Use of Eye Tracking as an Innovative Instructional Method in Surgical Human Anatomy

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OBJECTIVE: Tobii glasses can record corneal infrared light reflection to track pupil position and to map gaze focusing in the video recording. Eye tracking has been proposed for use in training and coaching as a visually guided control interface. The aim of our study was to test the potential use of these glasses in various situations: explanations of anatomical structures on tablet-type electronic devices, explanations of anatomical models and dissected cadavers, and during the prosection thereof. An additional aim of the study was to test the use of the glasses during laparoscopies performed on Thiel-embalmed cadavers (that allows pneumoinsufflation and exact reproduction of the laparoscopic surgical technique). The device was also tried out in actual surgery (both laparoscopy and open surgery).

DESIGN: We performed a pilot study using the Tobii glasses.

SETTING: Dissection room at our School of Medicine and in the operating room at our Hospital.

PARTICIPANTS: To evaluate usefulness, a survey was designed for use among students, instructors, and practicing physicians.

RESULTS: The results were satisfactory, with the usefulness of this tool supported by more than 80% positive responses to most questions. There was no inconvenience for surgeons and that patient safety was ensured in the real laparoscopy.

CONCLUSION: To our knowledge, this is the first publication to demonstrate the usefulness of eye tracking in practical instruction of human anatomy, as well as in teaching clinical anatomy and surgical techniques in the dissection and operating rooms. (J Surg Ed 74:668-673. © 2017 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Tobii glasses, eye tracking, teaching human anatomy, teaching surgery

COMPETENCIES: Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

New technologies are increasingly applied to the field of medicine. In recent years, eye tracking has been used to teach and to hone skill sets in relation to clinical anatomy and surgical technique (particularly laparoscopy) and to explain image-guided diagnostic techniques such as ultrasound.

The use of single-camera technology to track eye movement is a well-established concept first described in airplane pilots in 1950.[1] New techniques have since been developed, and eye tracking has been documented using stationary cameras or cameras fitted to normal glasses. These glasses can record corneal infrared light reflection to track pupil position, to map gaze focusing in the video recording, and to calculate other parameters such as tracking rate or dwell time (used to measure the importance of the stimulus) and pupil dilation (used as a marker of effort and concentration).[2-4]

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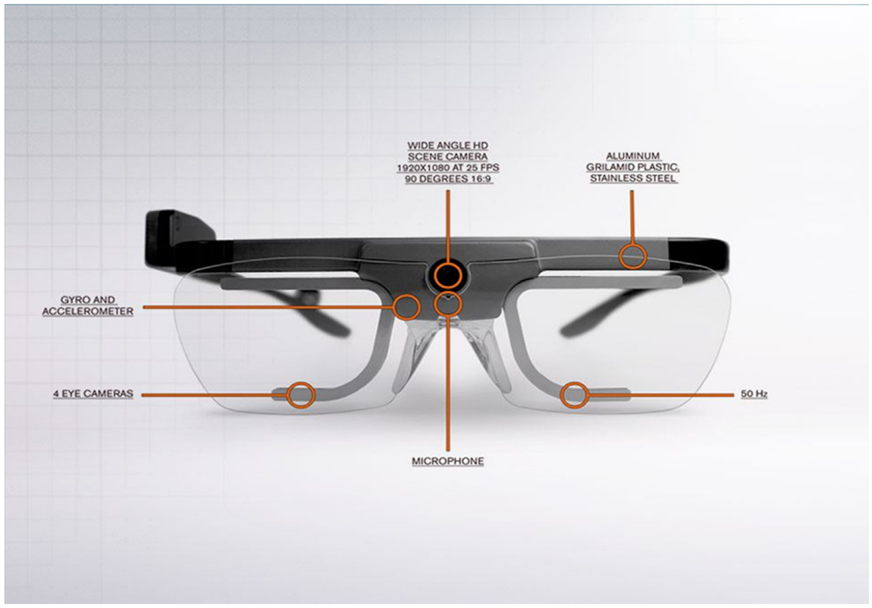

FIGURE 1. Tobii glasses with technical details. Characterics of the Tobii glasses. These glasses were equipped with the following: (1) high-definition scene camera to capture a video of everything in front of the participant at a 160° angle of vision; (2) microphone to pick up sounds from the participants and their surroundings; (3) eye-tracking sensors to track eye-gaze direction, among other parameters; (4) eye lighting system to support the eye-tracking sensors; (5) HDMI microconnector (to connect the Tobii glasses to the recording unit with the HDMI cable provided); (6) cable guide to hold the HDMI cable at the participant's back; (7) protective lenses; (8) computer with recording and analysis software; and (9) dissection room projectors to display the software image.

It has been suggested that measurement differences between subjects with different levels of surgical skill could be used as skill markers.[5,6] In fact, eye tracking has been proposed for use in assessment as well as in training and coaching as a visually guided control interface.[7] This could be of particular interest in surgical theaters, where aseptic conditions must be maintained. Visual orientation may be a greater problem in laparoscopic surgery and, therefore, the analysis and identification of efficient orientation strategies based on eye tracking have proven to be potentially helpful.[3,5]

MATERIAL AND METHOD

We performed a pilot study using Tobii glasses (Fig. 1) in the dissection room at the School of Medicine of the Miguel Hernández University in Elche, Spain. To record eye-tracking data, Tobii glasses are worn like normal glasses and weigh only 45 g. The visual field is 160° (horizontally), with minimal vision loss during extreme eye movements. The system must be calibrated separately for each participant by asking participants to look at a calibration card placed in front of them for several seconds. The investigator then starts recording the participant's vision through the Tobii glasses. Total battery time is 120 minutes, and the software is run on a Windows 8/8.1 tablet or Windows 7 or 8/8.1 computer. This allows the investigator to view the eye-tracking session both in real time (streaming by Wi-Fi or cable connection) and after recording. When watching a recording in real time, the participant can view a circle displayed in the video display of the camera used to record the scene with the built-in HD camera fitted to the Tobii glasses. This circle represents the participant's macular vision.

We found the Tobii glasses to be useful in teaching human anatomy in this context. To test them, the instructor wore the glasses while dissecting a forearm specimen. As seen in the videos, the images produced by the glasses show the instructor's visual field and a circle is used to point out the focus of eye gaze (specifically, macular vision), pointing out the element of interest by gaze. This means that the viewer will see the same image as the instructor at the same angle and with the same visual field. Images and sounds are transmitted by Wi-Fi to any computer or projector with a delay of less than 1 second. The Tobii eye-tracking glasses are fitted with a direct vision function that allows investigators to observe in the video exactly where the wearer is looking, and in real time to see the image on any Windows 8 tablet, while moving about freely in any environment, thanks to a Wi-Fi wireless connection. In addition, the device can record and then analyze different data such as the rate at which each point is observed. The circle is several seconds ahead of the hand location, as the gaze moves earlier to the structure to be dissected (Video 1 and 2).

We tested the use of Tobii glasses in a lecture class and with anatomical models. As the instructor explained the various structures shown on an anatomy card, he looked at them and then pointed them out on the monitor viewed by the students, with no need for a pointer (Video 1 and 2).

TABLE. Survey Administered

Please state your current status:
1. Medical student, 2. Instructor, 3. Practicing physician

After viewing the video tapes on the applications of Tobii glasses, do you:
1. Completely agree. 2. Agree. 3. Undecided. 4. Disagree. 5. Completely disagree

1. This could be a good tool during *theoretical classes* on anatomy, as it allows the instructor to point out structures over the place where the anatomical images are being shown.

2. This seems to be a good tool for use in dissection rooms during *prosection and dissection of anatomical structures* in the cadaver because structures pointed out with forceps may not always be visible from all angles, as the instructor's own body can interfere with students' line of sight.

3. This seems to be a good tool for use in *anatomical models* because structures pointed out with forceps may not always be visible from all angles, as the instructor's own body can interfere with students' line of sight.

4. This seems to be a very useful tool to point out anatomical structures while teaching applied anatomy in clinical medicine for *postgraduate courses*, using Thiel-embalmed cadaver models, which allows laparoscopic surgical techniques to be performed.

5. This might be a good tool for practical examinations in the dissection room because there is no need to touch structures directly, but simply to point them out "visually" and, therefore, to avoid the deterioration of anatomical specimens by preventing handling.

6. This might be a good tool for postgraduate instruction, as it allows structures to be pointed out to residents during *actual instructional laparoscopies*.

7. This might be a good tool for *specialization in more complex surgical techniques*, as it allows more expert surgeons to show novice surgeons the surgical maneuvers to be made during more complex laparoscopies.

8. The current cost of the glasses is approximately €20,000. Do you consider that this is an efficient product for acquisition by Schools of Medicine in the public university system, in the light of the effort to include innovative instructional strategies?

Please add any comments or remarks that you feel might be useful.

We also tested the glasses in laparoscopic procedures on Thiel-embalmed cadavers, which allow abdominal cavity pneumoinsufflation and exact reproduction of the surgical technique. After that we also probed them in a real laparoscopic procedure at "Virgen de la Arrixaca" University Clinical Hospital, Murcia, Spain (Video 2).

To measure the usefulness of this instrument, we designed an anonymous online survey (Table). A computer application from the University of Murcia (encuestas@um.es) contained a link to view Video 1 and the survey. This was sent to students from the School of Medicine at the University of Murcia as well as to instructors and physicians from the Department of Obstetrics and Gynecology at Virgen de la Arrixaca University Clinical Hospital.

RESULTS

A total of 62 completed surveys were returned, and participation was 54.8% among students, 21% among professors, and 24.2% among practicing physicians. The global survey results were highly satisfactory (Fig. 2).

Below we describe the overall results independent of status (medical student, instructor, or practicing physician) (Fig. 3). The items most highly valued, in order, with more than 80% answering "agree" or "totally agree" were for the questions that considered it a good tool during theoretical anatomy classes, for specialization in more complex surgical

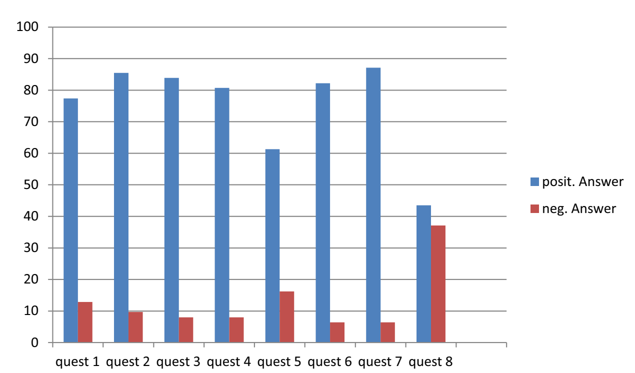

FIGURE 2. Overall survey results. Positive results ("Totally agree" or "Agree") are shown in blue. Negative results ("Disagree" or "Totally disagree") are shown in red.

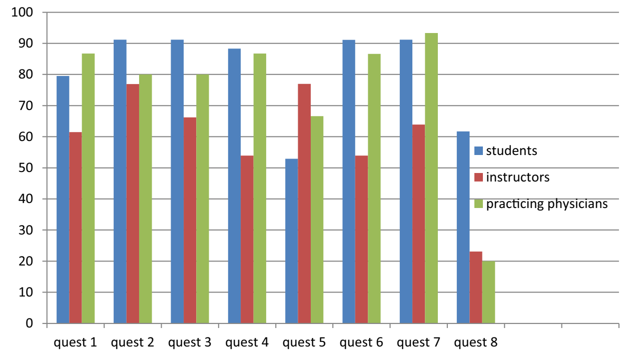

FIGURE 3. Survey results according to status. Positive results ("Totally agree" or "Agree") are shown for students, instructors, and practicing physicians.

techniques, during prosection and dissection of anatomical structures in the dissection room, and in anatomical models; and for postgraduation instruction in actual teaching laparoscopies and in laparoscopic surgical techniques in Thiel-embalmed cadavers. The worst results (61.3% positive opinions) were obtained by the questions on whether the Tobii glasses were a good tool for practical examinations in the dissection room and on whether it was an efficient product (43% positive opinions).

When breaking down the results according to status, the best evaluations were from students. This group answered "agree" or "totally agree" 90% of the time for the same items described earlier. The worst evaluations were for usefulness during practical examinations.

The worst overall evaluation was given by the instructors. Interestingly, the question best evaluated by this group was on the usefulness of the device in practical examinations, with 77% positive responses. Other responses evaluated highly were related to usefulness during prosection and dissection of anatomical structures, in anatomical models, and during learning of more complex surgical techniques.

Practicing physicians gave high evaluations to specialization in more complex surgical techniques (93.3% positive responses), to anatomy instruction applied to clinical medicine in postgraduate courses using Thiel-embalmed cadaver models (86.7% "agree" responses), and to actual teaching laparoscopies (86.6% positive evaluations). The worst evaluation was related to efficiency (20% positive responses).

The observational data available in this survey (at the end we wrote "Please add any comments or remarks that you feel might be useful") showed that eye-tracking technology allows visual instruction that improves completion times and reduces errors in a simulated environment (laparoscopy in Thiel cadaver). Surgeons also felt that less time was spent scanning the screen and that their instrument movements were more precise and less hesitant. Another interesting comment was that eye tracking was a possible tool that provided "a third hand" to the surgeon. An additional opinion was that eye tracking could aid communication between surgeons during surgery procedure, improve training, and assist in using surgical instruments.

DISCUSSION

To our knowledge, this is the first publication to demonstrate the usefulness of eye tracking in practical and theoretical instruction of clinical human anatomy as well as in teaching clinical anatomy and surgical techniques in the dissection room and in a real laparoscopic procedure. The device is easily manageable, even for first-time users, and it serves as a highly valuable tool for many types of qualitative research. We have used this system in radiologic image reading, anatomical models, cadaver dissection, and laparoscopy. Some techniques such as orotracheal intubations or spinal taps can only be performed when the person is properly positioned, making eye tracking an extremely useful tool when instructing or monitoring students' or residents' technique. The tool allows simple examinations or surgical operations to be monitored even when the instructor or physician supervising the procedure in real time is in another room, ensuring that the student is focusing on key elements for each situation. We also demonstrated its usefulness in the dissection room, where a pointer cannot be used during dissection due to the use of gloves.

Our literature review found no article that mentioned the use of this technology in medical school or clinical anatomy instruction, areas of great importance for postgraduate courses in which specialists learn, perfect, or innovate surgical techniques, although we did find an article in the field of nursing education.[8] We believe that eye tracking could be extremely useful for the practical teaching of human anatomy, as evidenced by our pilot study.

When anatomists perform dissections, students view the entire field and, unless instructed or pointed out, will not focus on the details seen by the dissector. We believe it would be useful for the student to see a circle on the monitor to point out the dissector's macular vision in real time, thus indicating the most interesting detail of the dissection.

Eye tracking can also be used to learn image-based diagnostic techniques such as ultrasound, computed tomography scan, or magnetic resonance imaging,[9,10] which also allows visual cues to be given in real time. This technology also allows real-time volumes to be calculated[11] that may be extremely useful when planning the best approach for each patient.

A number of studies have been published on the use of eye tracking in other clinical fields, including radiology,[12,13] surgery,[14-17] pathology,[18] and unit cares.[19] One study looked at the use of eye tracking to understand learning in students of gross anatomy; however, the study did not focus on using the tool to teach anatomy.[20]

Eye tracking has been used with virtual laparoscopy simulators[21] to compare specific skills between expert and novice surgeons, as it is enormously important to detect differences and to improve training and perfection in these techniques.

Wilson et al.[21] provide support for the usage of assessing strategic gaze behavior to better understand how surgeons use visual information to plan and control tool movements in a virtual-reality laparoscopic environment. For instance, these authors showed that gaze analyses revealed that experienced surgeons spent significantly more time fixating target locations than novices, who split their time between focusing on the targets and tracking the tools. Previous research[22] has demonstrated that experts are more likely to fixate on the target, whereas novices are more likely to track the tool as it moves toward the target. In virtual laparoscopy, it has been shown that the economy of movement of the left (nondominant) hand varied significantly between experienced and novice operators.[21] In video-assisted surgery, Kocak et al.[23] found that surgeons with greater experience tended to move their eyes less and to spend more time fixed on a given point. Experiments have also been conducted in virtual laparoscopy simulators to compare outcomes when only verbal instructions were given to novice surgeons and when verbal instructions were combined with visual cues given by a visual recording provided by eye-tracking vision.[7] It was concluded that surgeons took less time to complete a surgical task or step, showed greater precision, and committed no errors when the guidelines were given both verbally and visually simultaneously.

In another article,[6] the authors used real-time eye tracking during laparoscopic surgery undertaken by expert and novice surgeons and then analyzed these recordings. Eye-gaze patterns obtained from the expert surgeon should be recorded during the actual operation and then superimposed on the recorded surgical video. They found significant differences between the 2 patterns. Novice surgeons had eye-gaze patterns that often wandered from key areas of the operative field, whereas expert surgeons demonstrated closer eye-gaze patterns that focused on these key target areas. Expert surgeons developed an ability to scan over surgical sites using a replicable strategy over different trials. In contrast, novice surgeons did not develop a stable strategy and had a lower chance to copy the expert's visual strategy. This technology opens an opportunity to scrutinize a surgeon learning process in an objective way. These authors also demonstrated that gaze overlay is affected by the complexity of the surgical procedure. This would provide additional information to novice surgeons as to where the expert surgeons are focusing their attention during each step of the operation. Eyemetrics together with eye tracking while watching surgical videos can be used as adjuncts to assessing surgical skill and level of competence. The next step is to have a novice surgeon perform a laparoscopic task in the operating room while being supervised by an expert surgeon and to record the eye-gaze patterns of both surgeons while they are watching on the monitor, and then to analyze the differences between novice and expert surgeons during a real operation and how these differences can be used to assess surgical performance and competence. We have already tried out the device in actual surgery (both laparoscopy and open surgery), once it was shown that there was no inconvenience for surgeons and that patient safety was ensured. Video 2 is indicative of its applicability in clinical practice.

After this positive proof of concept, we will follow this line of research to provide quantitative results for parameters that measure the efficiency of learning.

CONCLUSION

We believe that Tobii glasses will also make it possible to monitor and shorten the learning curve of novice surgeons and will be particularly useful in postgraduate education (courses and congresses) in the human anatomy dissection rooms increasingly used in our setting, where Thiel-embalmed cadavers are used. Another field that could be of vital importance is patient safety, as the glasses could be used to record real surgeries and examinations, confirming that the physician has performed an accurate examination and remained alert at all key points of the procedure.

DISCLOSURE

The authors declare that they have no financial interest or benefit that has arisen from the direct applications of their research.

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SUPPLEMENTARY MATERIAL

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jsurg.2016.12.012.