Reading Strategy Training: Automated Verses Live

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Abstract

This study examined the effectiveness of Self-Explanation Reading Training (SERT) and an automated version of this intervention called Interactive Strategy Training for Active Reading and Thinking (iSTART) in improving science text comprehension. College students (N=297) were assigned to one of three conditions: SERT (trained by a human instructor), iSTART (trained by a computer), or no treatment control. Participants read a text on cell mitosis and answered text-based and bridging inference questions. There was a significant overall effect of condition indicating that both iSTART and SERT out performed controls on comprehension. However, this effect was modulated by question type: both SERT and iSTART significantly enhanced comprehension for text-based questions, but the effect was not reliable for bridging inference questions.

Introduction

Many students have difficulty understanding what they read; in particular, many students have trouble comprehending science texts (Bowen, 1999; Snow, 2002). Problems associated with comprehension are augmented by the lack of strategic reading interventions in classrooms: students seldom use high-level comprehension strategies that promote deep comprehension (Cox, 1997; Garner, 1990).

One way to improve comprehension is to teach reading strategies that encourage deeper processing of the text. Interventions that promote deeper processing such as self-explanation and elaborative interrogation have been successful in improving student comprehension (e.g., Chi, De Leeuw, Chiu, & LaVancher, 1994; Pressley, Wood, Woloshyn, Martin, King, & Menke, 1992). For example, McNamara (in press) has reported positive learning gains for her Self–Explanation Reading Training (SERT). SERT is a modified version of the self-explanation learning strategy (e.g., Chi et al., 1994). The SERT training program helps improve comprehension by encouraging students to utilize various sub-strategies to build strong connections between the reader's knowledge and the text. SERT teaches students various reading strategies, including comprehension monitoring, logic and common sense/elaboration, paraphrasing, bridging inferences, and prediction to improve their ability to explain text and understand it at a deeper level.

McNamara (in press) examined the effectiveness of SERT with college students who varied in prior knowledge of science. Half of the participants learned to self-explain and use reading strategies while reading four science texts. The other half of the participants read aloud the texts and answered questions concerning them. After the training phase, the two groups' ability to self-explain was compared. They also answered text-based and bridging-inference questions about the text that they had all self-explained. The results indicated that low-knowledge readers who were trained to use SERT outperformed control participants on measures of text comprehension. However, this advantage only occurred for text-based questions. In addition, protocol analyses of the readers' self-explanation indicated that the low-knowledge readers improved in terms of their ability to paraphrase the text, and more importantly, in their ability to use domain-general knowledge (or logic and common sense) to make sense of the text. Not having the requisite knowledge, they were not able to make inferences requiring domain specific knowledge while reading. Nonetheless, they showed the same level of comprehension on the text-based measures as did the high-knowledge readers, and substantially greater performance than their low-knowledge counterparts. These findings are particularly encouraging because it demonstrates improvement for the students who need the training the most: the low-knowledge students.

The present study compares the effectiveness of SERT and a similar, but automated version of the training, called Interactive Strategy Training for Active Reading and Thinking (iSTART; McNamara, Levinstein, & Boonthum, in press). Automating the core aspects of SERT training has several advantages including self-paced learning and standardized training. iSTART is a computer program that uses automated agents to provide SERT-based training to students. The program, like SERT, has three sections, introduction,

demonstration, and practice. The program has both vicarious and interactive components to enhance learning. The students learn vicariously by watching "agent students" interact and learn strategies taught by a "teacher agent." Later the student interacts with the program, and the system provides feedback on the student's performance.

While automating the SERT intervention has several advantages, one potential problem is that automation may influence the effectiveness of SERT. For example, during live SERT training, students practice with a partner while self-explaining. In iSTART, human peer interaction does not occur. In light of the work on reciprocal teaching (e.g. Palincar & Brown, 1984), removing human peer interaction may diminish the effectiveness of the training. The goal of this study was to examine whether the automated iSTART was as effective at improving comprehension as the live SERT training. Participants were assigned to one of three conditions: live SERT (trained by a human instructor), iSTART (trained by the computer program) and a control condition which had no training (and instead read a text and answered questions concerning it). One week after the training phase, participants read a passage on cell mitosis (see McNamara, 2001; McNamara, in press). The dependent measure was the total proportion of correct answers (both text-based and bridging-inference questions) based on the passage. It was expected that SERT would out perform controls because previous research showed a facilitative effect of SERT on comprehension (McNamara, in press). It was expected that iSTART training would also improve comprehension compared to controls. This prediction was made based on research that has shown the benefits of automated agents on learning (e.g., Anderson, Corbett, Koedinger, & Pelletier, 1995; Du Boulay, 2000; Graesser & Person, 1994).

Finally, we were also interested in uncovering any spontaneous strategies used by control students in our study. Prior research has indicated that the average student is not particularly strategic when learning from text (Cox, 1997; Garner, 1990). After reading the passage on mitosis, participants in all three conditions were asked to indicate what strategies they used to help them understand what they read. We predicted that both the SERT and iSTART conditions would indicate strategies such as those taught in the training session. A higher reported use of SERT strategies in the training condition serves as a manipulation check for whether the trained participants actually used the strategies to comprehend the text. Moreover, our secondary goal was to examine what, if any, strategies would be reported by the untrained participants.

Method

Participants

The sample consisted of 297 biology college students from Old Dominion University. There were 87 males and 210 females and the average age was 21 years old (SD=4.58). The students participated during the laboratory sessions of their Introductory Biology Course. Each lab was randomly assigned to one of the three conditions. The students received extra credit in the course for participation.

Materials

Two sets of individual difference measures were used to gauge students' cognitive ability: reading skill and prior knowledge. Reading skill was measured by Nelson-Denny Reading Skills Test. The test consisted of 38 multiple-choice questions designed to assess comprehension on several short text passages. Prior knowledge was measured by a 54-item multiple-choice test on general science knowledge and the humanities. The test consisted of questions drawn from biology, art, literature, history, geology, political science, and psychology.

Participants in the SERT condition were given a short list of five reading strategies (i.e., comprehension monitoring, paraphrasing, elaboration, prediction, and bridging), a video transcript and note sheet (used during the video segment of training), and a booklet with more detailed descriptions of the strategies and examples of their use in self-explanations. Participants in the iSTART condition were given written instructions on how to use the iSTART system, and a short list of the reading strategies.

A passage on cell mitosis described the sequential stages involved in cell division, and included all the information required to subsequently answer a set of comprehension questions. The text was 650 words in length and had a Flesch Reading Ease 52 and a Flesch-Kincaid Grade Level 9.1. Comprehension was assessed using a set of 12 open-ended questions: six text-based and six bridging-inference questions. The answers to the text-based questions could be found in a single sentence within the passage, while the bridging-inference questions required the reader to integrate information from two or more sentences within the passage. Participants were also given a sheet of paper which asked if they had finished reading the text and which, if any, strategies they used to help them understand the text. Finally, participants were given a 260 word text on thunderstorms with a Flesch Kincaid Grade level of 8.6 and a Flesch Reading Ease 56. For control participants the text was accompanied by 8 open-ended questions.

Design and Procedure

The experiment had three phases: pre-testing, training and post-testing. All participants were given the individual difference measures during the pre-test phase. Participants first took the prior knowledge test (20 minutes) followed by the Nelson-Denny reading skill test (15 minutes). The following day the experimental training and control phases were conducted in a 2-hour session. The post-test phase occurred after a one-week retention period, during which all participants read and answered questions for the mitosis passage. Participants were given 30 minutes to read the passage and answer the questions. Students did not have the text available to help them once they began answering the questions.

Training

SERT: The SERT training session was conducted in a 2-hour session. SERT participants were told that the purpose of the study was to teach them strategies that would help them to better understand and remember what they read. Participants were first provided with a description and examples of self-explanation. The instructor then defined and provided examples for five reading strategies: comprehension monitoring, paraphrasing, elaboration, prediction, and bridging.

Participants then watched a video depicting a student reading and self-explaining a text about forest fires. Participants could refer to the accompanying video transcript during viewing. The video was paused at various points, and participants identified and discussed the strategies being used by the reader in the video.

Finally, the participants worked in pairs to practice self-explanation while reading the thunderstorms text. The participants took turns self-explaining, alternating after each paragraph. At the end of each paragraph, the partner who was listening (and not self-explaining) summarized the student's self-explanation.

iSTART: The iSTART training session was conducted in a 2-hour session. Participants in the iSTART condition were told that the purpose of the study was to teach them strategies that would help them to better understand and remember what they read. Participants were then given instructions on how to use the iSTART system, and they proceeded to go through the three sections of the program: introduction, demonstration, and practice. The practice section involved reading and self-explaining a text about thunderstorms one sentence at a time. Participants typed their self-explanations into the computer.

Control: Participants were told that the purpose of the study was to determine the types of strategies students use when they read. Participants read the thunderstorms text and indicated the strategies they used while reading. The participants answered corresponding questions to assess comprehension.

Testing

One week following training, all three groups of participants were asked to read the science text about cell mitosis (i.e., the low-coherence version used in McNamara, 2001). The participants were asked to use the strategies that they had learned or talked about the previous week. After reading the text, participants were asked to indicate what strategies they used to help them understand the text. They were then given the 12 open-ended questions to assess comprehension. Participants were given 30 minutes to read the text and answer the questions. The text was not available to the students once they began answering the questions.

Results

The effect of training on reported strategy use.

Our first question was whether training condition affected students' reported use of strategies one week after training when reading the cell mitosis text. Table 1 lists the percent of participants who indicated using SERT strategies, while Table 2 indicates the percent of participants who reported using non-SERT strategies. Students' self-reports of strategy use during reading were tabulated into 17 categories. The categories were devised based on a combination of a priori strategies reported in the literature, and strategies that were frequently mentioned in the students' responses. It is important to note that category membership is not mutually exclusive. That is, a participant could have listed more than one strategy, and therefore the percentages per condition will not sum to 100%.

Strategy	Control	iSTART	SERT
Bridging	0%	39.8%	38.5%
Prior Knowledge	7.3%	15.1%	17.7%
Elaboration	0%	17.2%	21.9%
Prediction	0%	14%	13.5%
Self-explanation	0.9%	23.7%	19.8%
Paraphrase	0%	46.2%	46.9%

Table 1 Percent of self-reported SERT/iSTART strategies by condition

Further calculations revealed that 77.2% of iSTART and 72.9% SERT participants reported using at least one of the reading strategies taught by the iSTART/SERT, whereas only 8.3% of control participants reported using these strategies ($\chi(2,297)=123.30$, $p<0.05$). A chi-square also revealed that more control participants (58.9%) indicated using more non-SERT strategies (i.e., 10 strategies listed in table 1 other than the six SERT strategies) than iSTART (10.9%) or SERT (30.25%) participants ($\chi(2,297)=60.79$, $p<0.05$). Although this measure does

not indicate whether they actually *used* these strategies (nor whether their self reports were all inclusive, i.e., they may not have reported some strategies) it does reveal that iSTART and SERT participants become sensitive to the notion of active reading strategies through training, and that this was retained one week later.

Strategy	Control	iSTART	SERT
Imagery	7.3%	0%	4.2%
Re-Read to understand	11.9%	1.1%	1.0%
Summarize	1.8%	0%	2.1%
Mnemonics	6.4%	1.1%	4.2%
Skim text	4.6%	2.2%	2,1%
Note taking	5.5%	0%	1.0%
Memorization	3.7%	0%	2.1%
Repetition	30.3%	8.6%	25%
Focus	9.2%	0%	2.1%
Key points	14.7%	1.1%	7.3%
No Strategy	16.5%	4.3%	1.0%

Table 2 Percent of self-reported non-SERT/iSTART strategies by condition.

The effect of strategy training on comprehension.

Our second question was whether SERT and iSTART training successfully improved comprehension for those students who reported using the strategies. All control participants (N=109) were included in this analysis. However, in the iSTART and SERT conditions, only participants who explicitly stated that they used one or more of the SERT strategies (comprehension monitoring, self-explanation, paraphrasing, prediction, bridging, elaboration, and prior knowledge use) were included in the analysis. We restricted this analysis to training participants who reported using the strategies after training because our question regarded the effects of training for those participants who attempted to use the SERT strategies to read and understand the cell mitosis text. Therefore, this manipulation check reduced the number of participants in the iSTART condition from N=92 to N=71, and reduced the number of participants in the SERT condition from N=96 to N=70. While it is interesting in itself that about 25% of the training participants did not attempt to use the reading strategies after training, there are many reasons why they might not (e.g., lack of motivation in the laboratory setting, lack of sufficient learning of the strategies, preference for other strategies). However, we cannot identify these reasons and those participants are not the focus of this particular analysis. The exclusion of participants who did not report any SERT strategies is a conservative effort. The self-report measure includes both participants who actually used the SERT strategies and those who said they used them, but did not use them in practice. In a similar vein, by retaining all the control participants, the control condition has an advantage because the analysis includes the participants who may use higher-level strategies and who may, therefore, be expected to score as well as the trained participants. A similar set of analyses which also excluded control participants who did not report any strategies produced a similar pattern of results as the analysis used here that did not exclude any control participants. Hence, the analyses reported below included all control participants

Differences in pre-test abilities

A one-way between-participants ANOVA was conducted on the student's pre-test level of prior knowledge to determine whether the groups differed as a function of pre-treatment knowledge. The results indicated that there were no differences between conditions, $F(2,233)= 1.47$, $MSE= 72.25$, $p>.05$, indicating that any difference between the conditions are unlikely due to pre-treatment levels of knowledge. Likewise, a between-participants analysis was conducted on the students' reading skill scores to determine whether the pre-treatment reading skill differed as a function of condition. The analysis revealed that there was no significant effect of pre-test reading skill, $F(2,233)= 2.05$, $MSE= 71.31$, $p>.05$, and thus, differences among the conditions are unlikely due to pre-treatment differences in reading skill.

Effects of condition

A repeated measures analysis of variance was conducted on comprehension scores including the within-participants variable of question type (text-based, bridging inference) and the between-participants variables of training condition and knowledge with reading skill as a covariate. There was a significant effect of question type, $F(1,229)= 23.57$, $MSE= 0.602$, $p<.05$, indicating that more text-based questions ($M=0.52$, $SD=0.26$) were answered correctly than bridging questions ($M=0.22$, $SD=0.17$). There was also an effect of knowledge, $F(1,229)= 35.14$, $MSE= 1.85$, $p<.05$) indicating that high-knowledge students ($M=0.28$, $SD=0.15$) scored higher than low-knowledge students ($M=0.45$, $SD=0.17$). The analyses revealed a significant effect for training condition, $F(2,229)= 3.94$, $MSE= 0.207$, $p<.05$) indicating that both iSTART ($M=0.39$, $SD=0.21$) and SERT ($M=0.39$, $SD=0.19$) participants scored higher than controls ($M=0.33$, $SD=0.22$). This effect was qualified by a significant interaction of question type and condition, $F(2,229)= 2.98$, $MSE= 0.076$, $p<.05$). Post hoc Least Significant difference tests revealed that SERT ($M=0.55$, $SD=0.23$, $p<.05$) and iSTART ($M=0.54$, $SD=0.24$, $p<.05$) participants scored higher than controls ($M=0.45$, $SD=0.27$) on text-base questions, but not bridging

questions (see Figure 1). No other effects were significant.

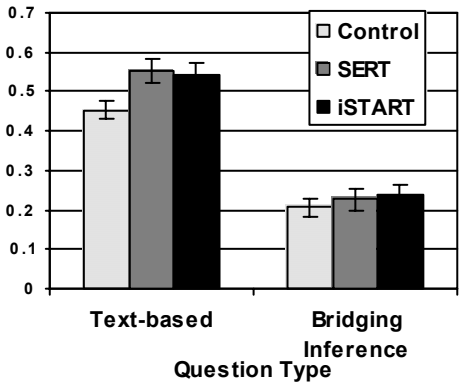

Figure 1. Proportion correct on the mitosis passage score as a function of condition and question type

To examine effects of reading skill, a second repeated measures analysis of variance was conducted on comprehension including the within-participants variable of question type (text-based, bridging-inference) and the between-participants variables of training condition and reading skill, with knowledge as a covariate. The analysis revealed a significant effect for question type, $F(1,229)=5.07$, $MSE=0.147$ $p<.05$, indicating that more text-based questions ($M=0.52$, $SD=0.26$) were answered correctly than bridging questions ($M=0.23$, $SD=0.17$). The main effect of training condition was reliable, $F(2,229)=4.69$, $MSE=0.239$ $p<.05$, indicting that iSTART ($M=0.39$, $SD=0.21$) and SERT ($M=0.41$, $SD=0.19$) participants scored higher than control participants ($M=0.33$, $SD=0.22$). This main effect was qualified by a significant interaction with question type, $F(2,229)=2.98$, $MSE=0.076$ $p<.05$. Post hoc Least Significant Difference tests revealed that iSTART ($M=0.54$, $SD=0.24$, $p<.05$) and SERT ($M=0.58$, $SD=0.23$, $p<.05$) participants scored higher on text-based questions compared to control participants ($M=0.46$, $SD=0.27$). But this effect was not found for bridging-inference questions. In sum, both SERT and iSTART improved students' comprehension compared to controls, particularly at the textbase level of understanding.

Finally, correlations between each of the 18 self-reported strategies and the total proportion correct on the mitosis passage. Six strategies were significantly correlated to comprehension. Five of the strategies were taught by the SERT/iSTART technique bridging, $r=.25$, self-explanation, $r=.19$, elaboration, $r= .14$, paraphrasing, $r=. .25$, predictions, $r=.12$, and one non-SERT/iSTART strategy, reread to understand, $r=.15$.

Discussion

The results of the present study are congruent with research demonstrating beneficial effects of reading-strategy training on understanding and learning (Chi et al., 1994; Pressley et al., 1992). First, the majority of SERT and iSTART participants reported the use of SERT strategies such as elaboration, using prior knowledge and making bridging inferences. Research has shown that high-level strategies such as prior knowledge use (Spilich, Vesonder, Chiesi, & Voss, 1979) and elaboration (Pressley et al., 1992) are much more effective than low-level strategies such as repetition. The current results suggest that both SERT and iSTART training encourage the use of higher-level strategies during reading, and that the self reported use of these strategies correlates with comprehension. The present findings also seem to support the views of Cox (1997) and Garner (1990): average untrained students are spontaneously unlikely to use higher-level strategies to help them better understand what they read.

In a related study, Best, Ozuru, and McNamara (2004) analyzed the content of students' self-explanations while interacting with iSTART. The researchers found that several of the participants indicated the use of high quality elaborations including logic/common sense and scientific reasoning. Many of these elaborations were knowledge building, which helps the reader more effectively explain the current sentence. However, the quality of the elaborations depended upon both the sentence difficulty and individual differences. In short, iSTART seems to promote the use of both high-level and high-quality comprehension strategies.

Second, and more importantly, the self-report data is bolstered by the findings from the comprehension data. Participants in both the SERT and iSTART conditions answered more text-based questions correctly than did control participants. Hence, the current study suggests that SERT and iSTART training encouraged many of the learners to use higher-level strategies, and when they did, comprehension for text-based information was facilitated. These findings are congruent with results reported by McNamara (in press) showing positive learning gains for students who were given SERT training. In that study, McNamara (in press) found evidence that SERT helped participants by encouraging them to use logic, common sense and general world knowledge. Moreover, the beneficial effects of training were most prominent for low-knowledge readers; that is, for the readers who need the training the most.

As in McNamara (in press), the facilitative effect of training in the current study did not extend to bridging-inference questions. One possible explanation is that participants did not have the specific domain knowledge required to make effective bridging inferences (cf., McNamara, in press). This interpretation is in accordance with the finding that

prior knowledge is important in generating inferences (e.g., Singer & Ritchot, 1996), particularly when text cohesion (the degree to which relations are made explicit) is low (McNamara, 2001). The mitosis text used here was taken from McNamara (2001), who manipulated text cohesion as an independent variable. The current study utilized the low-cohesion version of the mitosis text. Because text cohesion was low, readers require a greater degree of specific domain knowledge to generate the necessary inferences.

As found in previous studies (e.g., Anderson et al., 1995; Du Boulay, 2000; Graesser & Person, 1994), this research also confirms the effectiveness of computerized training, particularly those using automated agents as tutors. The benefits of automated tutors include self-paced learning, standardized training, and feedback tailored to the individual's progress. The results of the present work support the effectiveness of an automated tutoring system by showing that a computerized presentation of the SERT strategies (iSTART) was as effective as a presentation of the strategies by a human instructor. Given the current trend towards increasing classroom size and cutbacks in educational funding, this result suggests that automated trainers may provide a means for reducing the load on resource-strained educators.

In sum, this study adds to the literature by demonstrating that SERT and iSTART training increase the reported use of higher-level strategies during reading, and when used, the SERT and iSTART strategies enhance comprehension, at least for text-based information. More encouraging is the finding that the self-paced computer version of the training is as effective as the human delivered training.

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