ABSTRACT

Most courses based on distance learning focus on the cognitive domain of learning. Because students are sometimes inattentive or tired, they may neglect the attention goal of learning. This study proposes an auto-detection and reinforcement mechanism for the distance-education system based on the reinforcement teaching strategy. If a student is detected to be inattentive or fatigued, then the alert reinforcement feedback window is given; if the attentive time in learning has been reached, then encouraging reinforcement feedback is given. In distance education, the teacher could maintain the learning quality of students through this mechanism. Results of the simulative test and class experiment indicate that this mechanism detects the behavior of students with high accuracy. In other words, it can accurately identify learners who are inattentive or fatigued. The proposed mechanism can urge the inattentive learners to achieve the Attending Teaching goal, according to a comparison of results before and after the experimental class obtained from questionnaires and interviews. However, we also found that the mechanism could not effectively alleviate mental fatigue resulting from physiological exhaustion. Therefore, students who feel fatigued must be required to learn in a better mental state to avoid wasting time and learning without satisfying effects. This work presents a detection reinforcement mechanism and teaching procedure designed from the perspective of an Affective Domain Teaching Objectives. The proposed mechanism can accurately detect inattentiveness in students, thus helping teachers of distance education courses to handle the students’ learning conditions.

Keywords

Distance education, Image processing, Computer-based assessment, Affective domain teaching objectives

Introduction

Distance education enables learners to learn anytime and anywhere. In an attempt to meet the needs of the public in learning, various distance education websites, including teaching materials, teaching platforms, on-demand videos, etc., have been constructed in schools of different levels and related education institutes (Harasim, Hiltz, Teles, & Turoff, 1995). Students can access the websites freely, and decide for themselves how much time they wish to spend learning online. They can earn credits as long as the learning prescribed by the course is completed during a specified period and the related reports are handed in or the assessments are completed.

However, students might log in to an online course when they are fatigued or inattentive. Because the students are far away and out of the teacher’s control, teachers cannot effectively supervise students with poor self-discipline. The circumstances in which students need to learn by distance learning include suspension of classes because of an outbreak of an infectious disease, absence from school due to illness, or famous teachers (at home or overseas) being invited to give lessons through distance-learning technologies. Some students, especially pupils, might not have strong learning motivation or high self-control when their parents are too busy to supervise them. The students might not learn effectively when they are logged into the system. They might leave their seats to do something else or fall asleep. Teachers and parents cannot easily control the students’ learning environment, especially for younger students who are more easily distracted by environmental factors. The accumulated hours of attending the class cannot guarantee that students are learning attentively. Therefore, even if the student is distracted or feels fatigued after he or she has logged into the system, the teacher has no way of knowing this, and has no way of encouraging the student to learn attentively. Since the student has completed the required number of hours and has completed both the schoolwork and the assessment, the student can still earn the credit. Nevertheless, credits earned this way have little value. This is a common flaw of distance education (Mason, 1997; Rourke, Anderson, Garrison, & Archer, 2001).

If the student has neither left midway during the class, nor had another person attend the class as a substitute, but is learning attentively without feeling fatigued, then the accumulated class hours can be considered to have produced...
good learning effects, indicating that the distance education is of high quality. However, most current distance education research bases participation on the number of times a student contributes to a class discussion or the number of hours the student has spent in class (Pena-Shaff, Martin, & Gay, 2001). Satisfactory attendance and class hours are not equivalent to attentive participation (Mason, 1997). Hence, no technique is available to detect conveniently and precisely a distance-education student’s attention to learning.

Few studies have combined image recognition with the reinforcement mechanism in the distance education system. Webcams and image-recognition technology have been adopted to capture facial images in real time in order to detect fatigue in drivers (Eriksson & Papanikotopoulos, 1997; Grauman, Betke, Gips, & Bradski, 2001; Hamada, Ito, Adachi, Nakano, & Yamamoto, 2002). However, these techniques are mostly used to detect fatigue. Because the detection conditions are different from those of distance education, these techniques could not be applied to distance education directly. Furthermore, inattentive learning in distance education includes not only fatigue, but also other inattentive behavior, which must be assessed comprehensively before it can be judged. Effective management of the learning conditions of students in a distance education environment will help solve the problem by detecting students’ inattention and fatigue, and thus maintain good learning quality.

The conditions of students can be detected precisely by integrating these techniques with the development of the detection and reinforcement mechanism for distance education. After conducting Bayesian network assessment, if a student is found to be inattentive or fatigued, then the alert feedback is sent instantly (Grauman et al., 2001; Hamada et al., 2002). Additionally, encouraging feedback is sent if the learning attention of the student has lasted a period of time. The learning conditions of all students are recorded to promote good behavior in distance education students with above reinforcement principle, so that the teacher could also take hold of the attending condition of the students in class in order to achieve the learning attendance goal. Students who want to earn the degree or credit through examination would necessarily study hard. Students with a lower level of self-control would need to be supervised by teachers or parents. However, teachers and parents cannot always supervise. The distance education system needs the assistance of a reinforcement mechanism when students learn passively in distance education.

According to the teaching theory of operant conditioning, the application of a reinforcement principle in class can ensure that the learning behavior of the students is supervised and handled well (Goge & Broiler, 1992; Woalfolk, 1997). However, in distance education, since a teacher cannot easily observe the learning condition of students, teachers encounter difficulty in applying the reinforcement principle to encourage good learning behavior. Because elementary-school students might easily be distracted by the environment, or doze off, distance education cannot yet replace classroom education. Currently, distance education is mostly provided for adults or as remedial teaching, since it requires students to be in a good learning state to achieve optimum learning results. In this study, image processing and detection techniques enable distance-education teachers to manage the students’ learning condition. Remedying the defect of traditional distance education, which hinders teachers’ ability to take hold of the learning condition of students, means that the interaction in distance education courses becomes much more like that in traditional classes. Moreover, detection reinforcement mechanisms and teaching procedures are also designed to cope with the existing defects of distance education from the perspective of the Affective Domain Teaching Objectives. In addition to improving the accuracy of the detection mechanism and the actual learning attending effects of the reinforcement mechanism, detection simulation and class experiment also help distance education courses achieve good learning attendance. This work focuses on detecting inattention and fatigue in students, but not on the reasons for these behaviors. Hence, the detection process does not attempt to discriminate among detailed behavior. Teachers would need to perform such detailed detection.

Section II explores the operant conditioning theory, reinforcement strategy and image recognition technique. Section III discusses the design of the auto-detection and reinforcement mechanism, as well as the detection, recognition and reinforcement procedures for distance education. Section IV analyzes the auto-detection and reinforcement mechanism based on a practical simulative test and experiment class. Section V discusses the evaluation results and studies the effects of the mechanism on students’ attentiveness to learning in class. The final section draws conclusions and makes suggestions for future research.

**Literature review**

Many scholars have asserted that the Affective Domain Teaching Objectives must not be neglected when enhancing learning effects and cultivating a healthy personality (Gagne, Briggs, & Wager, 1985). The following purposes can
be deduced from the Affective Domain Teaching Objectives and the time to achieve goals at each stage: the learning objectives of each class period for achieving the attending and responding stage, the objectives of every unit course for obtaining the evaluation and organizing stage, and the objectives of a semester or academic year for achieving the characterizing stage (Lefrancois, 1982).

The reinforcement teaching strategy consolidates learning behavior by employing positive or negative stimuli in accordance with the behavior of the student (Martin & Briggs, 1986). The two reinforcements proposed in the operant conditioning learning theory are positive reinforcement and negative reinforcement. Positive reinforcement gives the student a positive incentive for desirable behavior, while negative reinforcement withdraws a desirable incentive as a result of undesirable behavior. Positive reinforcement is equal to a reward, while negative reinforcement is equal to punishment (Hilgard, 1962; Holt, B. J., & Hannon, J. C., 2006). Thus, giving a student instant feedback with the reinforcement teaching strategy, according to the response of the student, can achieve the learning attendance goal (Anderson, 1981; Saltz et al., 2007).

In applying the reinforcement strategy of operant conditioning in distance education activities, the distance factor prevents teachers from controlling the learning condition of the remote student and giving suitable incentives. Encouraging distance education learners to achieve the expected learning goal involves first detecting fatigued and inattentive behavior of the students participating in class. Besides blinking, yawning, wrinkling caused by yawning, and failing to look straight at the screen as the result of fatigue, inattentive behaviors such as leaving the seat, turning one’s head for chatting or running other application programs can also be detected by image recognition and detection (Eriksson & Papanikotopoulos, 1997; Gu & Ji, 2004; Wang, P., Tran, L. C., & Ji, Q., 2006).

For instance, a human figure can be easily distinguished from the background through the brain’s cognition of human features. Computer vision can adopt similar logic to the brain to obtain a correct facial region. Results of face image binarizing show that the pixels at the corner of the mouth are darker than those in the surrounding regions of the face. This property can be used to identify the possible location of the mouth (Ito, Mita, Kozuka, Nakano, & Yamamoto, 2002; Lee, Park, & Park, 2005; Smith, Shah, & Lobo, 2004). The following physiological responses are signs that a learner is fatigued: eyes closing; failure to look straight ahead; yawning; head turning right and left, and wrinkling between the eyes and above the nose due to yawning (Gu & Ji, 2004). Image recognition can be utilized to obtain some information quickly from facial expressions. For example, the darkest spots found by grayscale manipulation in the possible eye region, and adjusting the appropriate threshold value can be adopted to locate the pupils (Stiefelhagen, Yang, & Waibel, 1996). The eyes can be located from the location of the pupils (Lee et al., 2005; Miyakawa, Takano, & Nakamura, 2004). The eye-blinking variation can be calculated from the part with larger variation by capturing two successive images, then performing gray scale processing and image difference (Grauman et al., 2001).

A Bayesian network is a graphical decision-making tool. Haisong found that the Bayesian network is the best option to deal with such an issue of mental detection (Gu & Ji, 2004). Besides, the Bayesian network could be applied for evaluating or predicting the learning behavior of the distance education students (Xenos, 2004).

These image recognition and detection techniques could be used to recognize fatigued and inattentive behavior in a learner. Bayesian network assessment can reduce detection misjudgment and enhance accuracy. Such a mechanism in distance education could be applied to detect attentiveness of learners. Providing instant feedback in the reinforcement teaching strategy could help a teacher to supervise the students and prevent the students from being distracted, thus achieving the learning attentiveness goal.

**Design and implementation of inattention/fatigue detection system**

In the detection mechanism of this research, the images (15 images/sec.) captured with the webcam were collected for image detection processing. First, the system extracts the skin-color area, and defines the facial feature locations such as the eyes and lips. The system then employs different algorithms to find the feature variations. For instance, consider the features of the eyes. The system needs to decide whether the image is of a closed or open eye. For the mouth feature, the system must determine whether the image is of a stretched mouth. Next, the system must categorize and recognize these image processing results to detect whether the learner is inattentive, fatigued or dozing in class. These features are then assessed with the Bayesian network model. Based on the assessment results,
if the student is determined to have “inattentive behavior” or “feelings of fatigue,” then an alert is transmitted instantly to notify the teacher. The system then captures the real-time image, and delivers it to the server end. This is to record the student’s image and detected condition, so that the teacher can browse and check online.

In this investigation, “inattentive behavior” indicates something irrelevant to the course that a student is doing when not feeling fatigued. “feelings of fatigue” indicates that feeling mentally fatigued in learning owing to physiological exhaustion; characteristic behaviors include drowsiness and raised eye-blinking frequency.

Figure.1. Detection and recognition procedure
Detection procedure

Figure 1 shows the entire operation procedure of the detection and reinforcement mechanism. First, the face image is obtained from successive input images. If the width of the face is determined to be larger than the length of the face, then either the region obtained is probably not a human face or part of the background has a similar color to skin. After obtaining the face region, the image is horizontally segmented into equal parts. The eyes’ features can then be obtained from the top half image, and the mouth’s corner features from the bottom half-image. Next, after obtaining the mouth’s corners features, the middle coordinate of the mouth corners are utilized to segment the top half of the face into left and right parts. This is done for two reasons. The first is to shorten the processing time, and thus increase the accuracy of the eye features obtained. The second reason is that, the left eye and right eye can generally be separated into two independent images if the middle coordinate of the mouth can be obtained correctly, and if the vertical axis of this coordinate is adopted to segment the image.

In tracking eyes, the fast movement of the user, or the change in illumination in the searching space, might lead to gradual deviation in the eye template matching. Hence, the movement bound has to be defined. The coordinates of the horizontal or vertical axis between two successive images are compared when the tracing result is obtained. Tracking deviation is defined as a difference exceed in. The system needs to perform the detection again to prevent further feature misjudgments. In tracking the mouth location, the mouth coordinate location of the input image can be discovered merely from the variation of the movement of the eye features between two successive images.

In the successive image time duration, the user’s inattentive/fatigue behavior in every image can be identified, respectively. However, since the actual condition of the user cannot be inferred from only a single image, a second threshold must be defined. The first threshold indicates that the image time is an interval (T1), and the second threshold defines the number of alert events in this interval (T2). In the interval of T1, if the number of alert events exceeds T2, then the system sends an alert message that the learner might be distracted or fatigued. This study defines more than 15 images showing a user distracted or fatigued detected in the time interval of 30 images as evidence of inattentive behavior or feelings of fatigue. These two thresholds are defined because a fatigued person generally yawns for at least two seconds at a time. Because the system captures and detects 10 to 15 images per second, the time for detecting 30 images is about 2 to 3 seconds. If either inattentive behavior or feelings of fatigue is detected, then the system sends the alarm feedback message automatically to the student. Time with no detected inattentive or fatigued behavior is counted. The system sends a positive feedback message to a student automatically if five minutes pass with no inattentive or fatigued behavior.
Bayesian network assessment

A Bayesian network model was constructed in accordance with the variation probability of the learners’ facial expressions and behavior features for assessing whether a learner is with inattentive behavior or feelings of fatigue. The classified inattentive behavior features are defined as the two modes of learner leaving and inattention. “Learner leaving” indicates a student not sitting in front of the computer. “Inattention” might be the result of the learner using other application programs or gazing around, rather than concentrating on learning. For example, the behavior of leaving one’s seat after starting the system, turning one’s head for chatting or watching other things, or running other application programs at the same time, could directly affect the learning quality of a learner. Feelings of fatigue is defined as “Drowsiness” and “Falling Asleep.” The occurrence of drowsiness is defined by one of three occurrences: head nodding, eyes closing and yawning. Falling asleep is defined as eyes closed or head nodding as a result of dozing. Figure 2 illustrates the node causalities of these mental conditions.

Two thresholds for the eye-opening size are defined. If the detected result is less than the first threshold, then the student is detected to be in the state of drowsiness. If the detected result is lower than the second threshold, then the student is detected as having fallen asleep. “Head Turn” is detected according to the frequency of head turning. If a student turns his head or nods with a fixed frequency, he is detected as being in a state of having fallen asleep or in drowsiness. If the student turns his head to the fixed direction, then he is detected to be in a state of inattention.

System interface

Figure 3 depicts the system implementation interface, which includes the source image window, image processing window, image recording window, and the related control items of computer detection. The learner only needs to install and put the webcam above the computer screen and start the system to begin running the core programs. Figure 4 plots the image detection results. The horizontal axis represents the image time, and the vertical axis indicates the probability of inattentive behavior or feelings of fatigue. The system warns the user with sound effects once the number of inattentive or fatigued behaviors exceeds the threshold. Finally, the images and conditions are recorded in the server database for the teacher to check online. The system does not need to transmit all the images of a student to the server for processing. Therefore, problems with network bandwidth and server performance can be
avoided. Image processing is performed by the client computer. The system captures a face image of a student, and sends it to the server for recording only when the student is detected to have inattentive or fatigued behavior.

Methodology

Particulars

In this research, sixty sixth-grade students from elementary schools were sampled randomly and divided into two groups, with thirty students in each group. Because of the limited equipment in the experiment environment, only 30 personal computers were simultaneously available for the experiment. A computer classroom was employed as the test environment to simplify the simulation of possible behavior of students in distance learning. This is because the same learning situations experienced at home, such as chatting with other people, being inattentive, or feeling fatigued, are also found in a computer classroom. Additionally, the environment in a computer classroom can easily be changed to improve the detection accuracy. If the home environment is taken as the test environment, then the home light and background must be considered, and help from parents necessary. Although 100 percent accuracy cannot be achieved, adopting the Bayesian network assessment could reduce the incidence of detection misjudgments. To simulate the conditions of the distance education course and avoid the teacher affecting learning by students in the computer classroom, the teacher was only allowed to sit at the front of the classroom during the course. The teacher was separated from the students, and was not permitted to have direct contact with students or correct students’ behavior directly. The teacher was not visible to the students, and so did not affect their behavior.

Design

Research assumption: Teachers of distance learning courses who use the proposed detection and reinforcement mechanism show significant differences in guiding and managing the learning attention of students:

A. Independent variable: the proposed detection and reinforcement mechanism for distance education
B. Dependent variable: learning attention of students during the simulative distance education courses, determined by using the proposed detection and reinforcement mechanism
C. Variable control: Because Round 1 was devised to survey inattentive behavior in students, the teacher was asked to sit in front of the class without interfering in class management. Round 2 was designed to survey the feelings of fatigue caused by spending long hours in class. To prevent the students from being affected by incentives of
other external factors, the courses were given in two continuous classes, and the teacher was required to actively manage the class. A possible cause of fatigue in class might be having played with classmates during break time.

**Procedure**

The investigation was split into two parts, with the simulative test performed in the first part and the teaching experiment performed in the second part.

*Table 1. Experiment of round 1 “Inattentive Behavior” process chart*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time</th>
<th>Teaching activities</th>
<th>System operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st part</td>
<td>0–5 mins.</td>
<td>Webcam adjustment</td>
<td>Simulative detection</td>
</tr>
<tr>
<td>2nd part Stage A</td>
<td>5–35 mins.</td>
<td>Teaching experiment course 1-1</td>
<td>Without starting the detection and reinforcement mechanism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teaching topic: The advantages and disadvantages of nuclear power plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>35–40 mins.</td>
<td>Filling in the questionnaire scale for the 1st time in response to Stage A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0–5 mins.</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>Stage B</td>
<td>5–35 mins.</td>
<td>Teaching experiment course 1-2</td>
<td>Starting the detection and reinforcement mechanism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teaching topic: The choice between the resource use and environmental protection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>35–40 mins.</td>
<td>Filling in the questionnaire scale for the 2nd time in response to Stage B</td>
<td></td>
</tr>
<tr>
<td>Stage C</td>
<td>After class</td>
<td>Interviewing ten students by random choice</td>
<td></td>
</tr>
</tbody>
</table>

*Table 2. Experiment of Round 2 “Feelings of Fatigue” process chart*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time</th>
<th>Teaching activities</th>
<th>System Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st part</td>
<td>0–5 mins.</td>
<td>Webcam adjustment</td>
<td>Simulative detection</td>
</tr>
<tr>
<td>2nd part Stage A</td>
<td>5–35 mins.</td>
<td>Teaching experiment course 2-1</td>
<td>Without starting the detection and reinforcement mechanism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teaching topic: The advantages and disadvantages of thermal power plant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>35–40 mins.</td>
<td>Filling in the questionnaire scale for the 1st time in response to Stage A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0–5 mins.</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>Stage B</td>
<td>5–35 mins.</td>
<td>Teaching experiment course 2-2</td>
<td>Starting the detection and reinforcement mechanism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teaching topic: Garbage classification and resource recycle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>35–40 mins.</td>
<td>Filling in the questionnaire scale for the 2nd time in response to Stage B</td>
<td></td>
</tr>
<tr>
<td>Stage C</td>
<td>After class</td>
<td>Interviewing ten students by random choice</td>
<td></td>
</tr>
</tbody>
</table>

In the first part, the simulative test, the students participating in the experiment were asked to imitate the feature behavior of inattentive behavior (e.g., learner leaving, turning head to chat) or feelings of fatigue (drowsiness or
falling asleep) as defined in this research. Actual detection was then performed by the system. Environment adjustments were made to factors such as light and image view to guard against misjudgment in accordance with the detection results and misjudgment probability, thereby lowering the probability of detection misjudgment.

Distance education allows students to learn anytime and anyplace. Thus, students are able to study with classmates, teachers or parents, or on their own. To simulate different situations, the second part was divided into two rounds, each lasting 80 minutes and comprising two class periods. Each round was divided into three stages: A, B, and C. Every student was required to complete Rounds 1 and 2. The detection and reinforcement mechanism were not run in stage A, but were run in stage B. Ten students, five in each group, were interviewed during stage C. Tables 1 and 2 present results of the interviews. Round 1 was designed to survey inattentive behavior among students when they were learning with classmates. In order to simulate an actual distance education situation in which no teacher is around to maintain class order, the teacher was required not to play any part in class discipline. Round 2 aimed at surveying feelings of fatigue and simulated studying in the presence of a teacher in a classroom or around parents at home. The teacher was required to actively maintain class order to prevent the students from interacting with each other and affecting the appearance of fatigue during the actual teaching procedure. Two continuous classes were given in each round.

Tools

The Likert scale is the most common adopted approach for evaluating the learning attention of students (Kubiszyn & Borich, 1996). Therefore, this work performed a survey based on a Likert scale to measure inattention and fatigue among students. Table 3 shows the questions and statements utilized in the survey. The students filled in the questionnaire after completing the two stages of teaching courses. The results of the questionnaires indicated the levels of inattention and fatigue of students in class.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inattentive behavior (Round 1)</td>
<td>1. I was attentive during class.</td>
</tr>
<tr>
<td></td>
<td>2. I have chatted with classmates or left my seat during class.</td>
</tr>
<tr>
<td></td>
<td>3. I have done something irrelevant during class.</td>
</tr>
<tr>
<td>Feelings of fatigue (Round 2)</td>
<td>4. I was energetic in class.</td>
</tr>
<tr>
<td></td>
<td>5. I felt fatigued.</td>
</tr>
<tr>
<td></td>
<td>6. I was dozing during class.</td>
</tr>
</tbody>
</table>

After, the experimental class of ten students was sampled randomly and interviewed with the following questions related to this research:

A-1. Under what circumstances were you inattentive during class?
A-2. Did the teacher’s warning feedback make you more attentive in class?
A-3. Did the teacher’s encouraging feedback make you more attentive in class?
B-1. When did you feel sleepy in class?
B-2. Did the teacher’s warning feedback refresh you in class?
B-3. Did the teacher’s encouraging feedback refresh you in class?

Reliability test

Thirty more students were invited to test the reliability of the scale of this research. A pre-test was administered after these thirty students had finished the course of stage A, part 1. The pre-test was a reliability analysis by Cronbach α. The Cronbach α values were 0.8310 and 0.7790, showing that the results reached a satisfactory reliability standard.
Results and discussion

Results of simulative detection

The first part was simulative detection. The students were required to simulate the following actions: normal learning behavior of looking straight at the computer screen; inattentive behavior of learner leaving or turning head to chat, and feelings of fatigue. Feelings of fatigue included behavior of dozing, such as eyes closing, nodding, and yawning, (eyes narrowing and mouth opening). Table 4 shows the detection results of the sixty students.

Table 4. The result of the simulative detection

<table>
<thead>
<tr>
<th>Category</th>
<th>Simulative behavior</th>
<th>Number of students</th>
<th>Correct detection</th>
<th>Correct detection rate</th>
<th>Number of students</th>
<th>Correct detection</th>
<th>Correct detection rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Learning Behavior</td>
<td>Normal</td>
<td>60</td>
<td>10</td>
<td>83.33%</td>
<td>60</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>Inattentive Behavior</td>
<td>Learner leaving Inattention (turning head to chat)</td>
<td>60</td>
<td>55</td>
<td>91.67%</td>
<td>60</td>
<td>60</td>
<td>100%</td>
</tr>
<tr>
<td>Feelings of Fatigue</td>
<td>Fall asleep</td>
<td>60</td>
<td>57</td>
<td>95%</td>
<td>60</td>
<td>60</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Drowsiness</td>
<td>60</td>
<td>48</td>
<td>80%</td>
<td>60</td>
<td>58</td>
<td>96.67%</td>
</tr>
</tbody>
</table>

The partial misjudgments in the first simulative behavior detection were assumed to be mainly caused by the classroom light, eyeglass reflected rays, and webcam shooting angle. However, some misjudgments were found even after the teacher adjusted for these environmental factors, probably because the interval of the students’ simulative behavior was not long enough to reach the warning threshold defined by the system. Accurate judgment could be obtained after the students performed further specific behavior simulation. The simulative detection results demonstrate the inattention and fatigue of the students could be precisely detected through facial detection after adjusting the mechanism of this research.

After adjustment was made to precisely detect students’ inattentive behavior and feelings of fatigue, the teaching experiment was undertaken with the adjusted mechanism to avoid detection errors in the course experiment.

Teaching experiment and interview results:

Table 5 presents the frequency and paired t-test results for inattention in stages A and B.

Table 5. Table of inattention frequency and t-test, Round 1

<table>
<thead>
<tr>
<th>No.</th>
<th>Stage A</th>
<th>Stage B</th>
<th>t value</th>
<th>significance (two-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td>standard deviation</td>
<td>standard deviation</td>
</tr>
<tr>
<td>1</td>
<td>5 21 23 10 1</td>
<td>1 5 25 22 7</td>
<td>0.911</td>
<td>0.873</td>
</tr>
<tr>
<td>2</td>
<td>0 8 21 25 6</td>
<td>0.853 4 34 20 2 0</td>
<td>0.655</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0 6 32 18 4</td>
<td>0.751 5 34 19 2 0</td>
<td>0.671</td>
<td>9.7</td>
</tr>
</tbody>
</table>

The experiment of stage A, Round 1 was performed without using the proposed detection reinforcement mechanism. In response to proposition 1, “I was attentive during class,” only 18 percent of the students considered themselves to be attentive, while 43 percent considered themselves inattentive during class. In answer to question 2, “I have chatted with classmates or left my seat during class,” 51.7 percent of the students admitted that they had chatted with
classmates or left their seats during class. Only 13 percent of the students stated that they did not chat with classmates or leave their seats during class. In answer to question 3, “I have done something irrelevant during class,” 36.7 percent of the students admitted that they had done something irrelevant during class, while only 10 percent stated that they had done nothing irrelevant during the class. The questionnaire results reveal that in the distance education, without any detection reinforcement mechanism, most of the students were inattentive and would easily chat, leave their seats, or do something irrelevant.

An in-depth interview was held with ten students on question A-1, “Under what circumstances were you inattentive during class?” All ten students held the same opinion: that in a learning procedure like this, the teacher could not see the condition of the students and therefore would not be able to detect students chatting or leaving their seat for a while. Because being inattentive to the course would not influence the participation grade, the students could easily play truant.

In stage B, the experiment was conducted using the proposed detection reinforcement mechanism. In response to question 1, “I was attentive during class,” the percentage of students who still considered themselves to be inattentive fell to 10 percent, representing a reduction of 33 percent in comparison with the percentage in stage A, while 48.3 percent of the students considered themselves to be attentive during class, a rise of 30 percent in comparison with the percentage in stage A. The comparison results show that the proposed detection reinforcement mechanism increases the attention of the students in learning. In answer to question 2, “I have chatted with classmates or left my seat during class,” only 3 percent of the students admitted chatting or leaving their seats, a reduction of 48.7 percent from the percentage in stage A, while 63 percent considered that they did not do so, an increase of 50 percent in comparison with the percentage in stage A. In response to question 3, “I have done something irrelevant during the class,” only 3 percent of the students still admitted doing other things, a reduction of 33 percent from the percentage in stage A, while 65 percent of the students considered that they did not do so, a rise of 55 percent in comparison with the percentage in stage A. The comparison between stages A and B confirm that the proposed detection reinforcement mechanism discourages students from chatting, leaving their seats, or doing irrelevant activities during learning.

From the in-depth interview on question A-2, “Did the warning feedback of the teacher make you more attentive in class?” nine of the ten students agreed that the warning feedback from the teacher made them more attentive to the course. However, one student still showed no concern for the teacher’s warning. In response to A-3, “Did the encouraging feedback of the teacher make you more attentive in class?” Six students agreed that the encouraging feedback from the teacher helped them to become more attentive in class. The answers to these two interview questions indicate that teachers can increase the learning attention of their students by giving them timely feedback in class.

In distance education, students who are not self-disciplined enough easily exhibit inattentive behavior, thus reducing the learning results of distance education. Consequently, most current distance education programs are designed for adults, undergraduate learners or above, and do not yet replace the at-school curriculum designed for younger students. This is because such distance education focuses only on knowledge learning and provides no effective guidance. The effect of this experiment is particularly significant for elementary school students with little self-discipline. All ten interviewed students agreed, after a further interview, that they should not let themselves become distracted in class, because they would be given warning messages by the teacher if they were inattentive. Comparison results reveal that the proposed mechanism made students feel that the teacher was observing their learning, thus encouraging them to be attentive in class.

Table 6 lists the fatigue frequency and paired t-test results of stages A and B of Round 2.

<table>
<thead>
<tr>
<th>No.</th>
<th>Stage A</th>
<th>Stage B</th>
<th>( t ) value</th>
<th>significance (two-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3</td>
<td>4  5</td>
<td>1  2  3  4  5</td>
<td>standard deviation</td>
</tr>
<tr>
<td>4</td>
<td>3  22</td>
<td>23 10 2</td>
<td>0.91 2 10 32 15 1</td>
<td>0.72</td>
</tr>
<tr>
<td>5</td>
<td>0  4</td>
<td>21 26 9</td>
<td>0.82 0 4 23 25 8</td>
<td>0.80</td>
</tr>
<tr>
<td>6</td>
<td>8  19</td>
<td>26 7 0</td>
<td>0.87 9 23 23 5 0</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Table 6. Table of fatigue frequency and t-test, Round 2
The experiment in stage A was performed without applying the proposed detection reinforcement mechanism. In response to statement 4 in stage A, “I was energetic in class,” twelve students considered themselves to be energetic, while 25 considered themselves to be unenergetic. For statement 5, “I felt fatigued,” 35 students considered themselves to be fatigued, while only four students considered themselves not feeling fatigued at all. In answer to statement 6, “I was dozing during class,” seven students admitted that they had been dozing.

All ten students who participated in an in-depth interview on question B-1, “Under what circumstances did you feel sleepy in class?”, felt that interesting course content would make them less sleepy, while boring course content would make them sleepy. Eight students felt that staying long hours in class would affect their mental states. In particular, looking at the computer screen for a period of time would make the eyes fatigued. Seven students stated that they might not feel sleepy if the class could be given with high levels of interaction between the teacher and students or among the students, e.g., discussion or teamwork.

In stage B, the experiment was undertaken with the proposed detection reinforcement mechanism. In response to the questionnaire statement 4 in stage B, “I was energetic in class,” 16 students considered themselves to be energetic, while 12 students considered themselves unenergetic. Regarding statement 5, “I felt fatigued,” 33 students considered themselves fatigued, while only four students said that they did not feel fatigued at all. In response to statement 6, “I was dozing during class,” five students admitted that they had dozed off in class.

A comparison of data from stages A and B shows that the proposed detection reinforcement mechanism did not significantly decrease the mental fatigue of students during learning. Although this mechanism discouraged the students from being intentionally lazy, it made no significant difference to their feelings. Although two students could force themselves not to doze off in class as a result of the reinforcement mechanism, they still felt fatigued. Thus, the learning result for fatigued students was not good.

All ten students in the in-depth interview on questions B-2, “Did the teacher’s warning feedback refresh you in class?”, and B-3, “Did the teacher’s encouraging feedback refresh you in class?”, admitted that receiving encouraging feedback from the teacher would refresh them during class. However, warning feedback resulting from fatigue had no influence on student behavior. Seven students responded that although they felt like refreshing themselves, they still felt fatigued. In particular, only some of the students who were already dozing could still refresh themselves after receiving the warning from the teacher. The remaining students could not refresh themselves and might have dozed off in class again.

Thus, many factors affect the mental states of students for learning. As well as teaching materials, teaching methods must also be considered to improve the mental state of students, especially in distance education without face-to-face interaction. The external reinforcement mechanism did not improve the physiological responses of fatigue and the risk of dozing was not apparently minimized either. Additionally, the interview indicates that many factors influence the mental state of students. Some factors were associated with the lifestyles of the students, while others resulted from the content of teaching materials and the teaching methods of the teacher. The students still significantly affect their mental states even after receiving the warning feedback from the teacher. Therefore, simply warning a fatigued student does not work. Distance education enables learners to learn anytime and anyplace. The student should be asked to learn at another time in a better mental state. Learning reluctantly is a waste of time. Consequently, because external effects cannot minimize mental fatigue caused by physiological exhaustion, students who feel fatigued should be allowed to learn at another time, rather than being requested to refresh themselves.

**Conclusion**

Aside from recognizing inattention and fatigue in learners by employing image recognition and detection, this study also focuses on improving the accuracy with the Bayesian network assessment. No technology that combines image recognition with reinforcement mechanisms is yet available. This study utilizes the simplest approach to achieve this objective, a webcam. Although the Bayesian network assessment could not achieve 100 percent accuracy, it did reduce detection misjudgment.

Students might need to learn by distance education in different circumstances, for instance, when classes are suspended for infectious diseases, or when children are absent from school for illness. The proposed mechanism can
help teachers to recognize the learning conditions of students, and prevent students from learning inattentively after logging into the distance learning system. The teacher is able to observe the learning conditions of the students, making the interaction in distance education courses much more like that in at-school classes. Because the proposed mechanism cannot ensure 100 percent accuracy, in this research only be utilized to help teachers and parents to supervise students, and is not appropriate for use in assessment.

This mechanism was implemented and adopted to perform simulative tests and class experiments. Simulative test results reveal that the accuracy in detecting the feature behavior simulated by students is quite high. Thus, the mechanism can precisely detect learners who are inattentive or fatigued. Class experiment results show that the proposed mechanism can encourage inattentive learners to achieve the learning attention goal. However, mental fatigue caused by physiology can only be solved by requiring students to learn at another time in a better mental state to avoid wasting time. The proposed detection reinforcement mechanism and teaching procedure were designed from the perspective of Affective Domain Teaching Objectives, and can detect accurately the students’ inattentive learning Teachers of distance education courses thus explicitly controlling the learning condition of students avoiding the common difficulty in distance education of students’ exhibiting inattentive or fatigued behavior. The results of the simulative experiment class demonstrate that the mechanism of this research can detect inattentive behavior in students and encourage students to be attentive to learning.

The proposed mechanism can accurately detect the behavior induced by inattention and fatigue. However, although this mechanism can urge students to be attentive to learning, it cannot refresh students with mental fatigue resulting from physiological exhaustion. Other factors must be studied to gain an in-depth understanding of the impact of teaching strategies and content and presentation of teaching materials on learning by students. Distance education allows learners to learn anytime and anyplace, enabling a teacher to take preventive measures to relieve the learning fatigue induced by exhaustion or allow students to learn at times when they are not tired. Although the proposed mechanism is not mature and its outcome may not exactly meet the teaching or learning needs, it is a helpful starting point for this research issue. Accordingly, future research will perform in-depth studies on factors such as teaching materials and teaching methods. A distance education mode that can achieve the Affective Domain Teaching Objectives with the proposed mechanism in this research could hopefully be developed.

The simulative test was performed in a computer classroom to improve the detection accuracy given the limits of the image recognition and detection method, where the appropriate environmental conditions for image recognition could be easily met. Using the home as the test environment would require help from parents. For example, the home light and the angle of the webcam for the detection system would need to be adjusted according to various environmental conditions. This study aimed to detect inattentive learning behavior and did not classify such behavior specifically. Further detection and recognition of all aspects of student behavior would require more flexible and accurate image recognition and detection techniques or the integrated usage of other technologies.

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