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ReadGoGo! : Towards Real-Time Notification on Readers' State of Attention

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Abstract *– In this paper we present ReadGoGo!, a system that reminds readers when they are not focusing on the texts at hand. Towards developing such real-time system, we used a commercial ECG device, Mindwave by NeuroSky, to measure the attention level of readers, and combine the measurement with visual-based information. Existing related works involve only clinical experiments using EEG sensors to understand brain activities from specific set-ups. Little has been done to distinguish mental states between focusing and losing focus on word texts. In addition, there exist few market solutions, and most of them are not automated. The proposed system can automatically remind the reader when she/he is losing focus and eventually help the reader to quickly regain his/her focus on the text at hand. The implementation and usability analysis has demonstrated the ability of the proposed system to help readers regain attention during reading sessions.*

Keywords *– Real Time attention monitoring; Biofeedback; intelligent reading; EEG sensors*

I. INTRODUCTION

Biofeedback involves the design, development, and testing of smart instruments that measure physiological activities about a human user and generate an appropriate feedback response to enhance awareness of body-mind state [1]. With the availability of low cost and pervasive biomedical sensors, biofeedback is gaining momentum with multimedia and pervasive applications [2].

Mind wandering has been observed to cause a negative effect on productivity. Such loss of focus often leads to lack of task performance and leads to a superficial engagement with the intended activity [3]. Specifically, mind wandering has negative influence on comprehending difficult texts [4], as readers spend unnecessarily longer time to complete the text. As a consequence, often readers end up not being able to comprehend the texts thus having repercussions in individual's careers [5]. The problem may also be extended to other operations that require attention for proper and safe management such as surgical operations and driving. Mind wandering during these activities can have more serious consequence.

This study excludes the mental disorder such as attention deficit-hyperactivity disorder. We believe that the condition should be best dealt with specialized medical attention. Next, we distinguish mind wandering from a seemingly similar problem of absent-mindedness. Absent-mindedness can be understood as "mundane lapses of attention that occur when consciousness is absent" [6]. The causes are related to boredom or sleepiness. On the contrary, mind wandering is a phenomenon in which attention drifts away from the primary task to task-unrelated thoughts [7]. Its distinction from the absent-mindedness is that one still remains conscious about an activity, although the activity is not an intended one.

Mind wandering entails two types of attention fluctuations as discussed in [8]. First, it is the detachment of mind from the current activity. In other words, it is "a mental shift that allows information unrelated to the current situation to form the centerpiece of conscious thought." Second, it ability to detect that mind has wandered. This is called meta-awareness. One is mindful that she/he is not mindful about the task at hand.

From a research perspective, there are three possible approaches [9]. First, a method is developed to remind people that they are mind-wandering. This targets people who have little meta-awareness; because they are unable to notice that they are spending unnecessary time thinking about task-unrelated thoughts. This first approach will be the primary feature of our product. Second, we intend to develop a method that increases one's meta-awareness, so that one can first notify oneself first and shift one's attention back to the current task. This method aims to train the mind to be more mindful of his current mental state. Third, we intend to devise a method that calms the mind and as a result reduces mind wandering. In conclusion, the three approaches notifies one that one is mind wandering, helps one to be able to notify himself better, and reduces one's tendency to mind wander.

There are various solutions that exist that alleviate the problem described (such as [10] and [11]). In order to aid reading and focus in reading, there exist reading cards that help the student focus on the reading. The card has an empty slot to be placed on a line of texts. This helps one to concentrate on one particular sentence at a time. However, this does not deal with the mental state but only with visual focus. In addition, there exists a GPS model that is used at an industrial level that automatically calculates when the driver of a merchandising transport should rest. This solution seems like a temporary solution towards the problem that the driver losing focus while driving and possibly leading to accidents. In addition there are medications and drugs that enhance attention. Drugs intended for ADD ADHD as well as exercises for improved attention exists.

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The remainder of the paper is organized as follows: “Section 2 presents the related work and highlights the distinguished features of the proposed solution. In section 3, the proposed system overview and design details are introduced, section 4 discusses the device’s architecture and implementation, section 5 showcases the data measured by the device presents a discussion in this regard, finally section 6 draws the conclusion and provides perspectives for future work.

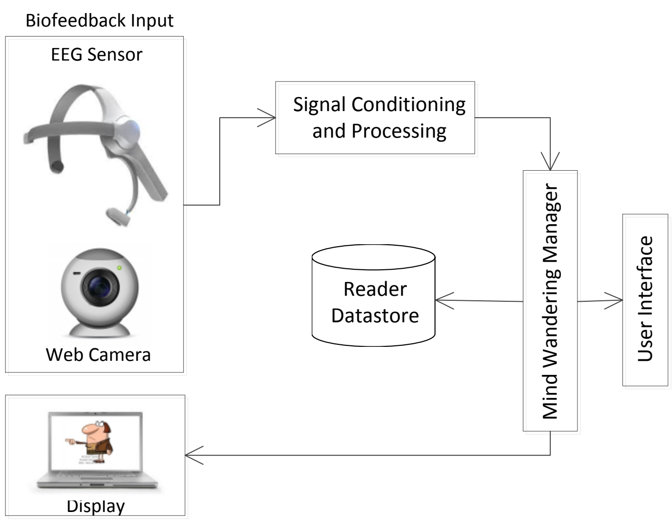

Figure 1: The software architecture for ReadGoGo system

II. RELATED WORK

Loss of focus often leads to lack of task performance and superficial engagement with an intended activity [3]. When the activity is reading, this loss of focus has negative influence on comprehending texts [4]. Readers unnecessarily spend more time to complete the text and may even develop disinterest in the text. The problem here is to measure the reader’s attention. Towards developing a real-time system to remind readers when they are not focusing on their text, the authors used a commercial product, Mindwave by NeuroSky [12], to measure the attention level of readers, and combine the measurement with visual-based feedback to alert the reader.

There has been much clinical work related to the use of EEG sensors to measure brain activities during reading comprehension. Baretta investigates how the brain comprehends texts differently by inserting unsuitable words into the content [10]. Baretta thus seeks to probe into the nature of comprehending texts rather than the level of engagement with the text. Another research examines the effect of music types on reading comprehension using EEG signals [9]. However, it does not aim to distinguish the mental states such as focusing or losing focus during a reading session. A commercial product, Mindwave by NeuroSky, is capable of measuring level of attention. However, there is little done in bringing the tool to measure level of focus in reading.

In order to aid reading through enhancing focus, there exist commercial reading cards. These cards have empty slots to be placed on a line of texts. This helps one to concentrate on one particular sentence at a time. However, it is not automated and it is not an intuitive way of reading. Besides that, there are many programs where readers have to go through workshops to learn strategies to increase attention level on reading. However, it requires readers to be disciplined enough to continue to practice those strategies. We therefore propose a system that can automatically reminds the reader when she/he is losing focus which in turn will help the reader to quickly regain his focus on the text at hand.

III. PROPOSED SYSTEM DESIGN

The software architecture for the ReadGoGo system is shown in Figure 1. The system is one-way without loop feedback where the EEG sensor and the webcam send information to the Mind Wandering Manager. The Mind Wandering Manager in turn outputs to the reader via a visual display whether the reader is focusing on the reading on the screen or not. The various components of the proposed architecture are explained here.

A. Biofeedback Input

The Biofeedback Input module reads physiological and/or psychology information about the human reader and feeds the Signal Conditioning and Processing component. In the proposed ReadGoGo! system, an EEG sensor that captures the reader’s level of concentration (mind wandering) and a web camera that tracks the eyes movements to confirm whether the reader is looking at the screen.

B. Signal Conditioning and Processing

The Signal Conditioning and Processing component minimizes (and possibly eliminates) signal artifacts such as noises due to user movements that severely deteriorate the mind wandering estimation and thus the quality of performance for the ReadGoGo! system.

C. Mind Wandering Manager

The Mind Wandering Manager is responsible for measuring the concentration of the reader and deriving an attention index. Through a calibrated threshold of attention value, the system decides if the reader is unengaged or the reader is focusing on the text.

However, the ECG device readings are not quite stable (due to the fact that the location of the sensor can have significant effects on the signal quality). Therefore, the Mind Wandering Manager implements an algorithm that calculates the attention if the quality of the incoming signal is good enough. Hence the proposed system will not derive a measurement and thus will not make a decision about the reader's attention until the ECG's algorithm validates the data.

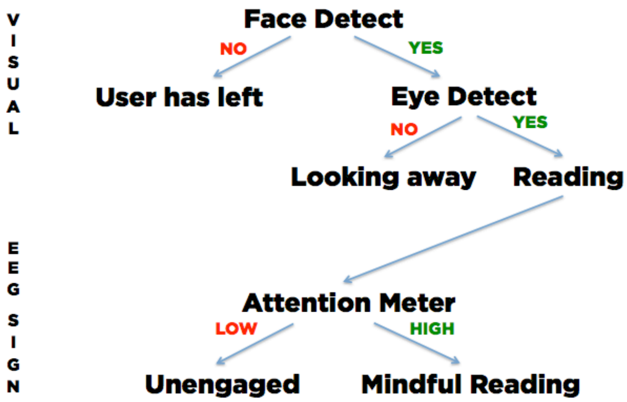

Figure 2: Flow in the processing unit

Figure 2 shows the flow chart of the algorithm implemented in the Mind Wandering Manager. If the face is detected, then the system takes the reading from the EEG sensor to determine whether the reader is focusing on the text at hand. However as soon as the reader's face disappears from the camera field, the reader is marked 'absent' and thus no attention measurements will be made. In case the reader comes back, the system will ask the user if she/he would like to reconnect. If the connection is achieved, a confirmation message will be displayed and the camera will be activated.

When the face is detected, the system searches for horizontal eyes using Viola Jones algorithm [13]. If for whatever case the user were to incline his/her head, the algorithm will not be able to detect the eye pair at an angle. This is a fair assumption because the natural position of head during reading is upright. When the user turn sideways, the size of eye pair detected will be smaller. With a pre-determined threshold and this means that the user is not looking at the screen. The idea is that the size of the box is greatest when the user is looking straight at the computer's screen.

D. Reader Datastore

The Reader Datastore is a database that stores the reader's profile, system configurations and settings, as well as performance data. Examples of user's profile information include, but not limited to, attention threshold and customization of responses (visual, auditory, or haptic feedback).

The reader profile is shown in Figure 3. *UserPersonalDescription* class includes personal information about the user such as name, age, date of birth or employment. *UserPhysiologicalState* stores physiological information about the user such as heart rate, blood pressure, as well as higher-level physiological states such as stress or fatigue. *UserAbilities* refer to user skills (education level, proficiency in specific languages, etc.). The *UserEnvironment* class described the ambient environment where the user is located. The *UserLocation* class describes the coordinates of the user location (using GPS data) or named locations.

The most important class is the *UserPreferences* class. It has relationships with key classes in the profile that allows specifying preferences depending on the context information such as the user environment or physiological descriptions. For instance, the *PreferedAttentionThreshold* parameter defines the threshold at which the application generates an alert signal for concentration levels.

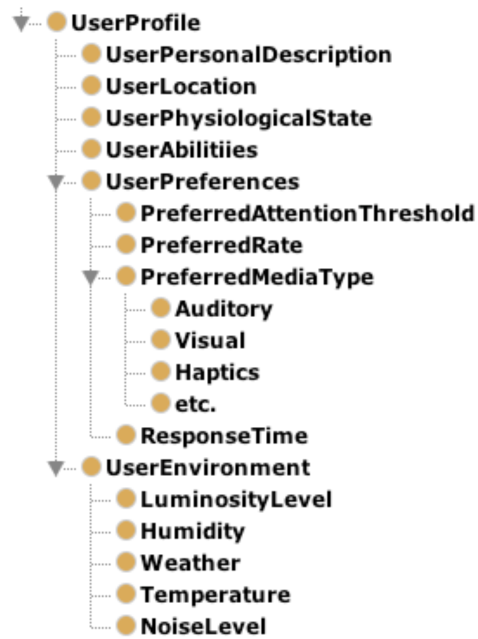

Figure 3: User profile structure

E. User Interface

The User Interface component is typically a Graphical User Interface (GUI) that facilities the interaction between the reader and the system. For instance, the user uses the GUI to set attention threshold for triggering alert signals, customize the alert signal (such as the image, video, and/or sound to be played for alerting), and displaying the performance data over time (the reader can display their level of concentration over time and analyze their concentration patterns).

F. Display

Once the system is started via the GUI, the camera is activated to perform a face search and an eye search. The face detection determines if the user is stationing in front of his laptop whereas the eye detection identifies whether the reader is looking at the screen or is visually distracted. As soon as the reader's attention level decreases beyond the defined threshold, a display alert is trigged. The display can be one or a combination of visual (such as the snapshot shown in Figure 4), auditory, or haptic feedback.

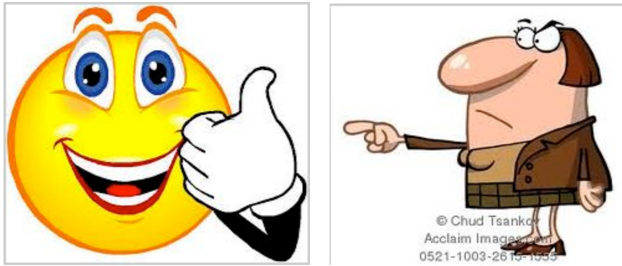

Figure 4: Examples of visual alert

IV. IMPLEMENTATION

Figure 5 shows the NeurosSky Mindwave headset on the user's head. The single contact sensor located on the frontal side of the head prevents any sort of possible interaction it might have with the head. The user is in front of the reading on his computer. The connection between the software and the headset takes place via Bluetooth.

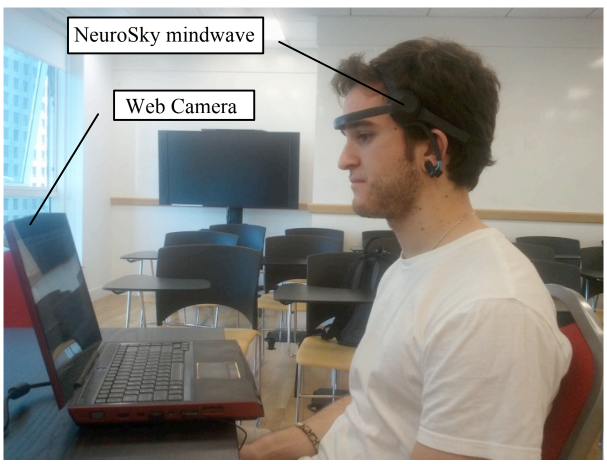

Figure 5: The reader is reading on the computer's screen with the EEG sensor mounted on his head

As shown in Figure 5, the system is composed of the following devices:

- NeuroSky mindwave EEG mobile headset equipped with a Bluetooth v3.0 Class 2 transceiver with transmission range of about 10 meters. The device implements a built-in algorithm to calculate attention, meditation, and blink.
- The computer has a Bluetooth adapter to enable communication with the headset device.
- An 640x480 integrated camera to capture the user's face and use common computer vision algorithms to track the eye movements.

V. MEASUREMENTS AND USABILITY

In this section, we present a demonstration of the ReadGoGo system and explore the usability and the cognition efficiency with specific class of human users; university students.

A. ReadGoGo! Demonstration

This section demonstrates various scenarios for the system implementation. Figure 6 shows when the user leaves the laptop. This is effective as the face detection is almost clear-cut and thus there is no need for making EEG measurements for mind wandering. Figure 7 shows the scenario when the user is reading but his attention level is below the attention threshold. The system therefore reminds the user to focus back on the reading (even if the user is looking at the screen as shown in Figure 7).

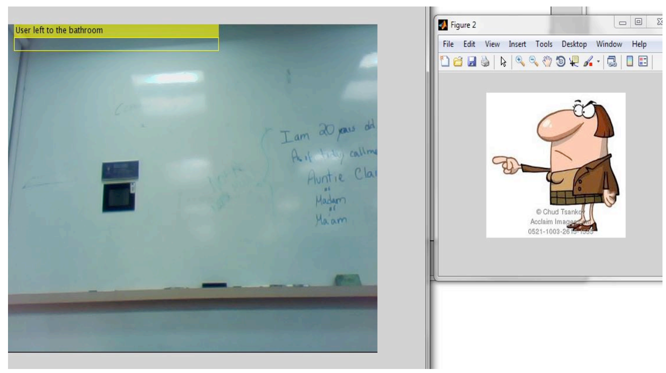

Figure 6: The reader has left the computer

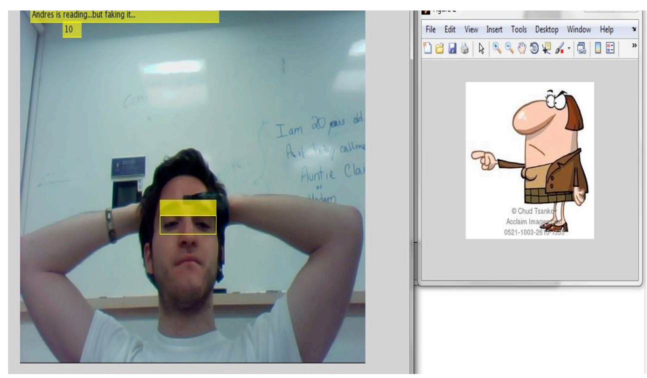

Figure 7: The reader is not looking at the screen

Figure 8 demonstrates the scenario when the reader is reading and his attention level is higher than the allocated threshold. The system shows that the reader is paying attention and thus presents an encouraging message (such as the image shown in Figure 8). Figure 9 shows the scenario when the user is in front of the computer, looking at the screen but having attention lower than the designated threshold. This is detected by the mind-wandering manager, which triggers the system to remind the user to concentrate.

Table 1: Subjects responses to four key questions in the questionnaire.

Subjects	*Q1: Use the system more than once?*			*Q2: Do you think the system has helped you increasing attention?*			*Q3: Did you feel uncomfortable that the system reads your brain signal?*			*Q4: Are you willing to buy the system if affordable?*		
	Yes	*No*	*Not sure*	*Yes*	*No*	*Not sure*	*Yes*	*No*	*Not sure*	*Yes*	*No*	*Not sure*
10 (female)	*7*	*2*	*1*	*8*	*1*	*1*	*3*	*7*	*0*	*7*	*2*	*1*
10 (male)	*8*	*2*	*0*	*8*	*2*	*0*	*1*	*9*	*0*	*7*	*1*	*2*
Total	*15*	*4*	*1*	*16*	*3*	*1*	*4*	*16*	*0*	*14*	*3*	*3*
% of total	*75%*	*20%*	*5%*	*80%*	*15%*	*5%*	*20%*	*80%*	*0%*	*70%*	*15%*	*15%*

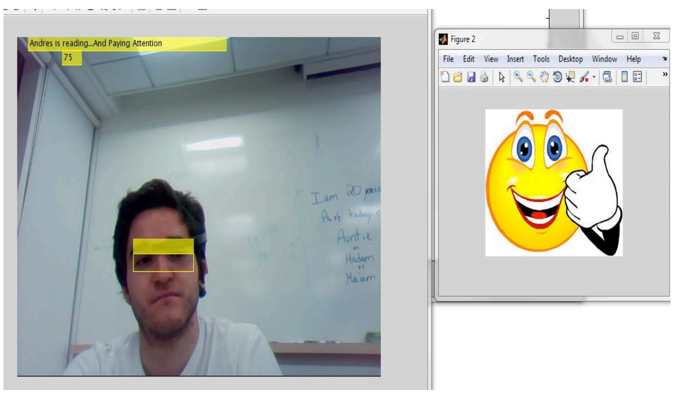

Figure 8: The reader is paying attention to the reading

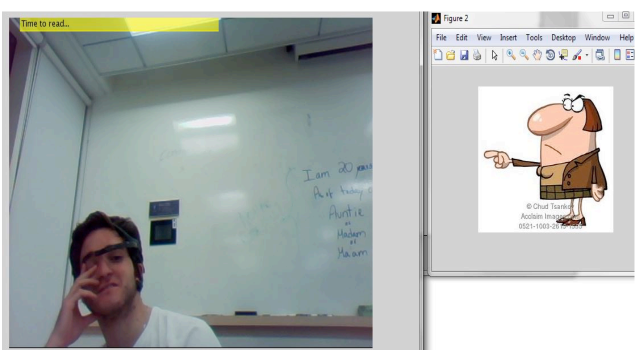

Figure 9: The reader is looking at the screen but not concentrating

A. Usability Study

The objective of this study is to explore the usability and effectiveness of the ReadGoGo! system as a tool to promote mind-wandering techniques for readers. This section discusses the participants, experimental setup and procedure used in this study, and the results.

Twenty adult subjects (10 male, 10 female) participated in the experiment; their ages ranged from 17 to 23 years. The subjects – students from New York University Abu Dhabi (NYUAD) – were picked from different majors including engineering, science, liberal arts, and social sciences. All participants used PC-based readings for more than 4 years.

For the usability evaluation study, the participant was seated in a regular classroom environment in front of a table, with the NeuroSky mindwave EEG mobile headset device put on, and a laptop in front of the participant. The participant was asked to use the EEG device until s\he feels comfortable with the device. We also used a camera and a microphone to record the scene and the user interaction, for further offline analysis. The participant was debriefed right after the experiment and asked to complete a questionnaire.

The participants got a short introduction about the EEG device, the system, and the usability study and were asked to think aloud whenever possible to get the optimal feedback (capture the heat of the moment reactions of the subjects). The participants were assigned a single task; to read continuously and as they do under normal conditions for 20 minutes. The concentration level is recorded during the exercise and visual feedback was provided to alert the user whenever they are not looking at the screen.

The most important four questions in the questionnaire are listed in Table 1 along with the results. As shown in Table 1, the results are promising. Eighty percent (80%) of the subjects confirmed that the system has increased their ability to concentrate on the reading task. Furthermore, only twenty percent (20%) of the participants felt uncomfortable using the system as it compromises their privacy by reading their brain signals. Seventy percent (70%) of the subjects have expressed interest in purchasing the system for affordable price. Finally, few subjects were observed distracted by continuously being worried about the system response. This behavior has however faded away with multiple sessions as the users got used to the system and felt more comfortable with the settings, particularly after they personalize the attention threshold parameter.

VI. CONCLUSION AND FUTURE WORK

ReadGoGo! uses two sources of input, from the webcam and from EEG sensor, to determine if the user is focusing on the reading on the computer's screen. The system helps the reader to quickly re-focus on the reading after mind-wandering or physical distractions. It also helps the readers be aware of their concentration levels which in turn help them to practice and learn how to increase their attention levels.

We are currently working on further differentiating between brain activities when the user is engaging in series of content that is dispersed and unrelated like Facebook posts and a series of related and coherent content like reading textbooks or writing essays. Furthermore, usability testing will be performed to confirm the system's merits and get user feedback about potential enhancements.

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