Toward Incorporating Bio-signals in Online Education Case of Assessing Student Attention with BCI

Mohammed Serrhini and Abdelamjid Dargham

Abstract Bio-signals acquired with sensors technologies are increasingly gaining attention beyond the classical medical domain, into a new paradigms such education. Attention is bio signal that can be measured and checked by Brain Computer Interface technology (BCI) through alpha wave (8–13 Hz) and beta wave (14–30 Hz) frequency measurement. Attention and learning are very dependent on one another. Student with attention deficits often have learning disabilities. According to many teachers' and professional researchers, it has been found that the student's attention is reducing. This paper talks about how to assess student attention in online education, during learning process students' attention is controlled by attention assessment system EEG based on (BCI). Attention Data are stored in database, and used for Signal processing algorithms to understand student knowledge advancement.

Keywords Online education · BCI · Attention in education · Bio signals · Human machine interaction · Mind brain · Education

1 Introduction

Researchers have now acquired so much information about how the brain learns that a new academic discipline has been born, called "educational neuroscience" or mind, brain, and education science, this emerging discipline of Mind, Brain, and Education (MBE) explore the benefits as well as the difficulties involved in integrating neuroscience into educational policy and practice.

M. Serrhini (✉) · A. Dargham
Faculty of Sciences, University Mohammed First Oujda,
BV Mohammed VI, Oujda, Morocco
e-mail: Serrhini@gmail.com

A. Dargham
e-mail: abdelmajid.dargham@gmail.com

Á. Rocha et al. (eds.), *Europe and MENA Cooperation Advances in Information and Communication Technologies*, Advances in Intelligent Systems and Computing 520, DOI 10.1007/978-3-319-46568-5_14

This field explores how research findings from neuroscience, education, and psychology can inform our understandings about teaching and learning, and whether they have implications for educational practice. Neuroscience research shows that the changes in the brain that underlie learning occur when experiences are active [1, 2]. With student-centered learning approaches, students are empowered to engage in active learning experiences that are relevant to their lives and goals. When a student is passively sitting in a classroom where the teacher is presenting decontextualized information that he/she is not paying attention to, the brain is not learning. The brain can focus on only one task at a time. Each shift of the brains attention requires increased mental effort and incurs a loss of information in working memory of the first task. In effect, the individual ends up doing two tasks poorly rather than one task well. Attention is an important part in the learning process both in real life circumstances and in computer-based instruction and provides the basis that informs motivation modeling [3, 4]. The brain not only juggles tasks, it also juggles focus and attention. When people attempt to perform two cognitively complex tasks such as driving and talking on a phone, the brain shifts its focus (people develop "inattention blindness").

Today, bio-signals acquired with sensors technologies are increasingly gaining attention beyond the classical medical domain, into a paradigm, which using the physical computing analogy [5], can be described as physiological computing. Physical computing, that deals with the study and development of systems that sense and react to the human body. The modern uses of bio-signals have become an increasingly important topic of study within the global engineering community and consequently, many evidences show that bio-signals are clearly a growing field of interest, where recent applications include: Human-Computer Interaction (HCI), which involve the interface between the user and the computer [6]; Quantified-self, giving people new ways to deal with medical problems or improve their quality of life; and many other disciplines.

The continuous or relaxing rhythms of the brain produce bio-signals called Brain Waves, they, are classified by frequency bands. Different brain waves frequencies correspond to behavioral and attentional states of the brain, and a traditional classification system has long been used to explain these different Electroencephalogram (EEG) rhythms. EEG is a measure of the brain's voltage fluctuations as detected from scalp electrodes sensors of the cumulative electrical activity of neurons.

Online Education (OE) used in modern engineering learning to help students studying remotely through the Internet [7]. Institutions may also show interest to apply MBE approach in OE. Nowadays, digital technology evolution allows facilitating integration of neuroscience bio-signal, it open new ways to include remotely some student mind parameters into online education, this make learning process as real as possible and more instructive. Attention and concentration plays a big role in learning process. In conventional classroom education guided by human teacher, student is usually alerted about risk that he/she incurs because of his/her inattentiveness. In distant education, intelligent tutoring system can plays teacher role to provide personalized teaching sessions and feedbacks for the specific needs

of each student, like alerting him about his/her low attention level. This becomes crucial for the success of future OE projects.

In this chapter, we introduce use of MBE approach to enhance student attention in online education. This paper is organized as following, after introduction, Sect. 2 will introduce readers with background materials to understand, the role of attention in learning, what is EEG bio-signal, brain computer interface (BCI) technology to capture and process this attention waves in order to check student concentration during interaction with learning material in online education, third section discuss proposed system overview (Architectural, Practical implementation, Use and gain), Sect. 6 we present some results with discussion.

2 Background

2.1 Attention and Concentration in Education

Attention is an important aspect of the learning situation [3, 4, 8]. Keller's strategies for attention underline "getting and sustaining attention" [9] before attracting on other strategies to motivate the student. Attention is one of the most intensely studied topics, and remains a major area of investigation within education, psychology and neuroscience. Keller's ARCS [8, 10] model for example, considers attention as the most fundamental element towards achieving motivation in the classroom (ARCS stands for Attention, Relevance, Confidence and Satisfaction). Areas of active investigation involve determining the source of the signals that generate attention, the effects of these signals on the tuning properties of sensory neurons, and the relationship between attention and other cognitive processes like working memory, learning and vigilance.

In computer mediated learning, attention has generated a growing body of research with the aim of identifying students' attention and responding appropriately given low states. In order to identify and reply researchers have employed Artificial Intelligence methods that allow personalizing the interaction. Artificial Intelligence in Education (AIED) has dealt with recognition of attention. For recognition side, researchers have employed two main methodologies: modeling using physiological clues [11, 12] and employing user-generated data [13, 14]. The results provide an indication of attention states during the interaction between a learner and an educational system. On the reaction side, researchers have investigated different ways of proposing corrective feedback if the detection shows low levels of attention.

The various approaches taken in AIED research have carried about benefits that translated into learning advances. Giving the relevance of attention in the learning gains, our approach considers reading user's attention (recognition) using physiological inputs. The physiological inputs, however, will be based on a Brain Computer Interface capable of measuring the learners' attention levels based on neural activity. We have chosen to combine these reading with intelligent notification System represented by notification alerts for each levels of attention of the students interacting with OE to determine when the user is paying attention to or not by only using the BCI.

2.2 EEG Attention Wave's Bio-signal

An electroencephalogram (EEG) is a measure of the brain's voltage fluctuations as detected from scalp by electrodes that can be used to measure an electrical signal of the human body, such as a brain wave. It is an approximation of the cumulative electrical activity of neurons. EEG signal changes according to the brain activity states. Depending on these states, we can distinguish several rhythms (waves). EEG activity has been used mainly for clinical diagnosis and for exploring brain function (attention, meditation, stimulus, etc.).

Attention is the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. Attention has also been referred to as the allocation of processing resources, it is a brain activity. A brain activity produces electrical signals that can be measured from the human scalp by Hans Berger from 1929 [15]. When subject must keep attention, brain wave signal always appear in frontal lobe and parietal lobe (Fig. 1 shows brain attention lobe) of the human brain when he/she is in an alert situation as mentioned by [16, 17].

The continuous or resting rhythms of the brain, "brain waves", are categorized by frequency bands. Different brain wave frequencies correspond to behavioral and attentional states of the brain, and a traditional classification system has long been used to characterize these different EEG rhythms are (Alpha waves, Beta, Theta, Delta, Lambda, and Vertex waves).

Generally, Alpha and Beta Waves Studied since 1920s found in Parietal and Frontal Cortex, Relaxed mean Alpha has high amplitude, Excited mean Beta has high amplitude, alpha waves (8–12 Hz) correlate with relaxation or rest state (Fig. 2

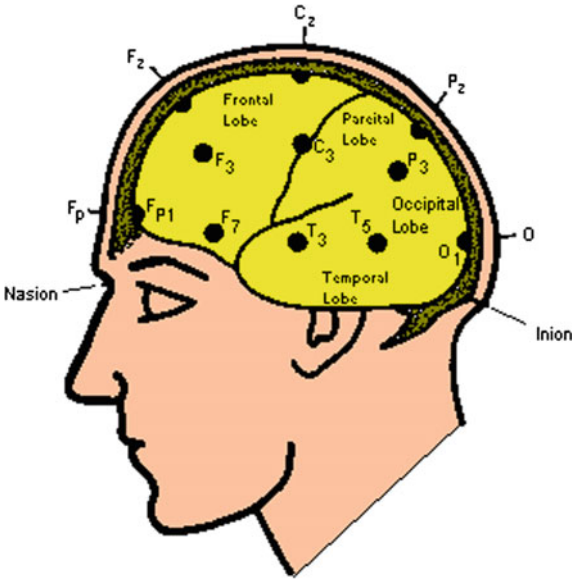

Fig. 1 Brain lobes

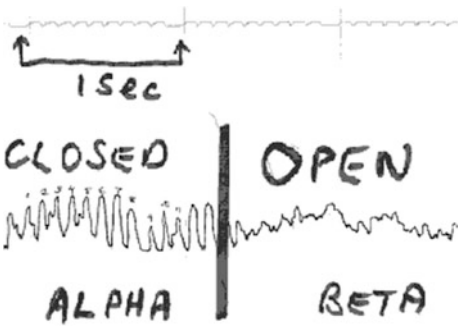

Fig. 2 Eyes alpha and beta signal

shows an example)., while beta waves (13–30 Hz) correlate with mental attention, concentration and active thinking. However, human brain waves generally include all of these waves and vary dynamically.

2.3 Brain Computer Interfaces (BCI)

In recent years, we can observe a growing interest in BCI. The main advantage of the communication between brain and computer is its "directness". BCI, are input devices that use the brains' electrical activities to allow communication between users and computers. Normally, BCI's are used to activate commands based on specific reading or to measure neural activity of interest such as attention, anxiety or relaxation, and stimulus etc.

User wears headset with EEG sensors on it to record neural activity. The 26 sensor electrodes were organized according to the 10–20 standards for EEG location. The sensors were recorded as interleaved channels of signed 32 bit integers at a rate of 500 samples per second.

The channels were separated into individually named files and converted to (American Standard Code for Information Interchange) ASCII format for simplicity of loading on different systems for furthers processing Table 1.

There are two type of BCI:

Invasive: It is the brain signal reading process which is applied to the inside of grey matter of brain.

Non Invasive: It is the most useful neuron signal imaging method which is applied to the outside of the skull, just applied on the scalp.

There are three main consumers-devices commercial competitors in this area which selling a non invasive BCI.

Neural Impulse Actuator from April 2008,

Emotiv Systems 2009,

NeuroSky 2009 developed MINDSET easy to use BCI headset for less than 100 dollars.

Table 1 Example of Packet Data

Byte:	Value	Explanation
[0]	0xAA	[SYNC]
[1]	0xAA	[SYNC]
[2]	0x08	PLENGTH] (payload length) of 8 bytes
[3]	0x02	[CODE] POOR_SIGNAL Quality
[4]	0x20	Some poor signal detected (32/255)
[5]	0x01	[CODE] BATTERY Level
[6]	0x7E	Almost full 3 V of battery (126/127)
[7]	0x04	[CODE] ATTENTION eSense
[8]	0x30	eSense Attention level of 48 %
[9]	0x05	[CODE] MEDITATION eSense
[10]	0x12	eSense Meditation level of 16 %
[11]	0xE3	[CHKSUM] (1's comp inverse of 8-bit Payload sum of 0x1C)

2.3.1 NEUROSKY Headset

NeuroSky startup has developed technologies based on a non-invasive, dry, bio sensor to read electrical neuron-triggered activity in the brain to determine states of attention and relaxation. NeuroSky headset is used as wearing device, this low-cost, easy to use headset developed for leisure, non-clinical human-computer interaction. Neurosky is a neural activity produces a faint electrical signal that constitutes the basis for EEG-based NeuroSky readings. To do so, it detects these signals using three dried electrodes and decrypts them by applying algorithms to disambiguate multiple signals and give coherence to the interpretations. TinkGear is the technology inside every NeuroSky product that includes onboard chip that processes all data and provides these data to software's and applications in digital form for further data processing and commands, an example of provided data are given in Table 1.

To us, the originality of using NeuroSky in our research is its movability and easiness of use and the potential to apply it as an input device to for physiological, brain-generated relevant information.

3 System Overview

In online education proposed system that will assess student attentiveness with BCI during his interaction learning materials as depicted in Fig. 3, all the interaction is accessed by students through internet via a common Web Browser (Internet Explorer, Mozilla Firefox, Google chrome etc.) and grants control of the simulation materials or laboratory equipment's using a user-friendly Graphical User Interface (GUI). Through this GUI students learn remotely and they receive notification alert of the lack of attention during learning process. To begin session student launches Web Browser and wears his/her Neurosky BCI headset. A high-level Web

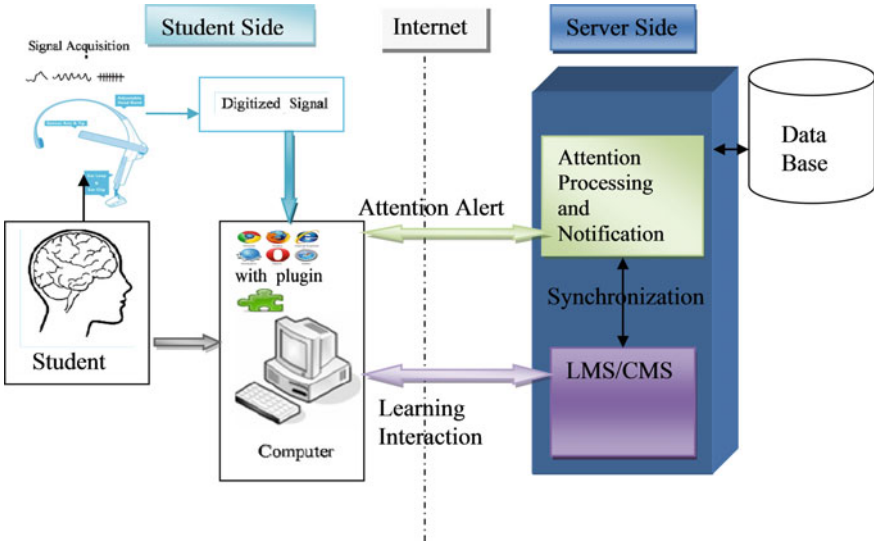

Fig. 3 System architecture

Application programming interface (API) was developed to capture attention and concentration wave's values, send them to attention processing algorithm, and return feedbacks to student.

4 System Use and Gain for Student

4.1 How Student Use System

As shown in experiment process flowchart (Fig. 4) student access system after successfully login via a common login PHP web page, firstly Java-script program will automatically check the presence of the needed Plug-ins in his/her browser, if not installed, a web-link is provided to download and to install them, the update of these plug-in is assured automatically in all majors browsers, then system will invite student to connect his headset, Neurosky headset is plug and play technology so it can be easy pared with student system, thereafter student choose the experiment or simulation that he/she want to practice, the system will remember him to do Pre-check test of the headset (physical state, battery power level, and other abnormalities) battery level is checked also during interaction via byte 5 Data stream (Table 1). Subsequently system will check if the head-set is correctly primed, if not, student is prompted to re-check his headset, an additional helps materials can be provided to help him/her to perform this task. If no problem the system will synchronizes the start of the learning material and ITS, during

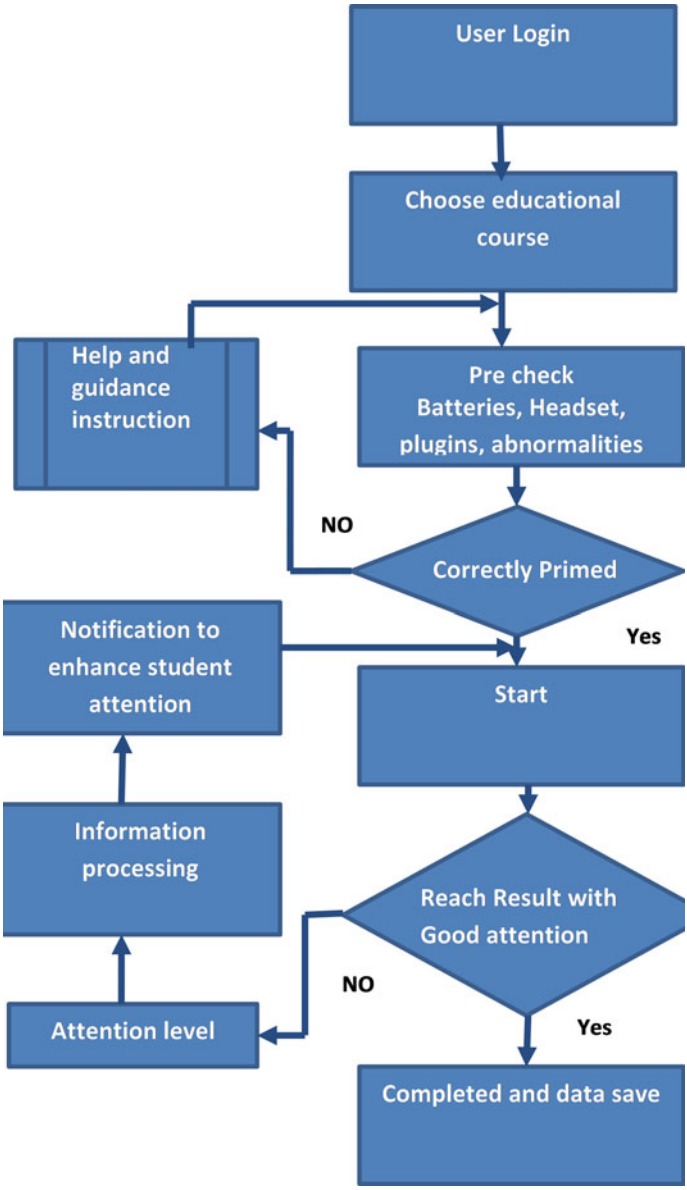

Fig. 4 Flow chart of system use

interaction with Web-Lab experiment/simulation materials, ITS modules read EEG Data acquisition through TCP/IP protocol, and parses student signal to detect his/her attention level dynamically.

For any attention detected abnormalities, Attention processing modules will find appropriate reaction according to predefined strategies until good results in learning process are reached with good attention level. Teachers or institution may be interested also in further data analysis to understand which parts of e-learning system provoke lack of students attention, because of bad system design like (loud various alarms, wrong positioning of webcam, indistinguishable number in counter, etc.), this will help for future system materials enhancement; data can be stored in database, and used for Signal processing, data analysis, and data presentation, this can be programmed in (Math-Lab, Ms-Excel, OpenVibes, etc.). There are some common digital signal processing algorithms often used for EEG study by the researchers, for example, Fast Fourier Transform (FFT), Bispectral Power Spectrum and Power Spectral Density (PSD), Wavelet Transform (WT), filter theorems etc.

4.2 Strategies and Reaction for Attention Student Gain

Main gain of this approach is that student learns online with good attention. By controlling his/her attention and to make students post-training attention level better than pre-training, in his research, Posner and Rothbart [18] thought that the attention training can not only enhance attention but also extend the influence to the other cognitive functions needed in our life, for example, intelligence. Posner and Raichle [19], also thought that attention training is a special repetitive practice concept with respect to some kind of specific cognitive function and make the efficiency of the subject's attention better. In OE attention and concentration plays a big role in learning process.

Student gain after use of such proposed system is not limited only to determine (detect) low or high levels of attention, but to improve or sustain learner's attention, this system should also provide feedback for the learner attention (react). Our model of attention considers Keller's approaches to sensitively deliver feedback aimed at educating or supporting the learner's attention. Table 2 presents Keller's strategies.

Table 2 Outputs taken from Keller's ARCS (REF) model

Attention value	Reaction type
0	1: Alerting student about the problems to receive attention signals
1–20	2: Change status quo like asking the learner to return at a later time or take a pause
21–40	3: Ask learner about lack of his/her attention, is the student tired? Does he/she found any troubles? Would he/she like to come back at a later time?
41–66.66	4: No notification attention is good
66.67–83.33	5: Learner whether he/she wants to explore more material or examples
83.34–100	6: Student receives felicitation message from teacher

5 Methodology, Experiences, and Results Discussion

Validation and usability of our methodology. Experience was conducted among students in the university enrolled in C programming course, an online course was developed, to get a better understanding of the way students use the learning materials and the way attention notifications enhances student attentiveness and concentration state during learning, data was collected by observations of a student's focus group. There were 40 subjects including 19 females and 21 males, all these subjects are taking C language programming course for first time, they are healthy and in good mental condition, most were familiar with computers, portable media players and smart phones. Their ages are between 18 and 26 years old.

Students interact with learning material around 9 min. Their attention and concentration level was measured and recorded for each taken chapter. Students get immediate alert notification when their attention level is low.

The results obtained as shown in results graphics (Figs. 5 and 6), it is clearly visible how well the student's attention level is enhanced noticeably from first test to third one. Notification plays consistently big role to improve students' attention with value of 12 % in each test, and around 24 % in global.

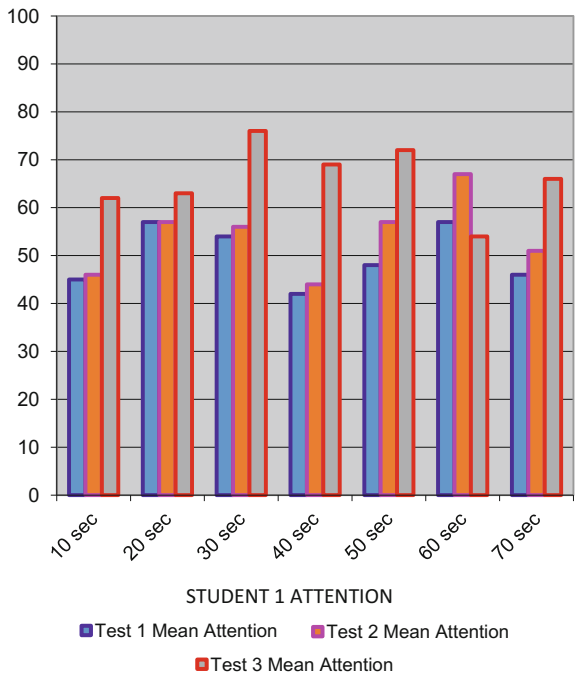

Fig. 5 Global attention results

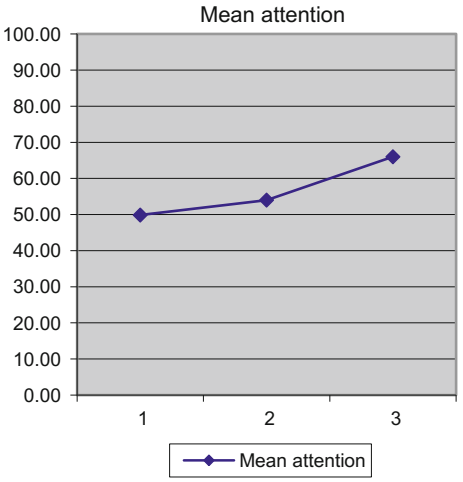

Fig. 6 Mean attention enhancement

6 Conclusion

Todays, all designed numerical devices and systems (Computers, smartphones, TV, Cars etc.) are integrating bio-signals to enhance human interaction. This article shows incorporating Bio-signals in online education, by combining neural input with interaction traits assisted with attention alerting system. The prototype of attention proposed on this paper is based on input from a Brain Computer Interface (BCI) named Neurosky. This headset offers the possibility of detecting brain waves associated to levels of attention. Given the importance of attention in education, we propose a model targeting attention in order to give personalized feedback to student and training him during learning. The innovation of our approach includes of combining a novel form of computer input with online education. Work for the future consists on integrating more brain waves such (Movement Imagination, P300, SSVEP and ERP-Analysis). Allow us to conclude the suitability of using it in educational with computers and whether our model approach can be used to enhance learning level.

References

1. Weinberger, N.M.: Cortical plasticity in associative learning and memory. In: Byrne, J.H. (ed.) Learning and Memory: A Comprehensive Reference. Oxford, UK, Elsevier Ltd (2008)
2. Winer, J.A., Schreiner, C.E. (eds.): The Auditory Cortex. Springer, New York, NY (2011)
3. Malone, T.: What makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games. Xerox Palo Alto Research Center, Palo Alto (1980)
4. Pintrich, P.R., De Groot, E.V.: Motivation and self—regulated learning components of classroom academic performance. J. Educ. Psychol. **82**(1), 33–40 (1990)

5. O'Sullivan, D., Igoe, T.: Physical Computing Sensing and Controlling the Physical World with Computers. Thomson, 1st edition (2004)
6. Graimann, B., Allison, B., Pfurtscheller, G.: Brain-Computer Interfaces. Springer (2011)
7. Mougharbel, I., El Hajj, A., Artail, H., Riman, C.: Remote lab experiments models: a comparative study. Int. J. Eng. Educ. **22**(4) 2006
8. Keller, J.M.: Motivational Design of Instruction. In: Reigeluth, C.M. (ed.) Instructional-Design Theories and Models: An Overview of Their Current Status, pp. 383–434. Erlbaum, Hillsdale (1983)
9. Rueda, M.R., Rothbart, M.K., McCandliss, B.D., Saccomanno, L., Posner, M.I.: Training, maturation, and genetic influences on the development of executive attention. In: Proceedings of National Academy of Sciences of the United States of America, vol. 102(41), pp.14931–14936 (2005)
10. Keller, J.M.: Strategies for stimulating the motivation to learn. Perform. Instr. J. **26**(8), 1–7 (1987)
11. Conati, C., Merten, C.: Eye-tracking for user modeling in exploratory learning environments: an empirical evaluation. Knowl. Based Syst. **20**(6), 557–574 (2007)
12. Picard, R.W., Vyzas, E., Healey, J.: Towards machine emotional intelligence: analysis of affective physiological state. IEEE Trans. Pattern Anal. Mach. Intell. **23**(10), 1175–1191 (2001)
13. Qu, L., Johnson, W.L.: Detecting the learner's motivational states in an interactive learning environment. In: AIED2005. IOS Press (2005)
14. del Soldato, T., du Boulay, B.: Implementation of motivational tactics in tutoring systems. Int. J. Artif. Intell. Educ. **6**, 337–378 (1995)
15. Berger, H.: On the electroencephalogram of man. In: Gloor, P. (ed.) The Fourteen Original Reports on the Human Electroencephalogram. AMBterdam (1969)
16. Robertson, I.H., Garavan, H.: Vigilant attention. In: Gazzaniga, M.S. (ed.) The Cognitive Neurosciences III, pp. 631–640. MIT, New York (2004)
17. Fan, J., McCandliss, B.D., Fossella, J., Flombaum, J.I., Posner, M.I.: The activation of attentional networks. Neuroimage **26**, 471–479 (2005)
18. Posner, M.I., Rothbart, M.K.: Educating the Human Brain. Washington, DC, American Psychological Association (2007)
19. Posner, M.I., Raichle, M.E.: Images of Mind. Scientific American Library, NY (1996)