British Journal of Educational Technology *Vol 45 No 5 2014* 959–980
doi:10.1111/bjet.12119

Web-based reading annotation system with an attention-based self-regulated learning mechanism for promoting reading performance

Chih-Ming Chen and Sheng-Hui Huang

Chih-Ming Chen is a distinguished professor of the Graduate Institute of Library, Information and Archival Studies at National Chengchi University. His main research interests include digital library, e-learning, data mining, and intelligent agents on the Web. Sheng-Hui Huang is a graduate student of the Department of Applied Electronics Technology at National Taiwan Normal University. Address for correspondence: Distinguished Prof Chih-Ming Chen, Graduate Institute of Library, Information and Archival Studies, National Chengchi University, NO.64, Sec. 2, ZhiNan Rd., Wenshan District, Taipei City 116, Taiwan. Email: chencm@nccu.edu.tw

Abstract

Due to the rapid development of information technology, web-based learning has become a dominant trend. That is, learners can often learn anytime and anywhere without being restricted by time and space. Autonomic learning primarily occurs in web-based learning environments, and self-regulated learning (SRL) is key to autonomic learning performance. Moreover, sustained attention to web-based learning activities can be challenging for students. Therefore, a web-based reading annotation system with an attention-based self-regulated learning mechanism (ASRLM), which is based on brainwave detection, is designed to enhance the sustained attention of learners while reading annotated English texts online, and thereby promote online reading performance. In total, 126 Grade 7 students in four classes at a junior high school in New Taipei City, Taiwan, are the participants. Among the four classes, two classes are randomly distributed to the experimental group and the other two classes are randomly distributed to the control group. The experimental group utilizes the ASRLM to support their reading of annotated English texts online, whereas the control group is not supported by the ASRLM while reading annotated English texts online. Experimental results show that sustained attention and reading comprehension of the experimental group are better than those of the control group. Moreover, the web-based reading system with ASRLM support promotes the sustained attention and reading comprehension of female learners more than those of male learners while reading annotated English texts online. Additionally, learners with high-SRL ability in the experimental group have better sustained attention and reading comprehension than those learners with low-SRL ability. Furthermore, the sustained attention and reading comprehension of the experimental group are strongly correlated, and the duration of sustained attention strongly predicts their reading comprehension performance.

Introduction

Due to the rapid growth of digital content, reading media have changed from paper to electronic forms. Therefore, reading or browsing digital texts through digital reading devices or assistive systems has become popular. Many studies have developed reading systems or tools to assist learners in online learning (Chen, Hwang & Wang, 2012; Rau, Chen & Chin, 2004; Su, Yang, Hwang & Zhang, 2010). A web-based reading annotation system is an effective assistive system

Practitioner Notes

What is already known about this topic

- A web-based reading annotation system is an effective assistive system that supports digital reading because it allows readers to add annotations, and underline and highlight text to increase reading comprehension via autonomic learning through web-based environments. However, sustained attention and self-regulated learning (SRL) with good attention control are key to autonomic learning performance.
- Sustained attention to learning content is regarded as the premise of effective learning. Consequently, sustained attention in digital reading allows students to focus on reading content and improve reading performance.
- Many studies have indicated that learners without the self-regulated learning (SRL) ability could not deeply comprehend complex topics in autonomic learning environments.

What this paper adds

- Based on the importance of sustained attention and self-regulated learning (SRL) in autonomic learning, this paper proposes a novel attention-based self-regulated learning mechanism (ASRLM) that contains five SRL indexes based on human electroencephalogram (EEG) signals to enhance the sustained attention of learners while reading annotated English texts online, and thereby promote online reading performance.
- The promotion of reading comprehension and sustained attention of learners with different genders and distinct SRL abilities are studied to confirm the positive effects of the ASRLM on online reading.
- The correlations among the reading comprehension, sustained attention, and five SRL indexes for learners who apply the ASRLM for online reading of annotated English texts are confirmed.

Implications for practice and/or policy

- This study finds that monitoring and reminding by the ASRLM can help learners achieve SRL goals and learners more actively read online, enhancing their reading performance and achievement of goals due to the feedback of SRL radar chart. Therefore, this study strongly suggests that web-based learning systems for autonomic learning should design SRL mechanisms to support effective learning and promote learners' self-regulated learning abilities.
- In recent years, human EEG signals have shown their potential applications in recognizing attention, cognitive load, and emotion. Particularly, EEG-based attention aware has relatively high potential for assisting diverse learners, assessing learning performance and providing feedback during learning processes in computer-assisted learning environments. Therefore, applying EEG-based attention aware technologies in educational settings should be further investigated.
- Many past studies indicated that attention is closely related to learning performance. However, this study finds that reading comprehension and sustained attention in the experimental group were strongly correlated, but not in the control group. Obviously, using the ASRLM to support online reading of English annotated texts was the key factor in the correlation between reading comprehension and sustained attention. In other words, designing effective learning contexts or assisted learning mechanisms for connecting correlation between learning performance and attention is very important in autonomic web-based learning environments.

that supports digital reading because it allows readers to add annotations and underline and highlight text to increase reading comprehension (Chen *et al*, 2012; Su *et al*, 2010). Research has indicated that annotations from previous readings had high utilization value for other learners, as they could increase the depth and width of reading comprehension for subsequent readers (Marshall, 1998; Wolfe, 2002, 2008). Moreover, sustained attention was considered a critical issue in cognitive psychology because of its close relationship with learning performance (Steinmayr, Ziegler, & Träuble, 2010). Simply, effective identification, learning and memory do not exist in a learning process without sustained attention (Broadbent, 1958). Psychologically, attention is regarded as a psychological activity when an individual responds to one or a part of various stimuli in learning processes and acquires perceived experiences (Boersma & Das, 2008). Apparently, sustained attention to learning content is regarded as the premise of effective learning. Consequently, sustained attention in digital reading allows students to focus on reading content and improve reading performance.

Furthermore, many studies have also indicated that learners without self-regulated learning (SRL) ability could not deeply comprehend complex topics via autonomic learning through web-based environments (Hannafin & Land, 1997; Jacobson & Archodidou, 2000). Some research also pointed out that students who do not effectively apply metacognition strategies to the SRL process do not effectively acquire knowledge in web-based learning environments (Azevedo, Cromley, & Seibert, 2004). Apparently, one's SRL ability cannot be ignored in web-based learning environments. Similarly, the SRL ability of individual learners when reading English texts with annotations online is also a key factor affecting reading comprehension performance. Chen, Wang and Chen (in press) proposed a SRL mechanism combined with a digital reading annotation system (DRAS) to enhance Grade 7 students to generate rich and high-quality annotations for promoting English-language reading performance. Their study confirmed that the reading comprehension of the learners was significantly improved when using the proposed DRAS with the SRL mechanisms to read English-language texts online. Additionally, Winne (1995) claimed that performing the SRL processes should include attention control. Attention control is a cognitive process that requires significant self-monitoring (Harnishferger, 1995). Often this process entails clearing the mind of distracting thoughts as well as seeking suitable environments that are conducive to learning (Winne, 1995). Thus, how to help students control their attentions by removing stimuli that may cause distractions and help them build up their attention spans for promoting SRL is an important issue.

Pintrich and DeGroot (1990) showed that learners with high learning performance could better arrange learning time, set definite learning goals and apply various strategies to learning than those with low learning performance. Additionally, learners with high learning performance had better self-efficacy, self-learning and self-monitoring skills while learning. Conversely, learners with low learning performance did not understand how to learn effectively and passively, leading to low learning achievement and a gradual loss of learning power and the learning objective. Moreover, gender differences in education have been recognized as an important research focus for a long time (Yukselturk & Bulut, 2009). Several previous studies claimed that male and female learners use SRL strategies during their learning processes differently (Wolters & Pintrich, 1998; Zimmerman & Martinez-Pons, 1990). Zimmerman and Martinez-Pons (1990) determined that girls tend to employ self-monitoring, goal setting, planning and structuring of their study environment more often than boys. Wolters and Pintrich (1998) confirmed that gender differences in motivational and cognitive strategies existed during SRL.

In recent years, human physiological signals have been successfully applied to be valid measurement tools to assess emotion (Chen & Sun, 2012; Chen & Wang, 2011) and attention (Rebolledo-Mendez *et al*, 2009). Based on the importance of sustained attention and SRL with

good attention control in autonomic learning, the MindSet earphone developed by NeuroSky (San Jose, CA, USA) (http://www.neurosky.com/) based on human electroencephalogram (EEG) signals was applied to develop an attention-based self-regulated learning mechanism (ASRLM) that contains five SRL indexes. This mechanism allowed learners to set SRL goals, monitor SRL status and reflect SRL outcomes according to individual learning plans associated with sustained attention, in order to support a web-based reading annotation system for online reading. This study expected that this mechanism can enhance learners' sustained attention during autonomic learning while reading online and promote reading comprehension through such ASRLM characteristics as recording, quick analyses and presentation of diverse self-regulation conditions. Moreover, the promotion of reading comprehension and sustained attention of learners with different genders and distinct SRL abilities are studied to further confirm the positive effects of the ASRLM on online reading. In conclusion, the research questions of the study include whether significant differences exist in the reading comprehension and sustained attention of learners and different gendered learners who read online with and without the ASRLM for English texts with annotations; whether significant differences exist in the reading comprehension and sustained attention of learners with distinct SRL abilities who apply the ASRLM for online reading of English texts with annotations; whether significant correlations exist among the reading comprehension, sustained attention and five SRL indexes for learners who respectively apply and do not apply the ASRLM for online reading of English texts with annotations.

Literature review

SRL

Many researchers have designed SRL assistive systems for students actively planning their learning goals: SRL was defined as a learning method, including goal setting, strategy use, self-monitoring and self-reflection, for learning certain skills (Boekaerts, 1997; Pintrich, 2000; Zimmerman & Schunk, 2001). Zimmerman, Bonner and Kovach (1996) argued that the SRL cycle covered four closely related processes: (1) self-evaluation and monitoring process evaluated the status of a learner on certain learning tasks and to observe and record the learning performance and results to assess individual learning efficacy; (2) goal setting and strategy planning referred to how a learner analyzes learning tasks, sets specific learning goals and plans or carefully considers the strategies to achieve these goals; (3) strategy implementation and monitoring referred to how a learner performs certain learning strategies and monitors the accuracy of the learning strategies; and (4) strategy outcome monitoring indicated how a learner pays attention to correlations between learning results and the learning strategic processes in order to determine the effectiveness of the learning strategies. Obviously, the goals of the above-mentioned SRL cycle were to assist students in self-observation and self-evaluation, setting goals and using learning strategies, and monitoring learning processes to enhance the learning performance by self-reflection and further adjust learning methods. According to past research, students with high learning performance presented more definite goals for learning, utilized more effective strategies for learning processes, more frequently monitored the learning processes, and adjusted learning steps according the learning results than students with low learning performance (Pintrich & DeGroot, 1990).

Moreover, many studies focused on developing effective systems that assist in SRL and enhance SRL performance. Roscoe, Segedy, Sulcer, Jeong and Biswas (2013) designed a teachable agent system called Betty's Brain to support SRL and strategy use of Grade 7 middle school students on topics in climate change and thermoregulation. Their study confirmed that use of SRL-supportive tools was positively correlated with learning outcomes. Moreover, Goh, Seet and Chen (2012) investigated the impact of adopting persuasive short messaging service (SMS) on promoting undergraduate students' SRL strategies while attending an introductory information systems course over a 12-week trimester. Their study demonstrated a positive impact of persuasive SMS

on students' learning and suggested that the intervention is able to improve students' SRL effort. Niemi, Nevgi and Virtanen (2003) established an IQ FORM, a web-based interaction tool, to assess learners' learning motivation, learning efficacy and SRL ability and provide an online SRL tool, which was beneficial for learners with learning troubles or without favorable learning strategies and skills. Shih, Chang, Chen and Wang (2005) developed a SRL system for mobile learning that provided learners with a learning environment in which they could arrange a learning schedule and allow learners to manage learning time through mobile devices. This system assisted students in cultivating individual SRL ability and provided learners with a portable personalized learning environment. Chang (2005), who studied learners' motivation in web-based learning environments with the Motivated Strategies for Learning Questionnaire SRL Scale, indicated that SRL strategies could enhance learning motivation. Chen (2009) established an SRL-assisted mechanism in a personalized e-learning system (PELS) to support personalized learning, proving that the constructed SRL system could enhance learners' SRL abilities and promote their learning performance.

Furthermore, past research identified the effects of appropriate feedback on the self-reflection of learners receiving assistance in the learning process (Butler & Winne, 1995; Ley & Young, 2001). In an educational environment, feedback was regarded as learning reinforcement that could improve learning performance (Chi, DeLeeuw, Chiu & LaVancher, 1994; Mory, 2003). Many studies also asserted that appropriate external feedback could effectively enhance SRL (Butler & Winne, 1995; Mory, 2003; Winne & Hadwin, 1998). Thus, a novel ASRLM, which dynamically displays individual SRL states, including the learning time achievement index, sustained attention index, effort index, learning ability index and reading index via a SRL radar chart, was designed to support online reading of English texts with annotations in a web-based reading annotation system. Moreover, the proposed ASRLM also promptly offers encouraging words or prompts according to an individual learner's SRL situations. This study aims to explore the effects of online reading with ASRLM support on learners' sustained attention and on the promotion of reading comprehension.

Effects of attention on learning

Since the 1970s, attention research has been important in the psychological field. James (1983) regarded attention as a psychological process comprised of focus and concentration, which enhances cognition speed and accuracy. Solso (1995) defined attention as the degree of focus or concentration on specific affairs. Nideffer (1976) divided attention into attention width and direction. Attention width referred to the amount of a learner's focus on external affairs. Attention direction, conversely, referred to attention to an external affair. Sohlberg and Mateer (1989) further regarded attention as a multidimensional structure comprising concentration and continuity. The degree of concentration indicated the degree of focus and attention on one of many stimuli. Learning was ineffective when a learner did not pay attention to learning content. Continuity was the period that an individual paid attention to a specific task. When continuity was short, long-term learning would not be achieved and learners were likely to be impatient and distracted.

Attention is closely related to learning performance. In other words, identification, effective learning and memory do not exist when learning without attention (Broadbent, 1958). Jensen (1998) regarded attention in educational contexts as focused concentration. Cognitive psychologists considered learning as a learner actively proceeding cognition processes, including attention, comprehension, perception and organization. The viewpoint suggested that messages would be handled and memorized when learners paid attention to learning process (Broadbent, 1958). Corno (1993) argued that attention could enhance the learning performance of learners with ordinary learning motivation or competitive intention. As a result, instructors could improve

learning quality for learners by stressing learner attention and providing effective learning strategies. Additionally, Winne (1995) claimed that attention control is an essential factor affecting SRL. Harnishferger (1995) indicated that attention control for SRL is a cognitive process that requires significant self-monitoring. That is, learners must be able to control their attention in order to perform good SRL (Winne, 1995).

Generally, attention can be categorized as different forms, including focused attention, shifting attention, sustained attention, selective attention and divided attention (Driver, 2001; Lezak, Howieson & Loring, 2004; Wager, Jonides & Reading, 2004). This study mainly focused on sustained attention, which describes a fundamental component of attention characterized by the subject's readiness to detect rarely and unpredictably occurring signals over prolonged periods of time (Sarter, Givens & Bruno, 2001). To enhance the sustained attention of learners and further promote their online reading comprehension, this study thus presents the ASRLM, which is based on detected brainwaves of individual learners, to support reading annotated English texts online in a web-based reading annotation system. This study expected that the proposed ASRLM can help students control their sustained attention by removing stimuli that may cause distractions and help students build up their attention spans in an online reading environment.

Attention awareness and its applications in educational settings

Two attention measures are commonly utilized to assess a learner's degree of attention. One is an attention scale with set of questions answered by a learner (Das, 1986), and the other is a physiological signal measurement (Belle, Hargraves & Najarian, 2012; Groner & Groner, 1989; Moradi, Buračas & Buxton, 2012; Rebolledo-Mendez *et al*, 2009; Richards & Casey, 1991). Physiological signals are regarded as physiological characteristics of an individual, mainly controlled by the autonomic nervous system. The detector for physiological signals measures objective data without being affected by learner cognitive status. Past research used five measures, which were based on physiological signals, to assess the degree of attention: an EEG or brainwave signal (Rebolledo-Mendez *et al*, 2009), eye movement (Groner & Groner, 1989), electrocardiogram (Belle *et al*, 2012), blood oxygenation (Moradi *et al*, 2012) and heart rate variability (Richards & Casey, 1991). Among these physiological signal measures, EEG detects attention according to the selected features of α, β, δ and θ waves in human brainwaves, and the variation in the β wave in the EEG is strongly correlated with attention (Egner & Gruzelier, 2004). Moreover, several past studies showed that strong correlation existed between EEG and cognitive load (Kilseop & Rohae, 2005; Wilson, 2002). Bi and Fan (2011) also proposed a recognition model of multiemotion states from EEG based on Bayesian networks and showed that the proposed model performs well, and using EEG to detect multiemotion states is feasible. Restated, human EEG signals have shown their potential applications in recognizing attention, cognitive load and emotion. Moreover, EEG has been successfully applied to educational learning in recent years (Gerě & Jaušcvec, 1999; Hinton, Miyamoto & Della Chiesa, 2008; Li *et al*, 2010; Zhang & Lu, 2009). Among EEG applications in the education field, Gerě and Jaušcvec (1999) investigated the cognitive processes involved in learning information presented in multimedia and text format using EEG measures. Their research results support the assumption that the video and picture presentations induced visualization strategies, whereas the text presentation mainly generated processes related to verbal processing. Moreover, Li *et al*'s (2010) study extracted features from human EEG signals to identify learner's attention based on combining k-Nearest-Neighbor classifier and Naive Bayes classifier. Their study *integrated a* real-time EEG feedback and a learner's attention report into an affective learning system to improve learner's affective learning performance.

Moreover, Rapp (2006) indicated that attention aware systems have relatively high potential for assisting diverse learners, assessing student performance, providing feedback during curriculum development and adding value to computer-assisted teaching methodologies. Attention aware

systems should therefore be regarded as an additional component of the educators' assessment toolkit (Rapp, 2006). Currently, the most often employed mechanisms for detection of user attention are based on the observation of sensory cues of users' current activity and of the environment; however, nonsensory-based mechanisms that form a complete picture of the user's attentional state are also alternative approaches (Roda & Thomas, 2006). Moreover, Roda and Thomas (2006) proposed that attention aware systems should contain three major features: detection of user's current attentional state, detection and evaluation of possible alternative attentional states and strategies for focus switch or maintenance. However, to the best of our knowledge, the literature includes few studies of successfully developing attention aware systems in educational settings, particularly without study of applying attention aware systems in developing an attention-based SRL mechanism. Hsu, Chen, Su and Huang (2012) developed a reading concentration monitoring system for use with e-books in an intelligent classroom to help instructors find out the students' reading concentration rates based on an artificial bee colony optimization approach. Toet (2006) proposed that gaze-directed schemes, such as tracking eye movements, are an important enabling technology for developing attention aware systems. Based on EEG features strongly correlated with attention, this study utilizes the MindSet earphone, which is an attention detector developed by NeuroSky (http://www.neurosky.com/), to assess the degree of sustained attention in order to develop ASRLM for promoting attention control in SRL as well as facilitating online reading performance. In this study, attention detector based on EEG features aims to enable the development of ASRLM with high accuracy rate of attention recognition in order to enhance the sustained attention of learners while reading annotated English texts online.

Research methodology

Research architecture

Figure 1 shows the research architecture in this study, in which the independent variable is online reading with or without ASRLM support for annotated English texts. The experimental group applies the ASRLM, whereas the control group does not. Dependent variables are sustained attention of the two groups during online reading and reading comprehension. Sustained attention, based on the attention value identified by NeuroSky's MindSet earphone, is in the range of 0–100; the posttest score of a reading comprehension test reveals the level of reading comprehension; the background variables are gender and SRL ability, which are used to explore

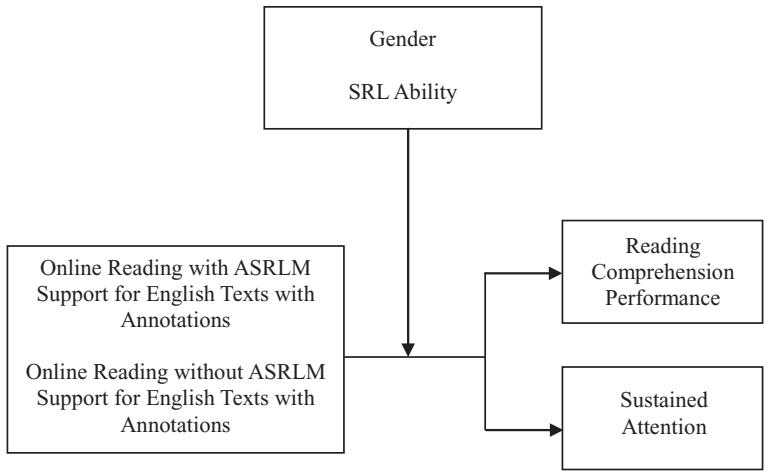

Figure 1: Research architecture of the study

differences in sustained attention and reading comprehension of the two groups; and control variables are the two groups using the same annotated English texts and the same online reading period.

Experimental design

This study applies the quasi-experiment nonequivalent control group design, as randomly selecting participants as a research target is a difficult task in actual teaching scenarios. The participants of the study were randomly recruited from Grade 7 students in four classes at a junior high school in New Taipei City, Taiwan. According to the nonequivalent control group design in quasi-experimental research, participants were randomly assigned to the experimental group and control group. The experimental group was randomly assigned from two of the four classes. The other two classes were assigned to the control group. The experimental group students performed their online reading with the ASRLM support for eight selected English reading texts with annotations, whereas the control group students performed online reading without the ASRLM support for eight selected English reading texts with annotations.

Experimental procedures

First, a reading comprehension pretest of eight selected English reading texts with annotations was applied to assess the English language proficiency of the two groups. Learners in both groups then wore the MindSet earphones, which assessed the degree of sustained attention in the learning process while reading the selected eight annotated English texts online. Both groups read the same English texts. After 30 minutes of self-learning, students were given the reading comprehension posttest. After acquiring sustained attention values and posttest results for reading comprehension for the two groups, this study assessed whether reading comprehension and sustained attention in the experimental group was better than those in the control group.

Research participants

Through several negotiations, Sansia Junior High School in New Taipei City, Taiwan, offered its assistance. In total, 126 Grade 7 students in four classes were randomly selected as participants, and their ages are between 12 and 13 years old. Two classes were randomly selected as the experimental group (33 males and 30 females), whereas the other two classes were the control group (33 males and 30 females).

Research tools

Web-based reading annotation system with support by the ASRLM

To assist in online reading of the English texts with annotations, the ASRLM was designed for learners, based on which SRL processes were quantified, to present as SRL indexes in a web-based reading annotation system. A learner can follow the following SRL steps to perform online reading with the ASRLM support.

(1) Setting SRL sheet. A learner should set the SRL sheet after logging into the web-based reading annotation system with the ASRLM support for online reading. The learner can set SRL sheet containing the items of learning time (5–45 minutes), number of learning units (units 1–8), effort level (1–10), sustained attention level (1–10), expected learning ability (3—3), current learning location and learning partners. Figure 2 shows the user interface of setting SRL sheet.

(2) Starting an online reading of annotated English texts and reminding learners' SRL status based on a SRL radar chart with five SRL indexes. After setting the SRL sheet values, the learner can start an online reading of annotated English texts and an SRL radar chart will appear on the left of the system user interface to indicate the learner's SRL status. Figure 3 shows the user interface of the web-based reading annotation system with the ASRLM. The blue area contained the setting learning time achievement index, sustained attention index, learning ability index, effort index

Figure 2: The user interface of setting SRL sheet

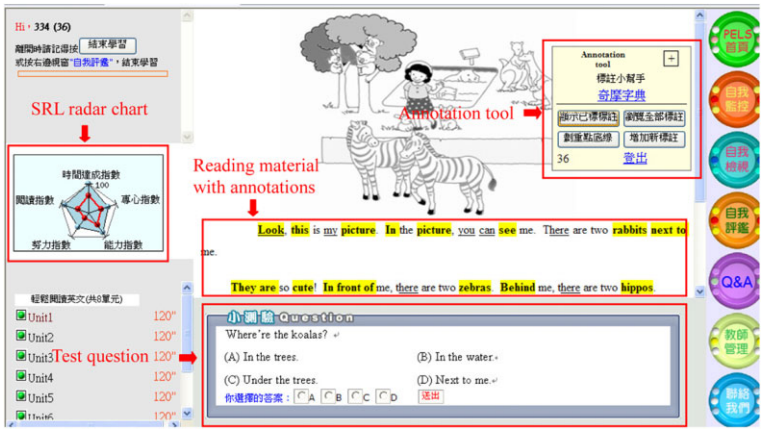

Figure 3: The user interface of the web-based reading annotation system with ASRLM for supporting online reading of an English text with annotations

and reading index determined by the SRL sheet set by the learner. The red area in the SRL radar chart showed the achievement status of the five SRL indexes. The learning time achievement index, sustained attention index and effort index scores were determined based on attention detection of brainwaves. Thus, the three SRL indexes are termed as attention-based SRL index. In contrast, the learning ability index and reading index, which were proposed in our previous study (Chen, 2009), were determined based on Item Response Theory (Baker, 1992) and reading rate of eight annotated English texts in the web-based digital reading annotation system. The reading index was determined as the rate between total number of annotated English texts and the amount of annotated English texts read by a learner. The learner ability index was dynamically estimated according to Item Response Theory (Baker, 1992)—learner responses to randomly selected test questions in an English text with annotations were collected. Attention detection and the three attention-based SRL indexes are explained further in the subsection of sustained attention detector based on EEG. Such an SRL radar chart could urge a learner to master differences between set SRL goals and SRL conditions, such that he or she actively and seriously performed online reading.

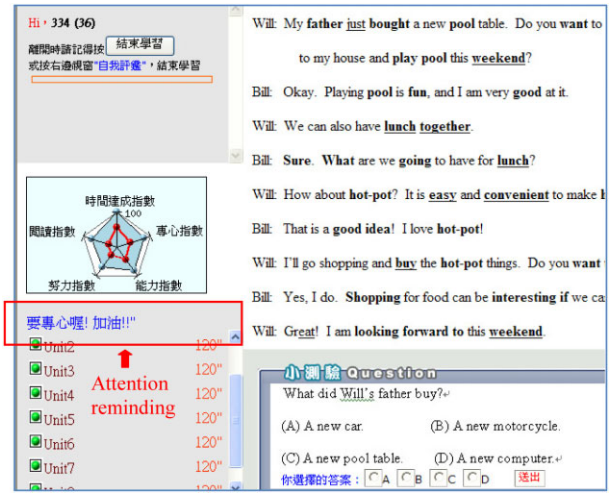

Figure 4: The user interface of sustained attention reminder

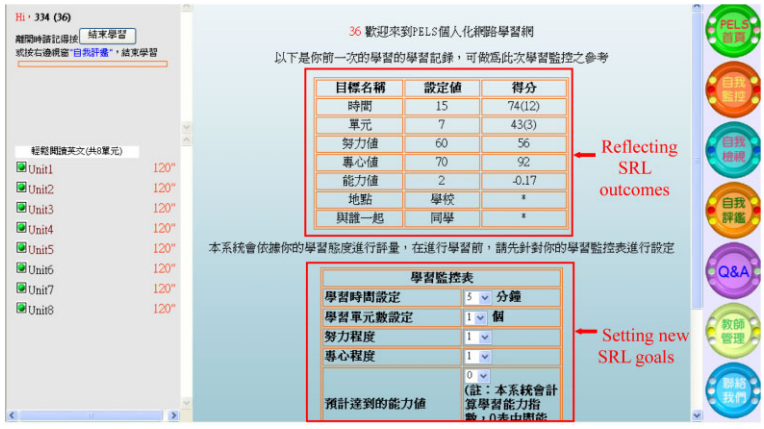

Figure 5: The self-inspection interface of reflecting SRL outcomes and setting new SRL goals

(3) Reminding learner to keep on good sustained attention based on attention reminder. When the ASRLM determined that the sustained attention of a learner was lowering than the setting SRL goals, three attention-based self-regulated indexes—learning time achievement, sustained attention level and effort level—were affected. To remind a learner to increase his or her sustained attention, the text displayed at the bottom of the SRL radar chart read, "Pay more attention! Cheer up!" In other words, in addition to displaying SRL radar chart for promoting SRL, the attention reminder provides another effective mechanism to remind learners for increasing their sustained attention. Figure 4 shows the sustained attention reminder interface.

(4) Performing self-reflection of SRL outcomes and setting new SRL goals. After an online reading process was terminated, the learner can reflect the SRL outcomes using the self-inspection interface, and then determine the new SRL goals. Figure 5 shows the self-inspection interface of reflecting SRL outcomes and setting new SRL goals. The self-inspection function assisted the learner in self-reflection, thereby helping him or her set new SRL goals and promoting SRL abilities and reading performance in an online reading of next cycle.

In short, this study designed two SRL assisted mechanisms to promote learners' sustained attention and reading comprehension performance in the proposed ASRLM. One is an SRL radar chart that can simultaneously show the current status and achievement status of five SRL indexes. Another is the attention reminder that can immediately provide text reminders for promoting learner's sustained attention when three attention-based SRL indexes performed by a learner was lower than the self-setting SRL goals.

Annotated English reading texts and question design for assessing reading comprehension

The eight selected English reading texts with annotations belong to different topics and were selected from the *English reading* textbook for Grade 7 students. Therefore, the difficulty levels of the eight annotated English reading texts are suited to the participants. The annotations in the eight selected English reading texts include vocabulary explanations, antonyms, grammar, phrases and relevant connections to promote reading comprehension. These annotated English texts were very suitable for self-reading because some supplementary annotations are included to promote reading comprehension. Furthermore, all pretest and posttest items for assessing prior knowledge and reading comprehension on the learning topics were designed by a senior English teacher. To ensure the pretest and posttest have the same difficulty, the reading comprehension tests used were the same in the study. However, to avoid the effect that some experimental participants might memorize the answers after performing the pretest, the order of answer sets in the pretest was different with the order of answer sets in the posttest. Moreover, to prevent the answers of the pretest being discovered by some experimental participants from textbooks or the Internet, the experimental procedures were designed to perform the continuous steps of the pretest, followed by 30 minutes of self-learning; then, the posttest was performed. The reading comprehension test comprised 16 items belonging to inference and comprehension type questions. Also, the estimation of item difficulty and discrimination by using classic testing theory shows that the average difficulty of the pretest and posttest items is moderate, and the discrimination of all pretest and posttest items is quite good. The results imply that the pretest and posttest items have high reliability.

Sustained attention detector based on EEG

The MindSet earphone, which resembles a standard stereoscopic wireless earphone, uses a comfortable noninvasive dry electrode, with which the user merely wore an earphone and placed the earphone's forearm on his or her forehead to measure an attention value with a range of 0–100 based on collected real-time EEG signals. The attention value, identified by a patented algorithm developed by NeuroSky, was wirelessly transmitted to a computer with a brainwave receiver (NeuroSky MindWave, 2011; http://press.neurosky.com/MindWave.html). Based on EEG-based sustained attention detector, this study measured the attention value of learners who read annotated English texts online to acquire quantified attention-based index values, including values on the learning time achievement index, sustained attention index and effort index, for developing an attention-based SRL mechanism. The three attention-based indexes are determined as follows:

(1) Learning time achievement index. Learning time with an attention value higher than 40 was regarded as effective learning time with focused attention. Effective learning time was further divided by total time spent reading to obtain the learning time achievement index.

(2) Sustained attention index. The sustained attention index, with a range of 0–100, had the same value as the attention value detected directly by the MindSet earphone.

(3) Effort index. Effective reading time, as determined by the MindSet earphone, was divided by the shortest learning time that reads the annotated English texts to obtain the effort index. The

Table 1: The measured attention values of the student groups with high-, moderate- and low-level Birdwatching *game score*

Group with different levels of Birdwatching *game score*	*Number of students*	*Average attention*	*Standard deviation of attention*
Group with high-level *Birdwatching* game score	6	67.07	8.93
Group with moderate-level *Birdwatching* game score	6	55.90	3.87
Group with low-level *Birdwatching* game score	6	51.18	4.12

shortest learning time for each annotated English text was *heuristically* determined by senior English teachers. The effort index was presented as 1 when its value exceeded 1.

A pilot study for confirming reliability and validity of sustained attention detector based on EEG

Moreover, a pilot study was conducted to ensure that attention values detected by the MindSet earphones were reliable and valid. In this pilot study, *Birdwatching*, an attention training game developed by Lumosity (http://www.lumosity.com/), was utilized. *Birdwatching* is an exercise designed to improve attention by increasing the spatial extent of visual information that can be processed in a short amount of time (Hardy, Drescher, Sarkar, Kellett & Scanlon, 2011). The goal is to score points by accurately identifying a letter in the center of the screen, while simultaneously detecting the location of a bird graphic in the periphery. The level of difficulty was adjusted automatically by decreasing the stimulus duration (range: 30–200 ms), increasing the eccentricity of the noncentral stimulus and increasing nonrelevant information (distractors). Sustained attention is the ability to maintain a consistent focus on some continuous activity or stimuli (Sohlberg & Mateer, 1989). Based on the rate of correctly identifying the message on the screen during a period of time, scores in *Birdwatching* game can fully reflect a participant's sustained attention on the identification of successive visual stimuli. Therefore, the scores were used to verify the reliability and validity of attention values detected by the MindSet earphone. In total, 18 Grade 7 students took part in the pilot study. The students were asked to wear the MindSet earphones while playing the *Birdwatching* game. The 18 students were divided into the student groups with high-, moderate- and low-level *Birdwatching* game score. The corresponding attention values measured by the MindSet earphones were also acquired. Table 1 lists the measured attention values of student groups with high-, moderate- and low-level *Birdwatching* game score.

One-way analysis of variance was first applied to test for significant differences in measured attention values among the three score-based groups. The results show that measured attention values differed significantly among the three groups ($F = 10.32$, $p = 0.002 < 0.05$). Scheffe's multiple comparison was further applied to compare measured attention values for the three groups in the *Birdwatching* game. The results show that the difference in measured attention value between the high-score group and moderate-score group was significant (average attention difference = 11.17, $p = 0.008 < 0.05$), and the mean attention value of the high-score group is significantly higher than the moderate-score group; the difference between the high-score group and low-score group for measured attention value was also significant (average attention difference = 15.89, $p = 0.000 < 0.05$), and the mean attention value of the high-score group is significantly higher than the low-score group. However, no significant difference existed between the moderate-score group and low-score group for measured attention value. Moreover, Pearson product-moment correlation analysis was then applied to the scores of all participants in the *Birdwatching* game and the attention values measured by the MindSet earphones to verify the correlations. The result shows that the two were strongly correlated ($r = 0.730$, $p = 0.000 < 0.05$). In addition to the pilot study, Rebolledo-Mendez *et al* (2009) also assessed

NeuroSky's usability to detect attention levels by defining a model of attention to fuse attention signals with user-generated data in a Second Life assessment exercise. Their research suggested that NeuroSky provides accurate readings regarding attention, as there is a positive correlation between measured and self-reported attention levels. The above results reveal that the MindSet earphone was a valid measurement tool to identify learner attention in this study.

Experimental analysis

Initial English ability analyses of learners in both groups

To cancel out the effect of the prior English abilities of learners on reading comprehension performance of posttest, the initial English abilities of learners in the two learning groups were pretested before performing the instructional experiment. The independent samples *t*-test was applied to confirm differences in initial English abilities of learners in the two learning groups. The *t*-test results show that the difference in pretest results for both learning groups were not significant ($t = -1.005$, $p = 0.317 > 0.05$), ie, learners in the two learning groups generally had equivalent English abilities.

Moreover, gender was analyzed by the independent samples *t*-test to assess the effects of prior English abilities for the two groups. Males in the experimental group and control group were tested first. The pretest result was not significantly different between the two groups ($t = -0.432$, $p = 0.667 > 0.05$), revealing that prior English abilities of males in both groups were equivalent. Females in the experimental group and control group were then tested; again, the pretest result did not differ significantly between the two groups ($t = -1.010$, $p = 0.317 > 0.05$). Additionally, pretest results of both genders in the experimental group were tested. The mean difference in pretest results for both genders in the experimental group were not significantly different ($t = -0.591$, $p = 0.557 > 0.05$). That is, learners of both genders in the experimental group had equivalent prior English ability.

Difference analysis of reading comprehension between both groups

This study applied the independent samples *t*-test to assess the difference in reading comprehension for both groups. Table 2 shows that reading comprehension results for the experimental group were better than those of the control group, and the difference was significant ($t = 3.381$, $p = 0.001 < 0.05$). This confirms that ASRLM support for online reading of annotated English texts had a positive effect on reading comprehension. Moreover, the effects of gender on reading comprehension performance were also analyzed. The difference in reading comprehension of males in both groups was not significant ($t = 1.348$, $p = 0.182 > 0.05$), whereas that of females was significant ($t = 3.848$, $p = 0.000 < 0.05$). That is, females in the experimental group had

Table 2: Independent samples t*-test of reading comprehension performance between the experimental group and the control group*

					t-*Test with equal mean*	
Test item	*Learning group*	*Number of learners*	*Mean*	*Standard deviation*	t	*Significance (two tailed)*
Entire posttest of reading comprehension	Experimental group	63	70.6349	16.449	3.381**	0.001
	Control group	63	60.4762	17.267		
Male posttest of reading comprehension	Experimental group	33	63.333	14.720	1.348	0.182
	Control group	33	57.879	17.986		
Female posttest of reading comprehension	Experimental group	30	78.667	14.559	3.848***	0.000
	Control group	30	63.333	16.259		

** indicates $p < 0.01$; *** indicates $p < 0.001$.

better reading comprehension than those in the control group. Zimmerman and Martinez-Pons's (1990) study confirmed that girls typically employed self-monitoring, goal setting, planning and structured their study environments more often than boys. This study inferred that this may be the main reason that online reading with ASRLM support assisted female learners than male learners in reading comprehension.

Difference analysis of sustained attention between the two groups

To discuss the effects of the ASRLM on sustained attention, the independent samples *t*-test was applied. Table 3 shows test results. Mean sustained attention in the experimental group was higher than that of the control group, and the independent samples *t*-test result of both groups reached the significant level ($t = 6.250$, $p = 0.000 < 0.05$). Thus, reading annotated English texts online with the ASRLM support increased the strength of sustained attention.

The effects of gender on sustained attention were further analyzed. Both genders in the experimental group had higher mean sustained attention than those in the control group, and independent samples *t*-test results of both genders in the experimental group and the control group respectively reached the significant level ($t = 3.354$, $p = 0.001 < 0.05$) ($t = 5.949$, $p = 0.000 < 0.05$). Thus, gender differences in sustained attention existed between the experimental group and control group. This study infers that the strength of sustained attention of both genders could be enhanced by the ASRLM. That is, gender would not affect whether sustained attention was promoted.

Difference analysis of reading comprehension and sustained attention for learners in the experimental group

To assess the effects of ASRLM support on reading comprehension of both genders in the experimental group, reading comprehension performance of both genders was subjected to the independent samples *t*-test. Table 4 shows test results. The reading comprehension performance of females was significantly higher than that of males by the *t*-test result ($t = -4.151$, $p = 0.000 < 0.05$). Furthermore, the independent samples *t*-test was applied to test the significance of differences in sustained attention between both genders in the experimental group. The sustained attention of females was significantly higher than that of males by the independent samples *t*-test ($t = -3.844$, $p = 0.000 < 0.05$).

Difference analysis of reading comprehension and sustained attention of learners with distinct SRL abilities in the experimental group

To explore the difference in reading comprehension and sustained attention with ASRLM support among learners with distinct SRL abilities in the experimental group, the learning time

Table 3: Independent samples t*-test of sustained attention between the experimental group and the control group*

					t-*Test with equal mean*	
Test item	*Learning group*	*Number of learners*	*Mean*	*Standard deviation*	t	*Significance (two tailed)*
Entire sustained attention	Experimental group	63	64.518	5.607	6.250***	0.000
	Control group	63	57.837	6.369		
Male sustained attention	Experimental group	33	62.177	5.760	3.354**	0.001
	Control group	33	57.330	5.975		
Female sustained attention	Experimental group	30	67.094	4.181	5.949***	0.000
	Control group	30	58.393	6.834		

** indicates $p < 0.01$; *** indicates $p < 0.001$.

Table 4: Independent samples t*-test of reading comprehension performance and sustained attention of learners in the experimental group*

Test item	*Learning group*	*Number of learners*	*Mean*	*Standard deviation*	t-*Test with equal mean* t	*Significance (two tailed)*
Reading comprehension performance	Males	33	63.333	14.720	–4.151***	0.000
	Females	30	78.667	14.559		
Sustained attention	Males	33	62.176	5.761	–3.844***	0.000
	Females	30	67.094	4.182		

*** indicates $p < 0.001$.

Table 5: Independent samples t *test of reading comprehension performance and sustained attention of the learners with distinct SRL abilities in the experimental group*

Test item	*Learning group*	*Number of learners*	*Mean*	*Standard deviation*	t-*Test with equal mean* t	*Significance (two tailed)*
Reading comprehension performance	High-SRL Group	32	78.438	12.472	4.341***	0.000
	Low-SRL Group	31	62.581	16.323		
Sustained attention	High-SRL Group	32	67.358	3.441	4.701***	0.000
	Low-SRL Group	31	61.587	5.937		

*** indicates $p < 0.001$.

achievement index, sustained attention index, effort index, learning ability index and reading index in the SRL radar chart were used to compute the SRL abilities of learners. The five indexes were normalized to values of 0–1. The average sum of the five normalized indexes was used to group learners into a high-SRL group or low-SRL group. Learners with higher than the average value were assigned to the high-SRL group, whereas those with lower than the average value were assigned to the low-SRL group. Another more extreme scheme than the current approach is that the SRL abilities of participants falling in the top 27% were considered to be the high-SRL group and those in the bottom 27% to be the low-SRL group, respectively. To avoid leading to small sample sizes, the study adopted the average approach to identify all participants as high-SRL group and low-SRL group. Reading comprehension and sustained attention for the two groups were subjected to the independent samples *t*-test. The results show that reading comprehension of the high-SRL group was significantly better than that of the low-SRL group by the independent samples *t*-test ($t = 4.341$, $p = 0.000 < 0.05$) (Table 5). Those with high-SRL ability had better reading comprehension than those with low-SRL ability. The effects of SRL ability on sustained attention in the experimental group were further discussed. The sustained attention of the high-SRL group was significantly higher than that of the low-SRL group by the independent samples *t*-test ($t = 4.701$, $p = 0.000 < 0.05$). That is, SRL ability affected the sustained attention of learners in the experimental group.

Correlation analysis of reading comprehension, sustained attention, and five SRL indexes in the experimental group

Pearson product-moment correlation was applied to analyze the strength correlations among reading comprehension, sustained attention and the performance on the five SRL indexes for learners in the experimental group. The sustained attention index, measured directly by the EEG,

was omitted from analysis because it had the same value as the attention value identified by MindSet earphone. Experimental results show that strong positive correlations ($r = 0.683$, $p = 0.000 < 0.05$) existed between reading comprehension and sustained attention, and between reading comprehension and the effort index ($r = 0.521$, $p = 0.000 < 0.05$), the learning time achievement index ($r = 0.626$, $p = 0.000 < 0.05$) and learning ability index ($r = 0.545$, $p = 0.000 < 0.05$) but not between reading comprehension and the reading index (Table 6). Learners in the experimental group with good reading comprehension had higher sustained attention, effort level, learning time achievement and learning ability. Moreover, strong correlations existed between sustained attention and the effort index ($r = 0.550$, $p = 0.000 < 0.05$) and learning time achievement index ($r = 0.644$, $p = 0.000 < 0.05$) in the experimental group. The correlations were logical because the effort index and learning time achievement index were all attention-based SRL indexes mainly determined by effective reading time, which was detected by the attention value from the MindSet earphone.

As reading comprehension and sustained attention in the experimental group were strongly correlated, linear regression analysis was further applied to confirm whether sustained attention can successfully predict reading comprehension performance. The results show that sustained attention can effectively predict the reading comprehension performance and explained as much as 46.64% of the variance in the reading comprehension performance (Table 7). The linear regression equation was [reading comprehension performance = 2.005 × sustained attention − 58.696].

Table 6: Correlation analysis of the reading comprehension performance, sustained attention, and various SRL indexes in the experimental group

	Reading comprehension performance		*Sustained attention*	
	Pearson correlation	*Significance (two tailed)*	*Pearson correlation*	*Significance (two tailed)*
Reading comprehension performance	1		0.683***	0.000
Sustained attention index	0.683***	0.000	1	
Effort index	0.521***	0.000	0.550***	0.000
Reading index	0.100	0.437	0.199	0.117
Learning time achievement index	0.626***	0.000	0.644***	0.000
Learning ability index	0.545***	0.000	0.193	0.130

*** indicates $p < 0.001$.

Table 7: Linear regression analysis of the reading comprehension performance and sustained attention in the experimental group

Model summary			*Nonstandardized coefficient*		*Standardized coefficient*		
Selected variable	R	R^2	*Estimated* β	*Standard error*	*Beta distribution*	t	*Significance*
(Constant)	0.683	0.4664	−58.696	17.760	0.683	−3.305**	0.002
Attention			2.005	0.274		7.309***	0.000

** indicates $p < 0.01$; *** indicates $p < 0.001$.

Table 8: Correlation analysis of the reading comprehension performance and sustained attention in the control group

	Posttest result			*Sustained attention*		
	Pearson correlation	*Significance (two tailed)*	*Number of learners*	*Pearson correlation*	*Significance (two tailed)*	*Number of learners*
Reading comprehension performance	1		63	0.193	0.129	63
Sustained attention	0.193	0.129	63	1		63

Correlation analysis of the reading comprehension and sustained attention in the control group
Compared with the correlation analysis results in the experimental group, this study found that no significant correlations existed between reading comprehension performance and sustained attention in the control group (Table 8). The results show that learners in the control group were likely to be idle and distracted while reading annotated English texts online, such that reading comprehension and sustained attention were not correlated, despite the fact that learners were interested in the content and appeared to participate. Obviously, the ASRLM support may be the key factor such that significant correlations between sustained attention and reading comprehension in the experimental group learners existed when reading the annotated English texts online.

Discussion

This study shows that learners with ASRLM support when reading annotated English texts online actively set individual SRL goals based on their predetermined learning goals. Moreover, learners adjusted these SRL goals according to their previous learning conditions when logging into the system again. Furthermore, this study found that monitoring and reminding by the ASRLM can help learners achieve SRL goals. Additionally, learners more actively read online, enhancing their reading performance and achievement of goals due to the feedback of SRL radar chart. Experimental results demonstrate that the experimental group had significantly better reading comprehension than the control group, proving that the ASRLM promoted reading comprehension. Past research proposed an SRL cycle with the four steps of self-evaluation and monitoring, goal setting and strategic planning, strategy implementation and monitoring, and strategy outcome monitoring, which could assist learners in enhancing their learning performance (Boekaerts, 1997; Pintrich, 2000; Zimmerman & Schunk, 2001). Additionally, Chen (2009) proposed a SRL system for effective mathematics learning on a PELS. This study proves that the web-based reading annotations system with ASRLM support assisted learners in sustaining their attention and promoting reading comprehension when reading online. The reading comprehension of females with ASRLM support was better than that of males with ASRLM support. That is, a gendered difference in reading comprehension with ASRLM support exists. Several previous studies also claimed that male and female learners used SRL strategies differently during their learning processes (Lee, 2002; Wolters & Pintrich, 1998; Zimmerman & Martinez-Pons, 1990). Zimmerman and Martinez-Pons (1990) determined that girls typically employed self-monitoring, goal setting, planning and structured their study environments more often than boys. Wolters and Pintrich (1998) confirmed the existence of gender differences in motivational and cognitive strategies during SRL. Lee (2002) also indicated that gender differences in motivational and behavioral learning strategy components existed in cyber-learning contexts.

The study also found that learners would set various SRL indexes according to their abilities before reading annotated English texts online and adjust their SRL goals according to previous

learning conditions when logging into the system again. During online reading, learners would pay more attention to reading learning because of their self-regulation goals set on the SRL radar chart and the attention reminder under the chart. Experimental results show that significant differences in sustained attention existed between the two groups, and the experimental group was better than the control group. The ASRLM enhanced the sustained attention of learners. Moreover, the ASRLM support for online reading assisted both genders in sustained attention, but gender did not affect the promotion of sustained attention. However, female learners had better sustained attention than male learners, revealing the gender difference. In terms of SRL abilities of learners in the experimental group, reading comprehension performance of the high-SRL group was higher than that of the low-SRL group, as was sustained attention. Obviously, SRL also involves metacognitive skills, that is, understanding one's own cognitive skills, including memory, attention and problem solving, enabling learners to make the best use of their knowledge and skills (Flavell, 1979; Pressley, 1995).

Reading comprehension and sustained attention in the experimental group were strongly correlated. In other words, learners with high reading comprehension performance had higher sustained attention than learners with low reading comprehension performance. This finding is consistent with that of Lam and Beale (1991) for normally developing children, indicating that attention factor ratings were strongly correlated with reading comprehension scores. Moreover, Margolis (1972) also found a strong relationship between sustained attention and reading achievement test scores. Nevertheless, reading comprehension and sustained attention in the control group were not correlated. It is obvious that using the ASRLM to support online reading of English annotated texts was the key factor in the correlation between reading comprehension and sustained attention.

Reading comprehension in the experimental group was correlated with the self-regulated index scores for sustained attention, effort, learning time achievement and learning ability. Obviously, learners paid more sustained attention to online reading when monitored and reminded by the ASRLM. Sustained attention was strongly correlated with the SRL index values for effort and learning time achievement, revealing that learners with good sustained attention had good effort and long effective learning time. These results are consistent with those in several studies (Harnishferger, 1995; Kuhl, 1985; Winne, 1995). Winne's (1995) study indicated that learners had to be able to control their sustained attention in order to perform good SRL. Harnishferger (1995) claimed that sustained attention control was a cognitive process requiring significant self-monitoring. Additionally, Kuhl's (1985) study confirmed that students' academic outcomes increased with focused time spent on task.

Conclusions and future work

Based on use of the ASRLM, which was developed with EEG detection technology, to assist students reading annotated English texts online, this instructional experiment proves that ASRLM support enhances reading comprehension and sustained attention. Compared with male learners, analytical results show that the ASRLM provides more significant benefits for reading comprehension and sustained attention for female learners. Moreover, the ASRLM simultaneously enhanced the sustained attention of both genders. High-SRL learners with ASRLM support for reading annotated English texts online had better reading comprehension and sustained attention than low-SRL learners. Also, sustained attention and reading comprehension of learners in the experimental group were strongly correlated. Importantly, the sustained attention and reading comprehension of learners in the experimental group had a linear regression relationship with favorable predictability, showing the learners with high sustained attention had good reading comprehension performance. Conversely, the sustained attention and reading comprehension performance of learners in the control group were not strongly correlated. Additionally,

reading comprehension and scores on the SRL indexes for sustained attention, effort, learning time achievement and learning ability of the learners in the experimental group were strongly correlated. Thus, learners with good reading comprehension had a high effort level, long effective learning time and good learning ability. Sustained attention and scores of SRL indexes for effort and learning time achievement were strongly correlated, indicating that learners with good sustained attention expended considerable effort and effective learning time when reading online.

Additional studies are warranted. First, participants could be expanded to primary school students, senior high school students or college students to confirm whether participants with different academic levels generate different outcomes when reading online with and without ASRLM support for English annotated texts. Moreover, the learning period for online reading of English annotated texts could be extended to observe SRL variations, such that observations are close to real web-based learning conditions. Furthermore, physiological signal detection technology for determining attention-based SRL indexes could be integrated with other sensing technologies, such as video monitoring and recognition, eye-tracking and behavior monitoring and identification, to more precisely detect learners' learning behaviors and enhance the accuracy of SRL detection. Moreover, the proposed ASRLM could also be implemented on mobile devices, like tablet PCs, and mobile phones, to achieve ubiquitous learning with SRL support. Finally, the participants who have the SRL abilities that are higher and lower than the average SRL ability are respectively identified as high-SRL group and low-SRL group in this study. Further work can consider identifying high-SRL group and low-SRL group by a more extreme approach than such as identifying the participants with highest SRL abilities (top 27%) as high-SRL group and lowest SRL abilities (lowest 27%) as low-SRL group.

References

Azevedo, R., Cromley, J. G. & Seibert, D. (2004). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? *Contemporary Educational Psychology*, *29*, 344–370.

Baker, F. B. (1992). *Item response theory: parameter estimation techniques*. New York: Marcel Dekker.

Belle, A., Hargraves, R. H. & Najarian, K. (2012). An automated optimal engagement and attention detection system using electrocardiogram. *Computational and Mathematical Methods in Medicine*, 1–12.

Bi, L. & Fan, X. (2011). Emotion recognition from EEG based on Bayesian networks. *Energy Procedia*, *11*, 278–285.

Boekaerts, M. (1997). Self-regulated learning: a new concept embraced by researchers, policy makers, educators, teachers, and students. *Learning and Instruction*, *7*, 161–186.

Boersma, H. & Das, J. P. (2008). Attention, attention rating and cognitive assessment: a review and a study. *Developmental Disabilities Bulletin*, *36*, 1&2, 1–17.

Broadbent, D. E. (1958). *Perception and communication*. London: Pergamon press.

Butler, D. B. & Winne, P. H. (1995). Feedback and self-regulated learning: a theoretical synthesis. *Review of Education Research*, *65*, 3, 245–281.

Chang, M. M. (2005). Applying self-regulated learning strategies in a web-based instruction: an investigation of motivation perception. *Computer Assisted Language Learning*, *18*, 3, 217–230.

Chen, C. M. (2009). Personalized e-learning system with self-regulated learning assisted mechanisms for promoting learning performance. *Expert Systems with Applications*, *36*, 5, 8816–8829.

Chen, C. M. & Sun, Y. C. (2012). Assessing the effects of different multimedia materials on emotions and learning performance for visual and verbal style learners. *Computers & Education*, *59*, 4, 1273–1285.

Chen, C. M. & Wang, H. P. (2011). Using emotion recognition technology to assess the effects of different multimedia materials on learning emotion and performance. *Library & Information Science Research*, *33*, 244–255.

Chen, C. M., Wang, J. Y. & Chen, Y. C. (in press). Facilitating English-language reading performance by a digital reading annotation system with self-regulated learning mechanisms. *Educational Technology & Society*.

Chen, Y. C., Hwang, R. H. & Wang, C. Y. (2012). Development and evaluation of a Web 2.0 annotation system as a learning tool in an e-learning environment. *Computers & Education*, *58*, 4, 1094–1105.

Chi, M. T. H., DeLeeuw, N., Chiu, M. & LaVancher, C. (1994). Eliciting self explanation improves understanding. *Cognitive Science*, *18*, 3, 439–477.

Corno, L. (1993). The best-laid plans: modern conceptions of volition and educational research. *Educational Researcher*, *22*, 14–22.
Das, J. P. (1986). *Attention checklist*. Edmonton, Canada: J. P. Das Developmental Disabilities Center, University of Alberta.
Driver, J. (2001). A selective review of selective attention research from the past century. *British Journal of Psychology*, *92*, 53–78.
Egner, T. & Gruzelier, J. H. (2004). EEG biofeedback of low beta band components: frequency-specific effects on variables of attention and event-related brain potentials. *Clinical Neurophysiology*, *115*, 131–139.
Flavell, J. (1979). Metacognition and cognitive monitoring: a new area of cognitive development inquiry. *American Psychologist*, *34*, 906–911.
Gerě, I. & Jaušcvec, N. (1999). Multimedia: differences in cognitive processes observed with EEG. *Educational Technology Research and Development*, *47*, 3, 5–14.
Goh, T. T., Seet, B. C. & Chen, N. S. (2012). The impact of persuasive SMS on students' self-regulated learning. *British Journal of Educational Technology*, *43*, 4, 624–640.
Groner, R. & Groner, M. T. (1989). Attention and eye movement control: an overview. *European Archives of Psychiatry and Neurological Sciences*, *239*, 1, 9–16.
Hannafin, M. J. & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science*, *25*, 167–202.
Hardy, J. L., Drescher, D., Sarkar, K., Kellett, G. & Scanlon, M. (2011). Enhancing visual attention and working memory with a web-based cognitive training program. *Mensa Research Journal*, *42*, 2, 13–20.
Harnishferger, K. K. (1995). The development of cognitive inhibition: theories, definitions, research. In F. N. Dempster & C. J. Brainerd (Eds), *Interference and inhibition in cognition* (pp. 176–206). San Diego: Academic Press.
Hinton, C., Miyamoto, K. & Della Chiesa, B. (2008). Brain research, learning, and emotions: implications for education research, policy, and practice. *European Journal of Education*, *43*, 87–103.
Hsu, C. C., Chen, H. C., Su, Y. N. & Huang, K. K. (2012). Developing a reading concentration monitoring system by applying an artificial bee colony algorithm to e-books in an intelligent classroom. *Sensors*, *12*, 10, 14158–14178.
Jacobson, M. & Archodidou, A. (2000). The design of hypermedia tools for learning: fostering conceptual change and transfer of complex scientific knowledge. *Journal of the Learning Sciences*, *9*, 149–199.
James, W. (1983). *The principles of psychology*. New York: Holt.
Jensen, A. R. (1998). *The g factor: the science of mental ability*. Westport, CT: Praeger.
Kilseop, R. & Rohae, M. (2005). Evaluation of mental workload with a combined measure based on physiological indices during a dual task of tracking and mental arithmetic. *International Journal of Industrial Ergonomics*, *35*, 11, 991–1009.
Kuhl, J. (1985). Volitional mediators of cognition–behavior consistency: self-regulatory processes and action versus state orientation. In J. Kuhl & J. Beckman (Eds), *Action control: from cognition to behavior* (pp. 101–128). New York: Springer.
Lam, C. M. & Beale, I. L. (1991). Relations among sustained attention, reading performance, and teachers' ratings of behavior problems. *Remedial and Special Education*, *12*, 40–47.
Lee, I. S. (2002). Gender differences in self-regulated on-line learning strategies within Korea's University context. *Educational Technology Research and Development*, *50*, 1, 101–109.
Ley, K. & Young, D. (2001). Instructional principles for self-regulated learning. *Educational Technology, Research and Development*, *49*, 2, 93–102.
Lezak, M. D., Howieson, D. B. & Loring, D. W. (2004). *Neuropsychological assessment* (4th ed.). New York: Oxford university press.
Li, X., Zhao, Q., Liu, L., Peng, H., Qi, Y., Mao, C. *et al* (2010). Improve affective learning with EEG approach. *Computing and Informatics*, *29*, 557–570.
Margolis, J. (1972). *Academic correlates of sustained attention*. Unpublished doctoral dissertation, University of California, Los Angeles.
Marshall, C. C. (1998). Toward an ecology of hypertext annotation. *The ninth ACM conference on hypertext and hypermedia: links, objects, time and space—structure in hypermedia systems: links, objects, time and space—structure in hypermedia systems*, 40–49.
Moradi, F., Buračas, G. T. & Buxton, R. B. (2012). Attention strongly increases oxygen metabolic response to stimulus in primary visual cortex. *Neuroimage*, *59*, 1, 601–607.
Mory, E. H. (2003). Feedback research revisited. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology: a project of the Association for Educational Communications and Technology* (2nd ed.). (pp. 745–783). Mahwah, NJ: Lawrence Erlbaum.

NeuroSky MindWave (2011). Retrieved December 4, 2011, from http://press.neurosky.com/MindWave.html

Nideffer, R. M. (1976). Test of attentional and interpersonal style. *Journal of Personality and Social Psychology*, *34*, 3, 394–404.

Niemi, H., Nevgi, A. & Virtanen, P. (2003). Towards self-regulation in web-based learning. *Journal of Educational Media*, *28*, 49–71.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds), *Handbook of self-regulation* (pp. 451–502). San Diego, CA: Academic Press.

Pintrich, P. R. & DeGroot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*, 1, 33–40.

Pressley, M. (1995). More about the development of self-regulation: complex, longterm and thoroughly social. *Educational Psychologist*, *30*, 4, 207–212.

Rapp, D. N. (2006). The value of attention aware systems in educational settings. *Computers in Human Behavior*, *22*, 4, 603–614.

Rau, P. L. P., Chen, S. H. & Chin, Y. T. (2004). Developing web annotation tools for learners and instructors. *Interacting with Computers*, *16*, 163–181.

Rebolledo-Mendez, G., Dunwell, I., Martínez-Mirón, E., Vargas-Cerdán, M., de Freitas, S., Liarokapis, F. *et al* (2009). Assessing NeuroSky's usability to detect attention levels in an assessment exercise. In: HCI, New Trends, 149–158.

Richards, J. E. & Casey, B. J. (1991). Heart rate variability during attention phases in young infants. *Psychophysiology*, *28*, 43–53.

Roda, C. & Thomas, J. (2006). Attention aware systems: theories, applications, and research agenda. *Computers in Human Behavior*, *22*, 4, 557–587.

Roscoe, R. D., Segedy, J. R., Sulcer, B., Jeong, H. & Biswas, G. (2013). Shallow strategy development in a teachable agent environment designed to support self-regulated learning. *Computers & Education*, *62*, 286–297.

Sarter, M., Givens, B. & Bruno, J. P. (2001). The cognitive neuroscience of sustained attention: where top-down meets bottom-up. *Brain Research Reviews*, *35*, 146–160.

Shih, K. P., Chang, C. Y., Chen, H. C. & Wang, S. S. (2005). A self-regulated learning system with scaffolding support for self-regulated e/m-learning. *The 3rd IEEE international conference on information technology: research and education*, 30–34.

Sohlberg, M. M. & Mateer, C. A. (1989). *Introduction to cognitive rehabilitation*. New York, NY: Guilford Press.

Solso, R. L. (1995). *Cognitive psychology* (4th ed.). Boston: Allyn and Bacon.

Steinmayr, R., Ziegler, M. & Träuble, B. (2010). Do intelligence and sustained attention interact in predicting academic achievement? *Learning and Individual Differences*, *20*, 14–18.

Su, A. Y. S., Yang, S. J. H., Hwang, W. Y. & Zhang, J. (2010). A Web 2.0-based collaborative annotation system for enhancing knowledge sharing in collaborative learning environments. *Computers & Education*, 55, 2, 752–766.

Toet, A. (2006). Gaze directed displays as an enabling technology for attention aware systems. *Computers in Human Behavior*, *22*, 4, 615–647.

Wager, T. D., Jonides, J. & Reading, S. (2004). Neuroimaging studies of shifting attention: a meta-analysis. *NeuroImage*, *22*, 1679–1693.

Wilson, G. F. (2002). An analysis of mental workload in pilots during flight using multiple psychophysiological measures. *International Journal of Aviation Psychology*, *12*, 1, 3–18.

Winne, P. H. (1995). Inherent details in self-regulated learning. *Educational Psychologist*, *30*, 173–188.

Winne, P. H. & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds), *Matecognition in educational theory and practice* (pp. 277–304). Hillsdale, NJ: Erlbaum.

Wolfe, J. (2002). Annotation technologies: a software and research review. *Computers and Composition*, *19*, 4, 471–497.

Wolfe, J. (2008). Annotations and the collaborative digital library: effects of an aligned annotation interface on student argumentation and reading strategies. *International Journal of Computer-Supported Collaborative Learning*, *3*, 2, 141–164.

Wolters, C. A. & Pintrich, R. (1998). Contextual differences in student motivation and self-regulated learning in mathematics, English, and social studies classrooms. *Instructional Science*, *26*, 27–47.

Yukselturk, E. & Bulut, S. (2009). Gender differences in self-regulated online learning environment. *Educational Technology & Society*, *12*, 3, 12–22.

Zhang, W. & Lu, J. (2009). The practice of affective teaching: a view from brain science. *International Journal of Psychological Studies*, *1*, 1, 35–41.

Zimmerman, B. J., Bonner, S. & Kovach, R. (1996). *Developing self-regulated learner: beyond achievement to self-efficacy*. Washington, DC: American Psychological Association.
Zimmerman, B. J. & Martinez-Pons, M. (1990). Student differences in self-regulated learning: relating grade, sex, and giftedness to self-efficacy and strategy use. *Journal of Educational Psychology*, *82*, 1, 51–59.
Zimmerman, B. J. & Schunk, D. H. (2001). Reflections on theories, identities, and actions of self-regulated learners. In B. J. Zimmerman & D. H. Schunk (Eds), *Self-regulated learning and academic achievement: theoretical perspectives* (pp. 289–307). Mahwah, NJ: Lawrence Erlbaum.