Measuring Student Alertness Using the X2-30 Eye-Tracker

A study in the suitability of the X2-30 eye-tracker to measure alertness in a learning environment.

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Mätning av Studenters Vakenhet med en X2-30 Eye-Tracker
En studie gällande lämpligheten av X2-30 eye-trackern för att mäta vakenhet i en inlärningsmiljö

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Abstract
This study has investigated the suitability of the eye-tracker X2-30 from Tobii when measuring a student’s alertness level. To be able to determine the suitability of the X2-30 two different environments and two different subjects has been used. The environments were a lecture and webinars, and the two subjects were the two male authors of this study.

The results indicate that the eye-tracker X2-30 can be useful when it’s used under optimal circumstances (i.e. webinars), since it needs to have few disturbing factors when gathering data. These factors regard the subjects not moving out of the tracking area, i.e. the area of which the X2-30 is able to track the eye, and consequently it also means that the subject needs to be careful not to move the hardware. When used under optimal circumstances it was possible to obtain accurate data regarding pupil behaviour and somewhat accurate data regarding blink rate, making data relevant and the equipment suitable for measuring of alertness under the correct circumstances.

Sammanfattning
Denna studie undersöker lämpligheten hos Tobii ABs X2-30 eye-tracker för att mäta en students vakenhet. För att avgöra lämpligheten så har tester gjorts i två olika miljöer och med två olika försökspersoner. Miljöerna var en föreläsning och ett flertal webinars medan försökspersonerna var de två manliga författarna av denna studie.

Resultaten indikerar att X2-30 kan vara användbar när den används under optimala omständigheter, det vill säga webinars, då den kräver så få störande faktorer som möjligt. Dessa faktorer rör utrustningens mätzon och att försökspersonen inte lämnar denna, samt att hårdvaran inte flyttas under mätning. När utrustningen användes under optimala förhållanden så var det möjligt att få precis data rörande pupillens beteende och ganska korrekt data rörande blinkfrekvens vilket gör utrustningen lämplig för mätning av vakenhet under rätt omständigheter.
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Introduction

Current teaching styles in classroom are not optimal according to research. About forty years ago there was a book published by Dr. Donald Bligh named What’s the use of lectures? (Bligh, 2000). The book had a lot of evidence, especially in regards to science lectures, where it was proven that classroom-style-teaching is not optimal. In fact, the only thing this method of teaching is good for is information transfer but it’s not proven to be better than other forms of information transfer. Dr John Medina, a researcher in the area of molecular biology focused on the genes involved in human brain development and the genetics of psychiatric disorders, made a statement supporting Dr. Bligh’s argument. He stated that if a lecture was a business, it would have an 80% failure rate on achieving its goal, namely teaching students (Medina, 2008).

Even though lecture-based teaching is still very much present, there have been some significant changes in the technical arena. The authors of this study believe that some state-of-the-art technology have the potential of optimizing the teaching environment. An investigation will take place regarding the eye-tracking technology, in this case the X2-30, as a possible tool to help pave the way for real-time alertness measuring in lectures. Being one step closer to be able to measure a student’s alertness level in real-time gives the teacher a better opportunity to detect what segments of the lecture was not relatively compelling or simply too hard for the students to understand.

Objective

The objective is to contribute with research that can help pave the way of integrating technology into classrooms (this will be further elaborated in the Future work section). A thesis written last year (2015) investigated the same area, i.e. a students’ alertness level in the classroom but with face-detection technology (Lindelöf & Eriksson, 2015). It inspired this report to continue the same path but with eye-tracking technology.

In regards to today’s learning style in a lecture environment, keeping the attention of a student during a lecture is a challenge. There is a logical deduction of the relation between the students learning process and the amount of time they actually are alert (Davis, 2009) (Gross Lucas & Bernstein, 2015). In addition, the previous section mentioned that there are technology fields that are making great advances and that they may have tools that can help the academic world to better their learning infrastructure. Thus, in this report we are going to explore the possibilities of using some specific state-of-the-art-technology to measure the alertness of students, namely eye-tracking technology. It is important to highlight that the study is not offering a complete solution to the implementation problem but rather additional knowledge with which we can better understand the complexity of having technology interacting with students. This report may direct future studies in the right direction so that less time is spent on groundwork.
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It was implicitly mentioned earlier that the dependencies on technical resources is critical. For this thesis, a considerable amount of time has been spent on acquiring the necessary equipment to gather data. The effort has resulted in us getting eye-tracking equipment from Tobii and monetary resources from the KTH department CSC grundutbildning to rent the equipment from Tobii. The authors of this report are grateful for the help and redirects the reader to the section of acknowledgements for more details.

To concretize our research question for this thesis it has been formulated as follows:

*How suitable is the Tobii Pro X2-30 eye-tracker when measuring a student’s alertness level?*

**Approach**

To address the research question, there is a wide range of functionalities that an eye-tracker can offer when tracking the gaze of an individual. The functions that we are going to use regards mainly behaviour of the pupil but the potential of blinking and eye closure will also be considered. These three factors caught our attention when reading previous studies that relates to the subject of this report. More of this is explained under the Alertness section in the Background.

In order to strengthen the legitimacy of this study there will be a pre study of psychological literature and research which relates to alertness. This will also include a dialog with experts in the field.
Background

Alertness
In this study alertness is defined as an individual being aware and attentive of its surrounding. This definition has been used in extensive research done in the automobile industry. It has been shown that there is a connection between an individual’s alertness level and their blink frequency. Eyelid closure of over 2 seconds is indicative of drowsiness. One standardized measure of alertness is the PERCLOS test in which the subject’s eyes are recorded over one minute. The proportion of the time that their eyes are closed is measured and can be used as a measurement of alertness (Dinges, et al., 1998). There is research showing that eyes rolling upward and sideways are signs of drowsiness (Wierwille & Ellsworth, 1994).

Measurements relating to pupil size and its variations has been found to be another effective measurement of alertness. It has been shown that computerized analysis is able to have a high rate of correlation with the judgements of experts on pupil analysis when determining alertness (McLaren, et al., 1992).

Stanford Sleepiness Scale
The Stanford Sleepiness Scale is a subjective measure of alertness using a seven-graded scale. A subject will judge their own alertness with a value from 1 to 7 where 1 is fully alert and 7 is ‘struggling to remain awake’. Failure to answer is regarded as the subject being asleep (Stanford, u.d.).

Eye-tracking
How does it work?
There are many technical approaches but they generally include a light source and a camera. The light source, which normally is infrared technology, sends light to the eye. The camera then tracks the reflection of this light source and dynamically updates the position of the eye through gathered data. In a more detailed explanation, the data is used to extrapolate the rotation of the eye which in turn gives back the position of the individual gaze. In addition, you can measure the frequency of eye blinks and the diameter of the pupil which is related to human emotions (Crane & Steele, 1985).

Tobii Pro X2-30 Eye-Tracker
The Tobii Pro X2-30 eye-tracker is a portable eye-tracker primarily intended for use in research. It has a capture rate of 30Hz with a gaze sampling variability of 2Hz. The system latency is 50-70ms and it has an immediate gaze recovery time for blinks. Gaze data can be captured in a tracking zone in front of the tracker with dimensions 50x36cm at a range of 70cm. The range of the tracker is 40-90cm (Tobii AB, 2015).
Tobii Pro Analytics SDK
The Tobii Analytics SDK is a collection of development tools used to interact with a number of Tobii devices. These tools allow for the collection of eye-tracking data in real time. The SDK has API bindings for C#, Python 2.7, C++ and MATLAB. Using the SDK, it is possible to retrieve eye positions in 3D space, gaze position (both 3D and 2D) and pupil size. Additionally, it is possible to access a time stamp and validity data for each reading (Tobii AB, 2013).
Method

Test design
In order to test alertness a test was developed. It functions as follows:

1. The subject is placed in front of a computer displaying a video lecture.
2. The subject is given a questionnaire based on the Stanford Sleepiness Scale (Stanford, u.d.).
3. Eye-tracking footage and video footage is captured through the entire experiment.
4. Every 15 minutes the subject selects their current level of alertness from the Stanford Sleepiness Scale.

While we attempt to follow this test as closely as possible we diverted from it on one occasion to perform the test in a real lecture environment. All steps except 1 were followed with the addition of the lecture also being recorded.

The use of the Stanford Sleepiness Scale was based on its ease of use to the subject while also providing a reasonably high level of detail. Being a subjective measurement it can’t be properly compared between subjects but is useful when looking at variations in a single session.

Since the purpose of this study is to evaluate the possibility of using the X2-30 in these conditions it will be the one used in step 3 of the test. Video footage is captured using web cameras placed in front of the subject. This could be done using any video camera since the purpose is only to have a reference for human analysis.

Subjects
Two adult male students ages 28 and 22, hereafter referred to as Subject 1 and 2 respectively, were used for this study. The volunteers are the two authors of this report and were picked on the basis of their expressed interests, availability and health. There was also the factor of lending out the rented eye-tracking equipment which is expensive, delicate and where there is only one unit, hence making the authors the only volunteers. The two subjects were healthy and non-smokers who consumed no more than one cup of coffee per day.
Results

The following results are plots of pupil size of the subject with respect to time. In each graph the x-axis will be time in minutes while the y-axis is size in millimetres. Additionally, the results from the Stanford Sleepiness Scale questionnaire will be included on the same graph as red dots. For these results the x-axis will still represent time in minutes but the y-axis will represent the unit-less values from the Stanford Sleepiness Scale. Additionally, these values will be inverted to provide an intuitive interpretation of higher values equalling higher attention.

The graphs are separated by left and right pupil. A 20th degree polynomial fitted to the data for both the left and right pupil is also presented in all graphs for easier comparison. The red curve represents the left pupil while the green curve represents the right pupil. The choice of 20th degree polynomials was possible due to the large amount of data points generated, avoiding the issue of overfitting.

Figure 1: Subject 1 taking part of real lecture.
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Results

Figure 2: Subject 1 watching online lecture.

Figure 3: Subject 2 watching online lecture.
Results

Figure 4: Subject 2 watching online lecture.

Figure 5: Zoomed in version of Figure 4.
Discussion

In all of the figures there is a noticeable long term change in pupil size. In figure 5 we also have an example of the graph in figure 4 zoomed in on a small interval of about 25 seconds. What's interesting here is that it's possible to discern a wave pattern which suggests that the X2-30 eye-tracker could be used for pupillometric analysis. According to both McLaren et al. and Bitsiosis et al. pupillometry is a reasonable measure of alertness. The X2-30 has higher capture rate than the equipment used by either of the two teams at 30Hz rather than 5Hz and 25Hz respectively (McLaren, et al., 1992) (Bitsios, et al., 2006).

We were not able to determine the accuracy and precision of the pupil measurements of the X2-30 but it is reasonable to assume that it is at least as capable as the equipment used by McLaren et al. and possibly also the one used by Bitsios et al. While we were unable to implement the methods used by either of these teams they do seem promising and compatible with the hardware that we used.

In Figure 1 there are a lot of areas with a lack of valid data points. This is the only recording made in a real life lecture situation and a flaw in the way the session was conducted resulted in this bad data. The X2-30 is designed to track a subject watching a screen. While it is possible to use it for non-screen readings we failed to take into account that it would have to be placed differently. This led to a large number of failed readings while the subject was looking at the lecture, and thus above the X2-30 zone of tracking. This issue can most likely be avoided using proper positioning of the tracker.

The X2-30 is very quick at discovering a newly opened eye and as such it is suitable for the measurement of blink time and frequency. It has the issue of not being able to differentiate between a subject looking outside of the tracking zone and one with their eyes closed. It is possible that this can be solved using the eye and gaze position, both measurable using the X2-30. This has not been properly explored by us but seems like it might have potential.
Limitations
The X2-30, while fairly small and discrete, is still somewhat noticeable when in use (see Picture 1). This relates to the Hawthorne effect, the issue of subjects knowing that they are being monitored and thus changing their behavior (Festinger & Katz, 1953). The feeling of constant supervision that the presence of the X2-30 induces might influence test results.

The eye-tracker comes with a tape strip which is intended to attach the eye-tracker to the screen in order to keep it stable during data gathering (see Picture 2). Due to us not having permanent ownership of the equipment we had to do without using this strip and instead relied on avoiding disturbing the eye-tracker while recordings were made. Still, this is not a perfect solution and some errors may have been caused due to this issue.
Conclusion
Measuring attention of students is a complex task with many different factors which should be taken into account when developing a system to perform this task effectively. The X2-30 seems to be a promising tool in the measurement of student attention in lectures. There are some issues regarding the tracking zone. Additionally, the price of the equipment is prohibitive of large scale use. The X2-30 is only usable at short range and can only track a single person at a time which would demand one device per user in a multi-person system.

In conclusion, for commercial use the X2-30 seems to be overly precise and expensive, while also greatly limited in ease of use in large scale. For research in such fields as pedagogy the X2-30 could be a valuable tool. Providing high level of detail and many different measurements it seems ideal for this sort of environment.
Future work
As it was implicitly stated in the introduction, this was a part of a broader vision that involved implementing alertness measurement equipment in lecture halls to help optimize the learning process. A final delivery/product in the future could be a device that is placed in the front of the students, near the lecturer (see Picture 3), that scans the audience for their alertness level. It uses motion detection, face detection and machine learning to achieve precision. Eye-tracking technology, with a favourable hardware implementation, can help to achieve precision if the data can be mapped to a corresponding data from face detection. Eye-tracking technology is thus used to strengthen the credibility of another technology.

The study made by Lindelöf and Eriksson (2015) investigated a similar perspective but with Face detection, though not with this vision in mind (Lindelöf & Eriksson, 2015). We have investigated with the eye-tracking technology and we hope that next year’s students may investigate the same perspective but with another technology such as motion detection. A theory is that motion detection can play an important role on measuring the accumulated movement in classroom and hence giving another piece of data that can help to achieve this final delivery. The theoretical result could be that a lecturer doesn’t need to concern himself with asking students if they understood what was just explained, instead there will be a screen that displays the alertness level of the students. Consequently, the lecturer will be able to pin point what slide, what definition, what mathematical problem was hard to understand and redesign the lecture accordingly.

Picture 3
Acknowledgment

Thanks to Tobii (Martin Norrefeldt) - For renting us their (cutting edge) equipment to gather data for a very reasonable price.

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References

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