# A pilot study of eye-tracking devices in intensive care

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***Background.*** *Eye-tracking devices have been suggested as a means of improving communication and psychosocial status among patients in the intensive care unit (ICU). This study was undertaken to explore the psychosocial impact and communication effects of eye-tracking devices in the ICU.*
***Methods.*** *A convenience sample of patients in the medical ICU, surgical ICU, and neurosciences critical care unit were enrolled prospectively. Patients participated in 5 guided sessions of 45 minutes each with the eye-tracking computer. After completion of the sessions, the Psychosocial Impact of Assistive Devices Scale (PIADS) was used to evaluate the device from the patient's perspective.*
***Results.*** *All patients who participated in the study were able to communicate basic needs to nursing staff and family. Delirium as assessed by the Confusion Assessment Method for the Intensive Care Unit was present in 4 patients at recruitment and none after training. The device's overall psychosocial impact ranged from neutral (−0.29) to strongly positive (2.76). Compared with the absence of intervention (0 = no change), patients exposed to eye-tracking computers demonstrated a positive mean overall impact score (PIADS = 1.30;* $P = .004$*). This finding was present in mean scores for each PIADS domain: competence = 1.26, adaptability = 1.60, and self-esteem = 1.02 (all* $P < .01$*).*
***Conclusion.*** *There is a population of patients in the ICU whose psychosocial status, delirium, and communication ability may be enhanced by eye-tracking devices. These 3 outcomes are intertwined with ICU patient outcomes and indirectly suggest that eye-tracking devices might improve outcomes. A more in-depth exploration of the population to be targeted, the device's limitations, and the benefits of eye-tracking devices in the ICU is warranted. (Surgery 2016;159:938-44.)*

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The need for effective patient communication is heightened during critical illness. However, approximately 40% of patients in the intensive care unit (ICU) require mechanical ventilation, precluding them from verbal communication.[1] These patients are at risk for adverse events owing to limited movement, difficulty communicating, and their inability to signal for help. They are also prone to negative psychological outcomes. Ineffective communication in the ICU may lead to ICU psychosis in both patients and family members.[2-5] Maintaining patient safety and reestablishing a positive psychosocial state are crucial in intensive care.[6-8] These conditions are particularly difficult to achieve without patient communication.

Critically ill patients requiring mechanical ventilation typically receive an endotracheal tube or tracheostomy tube. With a tracheostomy tube, several methods of maintaining communication are possible, including a 1-way speaking valve, leak speech, and digital occlusion. All require tracheostomy cuff deflation,[9-11] which may not be tolerated. Thus, with an endotracheal or tracheostomy

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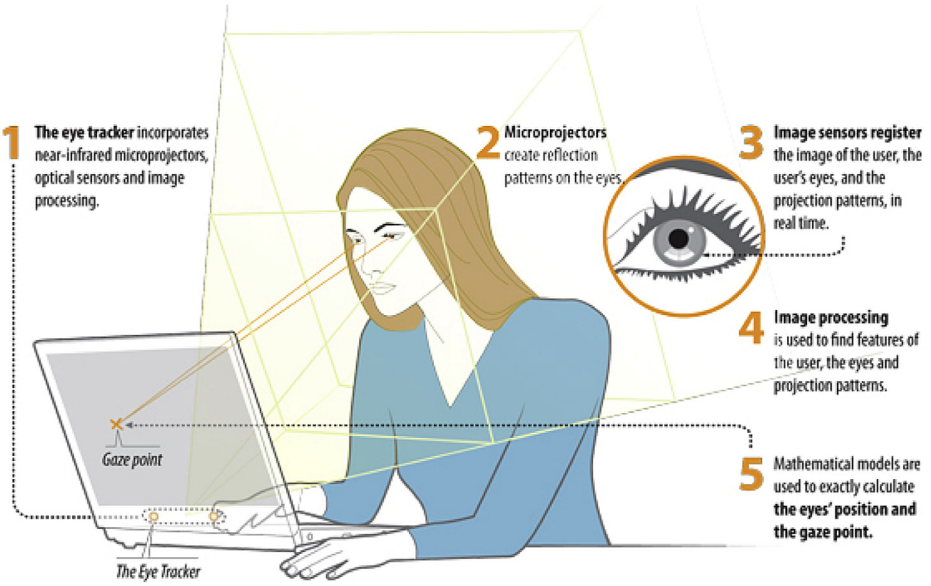


**Figure.** Eye-tracking communication devices.

tube, patient communication often relies on facial expressions, gestures, and writing. Augmentative and alternative communication systems including picture recognition or writing boards are often employed as well. These modes of communication may prove ineffective and can result in frustration for the patient and health care staff.[12]

In this situation, an advanced technological aid such as an eye-gaze computer may address the unmet communication need. Eye-tracking communication devices detect eye movement and position then integrate the data to create a gaze point for computer screen selections (Figure).[13] Patients with amyotrophic lateral sclerosis have typically been the target population for these devices.[14,15] Another suggested use as a communication device in the ICU has not been well-examined.[16] To date, only 1 study has assessed eye-tracking communication devices in the intensive care setting.[17]

The objective of this study was to implement eye-tracking devices in intensive care as a communication aide and to elucidate the resulting psychosocial impact. We hypothesized that the device would be used successfully by patients for communication and would have a significant positive impact on the patient's psychosocial status.

## METHODS

**Design and patients.** This study was a pilot prospective trial conducted in 3 tertiary ICUs noncontinuously over 10 months between June 2013 and May 2014. The study attempted to prospectively enroll all eligible patients during normal working hours (Monday–Friday, 9 AM–5 PM). Participants were recruited from the surgical ICU, medical ICU, and neurosciences critical care unit at The Johns Hopkins Hospital, Baltimore, Maryland. The Johns Hopkins Medicine Institutional Review Board approved the study.

Patients in participating ICUs who were mechanically ventilated or dysarthritic were screened. From these patients, nursing, speech language pathology, or occupational therapy staff identified those who were cognitively capable of communicating but failed to do so with available methods. Study staff subsequently approached these patients and included those who were sufficiently awake and alert as assessed by the Richmond Agitation Sedation Scale (RASS). Patients were excluded from the study if they were unable to demonstrate understanding through eye/head/physical movement, were unable to comprehend English, had eye injuries limiting their vision, were significantly sedated/agitated (RASS $> 2$ or RASS $\leq -2$), or could communicate through writing or verbally.

**The eye-tracking device.** The Tobii C12 eye-tracking computer (Model C12 Communication Device, Tobii Technology, Stockholm, Sweden) has a camera-based eye-tracking system in which the camera and light source are permanently affixed to a monitor. The computer uses infrared diodes to produce reflection patterns on the corneas in the user's eye. Two specialized sensors capture corneal reflections at 30–40 Hz (or 30–40 images per second) to determine where the patient's eyes are looking and their position in 3-dimensional

space. A brief calibration process requires the user to track 9 points on the screen while image processing algorithms detect features of corneal reflection patterns. These patterns are then translated to a gaze point on screen. This allows the sensor to follow the patient's eyes and translate gaze to cursor movement.[13] The eye-tracking computer is an off-the-shelf, commercially available system that runs on a Windows 7 operating system. For this study, the device was mounted on a wheeled stand that allowed the device to be both easily transported and suspended over the patient. Several graphical user interfaces were customized for the study using symbols matched with words. The device allows users to communicate by dwelling on text or symbols that then generate speech automatically or when prompted. Through the device, the user also has full access to the Internet, social media, and email.

**Study outcome measures.** The primary outcome measure was the Psychosocial Impact of Assistive Devices Scale (PIADS). It was used to determine impact on quality of life and, indirectly, usability. The PIADS[18,19] is a reliable and sensitive measure for a wide variety of study populations.[20,21] It consists of 26 self-reported items that are used to assess functional independence, well-being, and quality of life. For patients who are unable to fill out the questionnaire on their own, the caregiver or trainer may assist.[22] Patients indicate the assistive device's impact on each of the 26 items, rating them on a 7-point Likert scale from −3 (maximum decrease) to +3 (maximum increase). The PIADS contains 3 subscales for competence, adaptability, and self-esteem. The competence subscale consists of 12 items and measures competence and efficacy, indicating the patient's sense of performance and productivity. The adaptability subscale consists of 6 items and measures willingness to try new things and take risks, indicating the enabling aspects of the assistive device. The self-esteem subscale consists of 8 items and indicates feelings of emotional health and happiness, indicating self-confidence and emotional well-being.

The PIADS was developed as a means of assessing quality of life for physically limited or disabled populations. This is the first known application of the PIADS to an ICU population. The PIADS has been widely applied to assessing assistive devices and particularly eye-tracking devices[14] and, therefore, was chosen as the assessment tool for this study.

The RASS and Confusion Assessment Method for the Intensive Care Unit (CAM-ICU) were used to assess the cognitive function of patients on a daily basis. The RASS is a highly reliable and valid assessment of sedation and agitation for a broad spectrum of adult ICU patients. It is completed by a health care professional assessing the patient for responsiveness and indicates the patient's level of agitation/sedation ranging from +4 (combative) to −5 (unarousable).[23] The CAM-ICU is a highly sensitive evaluation of delirium during and after mechanical ventilation in critically ill patients. A health care professional completes a series of assessment variables and tests the patient for attention and cognition with a positive result (delirium present) or negative result (no delirium present).[24] Used together, the RASS and CAM ICU are an excellent means of assessing delirium and sedation.[25,26]

**Study process.** Patients were introduced to the eye control computer and orally consented to begin participation in the study. Speech language pathology or occupational therapy specialists worked with the patient for 5 usage sessions on consecutive weekdays between 9 AM and 5 PM. Each session lasted approximately 45 minutes, during which patients were prompted to spell out notes, indicate their needs via picture sets, and play simple memory games. At each session, the CAM-ICU and RASS scores were determined. The patient was permitted to use the device at will outside of training sessions to communicate with family, nursing staff, and physicians, but data on these sessions were not collected. Upon completion of the 5 usage sessions, patients were assessed with the PIADS. All 12 patients included in the study completed the five 45-minute sessions before assessment; patients who failed to complete the 5 training sessions were not included in this study. Patients used the eye-tracking device or basic head gestures to indicate their response (a number between −3 and +3, or between strongly negative to strongly positive) to each of the 26 questions. The PIADS was read and physically completed by speech language pathology/occupational therapy staff. PIADS administration took ≤15 minutes.

**Statistical analysis.** The PIADS survey scores were collected, entered, and analyzed for an overall psychosocial impact. The means were compared to an alternate hypothesis of no effect (0) using a 1-sample Student *t* test. All PIADS questions and the 3 PIADS subscores of competence, adaptability, and self-esteem were analyzed for significance. Analysis was conducted using GraphPad Prism 6 software (GraphPad Software, Inc, La Jolla, CA).

## RESULTS

A total of 12 patients successfully completed the study protocols during 10 months of

**Table I.** Patient characteristics ($n$ = 12)

| *Value* | n | % |
|---|---|---|
| Age | | |
| Mean ± SD | 55.2 ± 13.1 | |
| Range | 33–73 | |
| Gender | | |
| Male | 3 | 25 |
| Female | 9 | 75 |
| Intensive care unit | | |
| Medical | 3 | 25 |
| Surgical | 4 | 33 |
| Neurosciences | 5 | 42 |
| Duration of stay at assessment | | |
| Mean ± SD | 26.1 ± 22.7 | |
| Range | 8–87 | |
| Airway status | | |
| Tracheostomy | 8 | 67 |
| Endotracheal intubation | 3 | 25 |
| Self-maintained | 1 | 8 |
| Cause of disability | | |
| Neuromuscular | 4 | 33 |
| Neurologic | 3 | 25 |
| Musculoskeletal | 2 | 17 |
| Organ failure | 2 | 17 |
| Sepsis | 1 | 8 |

*SD*, Standard deviation.

nonconsecutive enrollment. Patient characteristics are reported in Table I. Data on screening and total patients recruited who failed to finish the study protocol were not collected. Only 1 patient refused to continue participation in the study after receiving training with the device.

At the initial training session, four patients were positive for delirium as assessed by the CAM-ICU (Table II). By the second day of training, only 1 patient remained CAM-ICU positive. From the third day and onward, no patients were considered delirious. Before the introduction of the eye-tracking device, all patients relied on mouthing words or blinking to communicate. After the intervention, all patients were able to communicate a minimum of basic needs by selecting buttons from preset guided user interface screens during their first usage session. All patients were able to communicate essential needs to health care staff and family, including "hungry," "thirsty," "bathroom," "nurse," "pain," "hot," "tired," and more. One-half of the patients ($n$ = 6; 50%) were able to use the keyboard guided user interface to write full sentence messages by the end of the study. Several patients ($n$ = 3; 25%) were able to manipulate the computer to a greater extent and have discussions regarding their care or communicate via social media with friends and family.

Patients reported the psychosocial impact of the eye-tracking computer to be moderately positive (mean, 1.30), a significant effect when tested against no change ($P$ = .0044). PIADS scores (Table III) indicated that adaptability was the most significantly impacted by the device. On average, patients rated the device as having positive effects on their ability to adapt, competence level, and self-esteem.

Patients indicated that the device positively affected their happiness and ability to participate. However, the device did not significantly decrease patients' confusion level or frustration. Six patients found that the device increased their frustration (50%), whereas 3 of those patients felt that the device moderately or strongly increased their frustration. One patient felt the device increased her confusion, albeit only slightly (+1), and 6 of the remaining patients felt that the device decreased their confusion.

## DISCUSSION

Despite the many interventions currently used, some patients remain unable to communicate during their intensive care stay. Eye-tracking devices may allow some of these patients to reestablish communication. In our study, we found that all willing and capable patients effectively communicated basic needs using an eye-tracking device. Moreover, the PIADS results indicated that adaptability and "ability to participate" were the most strongly impacted metrics surveyed, indirectly suggesting an increased ability to interact with the ICU environment. Without eye-tracking, these patients would not have been able to communicate with health care staff or family members beyond blinking or mouthing words.

As evidenced by the PIADS results, patients reported that use of the eye-tracking device increased feelings of adaptability, competence, self-esteem, happiness, and ability to participate, and it decreased confusion. These results suggest that eye-tracking devices may be an effective tool for bolstering the psychosocial status in a population of ICU patients. This aligns with the results from the only previous study on eye-tracking in intensive care.[14] However, a potential negative psychosocial effect was identified in this study. Patient frustration may increase during usage and negatively affect the patient's psychosocial status. Generally, the patients' desire to communicate overrode the challenges of usage, and 2 of the 3 patients who rated the effect of the device to be strongly frustrating (−3) considered it to be moderately positive overall. Owing to our study

**Table II.** Confusion Assessment Method for the Intensive Care Unit and Richmond Agitation Sedation Scores

| *Variable* | *Day 1,* n *(%)* | *Day 2,* n *(%)* | *Day 3,* n *(%)* | *Day 4,* n *(%)* | *Day 5,* n *(%)* |
|---|---|---|---|---|---|
| Confusion Assessment Method for the ICU | | | | | |
| Delirium present | 4 (33) | 1 (8) | 0 | 0 | 0 |
| Delirium absent | 9 (67) | 11 (92) | 12 (100) | 12 (100) | 12 (100) |
| Richmond Agitation Sedation Score | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 10 (83) | 12 (100) | 12 (100) | 12 (100) | 12 (100) |
| −1 | 0 | 0 | 0 | 0 | 0 |
| −2 | 2 (17) | 0 | 0 | 0 | 0 |

**Table III.** Psychosocial Impact of Assistive Devices Scale scores

| *Metric* | *Mean* | *Standard deviation* | *Range* | P *value (compared with no change)* |
|---|---|---|---|---|
| Subscale 1: Competence | 1.26 | 1.44 | −1.42 to 2.83 | .0115 |
| Subscale 2: Adaptability | 1.60 | 1.30 | 0.00 to 3.00 | .0013 |
| Subscale 3: Self-esteem | 1.02 | 1.24 | −1.00 to 3.00 | .0159 |
| Overall | 1.30 | 1.26 | −0.28 to 2.76 | .0044 |
| Happiness | 1.42 | 1.51 | −2.00 to 3.00 | .0076 |
| Confusion | −0.07 | 1.44 | −3.00 to 2.00 | NS |
| Well-being | 1.08 | 1.38 | 0.00 to 3.00 | .0199 |
| Quality of life | 1.50 | 1.45 | 0.00 to 3.00 | .0042 |
| Frustration | 0.17 | 2.25 | −3.00 to 3.00 | NS |
| Ability to participate | 2.00 | 1.21 | 0.00 to 3.00 | .0001 |

*NS,* Not significant.

design, we were unable to further investigate this effect, but future studies must consider the potential negative effects of eye-tracking device usage.

Increased communication and improved psychosocial status have been found to combat ICU psychosis and decrease negative outcomes.[27,28] In particular, eye-tracking devices could serve as a tool to decrease delirium by engaging patients that otherwise would not be able to interact with their environment. Given these potential affects the relationship between ICU outcomes and eye-tracking device usage should be explored.

The target population for eye-tracking devices has not been clearly identified. Nor has the minimum usage for positive impact. Our study examined only those patients who could use the eye-tracking device for 5 consecutive weekday sessions. This limited our study to a specific population with long ICU stays and stable cognition. It is unclear how many ICU patients have these characteristics during the course of a given year. However, 1 recent study suggests that nearly 50% of ICU patients mechanically ventilated for ≥2 days and awake, alert, and responding to verbal communication for a 12-hour period may be able to use communication tools.[29] This proportion combined with the project IMPACT results[1] suggests that approximately 20% of ICU patients could use eye-tracking devices. Future studies should examine the exact proportion of intensive care patients for which intervention with an eye-tracking device may be attempted with clear criteria for enrollment.

**Device limitations.** Patients often struggled to concentrate on the screen and maintain posture conducive to eye tracking. For some patients, keeping their eyes open enough to be tracked was difficult. An able-bodied individual is always required to place the device in position, turn on the device, and initiate the eye-tracking program. Unless the device was in place at a given moment, the patient could not use the device to communicate. In between sessions, a nurse or family member was required to set up the device and assist the patient with calibration, requiring some training. Additionally, the cost of an eye-tracking device and its upkeep may be an issue for patients and hospitals. The Tobii C12 model is no longer in production. However, the current market prices for eye-tracking systems (software and hardware)

range from approximately $2,000 to $8,000. Related costs of device maintenance and staff training have not been established. To fully assess the value of eye-tracking devices, a complete cost analysis for a hospital implementation of eye-tracking devices detailing the cost of devices, accessory equipment, upkeep, staff training, and patient training is required.

**Study limitations.** Our study enrolled a small number of patients, limiting the strength of our conclusions. The small sample size enrolled over a relatively long period (10 months) also suggests a limited target population. However, our inclusion criteria excluded a significant number of patients with <5 days of training. Without data on these patients, our study cannot provide an idea of the population that might benefit from eye-tracking devices. Owing to the wide variety of patients in our ICUs, the population enrolled varied greatly in diagnosis, prognosis, and cognitive ability. Our sample included several types of ICU patients, but the small sample size prevented an investigation of subpopulations.

Although the presence and type of communication was noted in this study, there was no measurement of communication ability. Patients, health care staff, and family members could not provide objective assessment of their experience. Although patients provided a subjective assessment of the eye-tracking device, they did not directly assess their communication. Thus, all conclusions regarding communication stem from study staff observations.

The data collected in this study cannot allow us to conclude that the patient's perceived greater well-being directly relates to the use of the eye-tracking device. Several alternative explanations may explain the patient's perceived greater well-being after using the device. In addition, the device may not be the critical factor in increasing communication. Greater time and effort directed toward communication with the patient may explain the patient's perceived greater well-being.

Data on patient familiarity with computer usage was not collected in this study. However, this may be an important factor affecting device utilization and the patient's experience. Future researchers should consider the impact of familiarity with computer usage when assessing eye-tracking devices.

Only 1 patient refused to use the device after an initial usage and assessment. This patient was not surveyed owing to a lack of exposure to the device. This study was not designed, nor was it able, to explore the reasons for early abandonment. It also did not include information on patients that began participation, but ultimately did not complete the study. Patients were lost before 5 days of training owing to transfer, decrease in function, increase in function, discharge, and death, but data on these patients were not maintained. It is crucial in future studies to explore the short-term impact of device usage and assess feasibility for this population of patients.

In conclusion, eye-tracking devices may be an effective tool to promote patient communication and increased psychosocial well-being in selected ICU patients. Although no ICU outcomes are measured in this study, we hypothesize that by addressing psychosocial status and communication ability with eye-tracking devices, these patients may have better outcomes. The methodology of this study limits the strength of our conclusions about the eye-tracking device's impact. Future studies should clearly identify the target population, assess communication between patients, health care staff, and family, and test an association with ICU outcomes.

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