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Learning from instructor-managed and self-managed split-attention materials

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Abstract

Summary: Instructor-managed physical integration of mutually dependent, but spatially separated materials, is an effective way to overcome negative effects of split-attention on learning. This study examined whether teaching students to self-manage split-attention materials would be effective for learning. Seventy-eight primary-school students learned about the water cycle, either by studying split-attention examples, integrated examples or self-managed split-attention examples. It was hypothesised that students who study instructor-integrated materials and students who study self-integrated materials would outperform students who study split-attention materials. The results showed that students learned more from instructor-integrated materials than from split-attention materials, thereby confirming the split-attention effect. The implications for future research on self-management are discussed.

Keywords

materials, attention, split, self, instructor, managed, learning

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Learning from Instructor-Managed and Self-Managed Split-Attention Materials

Abstract

Instructor-managed physical integration of mutually dependent, but spatially separated materials, is an effective way to overcome negative effects of split-attention on learning. This study examined whether teaching students to self-manage split-attention materials, would be effective for learning. Seventy-eight primary school students learned about the water cycle, either by studying split-attention examples, integrated examples, or self-managed split attention examples. It was hypothesized that students who study instructor-integrated materials and students who study self-integrated materials would outperform students who study split-attention materials. The results showed that students learned more from instructor-integrated materials than from split-attention materials, thereby confirming the split-attention effect. The implications for future research on self-management are discussed.

Keywords: Cognitive load theory, split-attention, self-management of cognitive load

Introduction

Cognitive Load Theory (CLT) (Chandler & Sweller, 1991; Sweller, 1988; Sweller, Ayres, & Kalyuga, 2011) is an instructional design theory that applies knowledge of human cognitive architecture to improve the effectiveness and efficiency of instructional materials (Paas, Renkl, & Sweller, 2003, 2004; Paas & Van Merrienboer, 1993). CLT is premised on an information processing view of learning, where knowledge is inputted to sensory memory, processed in working memory and stored and retrieved from long-term memory (Paas et al., 2004). The limited capacity of working memory is of critical importance to cognitive load theory, due to its pivotal role in encoding information (Ayres & Paas, 2008). If the cognitive processing undertaken in working memory exceeds the available capacity, learning may be ineffective (Sweller, 1988). Research in CLT has provided a range of instructional design techniques aimed to support students learning, such as the worked example effect (Sweller, 1998), problem completion effect (Renkl, Atkinson, & Grosse, 2004; Van Merriënboer, 1990), split-attention effect (Chandler & Sweller, 1991), modality effect (Tindall-Ford, Chandler, & Sweller, 1997), and the redundancy effect (Chandler & Sweller, 1994). These techniques support learning through reducing the processing of unnecessary information (extraneous load), whilst managing the inherent difficulty of the material (intrinsic load) and challenging learners to use working memory resources for processes that are relevant to learning (i.e., germane resources) (Sweller et al., 2011).

According to CLT, the split-attention effect is the diminishment in learning performance attributable to presenting mutually dependent, but spatially separated sources of information (e.g., text and diagram) in the visual modality, requiring the learner to invest precious cognitive processing resources in integrating the dispersed information (Ayres & Sweller, 2005). Empirical research has validated claims that spatially separated materials, increase extraneous load, due to cognitive resources being utilised for searching and matching the text to the diagram, thereby reducing available working memory resources needed for learning. One solution is to physically integrate the related visual sources of information, thereby reducing search and focussing attention on the essential principles to be learned (Chandler & Sweller, 1991). This instructor-managed integration of the mutually referring, but spatially separated sources of information, has been found to be an effective way to overcome the negative effects of split-attention materials on learning (Chandler & Sweller, 1991). The split-attention effect has been widely tested across disciplines such as engineering (Tindall-Ford et al., 1997), mathematics (Tarmizi & Sweller, 1988), physics (Ward & Sweller, 1990), biology (Chandler & Sweller, 1991) and geography (Purnell, Solman, & Sweller, 1991).

A mirror of the split-attention effect is known as the *spatial contiguity* effect (e.g., Mayer, 1989; Moreno & Mayer, 1999). According to Mayer and Moreno's cognitive theory of multimedia learning (Mayer, 2005; Mayer & Moreno, 2003) the spatial contiguity effect refers to learning enhancement when printed text and pictures are physically integrated or close to each other rather than physically separated. In addition, the cognitive theory of multimedia learning identifies the *temporal contiguity* effect, which refers to learning enhancement when visual and spoken materials are temporally synchronized, that is, presented simultaneously rather than successively (Mayer, 1997; Moreno & Mayer, 1999). Using meta-analytic techniques to 50 independent studies on spatial contiguity and temporal contiguity effects, Ginns (2006) found that for complex learning materials, reducing split attention between disparate but related elements of to-be-learned information can lead to learning gains.

An alternative solution to physically integrating the different sources of information is related to the modality effect (e.g., Tindall-Ford et al., 1997; for a meta-analysis, see Ginns, 2005). The modality effect can be defined as the educational practice to present the graphical information visually, and related textual information through an auditory mode. Using meta-analytic techniques to 43 experiments on the modality effect, Ginns (2005) found that students who learned from instructional materials using graphics with spoken text outperformed those who learned from graphics with printed text, especially on complex cognitive tasks.

Although physically integrating spatially or temporally separated instructional materials has been shown to be an effective technique of dealing with the negative effects of split attention on learning, recent research has found several alternative techniques to be effective as well. One notable example of such a technique is attention cueing, which uses visual (e.g., arrows) or verbal (e.g., hints) information to guide the learners' attention to relevant task aspects, thereby reducing spatial and temporal split attention (e.g., De Koning, Tabbers, Rikers, & Paas, 2010, 2011).

Although the split-attention or spatial-contiguity effect is supported by a wide body of research in CLT, Ginns' meta-analysis (2005) indicated that only two of the available 43 experimental studies used primary school children as participants (Bobis et al., 1993; Mwangi & Sweller 1998). In addition, those studies were only partly conducted in an authentic whole class setting, because the students were individually tested. Both Mwangi and Sweller's (1998) study, which used arithmetic materials, and Bobis, Sweller, and Cooper's (1993) study, which used geometry materials, found that the integrated format of instruction was more effective than the split-attention format of instruction.

The current study investigated the split-attention effect in a classroom setting with primary school children, but most importantly it examined whether teaching primary school students to self-manage their cognitive load in split-attention materials by manually integrating a diagram and accompanying text, would improve their learning from those materials. This research represents a new direction of CLT research, as it focuses on learnergenerated solutions to control cognitive load. Until now, CLT has exclusively focused on offering instructor-generated solutions to manage cognitive load. This new approach acknowledges that in the 'real world', students are frequently confronted with information sources that are not designed with consideration of cognitive load. Typically, learners are poorly equipped to deal with those materials. Self-management may benefit student learning by encouraging the learner to focus cognitive resources on key principles to be learned, thus assisting schema construction, and by encouraging active engagement with the learning materials, affording a form of learner control, which can have a positive influence on learning (e.g., Hasler, Kersten, & Sweller, 2007).

This research builds on two previous studies that investigated how university students can self-manage cognitive load when taught to manually integrate instructional materials with evident split-attention (Agostinho, Tindall-Ford, & Roodenrys, 2013; Roodenrys, Agostinho, Roodenrys, & Chandler, 2012). The study by Roodenrys et al. (2012) found positive effects on learning for learners in a self-managed split-attention condition, who physically manipulated print-based split-attention instructional materials by making connections between the text and diagram (drawing circles around text, and drawing lines and arrows from the text to the diagram). Whereas, near transfer test performance (i.e., new problems within the same domain) of learners who self-managed split attention was just as high as for learners who's split attention was instructor-managed (i.e., integrated materials), remarkably, their performance on a far transfer test (i.e., new problems within a new domain) was higher. The study by Agostinho, et al. (2013) examined how learners can self-manage split-attention using digital materials. Participants in the self-managed condition were required to move text objects closer to a diagram using a computer application. Although the results replicated a split-attention effect in a digital domain as the integrated condition outperformed the split-attention condition, the self-managed condition did not outperform the split-attention condition. Agostinho et al. (2013) suggested that the self-managed condition did not have an effect, because the instruction used in the digital environment might have stimulated the students to move text objects closer to the diagram, in a non-mindful way.

This study investigated whether the split-attention effect could be replicated with primary school students in a classroom context. It was hypothesized that participants who study integrated materials would outperform participants studying split-attention materials, because of a reduction in extraneous load by integrated instructional formats (Hypothesis 1, replication of the split-attention effect). Most importantly, this study examined whether teaching primary school children to self-manage authentic split-attention learning materials would have a positive effect on their learning from these materials. More specifically, it was investigated whether self-management by manually integrating textual information with related diagrammatic material through moving text, drawing arrows and highlighting text, would be more effective for learning than studying non-managed split-attention materials. It was assumed that the self-management tasks would assist in decreasing extraneous cognitive load as the requirement to physically establish correspondence between the diagram and related textual information would reduce split-attention and thus reduce extraneous load. Consequently, it was hypothesized that participants who are taught to self-manage cognitive load through moving text boxes closer to the diagram, drawing arrows to link information and highlighting key words, would outperform participants studying split-attention materials (Hypothesis 2).

Method

Participants and design

Participants were 78 Stage 3 students (upper primary, Years 5 and 6) from four science classes of an independent Sydney school. The experiment was conducted across four school days, over a period of two weeks and was integrated into the classroom programme as a classroom learning activity. Group testing was utilised and was conducted as part of the daily classroom routine for each of the four classes to provide a realistic setting. Within each class, students were assigned a participant number using the class roll.

Participants were randomly allocated to one of three conditions:

1. Split-attention condition: With spatially separated diagram and related text.
2. Integrated condition: With physically integrated diagram and related text.
3. Self-managed condition: With spatially separated diagram and related text, which could be manually integrated by the learners (move text boxes closer to the diagram, draw arrows to link the text boxes and highlight key words).

Materials and Procedure

The instructional material was based on the water cycle and presented in colour on a single A3 sheet of paper (29.7 x 42 cm) (see Figures 1 and 2). The water cycle was chosen as the subject matter for the instructional material, as it was relevant to the school curriculum and allowed the information to be presented in a diagrammatic format, in order to investigate how students can self-manage split-attention material. The topic of the water cycle also ensured the content was novel to Year 5 and Year 6 students as it was based on New South Wales Stage 4 (Year 7 and Year 8) Board of Studies syllabus outcomes (BOS NSW 2006, p. 36). The content imposed a high intrinsic load (high complexity), as understanding the processes of evaporation, transpiration, condensation, precipitation and surface run-off (Ben-zvi-Assarf & Orion, 2005) required several interacting elements to be held in working memory at one time if the instructional materials are to be understood (Sweller, Van Merrienboer, & Paas, 1998).

The instructional material was developed through the trialling of numerous versions with several students, ranging from Year 5 to Year 8, to gauge the complexity and clarity of the materials for the intended population. This was followed by a pilot study with twelve students from the Year 5 and 6 classes participating in the whole class experiment. The pilot study required students to "think out aloud", tested for students' prior knowledge of the water cycle, and determined final refinements to the experimental materials, such as time required for the learning and test phases. Analysis of students' verbal statements during the pilot study indicated that students had prior knowledge of the sun being a source of heat energy. To address this, novel information was added to increase the complexity and clarity of the instructional materials. For example, a text box that explained the sun as a source of heat energy was removed and a text box explaining convection (novel information) was added. The diagram and text presented to students in each experimental condition was identical in content, size and font specifications, but formatted for each of the three conditions as follows:

Split-attention condition: The diagram was positioned in the middle of the page and there were six text boxes positioned underneath the diagram in a row (see Figure 1).

Integrated condition: The content was formatted to reduce split-attention by integrating the text with the diagram (see Figure 2).

Self-managed condition: The instructional materials were identical to the split-attention condition, with the diagram positioned in the middle of the page and the six text boxes positioned underneath (see Figure 1). However the text boxes were provided as paper cut-out sections and attached to the page with blue-tack. Instructions for the self-managed condition were provided at the top of the page, which provided guidance on how to self-manage for split-attention (see Figure 3).

Figure 1 goes here

Figure 2 goes here

Figure 3 goes here

The experiment consisted subsequently of a training phase, an identification of prior knowledge phase, the learning phase, and the test phase. All phases were part of a classroom lesson.

A 9-point rating scale developed by Paas (1992) was used to measure participants' perceived amount of invested mental effort for each condition during the learning and testing phase. The options ranged from 1 (*very, very low mental effort) to 9 (very, very high mental effort).* The scale was modified for children to make it more user-friendly by delineating the extremities of the scale by shading the number scale from white, grey to black and including two icons (see Figure 4).

Figure 4 goes here.

Training phase. The training phase occurred on a separate day prior to Phases 2-4. The purpose of this phase was for the researcher to build rapport with the participants, introduce students to the mental effort rating scale and teach self-management techniques to the self-managed condition. During this phase, the participants were not informed of the instructional topic, or exposed to any of the testing materials used in the following phases. A lesson plan focusing on reading diagrams was designed by the researcher to ensure that participants in all four classes received the same information. The first half of the lesson involved introducing the mental effort rating scale to the class. To demonstrate the extremities of the scale, the participants rated their mental effort for completing a very simple origami activity followed by a very challenging origami activity for comparison. Students were informed that they would complete two mental effort-rating scales, one for the learning materials directly after the learning phase and the other for the test problems directly after the test phase. In the second half of the lesson, the self-managed condition was taught the three self-management techniques of moving text, drawing arrows and highlighting key words, by applying these techniques to an iPhone task. The tasks were demonstrated using a diagram of an iPhone, with five text boxes positioned underneath the diagram in paper cut-out sections and attached with blue-tack (see Figure 5). The researcher explicitly modelled each self-management strategy to the students and provided a clear explanation of how and why to perform each step. An excerpt of the script used in the classroom lesson is as follows:

I'm going to explain the 3 strategies you'll be using and give an example for each. You'll then complete the activity on your own.

a) Move the text boxes
Firstly, you will need to move and stick the boxes of information, where you think they best fit on the picture. By moving the text so that it's close to the diagram, you don't have to waste your thinking space looking for the information. This leaves more room in your brain to learn the material. To help you place the boxes in the right place, you should:
1) Read the text carefully for clues. This means reading EVERY single word in the text. It may seem like a lot of text to read and you might think you know the answer, but make sure you read ALL of the information, because it could be a test question! Let's read the first box out loud. It referred to a 'SIM card slot', so think about what this could look like.
2) Look at the picture carefully for clues. I can see two places on the picture that look like a slot, at the top and at the bottom. I'm thinking the one at the bottom is for the recharger, so I'm thinking I'll place the text box at the top.

b) Draw arrows
After you have moved the text boxes, you need to draw arrows on the picture to help you understand the different parts of the iPhone. Think about how the different parts work together and use arrows to link the different parts of the iPhone. E.g. draw arrow between the receiver and speaker to show how they relate.

c) Highlight key words
The last step is to highlight the key words in the information, to help you remember key words. Here's 3 highlighting tips!
1. Read all of the information in the text box first and then go back and highlight key words.
2. Don't highlight every word.
3. Think about possible test questions and highlight accordingly.

The self-managed condition was placed in a separate section of the classroom to the split-attention and integrated conditions, so that the other groups could not see the strategies being taught. This section was timed (20 minutes) and a script was used, to ensure consistency between the classes. While the researcher was teaching students in the self-managed condition, the participants assigned to the split-attention and integrated conditions engaged in a science design task focused on creating an iPhone App under the supervision of their classroom teacher.

Figure 5 goes here.

Identifying prior knowledge phase. Participants were firstly given two minutes to record anything they knew about the water cycle on a simple diagram.

Learning phase. The students were then given seven minutes to study the instructional material, either split-attention, integrated or self-managed. The instructional material was presented on an A3 piece of paper, which was folded in half and included in the 8-page instructional booklet. Immediately after students reviewed the instructional materials, they rated their perceived mental effort for the learning phase.

Test phase. A set time was allocated for the completion of each page of the test. Participants were not allowed to look ahead or turn back to pages of the test. Participants were given 5 minutes to complete the first page of the test, followed by 4 minutes for the second page and 3 minutes for the third page. The time limits were determined in the pilot study. The test consisted of six questions (the questions are provided in the appendix). Question 1a was a recall task requiring the literal recall of terms by labelling of six processes involved in the water cycle, for which students could receive 0-6 points. Question 1b was a near transfer task requiring understanding of the relationship between the six processes as students needed to explain each process in their own words, for which they could get 0-6 points. Questions 2, 3 and 4 were near transfer tasks requiring students to explain their understanding of key concepts in their own words, for which students could be awarded 0-5 points. Questions 5 and 6 were far transfer tasks requiring understanding of processes to be applied to a different context , for which students could be awarded 0-7 points. All questions were assessed objectively using a marking criterion. It was decided that minor spelling errors, e.g., 'percipitation' instead of 'precipitation', etc., would be overlooked. The questions were formatted on three A4 pages and instructions were provided at the top of each page. After completing all test questions students rated their overall perceived mental effort on the mental effort scale.

All participants received a single-sided 8 page A4-sized booklet which comprised a cover page, one question to ascertain prior knowledge, instructional material (either split-attention, integrated or self-managed materials presented on A3 sized paper and folded in half), mental effort rating scale for the learning phase, three pages of test questions and a mental effort rating scale for the test phase. Each student was randomly allocated to a group and their booklet was coded with an ID number to ensure participant anonymity. Participants were instructed not to look ahead at the pages until instructed. The researcher read out a script that informed participants they would be studying a diagram and then answering questions to assess the effectiveness of the instructional materials. A timer was used to ensure consistency for the timed components of the experiment. The importance of not disclosing what was studied was emphasised to the participants to prevent diffusion of treatment.

Results

One-way analyses of variance (ANOVAs) were used to analyse the effects of instructional condition on the following dependent variables; total test performance, recall performance, near-transfer performance, far-transfer performance, mental effort invested in the learning phase, and mental effort invested in the test phase. Means and standard deviations are presented in Table 1.

Table 1 goes here

Performance measures

Results from the one-way ANOVA for total-test score indicated a significant main effect between the three conditions, $F(2, 75) = 3.839$, $MSe = 24.562$, $p = .026$, $f = 0.34$. *Post-hoc* comparisons using Bonferroni contrasts revealed that test performance was higher in the integrated condition than in the split-attention condition, $p = .022$, $d = -0.74$ (95% confidence interval [CI]: -1.29, -0.17), indicating a medium effect size (Cohen, 1988). There was no significant difference between the self-managed and integrated conditions, $p = .930$, $d = -0.28$ (95% CI: -0.82, 0.27) and no significant difference between the self-managed and split-attention conditions, $p = .289$, although a medium effect size was obtained $d = -0.49$ (95% CI: -1.06, 0.07). The results of the one-way ANOVA for recall showed no significant effects between the conditions, $F(2, 75) = 2.552$, $MSe = 3.593$, $p = .085$, $f = 0.27$.

The results of the one-way ANOVA for near-transfer showed no significant effects between the conditions, $F(2, 75) = 2.046$, $MSe = 6.004$, $p = .136$, $f = 0.24$. Whilst comparisons between the split-attention condition and self-managed condition was non-significant despite the self-managed condition mean being higher than both the integrated and split-attention conditions, a medium effect size was obtained, $d = 0.58$ (95% CI: 0.01, 1.14).

Results from the one-way ANOVA for far-transfer questions indicated a significant main effect between the three conditions, $F(2, 75) = 5.977$, $MSe = 3.454$, $p = .004$, $f = 0.43$. *Post-hoc* comparisons using Bonferroni contrasts produced significant differences between the integrated condition and the split-attention condition, with the integrated condition outperforming the split-attention condition, $p = .003$, $d = 1.01$ (95% CI: 0.42, 1.56), indicating a large effect size (Cohen 1988). Whilst comparisons between the split-attention condition and self-managed condition were non-significant despite the self-managed condition mean being higher than split attention condition’s mean, a medium effect size was obtained, $d = 0.48$ (95% CI: -0.09, 1.03).

Mental effort ratings

Mental effort ratings were recorded at two points, after the learning phase and after the test phase, means and standard deviations are provided in Table 2. The Kruskal-Wallis test was used for mental effort ratings after the learning phase, as the core assumption of ANOVA was violated (Field, 2005). Results indicated no significant effect between the three conditions, with $H(2) = 1.063$, $p = .588$. Results from the one-way ANOVA for mental effort ratings after the test phase indicated no significant effect between the three conditions, $F(2, 75) = 0.249$, $MSe = 2.263$, $p = .780$, $f = 0.08$.

Table 2 goes here

Prior knowledge

An analysis of the mean and standard deviation of the question used to ascertain prior knowledge ($N = 78$) indicated limited prior knowledge, with $M = 1.83$ ($SD = 1.31$) out of a possible 12 marks. As expected, no participant was able to correctly identify and explain more than two of the processes involved in the water cycle. The maximum score obtained was 5 marks ($N = 2$) out of the possible 12 marks. Consequently, based on these results, the data from all seventy-eight participants qualified for inclusion in the analysis.

Compliance check

To be compliant, participants in the self-managed condition (Group 3) had to correctly perform the following three tasks: 1) Move and position the textual information on the correct place on the diagram; 2) Draw arrows to show links between the physical processes involved in the water cycle; 3) Highlight key words in the textual information

A review of Group 3 work samples indicated that all of the participants in Group 3 correctly performed task one, with the text boxes positioned in close proximity to relevant parts of the diagram. 92% of participants (23 out of the 25) drew arrows in the correct direction to show links between the physical processes and 88% participants (22 out of the 25) highlighted key words in the text boxes. Further analyses were performed on the data that excluded the two participants who did not draw arrows and the three participants who did not highlight key words. Excluding non-compliant participants resulted in higher mean test scores for the self-management group across all test items, this result was expected, as compliance suggests that the self-management strategies were undertaken, leading to enhanced schema development and subsequently increased understanding and improved test scores. ANOVAs were conducted with data from 73 participants, Group 1 (N = 25), Group 2 (N = 28) and Group 3 (N = 20), compared to Group 3 (N = 25) in the original data set. The overall pattern of results was the same as the original data with a split attention effect being validated but no statistical significance between Group 1 (split attention) and Group 3 (self manage).

Discussion

The results confirmed the split-attention effect (Hypothesis 1), with the integrated condition significantly outperforming the split-attention condition on the total-test and far-transfer test score. Although the split-attention effect is supported by a wide body of research in CLT, this is the first study to confirm the effect in a primary school classroom setting. With regard to recall and near transfer performance, the integrated condition did not differ from the split-attention condition. Hypothesis 2 that the self-managed condition would outperform the split-attention condition was not confirmed by the results. In addition, the results revealed that the self-managed condition did not differ from the integrated condition.

This is the only study that has investigated the self-management of the split-attention effect in a primary classroom using self-management strategies of moving, drawing and highlighting of textual information. Previous research on self-management of the split-attention effect has been conducted in a university context, using individual testing and primarily one self management strategy, moving of text to reduce split attention (Agostinho et al., 2013; Roodenrys et al., 2012). Both studies provided evidence to suggest that self-management may be an alternative to instructor managed integrated instruction, this study aimed to build on from these findings.

Examining Cohen's *d* for the total-test score in the present study shows some interesting results worthy of further research. Comparisons between the self-management and split-attention conditions resulted in a medium effect size (d = 0.49), and comparisons between the self-managed and integrated conditions, resulted in a low effect size (d = 0.28). For the near-transfer test items, despite non-significant results, the comparison between the self-managed and split-attention conditions showed a medium effect size (d = 0.58). This suggests that the additional tasks students had to perform in the self-managed condition (such as moving text and drawing arrows) may have provided some benefit to learning and certainly did not adversely influence learning. The supportive evidence provided by the fact that the means were in the expected direction with differences of moderate size, suggests that the sample size was too small for the effect to be statistically significant. Ultimately, further research is needed with a larger sample size to determine whether a statistically significant effect can be obtained and whether the effect size estimates can be replicated. Cohen's *d* for the difference between the total-test score of the integrated and split-attention conditions in the present study was medium (0.74), whilst for the far-transfer task it was high (1.01), suggesting that there was a significant practical benefit in utilising integrated instructions compared to the split-attention instructions.

Whilst, in this study the split-attention effect was confirmed for the performance data, the mental effort ratings did not reflect a split-attention effect. The 9-point mental effort rating scale, well used in cognitive load theory research, was modified to make it more user-friendly for children, namely by including two icons on the extremities of the scale. Participants in the experiment were then 'trained' on how to complete the mental effort ratings by applying it to the origami activity they completed. Despite the slight modification and training, the rating scale did not produce significant results. This could either suggest that the concept of subjectively rating mental effort for children is a difficult task, or that the training to self-manage did not work such that the students found it equally laborious in mental effort to understand the self-managed materials as they did the split-attention materials.

In the present study, students in the self-managed condition were required to perform three tasks (moving text, drawing arrows and highlighting key words). The task of moving text boxes is a specific strategy to reduce split-attention. The other two tasks of drawing arrows and highlighting are additional cognitive strategies, which were included in the study as a means to promote germane load (Schnotz & Kurschner, 2007). However it may be argued that the additional strategies may have had an adverse effect on learning with the moving of text, drawing arrows and highlighting key words increasing extraneous load. Evidence for this proposition is supported by integrated condition outperforming the self-management condition. Future research may benefit from isolating the self-management techniques, in order to measure the extent to which each technique impacts learning outcomes.

This study looked at the direct effects of teaching primary school students to self-manage split-attention materials with both learning and testing within the same domain. Whereas it is necessary to find conclusive evidence for the self-management effect in future studies with a larger sample size, it would also be interesting to study long-term effects within different domains. More specifically, it can be expected that students who have learned to self manage split-attention materials in one domain would be better equipped to learn from new split-attention materials in other domains than students who have learned with integrated examples and students who have learned with split-attention examples. Roodenrys et al. (2012) found some preliminary evidence for this assumption by showing that university students who had learned to self manage split-attention materials outperformed students who had learned from integrated examples when they were presented with conventional split-attention instructions in a new learning domain.

The self-management condition in the present study used physical movement of instructional materials to manage split-attention materials. Recent research in evolutionary educational psychology (Geary, 2008; Paas & Sweller, 2012) has informed CLT through distinguishing between *biologically primary* knowledge, which is acquired effortlessly due to its evolutionary basis, and *biologically secondary* knowledge, which is formally taught due to its cultural relevance. It has been proposed that *biologically primary* knowledge such as human movement can aid secondary knowledge attainment such as learning scientific concepts, through reducing the load placed on working memory (Sweller, 2008; for an empirical confirmation, see Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). Paas and Sweller (2012) describe the “human movement effect” which reflects the findings of neuroscience research on mirror neuron systems, that the specific brain regions involved in performing a movement oneself are also activated by observing someone else performing the same movement. In this context, a similar study could be conducted, with a fourth condition included to isolate the human movement effect (Paas & Sweller, 2012). The fourth group could observe the instructor physically integrating the text boxes with the diagram rather than performing the integration themselves (see, Agostinho, Tindall-Ford, & Bokosmaty, 2014). A relevant hypothesis could be that students who observe physical integration will perform as well as students who perform the physical integration for themselves, due to the proposed link between cognition and the human motor system (Geary, 2008; Paas & Sweller, 2012).

In summary, the results of the study reported in this paper supported the existing body of literature on the split-attention effect. However findings in this study were unique, as they validated the split-attention effect in an authentic, whole-class primary school setting using science material on the water cycle. Recommendations for practice included the need for primary school teachers to consider the split-attention effect when presenting instructional material to students. Findings reported in this study did not conclusively support hypothesis two, as the self-managed condition did not gain significantly higher results on test items, compared to participants who studied split-attention and integrated instructional materials. Future research will enable further insights about how students can effectively be taught to apply cognitive load theory principles themselves to self-manage cognitive load.

References

Agostinho, S., Tindall-Ford, S., & Roodenrys, K. (2013). Adaptive diagrams: Handing control over to the learner to manage split-attention online. *Computers & Education, 64*, 52-62.

Agostinho, S., Tindall-Ford, S., & Bokosmaty, S. (2014). Adaptive diagrams: A research agenda to explore how learners can manipulate online diagrams to self-manage cognitive load. In W. Huang (Ed). *Human centric visualization: Theories, methodologies and case studies* (pp. 529-550). Springer: New York.

Ayres, P., & Paas, F. (2008). Interdisciplinary perspectives inspiring a new generation of cognitive load research. *Educational Psychology Review*, *21*, 1-9.

Ayres, P., & Sweller, J. (2005). The split attention principle in multimedia learning. In R. E. Mayer (ed.), *Cambridge Handbook of Multimedia Learning*, edn.1, Cambridge University Press, New York, pp. 135-146.

Baddeley, A. D., Thomson, N., & Buchanan, M. (1975). Word length and the structure of short-term memory. *Journal of Verbal Learning and Verbal Behaviour*, *14*, 575-589.

Ben-zvi-Assarf, O., & Orion, N. (2005). A study of junior hi*gh school students' perceptions of the water cycle. Journal of Geoscience Education, 53*, 366-371.

Board of Studies New South Wales (BOS NSW). (2006). *Science and Technology K-6 Outcomes and Indicators*. NSW: Board of Studies.

Bobis, J., Sweller, J., & Cooper, M. (1993). Cognitive load effects in a primary-school geometry task. *Learning and Instruction, 3*, 1-21.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, *8*, 293-332.

Chandler, P., & Sweller, J. (1994). Why some material is difficult to learn. *Cognition and Instruction*, *12*, 185-233.

Clark, R., Nguyen, F., & Sweller, J. (2006). Applying cognitive load theory to instructional planning. In *Efficiency in learning: Evidence-based guidelines to manage cognitive load* (pp. 294-311). San Francisco: Pfeiffer.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioural Sciences* (2nd Ed.). New Jersey: Lawrence Erlbaum Associates.

Cooper, G., & Sweller, J. (1987). Effects of schema acquisition and rule automation on mathematical problem-solving transfer. *Journal of Educational Psychology*, *79,* 347-362.

De Koning, B. B., Tabbers, H. K., Rikers, R. M., & Paas, F. (2010). Attention guidance in learning from a complex animation: Seeing is understanding?. *Learning and Instruction, 20*, 111-122.

De Koning, B. B., Tabbers, H. K., Rikers, R. M., & Paas, F. (2011). Attention cueing in an instructional animation: The role of presentation speed. *Computers in Human Behavior, 27*, 41-45.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports* (Rev. Ed.). Cambridge, MA, USA: MIT.

Field, A. (2005). *Discovering Statistics Using SPSS*. London: SAGE Publications.

Geary, D. C. (2008). An evolutionarily informed education science. *Educational Psychologist*, *43*, 179-195.

Ginns, P. (2005). Integrating information: A meta-analysis of the spatial contiguity and temporal contiguity effects. *Learning and Instruction, 16*, 511-525.

Hasler, B. S., Kersten, B., & Sweller, J. (2007). Learner control, cognitive load and instructional animation. *Applied Cognitive Psychology, 21*, 713-729.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*, 1-19.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*, 43-52.

Miller, G. A. (1956). The magical number seven, plus or minus two; some limits on our capacity for processing information. *The Psychological Review*, *63*, 81-97.

Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of Educational Psychology, 91*, 358-368.

Mwangi, W., & Sweller, J. (1998). Learning to solve compare word problems: The effect of example format and generating self-explanations. *Cognition and Instruction*, *16*, 173-199.

Neath, I., Bireta, T. J., & Surprenant, A. M. (2003). The time-based word length effect and stimulus set specificity. *Psychonomic Bulletin & Review*, *10*, 430-434.

Paas, F. (1992). Training strategies for attaining transfer of problem-solving skills in statistics: A cognitive-load approach. *Journal of Educational Psychology*, *84*, 429-434.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist, 38,* 1-4.

Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instructional Science*, 3*2(1/2)*, 1-8.

Paas, F., & Sweller, J. (2012). An evolutionary upgrade of cognitive load theory: Using the human motor system and collaboration to support the learning of complex cognitive tasks. *Educational Psychology Review*, *24*, 27-45.

Payne, J. W. (1994). Thinking aloud: Insights into information processing. *Psychological Science*, *5*, 241-248.

Peeck, J. (1993). Increasing picture effects in learning from illustrated text. *Learning and Instruction*, *3*, 227-238.

Renkl, A., Atkinson, R. K., & Grosse, C. S. (2004). How fading worked solution steps works: A cognitive load perspective. *Instructional Science*, *32*, 59-82.

Roodenrys, K., Agostinho, S., Roodenrys, S., & Chandler, P. (2012). Managing one’s own cognitive load when evidence of split attention is present. *Applied Cognitive Psychology, 26*, 878-886.

Schnotz, W., & Kurschner, C. (2007). A reconsideration of cognitive load theory. *Educational Psychology Review, 19,* 469-508.

Spanjers, I. A. E., Van Gog, T., & Van Merrienboer, J. J. G. (2012). Segmentation of worked examples: Effects on cognitive load and learning. *Applied Cognitive Psychology*, *26,* 352-358.

Sweller, J. (1988). Cognitive load during problem solving: Effects of learning. *Cognitive Science, 12*, 257-285.

Sweller, J. (2008). Instructional implications of David C. Geary’s evolutionary psychology. *Educational Psychologist*, *43,* 214-216.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer.

Sweller J., Van Merrienboer J., & Paas F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, 10, 251-296.

Tarmizi, R. A., & Sweller, J. (1988). Guidance during mathematical problem solving. *Journal of Educational Psychology*, *80*, 424-436.

Tindall-Ford, S., Chandler, P., & Sweller, J. (1997). When two sensory modes are better than one. *Journal of Experimental Psychology: Applied*, 3, 257-287.

Van Merriënboer, J. J. G. (1990). Strategies for programming instruction in high school: Program completion vs. program generation. *Journal of Educational Computing Research, 6*, 265-285.

Van Merrienboer, J. J. G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review*, *17*, 147-177.

Valcke, M. (2002). Cognitive load: Updating the theory? *Learning and Instruction*, *12*, 147-154.

Ward, M., & Sweller, J. (1990). Structuring effective worked examples. *Cognition and Instruction*, *7*, 1-39.

Young, A. K. (2005). Direct from the source: The value of think-aloud data in understanding learning. *Journal of Educational Inquiry*, *6*, 19-33.

Condition	**Performance Measures**			
	Total-test Score	**Recall**	**Near-transfer**	**Far-transfer**
Max. Score	***24***	***6***	***11***	***7***
Split-attention (N=25)	8.96 (4.97)	2.88 (1.90)	4.16 (2.63)	1.84 (1.60)
Integrated (N=28)	12.71 (5.13)	3.93 (1.92)	5.21 (2.75)	3.61 (1.89)
Self-managed (N=25)	11.32 (4.73)	2.96 (1.86)	5.48 (1.83)	2.72 (2.05)

Table 1: Means and (standard deviations) for test scores

Condition	**Mental Effort Ratings**	**(Range: 1-9)**
	Learning Phase	**Test Phase**
Split-attention (N=25)	4.65 (1.44)	5.88 (1.76)
Integrated (N=28)	4.82 (2.06)	5.68 (1.36)
Self-managed (N=25)	4.70 (1.26)	6.05 (1.43)

Table 2 Means and (standard deviations) for mental effort ratings

Appendix: Test Questions

Test Questions

1a. Label the six processes involved in the water cycle

1b. B**riefly explain** what is happening in each process

2. Explain how clouds form.

3. What is the name of the process where plants lose water from their leaves into the air?

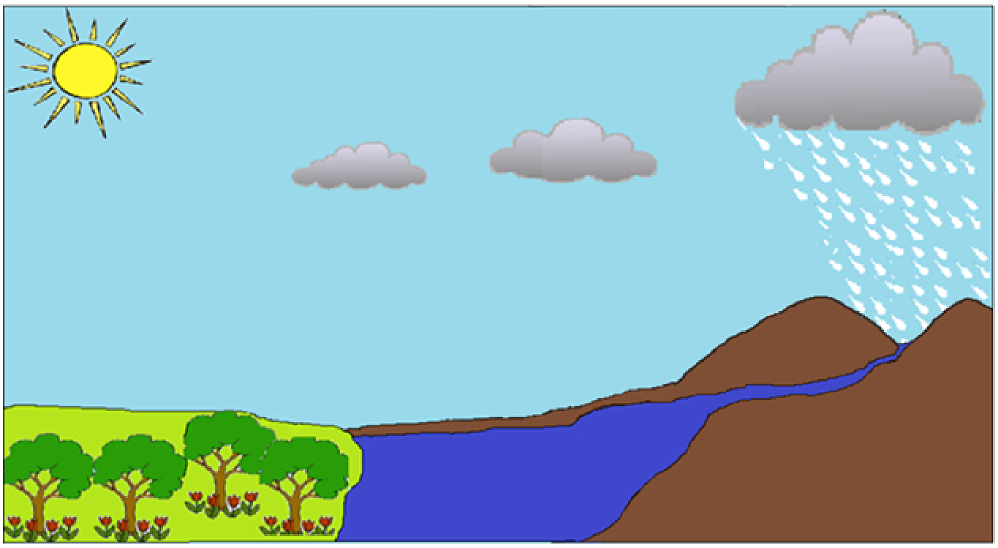
4. What is precipitation?

5. After you've had a hot shower, why do drops of water appear on the bathroom mirror?

6. A pot of water is being heated on the stove. The pot is covered with a glass lid. **Draw** and **label** on the picture what happens to the water as it is **heated up** and eventually **cools**.

The water cycle is the journey water takes as it moves from the land to the sky and back again!

1. Carefully read **ALL** of the text in the boxes below.
2. Use the text and picture to help you **understand** and **remember** how the **water cycle works**.



When water from the ocean is heated, it turns into gas and rises into the atmosphere. This process is called evaporation.	The loss of water from the leaves of plants through evaporation is called transpiration.	Rising air currents take the gas up into the atmosphere. This process is called convection.	As gas from plants and the ocean rises, it cools and changes back into liquid, forming clouds. This process is called condensation. Clouds are made up of water droplets and get bigger.	When clouds become too big from the water droplets, the water falls back to the earth. This process is called precipitation.	As water falls, it flows downhill over the land and eventually returns to the ocean. This process is called surface run-off.

Figure 1: Split-attention materials used for split-attention and self-managed conditions

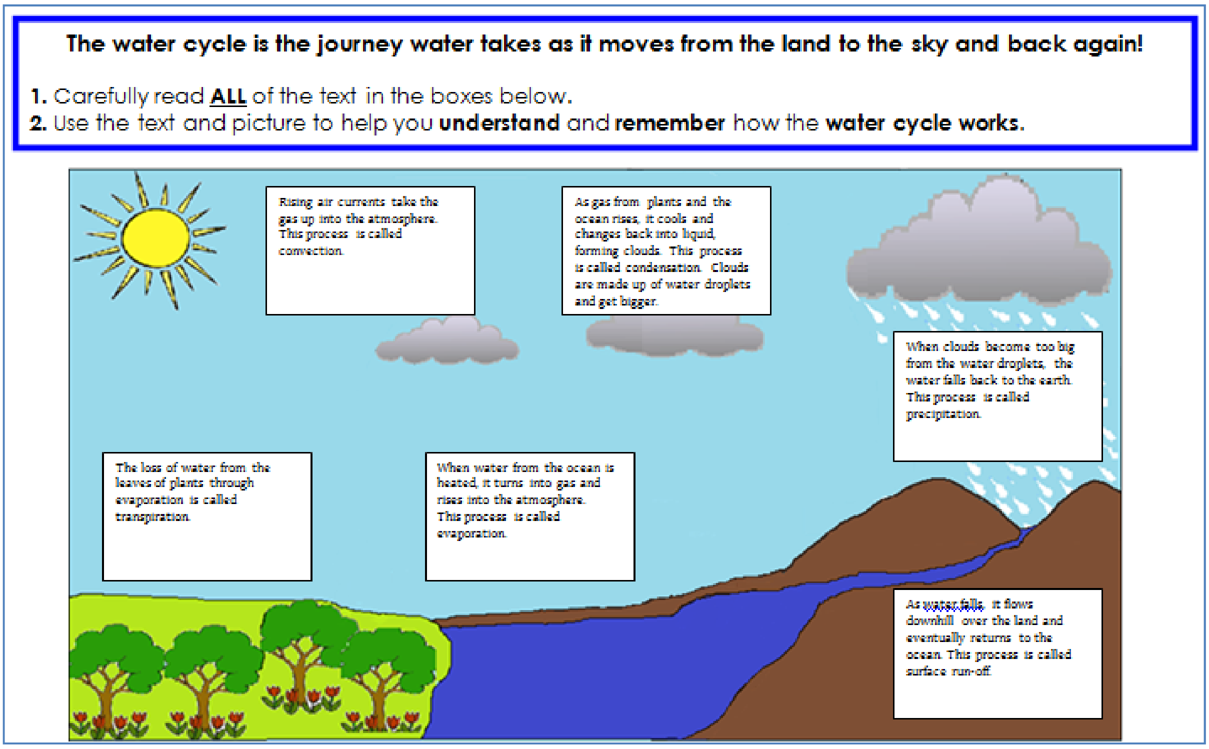


Figure 2: Integrated materials used for the integrated condition

The water cycle is the journey water takes as it moves from the land to the sky and back again!

1. Carefully read ALL of the text in the boxes below.

2. MOVE each text box onto the picture, to help you understand how the water cycle works.

3. DRAW arrows on the picture so you understand how the water cycle works.

4. HIGHLIGHT key words to help you remember how the water cycle works.

Figure 3: Guidance provided on how of self-manage for split-attention

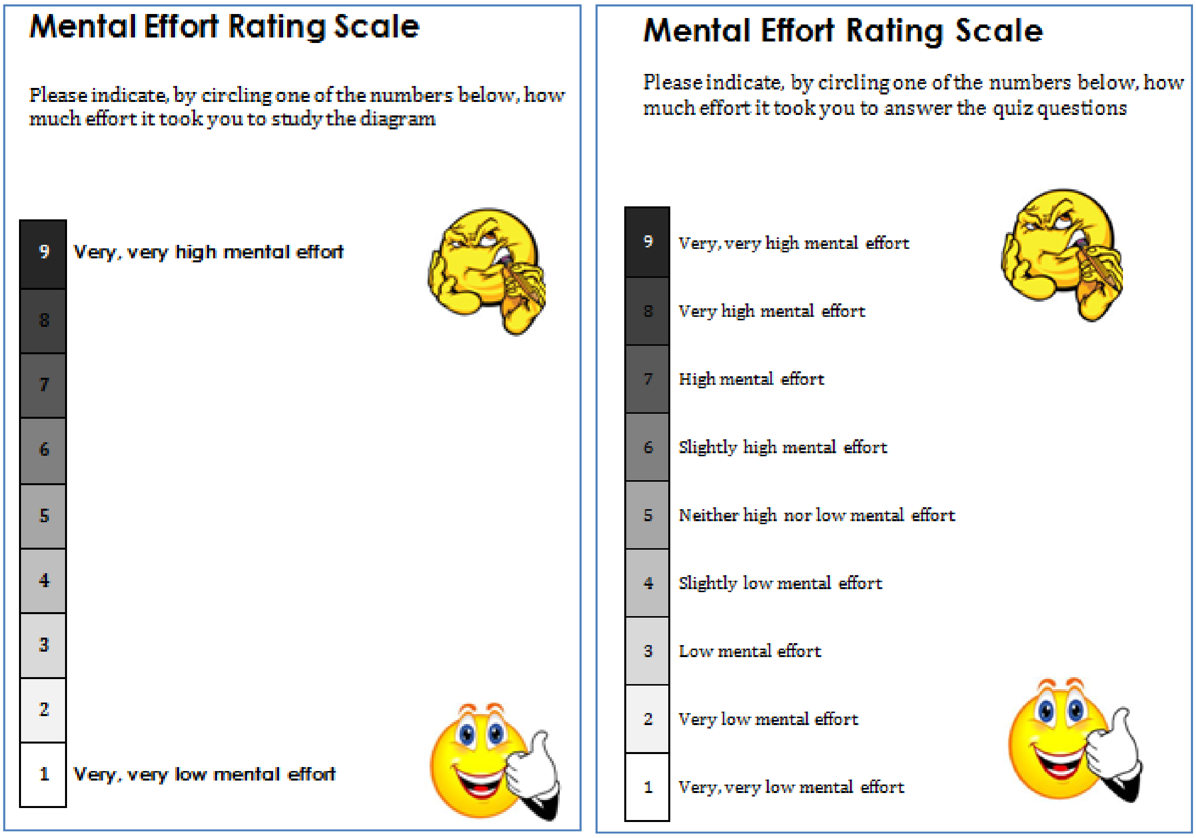


Figure 4: Mental effort rating scale used; figure on left used in Learning Phase and figure on right used in Testing Phase

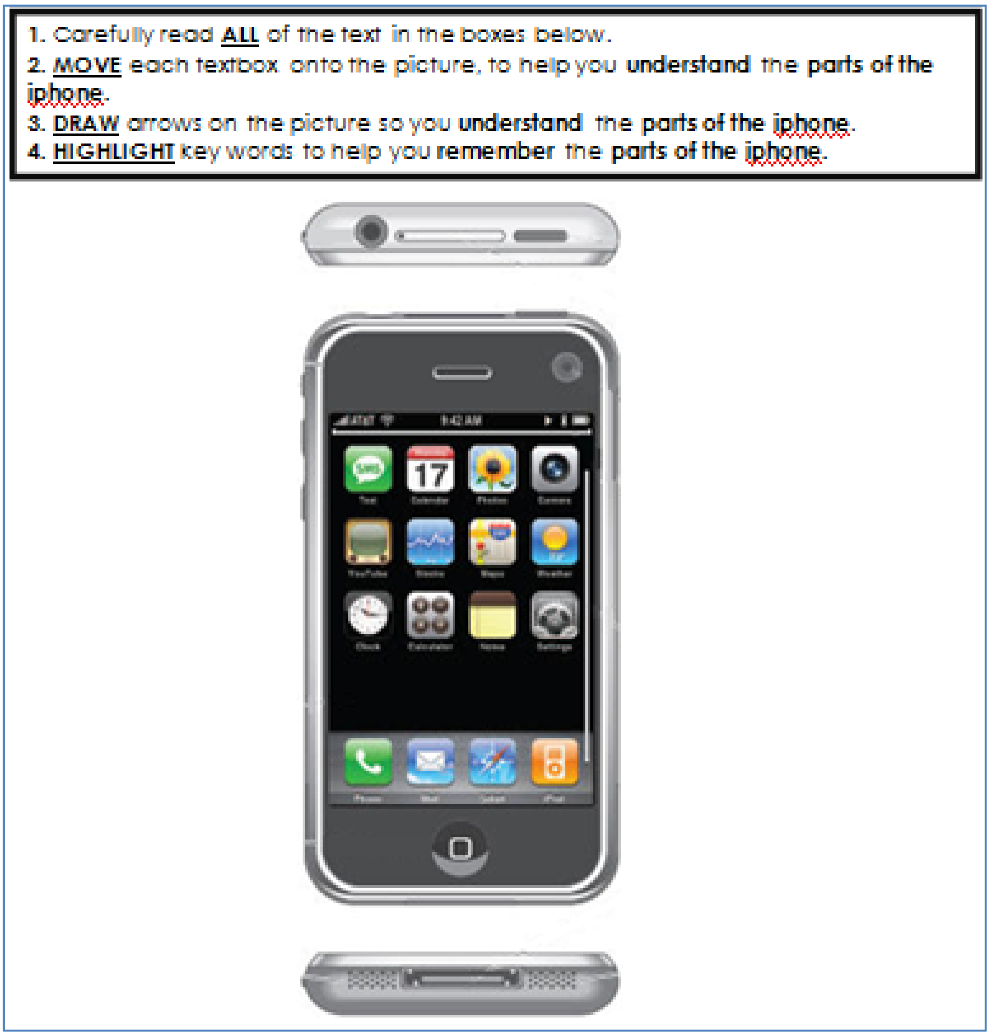


Figure 5: iPhone task used to teach the split-attention self-management techniques to the self-managed condition