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# **Title:** Eye-Tracking for Examining Nurses' Attention During Cardiac Arrest Simulations: A Feasibility and Acceptability Study

**Titre :** L'oculométrie pour examiner l'attention d'infirmiers et d'infirmières lors de simulations d'arrêt cardiorespiratoire : une étude de faisabilité et d'acceptabilité

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**Abstract**

**Introduction:** Eye-tracking offers a distinctive opportunity to assess nurses' clinical decision-making in simulation. Although its feasibility has been established in various scenarios, most studies have focused on a single participant, typically a physician in a leadership role. The application of eye-tracking in the challenging context of in-hospital cardiac arrest (IHCA) simulations, where nurses juggle diverse roles and undertake physical tasks such as chest compressions, has yet to be explored.

**Objectives:** This study aimed to assess the feasibility and acceptability of eye-tracking with nurses' during IHCA simulations. Additionally, the study aimed to describe eye-tracking metrics based on different resuscitation roles and to explore the relationship between eye-tracking metrics to pinpoint the most informative metrics for the design of future studies.

**Methods:** In this single-group observational study, 56 newly hired nurses wore eye-tracking glasses during IHCA simulations. The primary feasibility criterion was the proportion of usable eye-tracking data. Secondary criteria included recruitment rate, calibration time, and glasses acceptability. The relationship among eye-tracking metrics was investigated through correlation analyses.

**Results:** Calibration of the devices was rapid, and 85.7% of the data was usable. The glasses were comfortable, non-distracting, and did not impede nurses' vision or performance. Data were mapped for five areas of interest: the patient's head and chest, cardiac monitor, teammates, and resuscitation cart. Eye-tracking metrics exhibited variations based on resuscitation roles. Fixation count, fixation duration, and time to first fixation appeared to be the most informative metrics in IHCA simulation.

**Discussion and conclusion:** These findings demonstrate the feasibility and acceptability of analyzing nurses' eye-tracking data during IHCA simulations using a role-based approach. Future research should explore correlations with additional attention measures to enhance our understanding of nurse decision-making during cardiac arrest and improve educational strategies and outcomes.

**Keywords:** eye-tracker, clinical simulation, cardiopulmonary resuscitation, visual attention, nursing sciences



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**Résumé**

**Introduction :** L'oculométrie offre une avenue pour évaluer la prise de décision infirmière en simulation. Des études ont montré sa faisabilité dans divers scénarios, mais se sont surtout concentrées sur des médecins dans un rôle de leadership. Son application lors de simulations d'arrêt cardiaque, un contexte où les infirmiers et les infirmières assument plusieurs rôles et tâches physiques comme les compressions thoraciques, reste à explorer.

**Objectifs :** Évaluer la faisabilité et l'acceptabilité de l'oculométrie auprès d'infirmiers et d'infirmières lors de simulations d'arrêt cardiaque, décrire les métriques d'oculométrie selon différents rôles en réanimation et explorer les relations entre ces métriques pour identifier les métriques les plus informatives pour la conception de futures études.

**Méthodes :** Dans cette étude observationnelle à groupe unique, 56 infirmiers et infirmières ont porté des lunettes d'oculométrie pendant des simulations d'arrêt cardiaque. Le principal critère d'évaluation de la faisabilité était la proportion de données d'oculométrie utilisables. Les critères d'évaluation secondaires comprenaient le taux de recrutement, le temps de calibration et l'acceptabilité des lunettes. Des analyses de corrélation ont permis d'examiner la relation entre les métriques d'oculométrie.

**Résultats :** La calibration des lunettes a été rapide et 85,7% des données étaient utilisables. Les lunettes étaient confortables et n'entravaient ni la vision ni la performance. Les données ont été cartographiées pour cinq zones d'intérêt : tête et thorax du patient, moniteur cardiaque, coéquipiers et chariot de réanimation. Les métriques présentaient des variations en fonction des rôles. Le nombre de fixations, la durée des fixations et le temps jusqu'à la première fixation semblaient être les métriques les plus informatives.

**Discussion et conclusion :** Ces résultats montrent la faisabilité et l'acceptabilité de l'oculométrie pendant des simulations de réanimation cardiorespiratoire. Les recherches futures devraient explorer les corrélations avec d'autres mesures d'attention pour affiner notre compréhension de la prise de décision infirmière lors d'un arrêt cardiaque.

**Mots clés :** suivi oculaire, simulation clinique, réanimation cardiorespiratoire, attention visuelle, sciences infirmières

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## INTRODUCTION

In 2020, the incidence of adult in-hospital cardiac arrest (IHCA) in the United States was 17.16 per 1,000 admissions, and the survival rate to discharge was 22.4% (Tsao et al., 2022). When a patient experiences IHCA, prompt emergency response, including cardiopulmonary resuscitation with chest compressions, is paramount to improving outcomes (Panchal et al., 2020). In many hospitals, the emergency response is delegated to a cardiac arrest or code team. The roles within these teams typically include chest compressions, airway and ventilation, defibrillation and pacing, medication administration, documentation, and leadership (Michaelis & Leone, 2019; Mitchell et al., 2019).

During resuscitation, the entire code team engages in a decision-making process to identify the causes of the arrest and decide on a plan of action. However, critical situations such as IHCA can lead to high stress levels and cognitive overload, potentially impairing resuscitation performance, increasing the likelihood of errors, and jeopardizing patient safety (Krage et al., 2017; Vincent et al., 2021). Therefore, investigating health professionals' clinical decision-making during IHCA, including their focus of attention, could help improve our understanding of this process, identify potential sources of error, recognize learning needs, and develop effective strategies to address them in resuscitation education. However, the assessment of clinical decision-making often relies on observing and rating participants' performance, providing indirect and rater-dependent data (Lavoie et al., 2022). To overcome this challenge, eye-tracking offers a promising approach to provide more direct indicators of attention and clinical decision-making.

Eye-tracking devices measure the eye's position relative to the head or the environment. Three metrics are of interest for voluntary and overt visual attention (Duchowski & Duchowski, 2017). Fixations occur when the fovea, the central vision area of the retina, stabilizes over a static object. Their number and length indicate attention and the depth of cognitive processing. Smooth pursuits involve visually tracking a moving target, although capturing these movements can be more difficult. Saccades are rapid movements that redirect the fovea to a new location, reflecting a shift in attention. Research across various domains has consistently demonstrated strong correlations between eye-tracking metrics and attention (Duchowski & Duchowski; Zhang et al., 2020).

Earlier generations of eye trackers required individuals to remain still during data collection, typically in front of a screen (Blondon et al., 2015). Newer devices in the form of wearable glasses enable individuals to move their heads and navigate within their environment. Eye-tracking glasses have been employed in emergency response simulation studies with health students and professionals. These studies have explored a range of scenarios, including postpartum hemorrhage (Capogna et al., 2021; Desvergez et al., 2019), neonatal intubation or respiratory failure (Katz et al., 2019; Law et al., 2018; Wagner et al., 2020), trauma (Damji et al., 2019; McNaughten et al., 2018; White et al., 2018), and various critical care scenarios (Browning et al., 2016; Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Brandt et al., 2011; Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Wasmaier et al., 2011; Shinnick, 2016; Szulewski, Braund et al., 2019; Szulewski, Egan et al., 2019; Szulewski & Howes, 2014). However, none specifically focused on IHCA.

Pilot and feasibility studies have reported that between 7% and 22% of eye-tracking measurements were excluded mainly because participants' gaze was outside the glasses frame or the glasses were not calibrated correctly (Browning et al., 2016; Damji et al., 2019; Katz et al., 2019). Up to 20% of the 68 participants in these studies reported that the glasses were distracting or uncomfortable but not enough to affect their performance or decision-making. All participants reported being willing to wear eye-tracking glasses again in a future simulation.

According to observational studies, the position and duration of participants' fixations during emergencies would be distributed on the patient (35%; Damji et al., 2019; Law et al., 2018), their head (34%; Browning et al., 2016) or chest (24%; McNaughten et al., 2018), and on the monitor (16-33 %; Damji et al., 2019; Law et al., 2018). Between 5% and 13% of fixation time would be spent on other elements of the environment, such as teammates (Browning et al.; Damji et al.). In a comparative study, Shinnick (2016) found that expert nurses focused more on the monitor, while novices looked more at providers' prescriptions in the patient chart during a heart failure simulation. Experimental studies (Marjanovic et al., 2018; Mumma et al., 2018; Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Brandt et al., 2011; Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Wasmaier et al., 2011) and qualitative studies (Szulewski, Braund et al., 2019; White et al., 2018) also suggest differences in fixation position and duration between inexperienced and experienced participants.

In summary, previous studies have demonstrated the feasibility of mobile eye-tracking with health professionals and students in emergency response simulations. Despite the various scenarios, eye-tracking glasses have yet to be used in IHCA simulations, a unique setting where nurses often juggle multiple roles concurrently and engage in physical actions, such as chest compressions. In addition, most studies have focused on a single participant—often a physician in a leadership role—and very little data are available on nurses' attention during emergency response. Moreover, the variability in eye-tracking metrics reported across studies complicates the identification of which metrics offer explanatory potential in this context. Studies vary in the metrics they report for the same variables, with common metrics including the number of fixations, the total duration of fixations, the time to first fixation, the number of visits in an area of interest, and the number of saccades. This discrepancy raises questions about the relationships between commonly reported metrics and whether they provide unique information. Consequently, there is a need for further investigate these relationships to inform the development of research protocols.

Considering these issues, it is crucial to assess the feasibility and acceptability of eye-tracking and explore relevant eye-tracking metrics during IHCA simulations with nurses before proposing a more extensive study.

## OBJECTIVES

This study aimed to evaluate the feasibility and acceptability of eye-tracking during IHCA simulations with nurses. As secondary objectives, the study aimed to describe eye-tracking metrics according to nurses' resuscitation role and to explore the relationship between eye-tracking metrics.

## METHODS

This feasibility and acceptability study used a single-group observational design. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement and the Guidelines for reporting non-randomized pilot and feasibility studies were used to ensure complete and transparent reporting (Eldridge et al., 2016; Lancaster & Thabane, 2019). Data were collected from January 2022 to January 2023.

## 1. Participants and Setting

A convenience sample of newly hired nurses participating in the orientation program of a cardiovascular hospital in Montreal, Canada, was formed. Offered monthly, the program includes nine days of classroom activities and up to 25 days of preceptorship. Nurses receive the Basic Life Support – Provider course from certified Heart and Stroke Foundation of Canada instructors on the seventh classroom day. They also review how to operate defibrillators and the content of the resuscitation cart. Then, they participate in two simulations to practice these skills in groups of three to six, depending on the cohort size.

The simulations occur in a simulation room with a high-fidelity manikin (Laerdal, 2024). One instructor operates the manikin, and the other plays the role of a physician. Three ventricular tachycardia scenarios (10-20 min.) are used: 1) atrioventricular block requiring external pacing leading to an R-on-T phenomenon; 2) electrolyte imbalance; and 3) myocardial ischemia. Instructors prioritize the atrioventricular block scenario because it allows nurses to experiment with external pacing and defibrillation; they choose between electrolyte imbalance or myocardial ischemia for the second scenario.

All simulations begin with the patient feeling unwell but still responsive. One nurse is assigned to the initial assessment while the rest of the group waits outside the simulation room. After approximately seven minutes, the rhythm changes to ventricular tachycardia and the patient becomes unresponsive. The assigned nurse can call the rest of the group for help before or after the cardiac arrest occurs. The entire group then performs resuscitation, including chest compressions, airway management, defibrillation, and medication (i.e., epinephrine and amiodarone) as ordered by the instructor playing the physician. Participants were expected to perform comparable actions across the three scenarios, as they were required to adhere to the same resuscitation algorithm. The simulation ends after the first dose of amiodarone.

Newly hired nurses were eligible for the study if they participated in one of the IHCA simulations in the orientation program from January 2022 to January 2023. Exclusion criteria included uncorrected visual conditions or a corrective lenses prescription exceeding -5.00 or 5.00 diopter (since only corrective lenses within this prescription range could be accommodated with the eye-tracking glasses), as well as a history of photosensitive epilepsy or seizures, given that the eye-tracking devices emit infrared light.

## 2. Sample Size and Recruitment

The sample size was calculated based on the average proportion of usable eye-tracking recordings in previous studies (Browning et al., 2016; Damji et al., 2019; Law et al., 2018; McNaughten et al., 2018; Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Brandt et al., 2011; Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Wasmaier et al., 2011; Szulewski, Egan et al., 2019). Based on the estimate that 85% of the recordings would be usable, a total sample size of 49 participants would yield a precision of ±10%, a satisfactory level of precision for the primary feasibility criterion.

For recruitment, the investigators met with newly hired nurses during one of the first classroom days of the orientation program to introduce the study. They were given one week to decide whether to participate; they were informed that participation was voluntary and would not affect their employment. If three or more nurses from a cohort wanted to participate, one or two simulation sessions with data collection were scheduled. The usual simulation sessions without data collection were maintained for those who did not want to participate.

## 3. Procedure

Before the simulations, participants completed a sociodemographic questionnaire (i.e., age, gender, education, years of experience, visual conditions) in a room adjacent to the simulation room. A research assistant then installed and calibrated the eye-tracking device for each participant. A second research assistant timed the calibration procedure in a logbook. Because we had three eye-tracking devices available, we obtained data from a maximum of three participants per simulation. When more than three nurses were involved, they were asked to decide amongst themselves who would wear the eye-tracking devices. Since the simulations were conducted in groups, all nurses participating in a simulation still had to either volunteer to wear an eye-tracking device or agree to be filmed for research purposes. However, only nurses wearing eye-tracking devices provided data.

The eye-tracking device consisted of glasses (Tobii, 2020a) connected to a pocket-sized recording unit that participants clipped to their pants. The recording unit is controlled with an app (Tobii, 2020b) on a Surface Pro tablet (Microsoft Corporation, 2018). The tablet and recording units are connected through Wi-Fi or an Ethernet cable. Corrective lenses are fitted to the glasses according to the participant's prescription if necessary. The glasses are calibrated to their eye shape

and geometry to provide accurate gaze point calculation. Eye-tracking data are recorded at a sampling rate of 100 Hz.

Upon participants' arrival in the simulation room, the instructors provided briefing instructions regarding the environment, the manikin, the equipment, and the objectives of the simulation. After the briefing, participants were asked to exit the room and wait in the hall. The scenario ensued, with the assigned nurse performing the initial assessment while the others waited outside until called to help. Participants wore eye-tracking glasses until the instructors stopped the simulation.

After the simulation, participants returned to the adjacent room to remove the eye-tracking devices and complete the acceptability questionnaire. Then, they met with the rest of the group for an instructor-led debriefing not part of the study. If enough volunteers from the cohort agreed to participate, the procedure was repeated with the remaining participants in the second scenario.

## 4. Variables

The primary criterion to support the feasibility of a more extensive study was the proportion of usable eye-tracking recordings that could be analyzed. Other secondary criteria related to feasibility were the recruitment rate and the time to calibrate the eye-tracking device. In addition, research assistants documented factors that may have influenced the usable data rate and participants' comments, if any.

For acceptability, participants completed an adapted self-reported eye-tracking acceptability questionnaire used in a previous study on neonatal airway management (Wagner et al., 2020). The original questionnaire included 14 items rated on a 5-point scale (1-agree, 5-disagree) measuring distraction, comfort, and impairment of wearing eye-tracking glasses during simulation. Based on consultation with the research team and instructors, three airway-specific items were removed and replaced with four items relevant to IHCA scenarios, one impairment item was split in two, and one item was added to verify if participants would be willing to wear eye-tracking glasses for another research study, for a total of 17 items. For the questionnaire, higher scores in the domains of distraction (items 1-6), comfort (items 7-9), and impairment (items 10-14) suggest greater acceptability. Conversely, lower scores on the final three items (items 15-17) indicate a higher level of acceptability. There is no total score for this instrument.

The eye-tracking recordings consisted of first-person videos of the participants' visual field with a circle indicating where they were looking in real-time (i.e., fixations) and lines to illustrate eye movements (i.e., saccades). The recordings were imported into the Tobii Pro Lab analysis software version 1.207 (Tobii, 2022). The software identified all fixations (i.e., stabilization of the retina over a stationary object of interest for at least 60 milliseconds; Duchowski & Duchowski, 2017) and saccade (i.e., rapid eye movement to reposition the fovea to a new location in the environment; Duchowski & Duchowski) over the recordings using a built-in filter.

Fixations were manually mapped from the onset of cardiac arrest to the return of spontaneous circulation. Based on prior studies and consultation with the research team, five areas of interest were defined: 1) patient's head; 2) patient's chest; 3) cardiac monitor; 4) teammates; and 5) resuscitation cart or items from the cart. In addition, three events were delineated for each participant: 1) entire code (i.e., from the onset of cardiac arrest to the return of spontaneous circulation); 2) chest compressions (i.e., times during which the participant performed compressions without changing roles); and 3) airway management (i.e., times during which the participant managed the airway without changing roles). Fixation mapping and event definition were completed by one research assistant and verified by a second research assistant for accuracy.

Based on the data mapped to the five designated areas of interest, we extracted five individual metrics for each area of interest: 1) the number of fixations; 2) the total duration of fixations; 3) the time to first fixation; 4) the number of visits (i.e., number of times the gaze entered an area of interest); and 5) the number of saccades. These metrics were broken down into three independent events: 1) code duration (subtracting the moments when participants performed chest compressions and airway management); 2) chest compression duration; and 3) airway management duration.

These metrics were then categorized under four roles, assuming that participants' attention and gaze would depend on their alternating roles during the code: 1) documentation (i.e., code duration for participants who were in charge of documentation); 2) medication and defibrillation (M&D; i.e., code duration for participants who were in charge of defibrillation, medication administration, and the resuscitation cart); 3) compression (i.e., total chest compression duration); and 4) ventilation (i.e., total airway management time). Although the first two roles were mutually exclusive, participants had the flexibility to alternate between various roles during a simulation (e.g., one participant might have switched between M&D [Medication and defibrillation] and

compressions). However, each role was analyzed with independent data, indicating that participants' data were segmented according to their roles during the simulation (e.g., over a 7-min. recording, 5 min. of M&D and 2 min. of compressions). While not every participant undertook all four roles, each role was fulfilled by at least one participant wearing eye-tracking glasses in every simulation.

Because the length of events varied between participants, we standardized the duration of fixations within an area of interest as a percentage of the total time spent in that area relative to the overall duration of the event. For similar reasons, the number of fixations, visits, and saccades are reported as a frequency per minute.

## 5. Data Analysis

Statistical analyses were performed using IBM SPSS 28.0 (IBM Corporation, 2022). Sociodemographic data, feasibility indicators, acceptability scores, and eye-tracking metrics are summarized using descriptive statistics. Due to the majority of data not adhering to a normal distribution and the relatively small sample size, medians and interquartile ranges (IQR) are presented to mitigate the impact of outliers. Factors that may have influenced the rate of usable eye-tracking data are presented narratively.

To investigate the secondary objective of exploring the relationship between eye-tracking metrics, we conducted Spearman's rank-order correlation analyses. The purpose of this analysis was to evaluate the statistical interdependence of the metrics, as their calculations frequently rely on each other. By identifying which metrics exhibited high correlations and thus did not offer distinct information, the aim was to pinpoint the most informative metrics for the design of future studies. These analyses were interpreted using the thresholds proposed by Cohen (2013), categorizing the correlation coefficients as small (0.1 to 0.3), moderate (0.3 to 0.5), and large (greater than 0.5). Additionally, a sensitivity analysis was conducted by recalculating these correlations after excluding participants responsible for documentation, who typically have an oversight rather than a direct, hands-on role. This analysis was performed to assess whether this role difference could have influenced the outcomes. Nevertheless, the primary and the sensitivity analyses yielded consistent results, indicating no significant differences. Consequently, the results from the primary analysis are reported.

## ETHICAL CONSIDERATIONS

The study was approved by the hospital's Institutional Review Board (No. 2022-3038) and the university's Institutional Review Board (No. 2022-1826).

## RESULTS

Out of 87 nurses who took part in IHCA simulations during the orientation program, 68 agreed to participate in the study, and 56 wore eye-tracking glasses; Table 1 presents the characteristics of the 56 participants. Most identified as female (75.0%), had a bachelor's degree (64.3%), and had between 0 and 5 years of clinical experience (76.8%). The median age among participants was 29 years, with an IQR of 15 years.

Data were collected during 22 simulations with 15 cohorts ranging from three to 12 nurses. Most participants experienced the atrioventricular block scenario ($n$ = 35, 62.5%), while the others participated in the electrolyte imbalance ($n$ = 16, 28.5%) and myocardial ischemia ($n$ = 5, 9.0%) scenarios.

### 1. Feasibility of eye-tracking

A total of 68 nurses consented to participate in the study. However, one nurse was found ineligible after consenting due to her prescription being beyond the range of the study's requirements. Consequently, the recruitment rate was 77.9% of 86 eligible nurses. Eleven nurses agreed to participate in the study but could not do so because we did not have enough eye-tracking devices. Thus, data were collected for 56 participants (65.1% of 86 eligible nurses and 82.4% of 68 study volunteers).

For the primary feasibility criterion, we obtained 48/56 usable recordings (85.7%, 95%IC = 73.8-93.6%). Four recordings were missing due to hardware malfunction or handling errors by the research team. Three recordings were interrupted before the end of the simulation for unknown reasons. Another recording was complete, but the participant's hair obstructed the glasses during chest compressions, making it impossible to calculate gaze data.

**Table 1**

*Participant characteristics (N=56)*

| Characteristics | n | % |
|---|---|---|
| Gender | | |
| Female | 42 | 75.0 |
| Male | 14 | 25.0 |
| Job title | | |
| Nurse (with licence) | 29 | 51.8 |
| Pre-licensure | 27 | 48.2 |
| Highest degree | | |
| College diploma | 19 | 33.9 |
| Bachelor's degree | 36 | 64.3 |
| Master's degree | 1 | 1.8 |
| Years of clinical experience | | |
| <1 | 22 | 39.3 |
| 1-5 | 21 | 37.5 |
| 6-10 | 9 | 16.1 |
| ≥11 | 4 | 7.1 |
| Vision problem | | |
| None | 20 | 35.7 |
| Yes (at least one of the following) | 36 | 64.3 |
| Myopia | 27 | 75.0[a] |
| Astigmatism | 13 | 36.1[a] |
| Presbyopia | 6 | 16.7[a] |
| Other (hyperopia, strabismus) | 3 | 8.3[a] |
| Vision correction | | |
| Eyeglasses or contact lenses | 27 | 48.2 |
| Laser | 3 | 5.4 |

*Note*. [†]Missing data for three participants. [a] Percentages calculated from the number of participants who reported having at least one vision problem (*n* = 36).

Among the 48 recordings reviewed for analysis, three were briefly interrupted due to the eye-tracking glasses shifting position during chest compressions. Participants repositioned them after 95, 137, and 144 seconds of chest compressions, respectively. Despite these interruptions, we included these recordings in the analysis as they were mostly complete, adjusting the total duration of chest compressions accordingly.

The median time to install and calibrate the eye-tracking glasses was 45 seconds (IQR = 38). Calibration for most participants lasted under two minutes, except for five participants whose calibration time ranged from 4 to 10 minutes because of connectivity issues and difficulties finding the right lenses to match participants' prescriptions. Regarding connectivity issues, we tried to start three simultaneous recordings wirelessly in the first simulation, but the connection to two devices

was impossible because of Wi-Fi interference. This issue was prevented in the following simulations by starting the recording through an Ethernet cable instead of Wi-Fi. The median recording length was 7 min. 40 sec. (IQR = 3 min. 51 sec.).

## 2. Acceptability of eye-tracking

As shown in Table 2, the acceptability of the eye-tracking glasses was high. Overall, participants disagreed that eye-tracking glasses were distracting, uncomfortable, and impaired their vision or performance. Concerning distractions, the scores suggest that participants found the glasses slightly more distracting at the start of the scenario and during chest compressions than throughout the entire scenario, during defibrillation, or while administering medication. The main acceptability issue caused by the equipment was related to the eye-tracking glasses slipping off during chest compressions. This problem was resolved midway through the study by securing the glasses with safety cords.

**Table 2**

*Acceptability of eye-tracking during IHCA simulations*

| | Items rated on a 5-point scale (1-agree, 5-disagree) | Median (IQR) |
|---|---|---|
| | Eye-tracking glasses distracted me… | |
| 1. | … at the beginning of the scenario[a] | 4.0 (2.0) |
| 2. | … during the whole scenario | 5.0 (2.0) |
| 3. | … during chest compressions[b] | 4.0 (4.0) |
| 4. | … during defibrillation[b] | 5.0 (1.0) |
| 5. | … during medication administration[b] | 5.0 (1.0) |
| 6. | … because of the wire[a] | 5.0 (1.0) |
| | Eye-tracking glasses felt uncomfortable… | |
| 7. | … on my nose | 5.0 (2.0) |
| 8. | … on my ears | 5.0 (1.0) |
| 9. | … for my eyes[a] | 5.0 (2.0) |
| | Eye-tracking glasses… | |
| 10. | … impaired my visual field | 4.5 (2.0) |
| 11. | … impaired my ability to assess the patient[a] | 5.0 (1.0) |
| 12. | … impaired my ability to see the patient monitor | 5.0 (1.0) |
| 13. | … made me feel like I was not part of the team | 5.0 (0.0) |
| 14. | Eye-tracking glasses slid down my nose | 3.5 (4.0) |
| 15. | During the scenario, I forgot that I was wearing the glasses[a] | 3.0 (4.0) |
| 16. | I would wear eye-tracking glasses during a real code[a] | 3.0 (3.0) |
| 17. | I would wear eye-tracking glasses for a research study[a] | 1.0 (2.0) |

*Note*. [a] Missing data for 1-3 participants. [b] Missing data for 15-16 participants who did not perform this action.

Although 37 participants (66.1%) would wear eye-tracking glasses again for a research study, only 21 (37.5%) would wear them during an actual code. Examining these findings across participants' age, gender, job title, highest degree, and years of clinical experience revealed minimal or no differences.

### 3. Eye-tracking metrics

Table 3 presents the eye-tracking metrics. Based on fixation counts and duration, documentation (n=11) and M&D nurses (n=37) spent the most time looking at the resuscitation cart and items. Participants mostly looked at the patient's thorax during chest compressions (n=26) and thorax and head during ventilation (n=9). Across all roles, participants spent less than 10% of their time looking at their teammates and less than 5% at the cardiac monitor. The number of saccades followed the same trends. Participants typically looked at the patient's thorax first, except for those in charge of ventilation who first looked at the bag valve mask (i.e., coded as resuscitation cart) before quickly turning to the patient's head. Within the first 10 seconds of the code, documentation and M&D nurses looked at their teammates, the resuscitation cart, and the patient's head but not at the monitor before approximately 20 to 35 seconds. During the first 10 seconds of chest compressions, participants scanned all areas of interest except the resuscitation cart. During the first 10 seconds of airway management, they also scanned all areas of interest, except for teammates, which they looked at after about 20 seconds.

The number of visits per minute indicates that documentation and M&D nurses most frequently visited the resuscitation cart and their teammates. During chest compressions and ventilation, participants most frequently visited the patient's thorax, with the addition of the head for ventilators. Across all roles, participants visited the monitor least frequently.

Table 4 presents the correlations between eye-tracking metrics by area of interest during IHCA (excluding periods of chest compressions and airway management). As mentioned above, the objective was to determine which metrics showed higher correlations, indicating redundancy in the information they provided, and which metrics displayed low correlations, suggesting they offered unique insights. Fixation counts, fixation duration, visit counts, and saccades presented strong correlations with each other, signifying similar informational content. In contrast, time to first fixation demonstrated negative and small to moderate correlations with other metrics, highlighting its potential to offer distinct information.

**Table 3**

*Eye-tracking metrics during IHCA simulations*

| | Fixations count (n/min) | Fixation duration (%)[a] | Time to first fixation (sec) | Visit count (n/min) | Saccades (n/min) |
|---|---|---|---|---|---|
| Patient's head | | | | | |
| M&D | 3.1 (5.1) | 1.4 (2.2) | 10.5 (26.3) | 2.1 (1.7) | 0.8 (1.8) |
| Documentation | 2.1 (8.1) | 1.1 (4.0) | 5.3 (15.3) | 1.3 (3.0) | 0.5 (2.9) |
| Compression | 9.3 (17.9) | 4.2 (6.1) | 5.0 (14.7) | 2.7 (6.0) | 3.5 (7.4) |
| Ventilation | 25.0 (23.8) | 15.7 (15.9) | 0.2 (1.3) | 8.4 (3.1) | 10.7 (11.2) |
| Patient's thorax | | | | | |
| M&D | 13.0 (12.7) | 6.9 (7.5) | 0.7 (4.2) | 6.4 (5.4) | 4.6 (5.9) |
| Documentation | 13.8 (16.6) | 6.5 (8.9) | 0.0 (0.4) | 5.2 (3.9) | 6.5 (10.3) |
| Compression | 46.0 (35.6) | 27.5 (24.2) | 0.0 (0.0) | 8.6 (6.8) | 22.7 (27.9) |
| Ventilation | 39.3 (22.4) | 29.6 (19.8) | 1.8 (10.7) | 12.4 (3.3) | 21.7 (20.5) |
| Cardiac monitor | | | | | |
| M&D | 5.1 (7.1) | 2.8 (3.9) | 19.5 (46.7) | 1.9 (2.1) | 2.4 (4.5) |
| Documentation | 2.6 (5.5) | 2.9 (6.1) | 35.0 (119.3) | 1.0 (2.1) | 1.5 (3.4) |
| Compression | 2.6 (13.0) | 0.9 (5.8) | 11.7 (59.8) | 0.9 (3.1) | 0.8 (5.7) |
| Ventilation | 4.1 (7.2) | 4.3 (6.6) | 10.5 (81.9) | 1.5 (2.2) | 1.3 (3.5) |
| Resuscitation cart | | | | | |
| M&D | 58.8 (31.0) | 38.1 (29.0) | 3.7 (10.0) | 7.6 (3.5) | 33.2 (24.7) |
| Documentation | 76.6 (40.6) | 44.4 (32.7) | 8.3 (16.4) | 7.9 (4.8) | 49.2 (44.8) |
| Compression | 8.2 (15.4) | 4.8 (10.7) | 16.8 (17.6) | 3.9 (4.7) | 3.6 (5.3) |
| Ventilation | 6.7 (6.7) | 5.1 (4.7) | 0.0 (11.3) | 3.5 (2.7) | 2.8 (4.0) |
| Teammates | | | | | |
| M&D | 12.3 (10.6) | 6.8 (6.8) | 5.2 (11.5) | 6.5 (5.2) | 4.2 (4.4) |
| Documentation | 16.0 (15.9) | 6.8 (10.8) | 2.9 (9.3) | 7.0 (5.8) | 5.9 (6.8) |
| Compression | 14.7 (16.6) | 4.3 (7.5) | 7.6 (16.6) | 5.3 (6.9) | 5.4 (5.9) |
| Ventilation | 15.5 (15.1) | 4.8 (8.6) | 18.2 (24.1) | 5.1 (5.9) | 5.2 (5.3) |

*Note*. All data are medians (interquartile ranges). M&D = Medication and defibrillation. [a] The total does not reach 100% because fixations on areas outside the five designated areas of interest have not been included in the report.

**Table 4**

*Correlations between eye-tracking metrics by area of interest during IHCA*

| | Fixations count | Fixation duration | Time to first fixation | Visit count |
|---|---|---|---|---|
| Patient's head | | | | |
| Fixation count | 1 | | | |
| Fixation duration | 0.96* | 1 | | |
| Time to first fixation | -0.33* | -0.28 | 1 | |
| Visit count | 0.95* | 0.93* | -0.32* | 1 |
| Saccades | 0.75* | 0.71* | -0.35* | 0.65* |
| Patient's thorax | | | | |
| Fixation count | 1 | | | |
| Fixation duration | 0.87* | 1 | | |
| Time to first fixation | -0.43* | -0.42* | 1 | |
| Visit count | 0.80* | 0.77* | -0.38* | 1 |
| Saccades | 0.79* | 0.76* | -0.32* | 0.55* |
| Cardiac monitor | | | | |
| Fixation count | 1 | | | |
| Fixation duration | 0.73* | 1 | | |
| Time to first fixation | -0.20 | -0.24 | 1 | |
| Visit count | 0.87* | 0.66* | -0.29* | 1 |
| Saccades | 0.95* | 0.69* | -0.15 | 0.73* |
| Resuscitation cart | | | | |
| Fixation count | 1 | | | |
| Fixation duration | 0.74* | 1 | | |
| Time to first fixation | -0.18 | -0.12 | 1 | |
| Visit count | 0.04 | 0.12 | -0.14 | 1 |
| Saccades | 0.83* | 0.89* | -0.06 | 0.10 |
| Teammates | | | | |
| Fixation count | 1 | | | |
| Fixation duration | 0.89* | 1 | | |
| Time to first fixation | -0.18 | -0.03 | 1 | |
| Visit count | 0.93* | 0.87* | -0.15 | 1 |
| Saccades | 0.96* | 0.88* | -0.17 | 0.85* |

*Note*. All data are Spearman's correlation coefficients. *Correlation significant at the 0.05 level (2-tailed).

## DISCUSSION

The primary objective of this study was to assess the feasibility and acceptability of wearable eye-tracking devices for nurses during simulated IHCA. The results were positive: nurses were willing to participate, calibration of the eye-tracking glasses was rapid and easy, and most recordings were usable. In addition, nurses reported that the eye-tracking glasses were comfortable, not distracting, and did not interfere with their vision or performance during the simulations.

Regarding feasibility, the recruitment rate was higher than in other pilot and feasibility studies of simulation-based education with nurses (Gundrosen et al., 2014; Lapierre et al., 2023; Toubasi et al., 2015; Zordan et al., 2022), possibly because nurses participated during mandatory rather than optional, off-duty simulations. Installation and calibration of the eye-tracking glasses went quickly for most participants. The proportion of usable recordings (85.7%) was consistent with previous studies (Damji et al., 2019; Law et al., 2018), but the reasons for unusable recordings differed. Previous studies reported calibration issues or participants' gaze leaving the glasses frame. Instead, we experienced problems with the Wi-Fi connection due to interference between devices used simultaneously. In addition, the eye-tracking glasses sometimes fell off during chest compressions, and one participant's hair in front of the lenses made it impossible to calculate gaze data. However, we quickly implemented solutions, such as connecting the devices with an Ethernet cable, using a safety cord to hold the glasses in place, and asking that participants tie their hair back during the simulations. These simple measures provided usable recordings after implementation and are valuable lessons for future studies.

The acceptability results are consistent with previous research, which found that wearing eye-tracking glasses during emergency response simulations was acceptable (Damji et al., 2019; Katz et al., 2019). However, most participants were willing to wear the glasses again in a research context but not during an actual code. This finding is inconsistent with a study by Katz et al., who found that all participants were willing to wear eye-tracking glasses during an actual neonatal resuscitation, where the stress and stakes are arguably as high as in IHCA. One possible reason is that the glasses tended to fall off during chest compressions, which caused additional stress for the participants. This could also be because our sample consisted mainly of newly hired nurses with little clinical experience, compared to the study of Katz et al., where professionals (physicians and nurses) had an average of 6 years of experience in neonatal care. Thus, experience (and possibly self-efficacy) may influence the willingness to wear eye-tracking glasses during a real-world cardiac arrest, but this needs further exploration.

As secondary objectives, this study aimed to describe eye-tracking metrics in relation to nurses' roles during resuscitation and explore the relationship between metrics. We observed that nurses' attention was strongly tied to their role during resuscitation, which may hinder their overall situational awareness. For instance, the nurses in charge of documentation focused more on the resuscitation cart than on the patient, indicating a potential role overlap with M&D nurses and a

need for better information exchange to maintain a shared understanding of the situation. Data from compression and ventilation nurses were also similar regarding the patient's thorax but differed due to increased attention to the patient's head during ventilation. Interestingly, the patient's thorax was one of the primary areas of interest for participants, regardless of their role. This finding may reflect the emphasis on chest compressions in resuscitation guidelines and education (Panchal et al., 2020) or airway and breathing assessment in critical care nursing education (Douglas et al., 2016). Another surprising finding was how little attention participants paid to the cardiac monitor. Although the small number and duration of fixations on the monitor suggest that participants could quickly determine that the ventricular tachycardia was sustained, the fact that they rarely visited this area of interest implies that they tended not to monitor the patient's rhythm during resuscitation. It may also indicate that they only checked the monitor after defibrillation every two minutes, as recommended in resuscitation guidelines (Panchal et al.). These findings emphasize the significance of addressing attentional allocation and role clarity in resuscitation education to enhance healthcare providers' performance during IHCA events.

Although these results differ from previous studies in which participants focused on the patient and the monitor (Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Wasmaier et al., 2011), we used an IHCA scenario that differed from previous emergency response scenarios regarding clinical presentation and expected monitoring and interventions. These differences are a plausible explanation for the differences in the distribution of participants' attention. Recently, Al-Moteri et al. (2018, 2020) proposed an algorithmic approach to analyze eye-tracking data according to the logical progression of participants' actions in a web-based hypovolemic shock simulation. In this approach, participants received points when they fixated on important cues in the scenario and initiated appropriate actions. Such an approach may provide additional explanations of attention patterns in response to scenario-specific demands. It is also important to note that no one played the role of code leader during the simulations, as an instructor assumed this role. Therefore, comparisons of the current findings with previous studies of medical leaders during emergency response simulations should be made with caution.

Another difference from previous studies is the eye-tracking metrics analyzed. Fixation duration relative to an area of interest is the most commonly reported metric in simulation eye-tracking studies (Browning et al., 2016; Damji et al., 2019; Katz et al., 2019; McNaughten et al., 2018; Mumma et al., 2018; Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Brandt et al., 2011;

Schulz, Schneider, Fritz, Vockeroth, Hapfelmeier, Wasmaier et al., 2011). The number of fixations in an area of interest is also sometimes reported (Damji et al.; McNaughten et al.; Szulewski, Egan et al., 2019). These two metrics relate to visual attention: more prolonged and numerous fixations on an area of interest would indicate that the element is more important or valuable to the individual (Pauszek, 2023). It could also mean that the object of attention is confusing or difficult to process (Pauszek). In the present study, the number and duration of fixations exhibited similar patterns across most areas of interest, aligning with the number of visits and saccades. These findings suggest some redundancy across these four metrics.

The time to first fixation has been much less reported in previous studies (Szulewski, Egan et al., 2019; Szulewski & Howes, 2014). The time to first fixation would be related to the prioritization of data collection. In our results, the large variability in the interquartile ranges suggests that this metric may vary from one individual to another, regardless of role. However, it is interesting to note that time to first fixation was the only metric negatively correlated with the others, meaning that as the time to first fixation increased, the other metrics decreased. This may suggest that the longer an individual takes to look at an area of interest, the lower the priority and the fewer times it is looked at during the simulation. Additionally, it could indicate that individuals have less time to focus on an area of interest if they turn their attention to it later in the simulation.

Finally, we extracted the number of visits per minute to an area of interest, another rarer metric in previous studies (Katz et al., 2019). This metric seemed relevant to see whether the gaze frequently enters and exits an area of interest, perhaps because of its importance or complexity. However, our results showed that the number of visits was often similar to fixations and saccades, suggesting some informational redundancy. The only exception was the resuscitation cart, possibly because participants tended to spend more time in this area.

Based on these results and previous studies, the most informative eye-tracking metrics in simulated IHCA are fixation count or duration and time to first fixation. Visit count seems less relevant because it includes saccades, blinks, and invalid gaze data, thus correlating positively with fixations and saccades. Similarly, saccades revealed nothing more than the other metrics and, according to Pauszek (2023), would be strongly correlated with the number of fixations—as our results showed. By prioritizing these metrics, researchers can develop the evidence base to support educators in developing targeted interventions to enhance nurses' attentional allocation and performance in high-stress, time-critical situations.

## LIMITATIONS

Despite evidence of feasibility and acceptability design, this study had limitations. It was conducted at a single site with a small sample size, which prevented control for potential confounders such as simulation scenarios. Due to the small sample size, the exploratory inferential analyses' results should be taken cautiously. In addition, because the simulation scenario did not involve participants playing the role of medical leader, comparisons with previous studies are limited. Finally, eye-tracking offers many potential metrics, and we chose those used in previous simulation studies to avoid "fishing". Nevertheless, we know the increased risk of type 1 errors because we analyzed five metrics.

## CONCLUSIONS

This study was the first to collect simultaneous eye-tracking data in the dynamic setting of IHCA simulations involving physical actions and the presence of several nurses juggling multiple resuscitation roles. Another novel contribution is the differentiated analysis of eye-tracking metrics by role during resuscitation. Although we have shown that using eye-tracking devices to assess nurses' attention during simulated IHCA is feasible and acceptable, we have found that the relationship between eye-tracking metrics and individuals' cognitive processes is complex and needs to be clarified. Future studies should focus on relating different eye-tracking metrics with other relevant measures of attention. This could improve the assessment of nurses' attention, identify learning needs and sources of error in data collection and interpretation, and ultimately improve education to prepare nurses to manage IHCA.

**Authors' contributions:**

PL: conceptualization, methodology, investigation, formal analysis, writing – original draft, supervision, funding acquisition. AL: conceptualization, methodology, investigation, writing – original draft. IK: investigation, formal analysis, data curation, writing – original draft. AD: conceptualization, resources, writing – review & editing. NTJ: conceptualization, writing – review & editing. NRS: conceptualization, writing – review & editing. RB: investigation, formal analysis, writing – review & editing. MC: investigation, formal analysis, writing – review & editing. TM: conceptualization, methodology, investigation, writing – review & editing.

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The authors declare no conflict of interest.

## References


Al-Moteri, M., Cooper, S., Symmons, M., & Plummer, V. (2020). Nurses' cognitive and perceptual bias in the identification of clinical deterioration cues. *Australian Critical Care*, *33*(4), 333-342. https://doi.org/10.1016/j.aucc.2019.08.006

Al-Moteri, M. O., Symmons, M., Cooper, S., & Plummer, V. (2018). Inattentional blindness and pattern-matching failure: The case of failure to recognize clinical cues. *Applied Ergonomics*, *73*, 174-182. https://doi.org/10.1016/j.apergo.2018.07.001

Blondon, K., Wipfli, R., & Lovis, C. (2015). Use of eye-tracking technology in clinical reasoning: A systematic review. *Studies in health technology and informatics*, *210*, 90-94.

Browning, M., Cooper, S., Cant, R., Sparkes, L., Bogossian, F., Williams, B., O'Meara, P., Ross, L., Munro, G., & Black, B. (2016). The use and limits of eye-tracking in high-fidelity clinical scenarios: A pilot study. *International Emergency Nursing*, *25*, 43-47. https://doi.org/10.1016/j.ienj.2015.08.002

Capogna, E., Capogna, G., Raccis, D., Salvi, F., Velardo, M., & Del Vecchio, A. (2021). Eye tracking metrics and leader's behavioral performance during a post-partum hemorrhage high-fidelity simulated scenario. *Advances in Simulation*, *6*(1), 4. https://doi.org/10.1186/s41077-021-00156-2

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences* (Revised ed.). Academic press.

Damji, O., Lee-Nobbee, P., Borkenhagen, D., & Cheng, A. (2019). Analysis of eye-tracking behaviours in a pediatric trauma simulation. *Canadian Journal of Emergency Medicine*, *21*(1), 138-140. https://doi.org/10.1017/cem.2018.450

Desvergez, A., Winer, A., Gouyon, J. B., & Descoins, M. (2019). An observational study using eye tracking to assess resident and senior anesthetists' situation awareness and visual perception in postpartum hemorrhage high fidelity simulation. *PLoS One*, *14*(8), e0221515. https://doi.org/10.1371/journal.pone.0221515

Douglas, C., Booker, C., Fox, R., Windsor, C., Osborne, S., & Gardner, G. (2016). Nursing physical assessment for patient safety in general wards: reaching consensus on core skills. *Journal of Clinical Nursing*, *25*(13-14), 1890-1900. https://doi.org/10.1111/jocn.13201

Duchowski, A. T., & Duchowski, A. T. (2017). *Eye Tracking Methodology: Theory and Practice*. Springer.

Eldridge, S. M., Chan, C. L., Campbell, M. J., Bond, C. M., Hopewell, S., Thabane, L., & Lancaster, G. A. (2016). CONSORT 2010 statement: extension to randomised pilot and feasibility trials. *BMJ (Clinical research ed.)*, *355*, i5239. https://doi.org/10.1136/bmj.i5239

Gundrosen, S., Solligård, E., & Aadahl, P. (2014). Team competence among nurses in an intensive care unit: The feasibility of *in situ* simulation and assessing non-technical skills. *Intensive and Critical Care Nursing*, *30*(6), 312-317. https://doi.org/10.1016/j.iccn.2014.06.007

IBM Corporation. (2022). *IBM SPSS Statistics* (version 28.0) [Computer software]. https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-28

Katz, T. A., Weinberg, D. D., Fishman, C. E., Nadkarni, V., Tremoulet, P., Te Pas, A. B., Sarcevic, A., & Foglia, E. E. (2019). Visual attention on a respiratory function monitor during simulated neonatal resuscitation: an eye-tracking study. *Archives of Disease in Childhood Fetal & Neonatal Edition*, *104*(3), F259-F264. https://doi.org/10.1136/archdischild-2017-314449

Krage, R., Zwaan, L., Tjon Soei Len, L., Kolenbrander, M. W., van Groeningen, D., Loer, S. A., Wagner, C., & Schober, P. (2017). Relationship between non-technical skills and technical performance during cardiopulmonary resuscitation: does stress have an influence? *Emergency Medicine Journal*, *34*(11), 728-733. https://doi.org/10.1136/emermed-2016-205754

Laerdal. (2024). *SimMan ALS*. https://laerdal.com/ca/products/simulation-training/emergency-care-trauma/simman-als/

Lancaster, G. A., & Thabane, L. (2019). Guidelines for reporting non-randomised pilot and feasibility studies. *Pilot and Feasibility Studies*, *5*, 114. https://doi.org/10.1186/s40814-019-0499-1

Lapierre, A., Lavoie, P., Castonguay, V., Lonergan, A.-M., & Arbour, C. (2023). The influence of the simulation environment on teamwork and cognitive load in novice trauma professionals at the emergency department: Piloting a randomized controlled trial. *International Emergency Nursing*, *67*, 101261. https://doi.org/10.1016/j.ienj.2022.101261

Lavoie, P., Lapierre, A., Maheu-Cadotte, M.-A., Fontaine, G., Khetir, I., & Bélisle, M. (2022). Transfer of Clinical Decision-Making–Related Learning Outcomes Following Simulation-Based Education in Nursing and Medicine: A Scoping Review. *Academic Medicine*, *97*(5), 738-746. https://doi.org/10.1097/acm.0000000000004522

Law, B. H. Y., Cheung, P. Y., Wagner, M., van Os, S., Zheng, B., & Schmolzer, G. (2018). Analysis of neonatal resuscitation using eye tracking: a pilot study. *Archives of Disease in Childhood Fetal & Neonatal Edition*, *103*(1), F82-F84. https://doi.org/10.1136/archdischild-2017-313114

Marjanovic, N. S., Teiten, C., Pallamin, N., & L'Her, E. (2018). Evaluation of emotional excitation during standardized endotracheal intubation in simulated conditions. *Annals of intensive care*, *8*(1), 117. https://doi.org/10.1186/s13613-018-0460-0

McNaughten, B., Hart, C., Gallagher, S., Junk, C., Coulter, P., Thompson, A., & Bourke, T. (2018). Clinicians' gaze behaviour in simulated paediatric emergencies. *Archives of Disease in Childhood*, *103*(12), 1146-1149. https://doi.org/10.1136/archdischild-2017-314119

Michaelis, P., & Leone, R. J. (2019). Cardiac Arrest After Cardiac Surgery: An Evidence-Based Resuscitation Protocol. *Critical Care Nurse*, *39*(1), 15-25. https://doi.org/10.4037/ccn2019309

Microsoft Corporation. (2018). *Surface Pro tablet* (version 6). https://support.microsoft.com/en-us/surface/surface-pro-6-specs-and-features-ade5cfc2-e99a-6fd1-abbe-c0e8a8a3942d

Mitchell, O. J. L., Motschwiller, C. W., Horowitz, J. M., Friedman, O. A., Nichol, G., Evans, L. E., & Mukherjee, V. (2019). Rapid Response and Cardiac Arrest Teams: A Descriptive Analysis of 103 American Hospitals. *Critical Care Explorations*, *1*(8), e0031. https://doi.org/10.1097/cce.0000000000000031

Mumma, J. M., Durso, F. T., Dyes, M., Dela Cruz, R., Fox, V. P., & Hoey, M. (2018). Bag Valve Mask Ventilation as a Perceptual-Cognitive Skill. *Human Factors*, *60*(2), 212-221. https://doi.org/10.1177/0018720817744729

Panchal, A. R., Bartos, J. A., Cabanas, J. G., Donnino, M. W., Drennan, I. R., Hirsch, K. G., Kudenchuk, P. J., Kurz, M. C., Lavonas, E. J., Morley, P. T., O'Neil, B. J., Peberdy, M. A., Rittenberger, J. C., Rodriguez, A. J., Sawyer, K. N., Berg, K. M., Adult, B., & Advanced Life Support Writing, G. (2020). Part 3: Adult Basic and Advanced Life Support: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*, *142*(16_suppl_2), S366-S468. https://doi.org/10.1161/CIR.0000000000000916

Pauszek, J. R. (2023). An introduction to eye tracking in human factors healthcare research and medical device testing. *Human Factors in Healthcare*, *3*, 100031. https://doi.org/10.1016/j.hfh.2022.100031

Schulz, C. M., Schneider, E., Fritz, L., Vockeroth, J., Hapfelmeier, A., Brandt, T., Kochs, E. F., & Schneider, G. (2011). Visual attention of anaesthetists during simulated critical incidents. *British journal of anaesthesia*, *106*(6), 807-813. https://doi.org/10.1093/bja/aer087

Schulz, C. M., Schneider, E., Fritz, L., Vockeroth, J., Hapfelmeier, A., Wasmaier, M., Kochs, E. F., & Schneider, G. (2011). Eye tracking for assessment of workload: a pilot study in an anaesthesia simulator environment. *British journal of anaesthesia*, *106*(1), 44-50. https://doi.org/10.1093/bja/aeq307

Shinnick, M. A. (2016). Validating Eye Tracking as an Objective Assessment Tool in Simulation. *Clinical Simulation in Nursing*, *12*(10), 438-446. https://doi.org/10.1016/j.ecns.2016.06.001

Szulewski, A., Braund, H., Egan, R., Gegenfurtner, A., Hall, A. K., Howes, D., Dagnone, D., & van Merrienboer, J. J. G. (2019). Starting to Think Like an Expert: An Analysis of Resident Cognitive Processes During Simulation-Based Resuscitation Examinations. *Annals of Emergency Medicine*, *74*(5), 647-659. https://doi.org/10.1016/j.annemergmed.2019.04.002

Szulewski, A., Egan, R., Gegenfurtner, A., Howes, D., Dashi, G., McGraw, N. C. J., Hall, A. K., Dagnone, D., & van Merrienboer, J. J. G. (2019). A new way to look at simulation-based assessment: the relationship between gaze-tracking and exam performance. *Canadian Journal of Emergency Medicine*, *21*(1), 129-137. https://doi.org/10.1017/cem.2018.391

Szulewski, A., & Howes, D. (2014). Combining First-Person Video and Gaze-Tracking in Medical Simulation: A Technical Feasibility Study. *The Scientific World Journal*, *2014*, 1-4. https://doi.org/10.1155/2014/975752

Tobii. (2020a). *Tobi Pro Glasses 3*. https://www.tobii.com/products/eye-trackers/wearables/tobii-pro-glasses-3

Tobii. (2020b). *Glasses 3 controller app* (version 1.16.4). https://www.tobii.com/products/eye-trackers/wearables/tobii-pro-glasses-3/controller-app

Tobii. (2022). *Tobii Pro Lab analysis software* (version 1.207) [Computer software]. https://connect.tobii.com/s/lab-downloads?language=en_US

Toubasi, S., Alosta, M. R., Darawad, M. W., & Demeh, W. (2015). Impact of simulation training on Jordanian nurses' performance of basic life support skills: A pilot study. *Nurse Education Today*, *35*(9), 999-1003. https://doi.org/10.1016/j.nedt.2015.03.017

Tsao, C. W., Aday, A. W., Almarzooq, Z. I., Alonso, A., Beaton, A. Z., Bittencourt, M. S., Boehme, A. K., Buxton, A. E., Carson, A. P., Commodore-Mensah, Y., Elkind, M. S. V., Evenson, K. R., Eze-Nliam, C., Ferguson, J. F., Generoso, G., Ho, J. E., Kalani, R., Khan, S. S., Kissela, B. M., . . . Martin, S. S. (2022). Heart Disease and Stroke Statistics—2022 Update: A Report From the American Heart Association. *Circulation*, *145*(8), e153-e639. https://doi.org/10.1161/CIR.0000000000001052

Vincent, A., Semmer, N. K., Becker, C., Beck, K., Tschan, F., Bobst, C., Schuetz, P., Marsch, S., & Hunziker, S. (2021). Does stress influence the performance of cardiopulmonary resuscitation? A narrative review of the literature. *Journal of Critical Care*, *63*, 223-230. https://doi.org/10.1016/j.jcrc.2020.09.020

Wagner, M., Gropel, P., Bibl, K., Olischar, M., Auerbach, M. A., & Gross, I. T. (2020). Eye-tracking during simulation-based neonatal airway management. *Pediatric research*, *87*(3), 518-522. https://doi.org/10.1038/s41390-019-0571-9

White, M. R., Braund, H., Howes, D., Egan, R., Gegenfurtner, A., van Merrienboer, J. J. G., & Szulewski, A. (2018). Getting Inside the Expert's Head: An Analysis of Physician Cognitive Processes During Trauma Resuscitations. *Annals of Emergency Medicine*, *72*(3), 289-298. https://doi.org/10.1016/j.annemergmed.2018.03.005

Zhang, T., Yang, J., Liang, N., Pitts, B. J., Prakah-Asante, K. O., Curry, R., Duerstock, B. S., Wachs, J. P., & Yu, D. (2020). Physiological Measurements of Situation Awareness: A Systematic Review. *Human Factors*, 0018720820969071. https://doi.org/10.1177/0018720820969071

Zordan, R., Lethborg, C., Forster, J., Mason, T., Walker, V., McBrearty, K., & Torcasio, C. (2022). Development, implementation, and evaluation of a trauma-informed simulation-based training program for graduate nurses: A single arm feasibility and pilot study. *Nurse Education Today*, *117*, 105460. https://doi.org/10.1016/j.nedt.2022.105460