reread, as this was the control activity on which the study was based, (4) the final text comprehension score, as this should indicate the culmination of success of the metacognitive activities, and (5) the invested effort.

Inspection of Table 2 shows that the first two hypotheses were confirmed, in that (a) lower accuracy was strongly negatively correlated with posttest scores, and (b) participants with higher JOLs chose fewer paragraphs to reread. Unfortunately, we did not find a correlation between rereading activities and posttest scores, even when controlling for JOLs.

3.2. Aim 2: Effects of visualizations

The second aim of this study was to investigate whether a drawing intervention could help children to improve their monitoring accuracy, rereading choices, and reading comprehension scores. Descriptives with regards to the posttest scores, effort, judgment of learning, JOL accuracy and rereading choices for each

Table 2
Correlations Session 1.

	1	2	3	4	5	6	7	8	9
1. Prereading	1	0.091	−17	−0.7	−0.09	−0.03	0.01	0.09	−0.08
2. JOL1		1	−0.23*	−0.72**	−0.36**	0.24*	0.12	−0.02	−0.10
3. JOL1-acc			1	0.02	0.12	−0.10	−0.03	0.01	−0.05
4. Interreading				1	0.09	−0.01	0.06	0.12	−0.01
5. Rereading					1	−0.28**	−0.21*	0.10	0.25**
6. JOL2						1	0.77**	−0.71**	−0.11
7. JOL2-acc							1	−0.55**	0.08
8. Postreading								1	−0.16
9. Mental effort									1

Table 3
Means and standard deviations of the second session per condition.

	Control	Brief drawing	Long drawing
Prereading	3.00 (1.46)	2.89 (1.64)	2.62 (1.23)
JOL1	5.10 (1.22)	4.95 (1.45)	4.30 (1.54)
JOL1-acc	1.57 (1.12)	1.71 (1.09)	1.26 (1.07)
Interreading	3.74 (1.50)	4.29 (1.29)	4.16 (1.38)
Rereading	2.29 (1.79)	1.89 (1.35)	2.67 (1.76)
JOL2	5.53 (1.33)	5.14 (1.50)	5.02 (1.57)
JOL2-acc	1.71 (1.14)	1.75 (1.32)	1.86 (1.22)
Postreading	4.31 (1.59)	4.63 (1.60)	4.72 (1.69)
Mental effort	2.60 (.81)	2.58 (.89)	2.76 (.82)

Table 4
Correlations between drawing elements.

	Elements	Detail	Posttest	JOL accuracy
Elements	1	0.52**	0.25*	0.23*
Detail		1	−0.27*	−0.18
Score			1	−0.16
JOL accuracy				1

* $p < 0.05$.
** $p < 0.01$.

condition are presented in Table 3. JOL-scores were determined by adding together the certainty with which student thought they had understood each paragraph (seven paragraphs, rating 1–5). The JOL-accuracy is the absolute of the number of questions participants thought they had correct minus the actual number of correct questions, thereby ranging from zero to plus eight, with zero reflecting a perfectly accurate judgment.

In order to answer the second research question, we compared the data on several variables between the three conditions. Specifically, as the dependent variables are theoretically unrelated, we ran separate ANOVAs with Condition (no drawing vs. short drawing vs. long drawing) as the independent variable, with each ANOVA having either the pre-test, the first JOL, first JOL-accuracy, inter-reading test, restudy choices, second JOL, second JOL accuracy, post-reading test and mental effort as dependent variables. Significance levels were set at 0.05. Partial eta squared (η_p^2) is reported as a measure of effect size, with 0.01, 0.06, and 0.14, corresponding to small, medium, and large effect sizes respectively (Cohen, 1988, pp. 278–280).

Firstly, no differences between conditions were found with respect to the prereading ($F(2, 111) = 0.97$, $p = 0.38$, $\eta_p^2 = 0.017$), interreading ($F(2, 111) = 0.2.34$, $p = 0.10$, $\eta_p^2 = 0.04$), and postreading questions ($F(2, 111) = 0.62$, $p = 0.54$, $\eta_p^2 = 0.011$), the last of which specifically was not in line with our expectations.

Second, with regard to increased monitoring accuracy and improved rereading choices, we found two significant differences. The JOL made before the rereading choice, was different between conditions, $F(2, 111) = 3.64$, $p = 0.029$, $\eta_p^2 = 0.062$. Bonferroni post hoc analysis indicated that participants in the Long Drawing condition were more accurate than participants in the Brief Drawing condition ($p = 0.01$). We did not find this difference between the Long Drawing and Control conditions (although $p = 0.052$) or the Brief and Control conditions ($p = 0.56$). These differences were not found for the second JOL, after rereading the text ($p = 0.73$)

Furthermore, the number of rereading choices also differed significantly, $F(2, 111) = 3.18$, $p = 0.046$, $\eta_p^2 = 0.054$. Specifically, Bonferroni post hoc analysis showed that participants in the Long Drawing condition selected more paragraphs for restudy compared to participants in the Brief Drawing condition ($p = 0.013$). No significant differences were found between the Control condition and the Long Drawing condition ($p = 0.23$) or the Brief Drawing condition ($p = 0.38$).

Finally, we did find a group difference on mental effort, $F(2, 111) = 4.80$, $p = 0.045$, $\eta_p^2 = 0.09$ (medium effect). Bonferroni post hoc analysis showed that the long drawing condition required more mental effort than the control condition ($p = 0.031$) and the brief drawing condition ($p = 0.024$), which was in line with our expectations. No differences were found between the control and brief drawing conditions ($p = 0.94$).

3.3. Aim 3: Quality of drawings

Table 4 shows correlations between number of elements drawn, detail-level of the drawings, posttest scores and JOL-accuracy, indicating that most variables are positively correlated, except for the detail of the drawing and the score on the post-test, which were negatively correlated, and the JOL-accuracy with both the score on the text of Session 2 and the level of detail of the drawing were not significantly correlated.

Next to the general correlations, we also wanted to know whether there were any differences in number of elements or detail of drawings between the brief-drawing and long-drawing conditions. With regard to number of elements drawn, participants in the long drawing condition ($M = 4.49$, $SD = 1.61$) drew more elements compared to the short drawing condition ($M = 2.21$, $SD = 1.92$), $F(1, 80) = 33{,}74$, $p < 0.001$. With regard to the detail of these drawings, participants in the long drawing condition ($M = 2.40$, $SD = 1.00$) created drawings of higher detail compared to the brief drawing condition ($M = 1.63$, $SD = 1.44$), $F(1, 80) = 7.80$, $p = 0.007$.

4. Discussion

The aims of this paper were to investigate primary education students' monitoring and control processes in a self-regulated learning setting involving text comprehension, and whether a drawing intervention supports this process. Particularly the fact that this study focused in the effectiveness of drawing as a tool to improve monitoring accuracy and asked students not only to judge their understanding but also were required to use their judgments to select paragraphs to reread, takes previous empirical work in this area a step further.

With regard to our first research question, as to what extent judgments of learning, rereading choices, and reading comprehension scores correlate, the results of the first session show several interesting findings. A higher judgment of learning halfway through reading the text, correlated positively with JOL accuracy at that point and with higher JOL after rereading, but correlated negatively with the intermittent comprehension scores before rereading as well as the number of rereading choices. This seems logical, as a student who thinks he or she knows the material better, is likely to choose fewer paragraphs for restudy. The rereading activities correlated negatively with the JOL after rereading, but positively with JOL-accuracy after rereading and with mental effort. This is consistent with prior findings by Thiede et al. (2003) who showed that students indicated they would most likely study those paragraphs that they felt they knew least well (although the Thiede et al. study did not actually investigate whether they actually did and how this affected subsequent processing), and adds to this research that more rereading also inflicts more mental effort. JOL after rereading correlated negatively with the postreading questions and that JOL's accuracy. Finally, JOL-accuracy after rereading was positively correlated with the scores on the postreading questions. This last finding is consistent with prior research with adults and older children (Redford et al., 2012; Thiede et al., 2010, 2011) showing that more accurate JOLs are positively related to better text comprehension and complements prior research (e.g., De Bruin, Thiede, Camp, & Redford, 2011), in that children as young as Grade 4 are at least to some extent able to accurately monitor their reading comprehension. However, our results add to these findings by showing that this might not only apply to JOLs made while still learning, and might be mediated by the restudy choices made by students.

Interestingly, however, there was no significant correlation between the number of paragraphs that were reread and the eventual posttest score. So, rereading more paragraphs did not necessarily result in higher posttest scores. A plausible explanation for this could be that those who had already correctly monitored that they had understood a large part of the text, were less inclined to reread more, but still performed well on the post-test (cf. Kostons et al., 2012). Based on our study we cannot make definite claims about this issue as we only assumed (but did not check) that students actually reread the parts they had indicated for rereading, as was done in the study by De Bruin et al. (2011). By using data logging in a digital learning environment or using eye tracking to see which parts of a text were looked at during rereading could in future research can give more insights into this issue. This finding could also be due the act of filling in the test between the first and second reading. Students then know better what to expect of the final test, which should influence their monitoring performance (Thiede et al., 2011).

The second research question pertained to the effect of a drawing intervention during text comprehension on JOL accuracy, rereading choices, and reading comprehension posttest scores. Our results show a mixed pattern of findings. First, although we expected students who had the opportunity to draw, either briefly or long, would outperform students in the control group, we did not find such differences. The only differences that showed up were related to the Long Drawing condition: participants in that group on average were more accurate in their JOLs before rereading and selected more paragraphs to reread than the other two groups, which likely also led to more mental effort for this group in comparison to the other groups. However, these differences did not materialize in superior performance on the postreading questions, which might be related to the observation that the advantage of higher JOL accuracy also dissipated after rereading activities. Together, these findings are contrary to our expectations based on representation-based cues (Kintsch, 1998; Thiede et al., 2010; Zwaan & Radvansky, 1998), as participants in this long drawing condition were given the longest time to spend on creating a situational representation of the text.

Several reasons may underlie this unexpected finding. First, most of the literature seems to point in the direction that the *creation* of visualizations should aid in developing better situational models, not the availability of that visualization after it has been first created (De Koning & Van der Schoot, 2013; Thiede et al., 2011). As such, whereas the brief drawing condition seems to adhere to the timeframe wherein the creation of the situation model is captured, the long drawing condition elicits activities with the drawing after creation of the initial situation model, which are possibly superfluous and perhaps even detrimental to understanding the material during a second read. Second, the instruction on drawing focused only on what students had to do while reading the text for the first time, but there were no instructions what to do with the drawing after that, neither while answering questions about the text nor while reading the text for the second time. As such, students might not have had the wherewithal to know how to continue to use the drawing effectively. Third, the type of questions asked about a text may influence how effective an intervention. Specifically, the questions about the texts we used could be considered to have mostly aspects of recall involved, rather than interconnections or interpretations, which is common for texts written for students of that age. Van Meter and Garner (2005) indicated that drawing may help with deeper understanding, but does not necessarily aid in more superficial processing of text information.

Finally, an important influence of drawings on monitoring and rereading choices may be related to the way the drawing activity was organized. In this particular study, the choice was made to have a single drawing for the whole text. This choice was made deliberate, as the creation of a single coherent external model was what was aimed for and seemed to fit best with the concepts addressed in each of the two texts. However, even though children could expand, adjust, and refine their drawing from paragraph to paragraph, this was not explicitly instructed which may have led to misalignment with their task to monitor and reread on paragraph-level (while making/using a drawing that was aimed at text-level). It is possible that making several drawings at paragraph-level would positively influence monitoring and rereading choice accuracy. However, whether such storyboard-like drawings would be effective in the type of texts we used or would be more effective in the case of more narratively driven texts, is a matter for future research.

The other part of the answer to the third question comes from the mental effort measure and the qualitative analysis of the drawings. First, while we found no differences on post-test reading comprehension scores, we did find a difference on mental effort, with the long-drawing condition requiring more mental effort than both other conditions. If the creation of an external representation for a longer time imposes additional working memory load, this reduces working memory resources available for either the reading task or accurate monitoring (Van Gog et al., 2011), thereby actually hindering precisely what was supposed to be enhanced. The fact that the Long Drawing condition seemed to be doing well until rereading, can be viewed as evidence supporting this claim; although these students were making the right decisions, in the end extensive drawings might take mental resources away from actual text comprehension. These findings suggest that having students extensively externalize their representations may both help but also hinders their reading process, ability to monitor this process, and their understanding (i.e., the construction of a situational model), and provides a partial answer to our third research question; whether drawings are more effective when they are only available for a short time when reading the text for the first time, or whether these drawings need to remain available throughout answering questions about the text and rereading as well to be of a positive influence.

Second, our analyses of the drawings showed that drawing more elements seems to correlate with higher posttest scores, and participants in the long drawing condition drew more elements. Furthermore, drawing more elements also positively correlates with having a higher JOL accuracy. However, the level of detail in the drawing seems to detract from posttest scores. It thus seems that drawing could help with understanding a text, but only if these visualizations focus on conceptually relevant aspects rather than beautification of the drawing. It is important to note that while our instruction prior to the second session of our study (second text)explicitly included telling participants that their drawing would not be graded and was only aimed at supporting their reading comprehension, it is quite possible that students focused overly much on producing a good drawing rather than merely providing a reflection of their understanding. Perhaps with more guidance on what and how to draw readers may come more close to the idealized visual representation which have proven successful for concept mapping (De Bruin et al., 2011).

Future research is required to further investigate whether and how the creation of external representations is able to positively influence the monitoring process, restudy choices and text comprehension scores. This particular study, whilst not demonstrating any positive effect on reading comprehension scores, illustrated the importance of assisting the self-regulatory learning process when studying both monitoring and control processes.

Author note

The authors declare that they have no conflict of interest.

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