Development of a Versatile Experimental Platform for English Vocabulary Learning Based on Extended Biometric Information Analyses

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Abstract: This paper is a report on the development of a versatile experimental platform for practical educations including English vocabulary learning using smartphones based on some extended biometric information analyses. The implemented biological measurements include brainwave together with eye-blinking information, sphygmographic-wave with blood oxygen level ($\text{SpO}_2$), and variation of facial temperature distribution recorded by infrared thermography. Our latest development also includes our novel educational application, named KCCT Quick Response Trainer, which was newly developed to hone our students' QRP (Quick Response Performance). Our latest development has successfully incorporated the extended biometric analyses, together with our novel educational application, named KCCT Quick Response Trainer (KCCT-QRT), which was newly developed to hone our students' QRP (Quick Response Performance). All of the biometric data together with student's response data (all selected answer data with the selected timing data) were consolidated corresponding to each student's learning timeline. By utilizing this latest platform, we have proved that students' learning behaviors can be analyzed based on some meaningful biometric information analyses.

Keywords: Pulse Rate, Perfusion Index, Oxygen Level, Heart Rate Variability, Thermography, Brainwave, English Vocabulary Building

Introduction

Recently EFL (English as a Foreign Language) learning has become an essential requirement for most of the engineer candidates in many countries, as global cooperation and collaborations have become a significant responsibility for engineers. In our college which has been established and dedicated for young engineer candidates after completing 9th grade through 14th grade with a 5-year intensive course, successful students earn an associate degree in engineering. In our department of electrical engineering, about a half of them become engineers in all sort of major companies including Panasonic, Canon, Mitsubishi Electric and other electronics companies after the graduation. Another half students continue their study for additional two years in our college as advanced course students or by entering other universities as junior students, to earn a full bachelor degree which allows them to enter any graduate school. For those youths who designated their career in engineering in their younger days, EFL learning is a rather difficult subject, as their mother language has also not yet matured. As their performances in math, science, and engineering subjects are talented, most of them have a tendency to prefer technical activities rather than training their English communication skills. Meanwhile young engineer’s QRP (Quick Response Performance) is believed to play an important role to develop their communication capability, based on the last author’s* experience as a leading engineer in a global electronics company. We have assumed that the training the QRP aspect in EFL learning should enhance the development of their skills. Considering these circumstances, in order to fulfill the emerging responsibilities to train our students as engineers ready to collaborate globally, we have developed a novel English vocabulary building application, called KCCT Vocabulary Builder (KCCT-VB) using smartphones linked with a cloud data server, here KCCT stands for Kobe City College of Technology. Although our intention partially include the utilization of our students' familiarities to ICT technologies including smartphones for the purpose of our students' English vocabulary building, the real advantage is the intuitive UI (User Interface) based on the built-in touch panel display, which allows us to deliver a question with multiple choices as possible answers. As students do not have to operate any keys or pointing device, enabling them to choose the answer just by touching the particular choice, the developed platform has allowed us to measure an accurate response time for each answer choice. Those response time data are accumulated automatically in a cloud data server, and we have reported the findings which revealed our students English vocabulary building process in comparison with students in other countries at eLearn2011.¹)
Furthermore, we have utilized the brainwave sensor (Mindwave Mobile), made and supplied by NeuroSky Inc., as a real-time biological information in order to measure the student's psychological response data in terms of the attention (a degree of concentration) and the meditation (a degree of relaxation), and reported the findings on our students' attention characteristics at eLearn2013.\(^2\) The attention and meditation data are calculated based on the brainwave processing that is the proprietary technology developed by NeuroSky Inc. Though the system uses only a single dry electrode without any conductive gel at the forehead of the examinee (student), many research articles have already reported that it's usefulness is comparable with the conventional methods using conductive gel,\(^3\) that the system can discriminate between reading easy and hard sentences,\(^4\) that it can assess a cognitive load,\(^5\) and that it can indicate an individual's emotional change in terms of the attention and the meditation levels.\(^6\)

Moreover, in order to utilize the students' listening experiences, we have incorporated a listening mode on top of the reading mode in our KCCT-VB. The platform was carefully redesigned for a little bit larger popular device (Google's NEXUS 7-inch tablet), and reported in our former papers.\(^7\)\(^8\)

Besides, as a trial to enhance our students' engagements into the vocabulary building application, last year we have incorporated and looked into the battle mode as a gamificational approach. The developed application can accumulate not only our students' learning performances, but also some learning behavioral data with some inconscient biological data, including the brainwave together with the eye-blinking point of time and strength.\(^9\)

In this paper, further development of our KCCT-VB with further extended biological information measuring capabilities including the proven brainwave together with the eye-blinking timing and strength, sphygmographic-wave with blood oxygen level ($\text{SpO}_2$), and variation of facial temperature distribution recorded by infrared thermography, were detailed. The objectives of these developments have not been only to build the English vocabulary, but also to analyze the learning behaviors in order to enhance the students' learning experiences. Our latest development has successfully incorporated the extended biometric analyses into our proven KCCT-VB. On top of that, we have newly developed our novel educational application, named KCCT Quick Response Trainer (KCCT-QRT), which was specifically intended and designed to hone our students' QRP as detailed in our another paper.\(^10\)

All of the biometric data together with the students' response data (all selected answer data with the selected timing data) were accumulated in a cloud data server, and the data were proven to be able to be analyzed in order to unveil the students' learning behaviors.

### Development of the system

In order to analyze students' learning behaviors, the extended biological measurements have been implemented into our consolidated experimental platform as schematically depicted in Fig.1.

![Fig.1. The entire system of our developed experimental platform](image)
The first biological sensor directly connected to the learning application on Android tablet through Bluetooth is the single dry electrode brainwave sensor (Mindwave Mobile), which allows us to look into the student’s attention and meditation level representing a degree of concentration and relaxation, respectively, together with the eye-blinking timing and strength, based on the spectrum processing of the brainwave and the detection of eye-muscle potential.2,7-9)

The second biological sensor has been newly implemented into this system this time, which is a pulse oximeter (SR-700bs, Konica Minolta, Inc.) directly connected to our learning application on Android tablet through Bluetooth as illustrated in Fig.2. This newly equipped sensor allows us to monitor not only the pulse rate but also the PI (Perfusion Index) which is the ratio of the pulsatile blood flow to the non-pulsatile static blood flow as well as the blood oxygen level (SpO₂). Thanks to the recent remarkable improvement of the measurement accuracy, as much efforts were carried out to be utilized in some clinical applications, PI and SpO₂ are expected to bring us some meaningful insights even in our educational learning experiments. Furthermore, this sensor sends a series of sphygmographic-wave data which allows us to analyze the waveform in many aspects, including the variation in the time interval between heartbeats, referred as RRI (RR-Interval), where R is a point corresponding to the peak of the R-wave (the largest progression in a heartbeat as shown schematically in Fig.3), as well as a spectrum analysis of the sphygmographic-wave.

Further additional biometric sensor incorporated this time is a variation evaluation of the facial temperature distribution measured as an infrared thermography recorded by a thermal imaging camera (FLIR One, FLIR systems, Inc.) as shown in Fig.4.

One last additional sensor utilized this time is a 14-channel mobile EEG (electroencephalography) sensor with the conductive liquid soaked pads as electrodes (EMOTIVE EPOC+, Emotive, Inc.) connected to a separate mobile device to record the real time brainwave data. Although the data extracted from the single dry electrode brainwave sensor (Mindwave Mobile) have been proven to be trustworthy as detailed in the literatures 4-6 and our
former reports,\textsuperscript{2,7-9}) we have further incorporated another brainwave information in a different measurement setup in order to make sure our analysis.

Beside these newly implemented sensors into our experimental platform, we have developed a brand new learning application on top of our proven KCCT-VB(Vocabulary Builder), which is KCCT-QRT(Quick Response Trainer). Although this newly developed application is another learning application for the vocabulary building using the same 4000 basic words implemented both in the KCCT-VB and the KCCT-QRT, the KCCT-QRT has been intended and designed to hone our students' QRP as all of the four answer choices are given in images as shown in Fig.6. Even though an each question is given as a spoken word definition as which is same to the KCCT-VB, students can focus on their QRP more easily in the KCCT-QRT as they can grasp the meaning by digesting images rather than the fact that students have to know the four words themselves given as possible choices first of all in the KCCT-VB.

![Image of KCCT-QRT](image)

**Fig.6. User interface for the KCCT-QRT(Quick Response trainer)**

### Experiments and analyses

In order to analyze the students' learning behaviors based on the biometric information in order to realize more efficient learning experiences, the developed experimental platform was used practically for our 5\textsuperscript{th} grade students in our college with our conventional experimental conditions as detailed in our former papers.\textsuperscript{1,2,7-9}

First of all, we confirmed the fact that all of the students' biometric data, including the brainwave, the blinking point of time and strength, the pulse rate and the PI of the heartbeat, the blood oxygen level($\text{SpO}_2$), and the sphygmographic-wave from the sensors connected to the Android device which is used by our students for their vocabulary building, were recorded and accumulated onto our cloud server. Additional thermographic images as a movie file and 14-channel brainwave were also recorded and accumulated onto our cloud server. According to the time stamp information, all of these data were aligned chronologically in a single time line. All of these data were confirmed to be available all together for meaningful analyses.

For both of the newly developed KCCT-QRT as well as our conventional KCCT-VB, firstly a problem(a definition of a questioned word) is announced in English in a normal speed. At the same time, four answer choices are displayed as four words in KCCT-VB and four images in KCCT-QRT. Upon the selection of one choice by touching, the response data are recorded, and the score is increased by one for the correct choice while the score is decreased by one for the wrong choice. The announcement speed for the questioned word definition is also increased for the correct choice while the speed is decreased for the wrong choice. While the total experiment duration can be set to be any time period, it was set to be 3 minutes(180 seconds) for both of the KCCT-QRT experiments and the KCCT-VB experiments.
An example of student's biometric data from the pulse oximeter is shown in Fig.7. The pulse rate and the PI of the heartbeat, and the blood oxygen level (SpO₂), are sent from the pulse oximeter to the Android device through Bluetooth in every second. The sphygmographic-waveform data are also sent and recorded in the Android device.

Together with the attention and meditation level from the brainwave as well as blinking information (all reported in our previous papers²,⁷-⁹), newly implemented data including the pulse rate and the PI of the heartbeat, and the blood oxygen level (SpO₂), were analyzed on the course of 3 minutes (180 sec) experiment. Furthermore, in order to look into an evaluation of cognitive learning stress, the sphygmographic-wave were analyzed in three different procedures. The first one is an analysis in the histogram of RRI calculated from the sphygmographic-wave as shown in Fig.8. In this analysis, the narrower histogram is believed to be a reflection of more stressful conditions.
The second one is an analysis in the Lorentz plot of RRI as shown in Fig.9. In this analysis in the Lorentz plot, the smaller (more focused) distribution is believed to be a reflection of more stressful conditions. The third one is a comparison in the frequency spectrum of RRI as shown in Fig.10. In this analysis, the low-frequency (LF: often 0.04–0.15 Hz) and high-frequency (HF: often 0.15–0.40 Hz) spectral power are often discussed in connection with the psychological clinical studies.

Summary

We have newly developed a versatile experimental platform for practical educations using smartphones based on some extended biometric information analyses including the pulse rate, the Perfusion Index (PI), the sphygmographic-wave of the heartbeat, the blood oxygen level (SpO2), the variation of the facial temperature distribution on top of the proven brainwave and eye-blinking analyses.

We have also developed the new English vocabulary building application, named KCCT-QRT (Quick Response Trainer), which is intended and designed to hone our students' Quick Response Performance (QRP) as also detailed in our another paper.10

All of the biometric data together with student's response data (all selected answer data with the selected timing data) have been confirmed to be accumulated in our data server, and analyzed according to the each student's learning timeline. Using this platform, we have proved that students' learning behaviors can be analyzed in connection with the meaningful perceptions in the well-known psychological clinical studies.

References