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Full Length Article

A comprehensive study of parameters in physical environment that impact students' focus during lecture using Internet of Things

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ABSTRACT

We describe and analyze the impact of several parameters of the physical environment in a classroom on students' focus, where the term "focus" refers to the students' subjective feeling of their ability to concentrate on a lecture at a given moment. The primary goal is to identify those parameters that significantly affect students' focus during the lectures. We had measured several parameters in a real classroom environment using different low-cost smart devices. The research is based on the dataset collected from 14 recorded lectures attended by 197 students. We had measured five parameters of the physical environment and extracted 22 features from the lecturer's voice. After analyzing collected measurements, we had identified eight parameters that have shown to have statistically different values for "focused" and "not focused" segments. We used obtained dataset to test different classifiers and their ability to correctly classify "focused" against "not focused" segments of the lectures. We found out that AdaBoost M1 classifier had the best overall recognition accuracy (86.78%). After performing additional series of trials we identified three parameters that could be removed from the original dataset without changing classifier's accuracy, which left us five uncorrelated parameters that have shown to have significant impact on students' focus.

1. Introduction

Previous studies (Felder & Brent, 1999) have shown that students cannot stay fully focused throughout the lecture. It has been proved that student's attention begins to decrease approximately 10 min after the beginning of a lecture. At the end of a lecture, students remember 70% of the information presented in the first ten, and only 20% of the information presented during the last ten minutes of a lecture (Hartley & Davies, 1978). Therefore, detecting parts of the lecture where students' focus is decreased is important as some actions can be performed in order to stimulate their focus. If students are focused on the lecture most of the time, they would remember more information presented, and their benefit from the lecture would be maximized.

There are many studies that investigated the influence of different parameters on students' performance and achievements by comparing their results received after lecture (Bako-Biro, Clements-Croome, Kochhar, Awbi, & Williams, 2012; Bronzaft & McCarthy, 1975; Coley, Greeves, & Saxby, 2007; Crook & Langdon, 1974; Downs & Crum, 1978; Evans & Maxwell, 2007; Ito, Murakami, Kaneko, & Fukao, 2006; Johnson, 2001; Kyzar, 1977; Molhave, Bach, & Federsen, 1986; Murakami, Kaneko, Ito, & Fukao, 2006; Otto, Hudnell, House, & Molhave, 1992; Shaughnessy, Haverinen-Shaughnessy, Nevalainen, & Moschandreas, 2006; Wargocki & Wyon, 2007). It has been shown that there is a significant relationship between students' ability to concentrate and their academic performance (Egong, 2014), which indirectly indicates that the same parameters may have a high impact on students' focus as well. However, none of the previously conducted studies have considered the direct effect of these parameters on students' focus, as it requires their instant feedback. Additionally, studies are rarely investigating the influence of more than one parameter at the same time, and most experiments were conducted in the laboratory environments. To the best of our knowledge, there is no comprehensive study that has tried to simultaneously identify and analyze parameters that have a significant impact on students' focus in the real classrooms.

The development of different technologies results in changes and enhancements of the educational process as well. For example, education has largely been influenced by the ICT development, resulting in the emergence of different e-learning platforms, virtual learning environments, tele-education systems, etc. Therefore, it is expected that the recent emerge of Internet of Things (IoT) will

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change the teaching and learning process as well. As this concept is new, many standards for its key components are still missing. One of the organizations that promotes a unified approach to the development of technical standards defines Internet of Things "as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies" (ITU-T, 2015). Everything is based on a "thing" which can be defined as "object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks" (ITU-T, 2015). General device is defined as a "device that has embedded processing and communication capabilities and may communicate with the communication networks via wired or wireless technologies", including "equipment and appliances for different IoT application domains, such as industrial machines, home electrical appliances, and smart phones" (ITU-T, 2015). The range of new applications based on the IoT technology is broad and diverse, i.e. e-health, traffic, environmental monitoring, smart homes, smart classrooms, etc. This paper focuses on using IoT in smart classrooms. Smart classrooms can be defined as intelligent environments equipped with an assembly of many different kinds "of hardware and software modules such as projectors, cameras, sensors, face recognition module", and many more (Xie, Shi, Xu, & Xie, 2001). In our case, a smart classroom is equipped with a set of sensors able to monitor parameters of the physical environment (for example CO_2, temperature, humidity, noise) and a Bluetooth headset used to capture lecturer's voice. The aim of this study is to identify parameters of the physical environment in a classroom and evaluate their influence on students' focus. Selected parameters will be later used to implement smart classroom system that would be able to determine in real-time if the classroom environment is optimized to maximize student's ability to concentrate on a lecture at a given moment.

The main contributions of this manuscript are: (1) An innovative approach to analyze the impact of different parameters in the physical environment on students' focus, (2) Identification and the comprehensive analysis of the parameters in the physical environment that influence students' focus, (3) to the best of our knowledge this is the first attempt to measure, analyze and correlate features extracted from the lecturer's voice with the students' focus.

1.1. Literature review

Nowadays learning is becoming more interactive and modern classrooms are expected to be more student-centric. Learning Management System (LMS) is continually being improved by applying innovations from ICT field, such as integrating m-learning (Bogdanovic, Barac, Jovanic, Popovic, & Radenkovic, 2014), cloud computing (Despotovic-Zrakic, Simic, Labus, Milic, & Jovanic, 2013), or gLearning (Lytras & Ordoñez de Pablos, 2011). LMS is opening to Personal Learning Environment (PLE) (García-Peñalvo, Conde, Alier, & Casany, 2011), where PLE represents rather a new approach to the use of new technology in learning than a piece of software (Attwell, 2007). PLE is learner-centric and enables learners to have the control over the learning environment. Proposed PLE frameworks uses different technologies, such as mobile phones (Attwell, Cook, & Ravenscroft, 2009), Web 2.0 tools (Kompen, Edirisingha, & Monguet, 2009; Rahimi, Van den Berg, & Veen, 2015), distributed Web 2.0 tools (Juarros, Ibáñez, & Crosetti, 2014), social semantic web technologies (Halimi, Seridi-Bouchelaghem, & Faron-Zucker, 2014), and cloud services (Rizzardini, Linares, Mikroyannidis, & Schmitz, 2013). Furthermore, some researchers tried to blend personalized and conversational learning methods in classroom contexts (Atif, 2013) while others proposed a service-based approach to define mobile personal learning environments that facilitate communication with institutional learning platforms (Conde, García-Peñalvo, Alier, & Piguillem, 2013).

There are still very few studies that use IoT in the learning environments. Applications are mostly related to using technologies such as RFID or NFC for locating students and calculating their attendances (Chang, 2011; Shen, Wu, & Lee, 2014). In another application, IoT is used in synergy with crowdsourcing to create a model for smart e-learning environment, where students can provide preferred values of environmental variables that can later be used for creating optimal learning environment (Simic, Stavenovic, & Djuric, 2014).

Another smart classroom environment that is based on IoT technology presents a system that is capable to detect the level of students' interest in near real-time with the accuracy of 80% (Gligoric, Uzelac, Krco, Kovacevic, & Nikodijevic, 2015). During the experiment, the behavior of the students was monitored using a camera and a broadband microphone while lecturer's activity was measured by an accelerometer (built in a smartphone placed in his/her pocket). The stress in this study was on monitoring students and their activities while in the current work we have focused on monitoring environmental parameters. In addition, the present study is oriented to determine the impact of different environmental parameters on students' focus that will altogether with the previously determined level of students' interest enable us to better assess the lecture quality.

Another smart classroom environment related to this study is a classroom equipped with emotion monitoring system which is able to detect students' attention and emotion in real time (Luo, Zhou, Wang, & Shen, 2009). Student's attention is recognized by detecting and analyzing student's eye movement while student's emotion is recognized by short and long term features of speech. The system is able to give the lecturer an instant feedback if students are actively involved in the presentation. It is strictly designed for distance learning and is not intended to be used in "face-to-face" teaching.

There are few studies that investigate or review influence of more than one parameter on student's concentration, performance and/or achievements (Howarth & Hoffman, 1984; Mendell & Heath, 2005; Wargocki & Wyon, 2007). One such study investigated the influence of different weather variables on concentration; it was concluded that three predictor variables for concentration, in order of importance, were: humidity, temperature, and hours of sunshine (Howarth & Hoffman, 1984).

Different studies have been conducted to find the relationship between one of the parameters of the physical environment and students' performance or achievements. Parameters that have been explored so far include temperature (Pepler & Warner, 1968; Pilman, 2001; Schoer & Shaffran, 1973; Wargocki & Wyon 2007; Wyon, 1970), air quality (Bako-Biro et al., 2012; Coley et al., 2007; Ito et al., 2006; Molhave et al., 1986; Murakami et al., 2006; Otto et al., 1992; Shaughnessy et al., 2006; Wargocki & Wyon, 2007), and environment noise (Bronzaft & McCarthy, 1975; Crook & Langdon, 1974; Downs & Crum, 1978; Evans & Maxwell, 2007; Johnson, 2001; Kyzar, 1977).

Numerous studies confirmed the negative impact of inadequate temperature on student's performance (Pepler & Warner, 1968; Pilman, 2001; Schoer & Shaffran, 1973; Wargocki & Wyon, 2007; Wyon, 1970). Other studies are oriented to air quality, where the term "air quality" refers to the existence of specific gases or volatile organic compounds (VOC), amount of CO_2 as well as ventilation rates that supply a classroom with the outdoor air. A great number of studies support the statement that either low ventilation rate or high level of CO_2 has negative impact on student's performance (Bako-Biro et al., 2012; Coley et al., 2007; Ito et al., 2006;