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Research Article

Impacts of time pressure during the ICU handover safety check of critical care nurses: A randomised eye-tracking analysis

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ABSTRACT

Introduction: Safety checks during ICU handovers are error prone and often affected by stress, particularly time pressure. Standardized handover and safety-check procedures are lacking. We hypothesized that time pressure would negatively affect error detection and visual behaviour in ICU nurses performing handover safety checks.

Methods: We conducted a randomized eye-tracking study in April 2024 in a simulated ICU setting with a standardized patient and predefined hidden errors. All ICU nurses at our institution were invited to participate. Participants were randomized into four groups to assess the effects of time pressure and checklist use on error detection and gaze behaviour. The primary outcome was overall error recognition. Secondary outcomes included eye-tracking metrics (dwell time, entry time, revisits, and first visual intake duration) across predefined areas of interest (AOIs).

Results: Ninety-one ICU nurses were included. Overall, participants missed a median of 4 errors (IQR 3.0–5.0), including 3 major (IQR 2.0–3.0) and 2 minor errors (IQR 1.0–2.0). Under time pressure, participants missed significantly more errors (median 5.0, IQR 3.0–6.0) than those without time pressure (median 3.5, IQR 3.0–5.0; $p = 0.002$). Checklist availability did not significantly affect error detection, with a median of 4.5 errors missed (IQR 3.0–5.0) without a checklist versus 4.0 (IQR 3.0–5.0) with a checklist ($p = 0.651$). Eye-tracking analysis showed that the probability of missing errors was associated with altered gaze behaviour across all AOIs in time-pressured groups compared to non-time-pressured groups.

Conclusions: Time pressure significantly impaired error detection during ICU handover safety checks, whereas the use of the applied checklist was not associated with a measurable improvement in performance. Eye-tracking data demonstrated that time pressure was associated with distinct gaze behaviour patterns, suggesting altered visual attention during handovers.

Implications: Time pressure reduces error detection during ICU handovers, underscoring performance vulnerability under this condition. Strategies to reduce time pressure and assess checklist usefulness, which may improve patient safety, should be validated in further studies.

Introduction

Shift handover is crucial in maintaining continuity of patient care in the intensive care unit (ICU). During shift changes or new patient admissions, an error-free handover is important for patient safety. However, this process can be susceptible to errors including lack of communication or the failure to identify wrong drug dosages or technical issues, leading to professional dissatisfaction, increased costs and

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compromised patient safety [1]. Studies have shown that unstandardized handovers and inadequate safety checks result in up to 50% loss of information among ICU staff [2,3], potentially with severe consequences for patients. Contributing factors to ineffective handovers include working under time pressure, interruptions, lack of structured protocols or insufficient training [4–6].

Recently, checklists designed to increase safety in the ICU have been proposed [7,8]. They have proven effective in improving staff satisfaction, information retention, and error reduction under time pressure [9–11]. Despite benefits, the implementation and adherence to checklists remain insufficient and data on potential benefits is lacking [12]. In contrast, in surgery, safety checklists have been linked to reductions in complications [13,14].

Eye-tracking analyses visual behaviour [15–17] by tracking ocular movements using infrared light [15]. Gaze metrics evaluate visual behaviour, and studies show eye-tracking can assess visual behaviour in ICU settings, offering insights into patient care and potential sources of human error, such as during patient extubation or while using machines like ventilators [16–20]. Error detection during a shift start safety check was linked to distinct nurse gaze behaviour [17]. This study aimed to measure eye-tracking data in ICU nurses during a simulated handover safety check and evaluate the effect of unexpected time pressure, as well as the impact of a checklist on gaze metrics. We hypothesized that gaze behaviours and error detection would be influenced by time pressure.

Methods

Study design and study population

This was a prospective, randomized, simulated study conducted at the Cantonal Hospital St. Gallen (Switzerland). Participants were adult ICU nurses. All ICU nurses were approached and evaluated for inclusion in April 2024 (in total 105). The local Ethics Committee approved the study protocol (Ethikkommission Ostschweiz, BASEC Nr. 2023-01130, approval date: 21.09.2023). The study was conducted in accordance with the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards.

Patient and public involvement

No patients were included in this study. All participating ICU nurses gave informed consent.

Simulation room and built-in errors

The simulation room was equipped with a LifeCast Body Simulation mannequin (London, UK). The setup included vital sign monitoring and devices such as lines, syringe pumps, a ventilator and compression stockings (Fig. 1). A handover sheet included a summary of the patient's medical condition. The patient was a 65-year-old male hospitalized for sepsis and moderate ARDS resulting from Influenza A pneumonia, requiring non-invasive respiratory support and antibiotics. His condition worsened, mandating scheduling of a computed tomography (CT). The patient had comorbidities including hypertension, coronary heart disease, type 2 diabetes mellitus, peripheral vascular disease, and COPD (Gold 2B). He also had allergies (penicillin, latex). The setup is shown in Fig. 1.

We incorporated five critical and five minor errors. All errors were based on previous safety hazards from Critical Incident Reporting System (CIRS). Errors were classified as critical when considered potentially lethal and minor if the potential harm was not immediate (Table 1).

Procedure

Participants performed a shift handover safety check while being observed by eye-tracking. After receiving the case and instructions, they were randomly assigned to one of four groups: (1) no time pressure/no checklist, (2) time pressure/checklist, (3) time pressure/no checklist, or (4) no time pressure/checklist. Randomisation was done by drawing colour-labelled tags from an opaque bag, with 25 tags per group drawn sequentially to ensure equal group sizes. Recordings began after a three-point calibration of the eye-tracking glasses. Checklist-assigned participants received the checklist and preparation time before starting and were instructed to use it during handover (Supplementary Fig. 1), but its use was not mandatory. The German checklist was developed using the

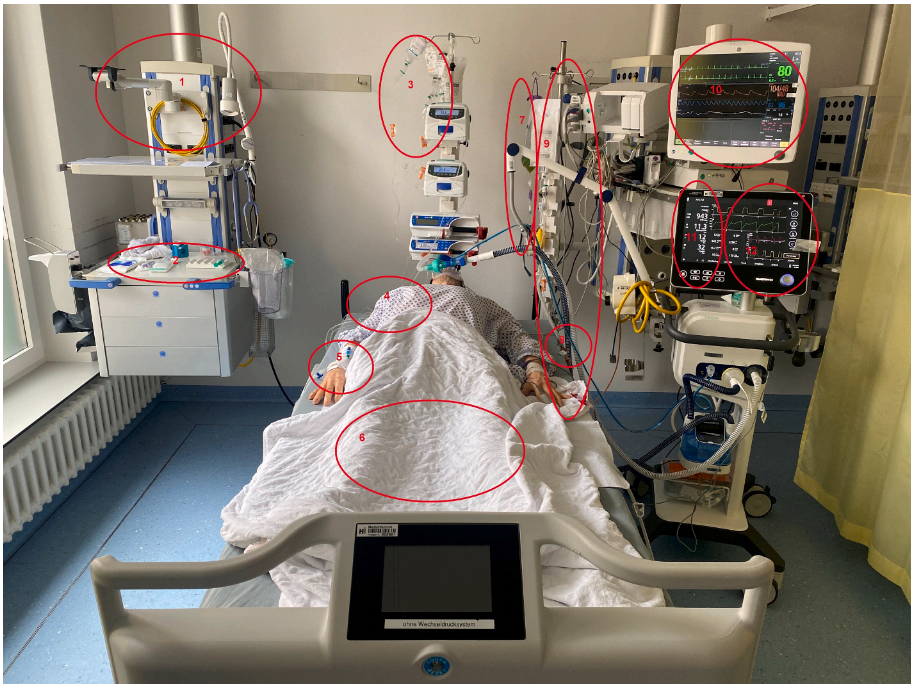

Fig. 1. Pre-specified Areas of Interest (AOI). Blank (1), Case Sheet & Prescription (2), Infusion & Air bubbles (3), Central venous line (4), IV Cannula (5), Stockings (6), Nutrition (7), Transducer (8), Pressure bag & Arterial line (9), Monitor (10), Ventilation pressure & tidal volume (11), Ventilator (12).

Table 1
Critical and minor errors.

Critical Errors	Minor Errors
1 Prescription error: Continued enteral nutrition despite imminent tracheal intubation	6 Risk of iatrogenic leg ischaemia: TED stockings used in peripheral artery disease
2 IV line error: Antibiotics infusion line filled with gas bubbles	7 Loss of pressure in arterial pressure bag
3 Medication error: Co-Amoxicillin despite allergy against Penicillin	8 False positioning of patient, lying flat instead of upper body 30°
4 Monitoring error: Arterial line transducer positioned to low	9 Risk of infection: central line 3 way valve not closed
5 Ventilator error: False Ventilator setting (tidal volume and inspiratory pressure too high)	10 IV Cannula left inserted inside a vein after disconnected

Overview of the pre-defined 5 critical and 5 minor errors based on the in-hospital Critical Incident Reporting System (CIRS).

Functional Resonance Analysis Method (FRAM) [21,22] and involved our head nurse. Participants had ten minutes to complete the task. Time-pressure groups were unexpectedly told after five minutes that only one minute remained because the patient needed the CT. Participants did not know they were in a time-pressure group until this notice, to reflect real-life sudden time constraints. Recognized errors were communicated to the study team. After recording, participants completed a questionnaire (Supplementary Table 1).

Data collection

We recorded eye-tracking data using the SMI Eye Tracking Glasses 2 Wireless System (Sensomotoric Instruments, Germany). This system captures the angle of view with an accuracy of 0.5° and records the scene at a resolution of 960x720 px at 30 frames per second (fps). Raw data was analyzed using SMI Be-Gaze 3.7 software. Error recognition by participants was noted and documented by the study team. In relation to the built-in errors, we pre-defined 10 specific areas of interest (AOIs) for the eye-tracking gaze analysis: monitor, respirator, ventilation pressure and tidal volume, arterial line, transducer, nutrition, stockings, intravenous cannula, central venous catheter, and infusion (Fig. 1). Fixations on the handover sheet and prescription, as well as irrelevant fixations (such as floor, surroundings, ceiling) were categorized as either 'case sheet & prescription' or 'blank,' respectively, and were excluded from the analysis (Fig. 1).

Outcomes

We hypothesized that time pressure might impact error detection and visual behaviour during the handover. Moreover, the impact of the checklist on error detection and visual behaviour was assessed. The primary outcome was the error detection rate during the shift start safety check assessing the impact of time pressure and the use of the checklist. As secondary outcomes, we compared specific eye-tracking metrics including dwell time (cumulated time spent on an AOI), entry time (time to first fixation of an AOI), revisits and first visual intake duration on different AOIs. We further computed error probability depending on gaze metrics by means of a linear mixed model analysis.

Statistics

Data were modeled by means of generalized linear mixed-effects models with a logistic link, considering the presence of a mistake in an AOI as dependent variables, and the eye-tracking measurements as fixed effects while accounting for subject and AOI as random effects. Logarithmical transformations were employed for non-normally distributed effects. p-Values for individual fixed effects were obtained by means of a likelihood ratio test. Statistical analysis was performed via a fully scripted data management pathway using the R Environment for Statistical Computing Version 4.4.1. A two-sided $p < 0.05$ was considered to indicate significance.

Results

Due to organizational reasons (leave, sickness, holiday), a total of 91 from 105 ICU were included, of whom 74 (81%) were female. No nurse declined to participate. Demographical data is shown in Table 2.

Occurrence of critical and minor errors

Every participant missed at least one error (Table 3). Participants missed a median of 4 errors (IQR 3.0–5.0) with a median of 3 major errors (IQR 2.0–3.0) and 2 minor errors (IQR 1.0–2.0). Comparing overall error rates, we observed significant differences between groups (group without checklist & with time pressure: 5.0 (IQR 3.5–6.0), group with checklist & with time pressure: 5.0 (IQR 3.2–6.0), group with checklist & without time pressure: 3.0 (IQR 3.0–4.0), group without checklist & without time pressure: 4.0 (IQR 3.0–5.0), $p = 0.018$).

The introduction of time pressure significantly influenced error rates, independent of checklist use (Table 3). Participants under time pressure committed a median of 5.0 (IQR 3.0–6.0) overall errors, which was notably higher compared to the median of 3.5 (IQR 3.0–5.0) observed in participants without time pressure ($p = 0.002$). This effect was also evident in the rates of critical and minor errors, independent of checklist use. For critical errors, the median was 2.0 (IQR 2.0–3.0) in the groups without time pressure and 3.0 (IQR 2.0–3.0) in the groups with time pressure ($p = 0.010$). Similarly, minor errors were more frequent in the groups with time pressure (median 2.0, IQR 1.0–3.0) compared to the groups without time pressure (median 1.0, IQR 1.0–2.0, $p = 0.029$).

The availability of the checklist was not associated with an impact on error rates (Table 3). Independent of time pressure, the overall error rate was a median of 4.5 (IQR 3.0–5.0) in groups without a checklist, compared to a median of 4.0 (IQR 3.0–5.0) in groups utilizing a checklist, with no statistical significance observed ($p = 0.651$). Similarly, no notable differences were identified in critical or minor errors. The median number of critical errors was 2.0 (IQR 2.0–3.0) in groups without a checklist, compared to 3.0 (IQR 2.0–3.0) in groups with a checklist ($p = 0.957$). For minor errors, the median was 2.0 (IQR 1.0–2.8) in groups without a checklist, compared to 2.0 (IQR 1.0–2.0) in groups with a checklist ($p = 0.449$), independent of time pressure (Table 3).

Gaze metrics on all errors

The specific eye-tracking data on entry time (ms), revisits (n), first visual intake duration (ms) and dwell time (ms) on all pre-specified AOIs corresponding to the pre-defined errors are detailed in Supplemental Fig. 2-5.

Error detection analysis

In the mixed model analysis considering all errors (major and minor), the odds ratio of committing or missing an error was 1.82 (95% CI 1.27 – 2.60, $p = 0.001$) for participants that were exposed to time pressure, and 0.92 (95% CI 0.64 – 1.31, $p = 0.648$) for participants using the checklist. The odds ratios for major errors were 1.80 (95% CI 1.18 – 2.80, $p = 0.009$) in the time pressured population and 1.02 (95% CI 0.66–1.58, $p = 0.930$) for the groups using checklists, for minor errors 1.82 (95% CI 1.09 – 3.06, $p = 0.023$) and 0.81 (95% CI 0.49 – 1.36, $p = 0.433$). Specific eye tracking gaze metrics differed between the four subgroups (Supplemental Fig. 2-5). In the two time pressure exposed subgroups, overall dwell time on all AOIs was 4138.88 ms (95% CI 383.67 – 7894.10) shorter compared to the whole cohort ($p = 0.031$), while the same effect was not noted for the two groups using a checklist (overall dwell time −505.91 ms, 95% CI −4261.12 – 3249.31, $p =$

Table 2
Baseline characteristics of included participants (n = 91).

	No checklist, time pressure (n = 23)	Checklist use, time pressure (n = 22)	Checklist use, no time pressure (n = 23)	No checklist use, no time pressure (n = 23)
Female Sex	17 (74%)	18 (82%)	21 (91%)	18 (78%)
Work Role				
ICU nurse with managerial function	8 (35%)	2 (10%)	3 (13%)	4 (14%)
Certified ICU nurse	1 (4%)	1 (5%)	1 (4%)	3 (13%)
ICU nurse student	14 (61%)	19 (86%)	18 /78%)	15 (65%)
Intermediate care (IMC) nurse	0 (0%)	0 (0%)	1 (4%)	1 (4%)
General professional experience (years)	12.0 (10.0–23.5)	12.2 (6.1–24.0)	15.0 (11.2–20.0)	20.0 (11.5–28.5)
ICU experience (years)	8.0 (4.5–17.0)	4.0 (3.0–20.0)	12.0 (3.0–14.5)	15.0 (4.0–23.5)
ROI (Room of Improvement) experience	13 (57%)	10 (45%)	16 (70%)	13 (57%)

Data are presented as numbers (percentages) and median [interquartile range], as appropriate.

Table 3
Occurrence of critical and minor errors.

Overall			
Number of all missed errors (critical and minor) *	4.0 (3.0, 5.0)		
Number of missed critical errors*	3.0 (2.0, 3.0)		
Number of missed minor errors*	2.0 (1.0, 2.0)		
Checklist	**Groups without checklist**	**Groups with checklist**	**P-value**
Number of all missed errors (critical and minor) *	4.5 (3.0, 5.0)	4.0 (3.0, 5.0)	0.651
Number of missed critical errors*	2.0 (2.0, 3.0)	3.0 (2.0, 3.0)	0.957
Number of missed minor errors*	2.0 (1.0, 2.8)	2.0 (1.0, 2.0)	0.449
	Groups without time pressure	**Groups with time pressure**	**P-value**
Number of all missed errors (critical and minor) *	3.5 (3.0, 5.0)	5.0 (3.0, 6.0)	0.002
Number of missed critical errors*	2.0 (2.0, 3.0)	3.0 (2.0, 3.0)	0.01
Number of missed minor errors*	1.0 (1.0, 2.0)	2.0 (1.0, 3.0)	0.02

Data presented as median [interquartile range]. * Refers to the median number of missed errors per participant. A missed error was defined as a safety hazard that was not recognized by the participant.

0.792). The time pressure subgroups had less revisits on all AOIs (−0.50, 95% CI −1.00 – −0.01, p = 0.047), while the groups with checklist did not show a significant effect (−0.34, −0.83 – 0.16, p = 0.184). There was no significant effect on entry time and first visual intake duration in the time pressure group nor the groups with checklists (entry time (ms): time pressure groups: 2236.87, 95% CI −26073.40 – 21599.65, checklist 9675.05, 95% CI −14175.19 – 33525.29), first visual intake duration (ms): time pressure groups: 10.06, 95% CI −29.56 – 49.68, checklist: 12.60, 95% CI −27.02 – 52.22) (Supplemental Fig. 2-5).

The probability of committing errors in relation to specific eye-tracking parameters (dwell time, entry time, revisits, first visual intake duration) on all AOIs were differentially associated between the time pressure exposed groups and to the groups without time pressure. Specifically, for participants experiencing time pressure, the log-odds for committing an error increased by 3.7e-05 [95% CI, 2.4e-06– 7.9e-05] for every millisecond of prolonged dwell Time, whereas participants not experiencing time pressure presented an exactly inverse association with decreasing log-odds for errors when presenting a prolonged dwell Time on an AOI. In other words, a dwell Time of 15 s in the time pressure group would translate to a predicted probability of 86 [95% CI 80–90] % of committing an error, whereas the same dwell time would only lead to a 76 [95% CI 69–82] % probability of committing an error in the group without time pressure. Similarly, the time pressure group presented increased log-odds (4.1e-06 [95% CI, −7.8e-07–9.1e-06]) of committing an error for every millisecond delay in entry time as opposed to the groups without time pressure. Furthermore, for every AOI revisit, time pressured participants had 1.41 [95% CI, 0.97 – 2.03] increased log odds of committing an error as opposed to participants without time pressure. This means, that whereas a time pressured participant revisiting an AOI 4 times would have a predicted probability of committing an error of 92 [95% CI 80–97] %, a participant without time pressure would have only a predicted probability of 75 [95% CI 63–83] % for the same number of revisits. Finally, also the first visual intake duration was associated with differentially increased log-odds of committing a mistake (0.0015 [95% CI, −0.0013 – 0.0044]) for every millisecond in the time pressure group, whereas the effect was inverse for participants without time pressure (Fig. 2).

Questionnaire

Participants reported that the eye tracker mildly interfered with performance (median 2.0, IQR 0.0–4.0) and minimally restricted mobility (median 1.0, IQR 0.0–3.0). Self-reported time pressure was moderate (median 4.0, IQR 2.0–6.0) with no group differences (p = 0.990). Thus, time pressure did not increase perceived stress. Among participants with a checklist, perceived usefulness was low, with 18% (n = 4) and 22% (n = 5) rating it as “rather not helpful.”

Discussion

This study examined error detection during simulated handovers. Our results support the hypothesis that time pressure was associated with missing errors, while the use of a checklist did not improve error detection.

Stress is a major contributing factor for medical errors [23] and can arise from time pressure, interruptions, and distractions, all of which impair cognitive performance and error detection. We induced time pressure due to its relevance in fast-paced ICU workflows and to reflect clinical reality, where unexpected events often reduce available time. This stressor was preferred over other heterogeneous stressors that are difficult to implement consistently in an eye-tracking study. Time pressure decreased error detection for both critical and minor errors, consistent with prior research showing that time pressure narrows attention, increases inattention, and impairs working memory [23–26]. The missing of both minor and clinically relevant errors indicates that time pressure reduces overall situational awareness rather than shifting prioritization to life-threatening conditions. Clinically, this failure to detect errors in high-risk environments could compromise patient safety and increase adverse events or mortality. These results highlight the need for strategies to minimize stress from time pressure. However, simulations of time pressure (which cannot be eliminated fully in ICUs)

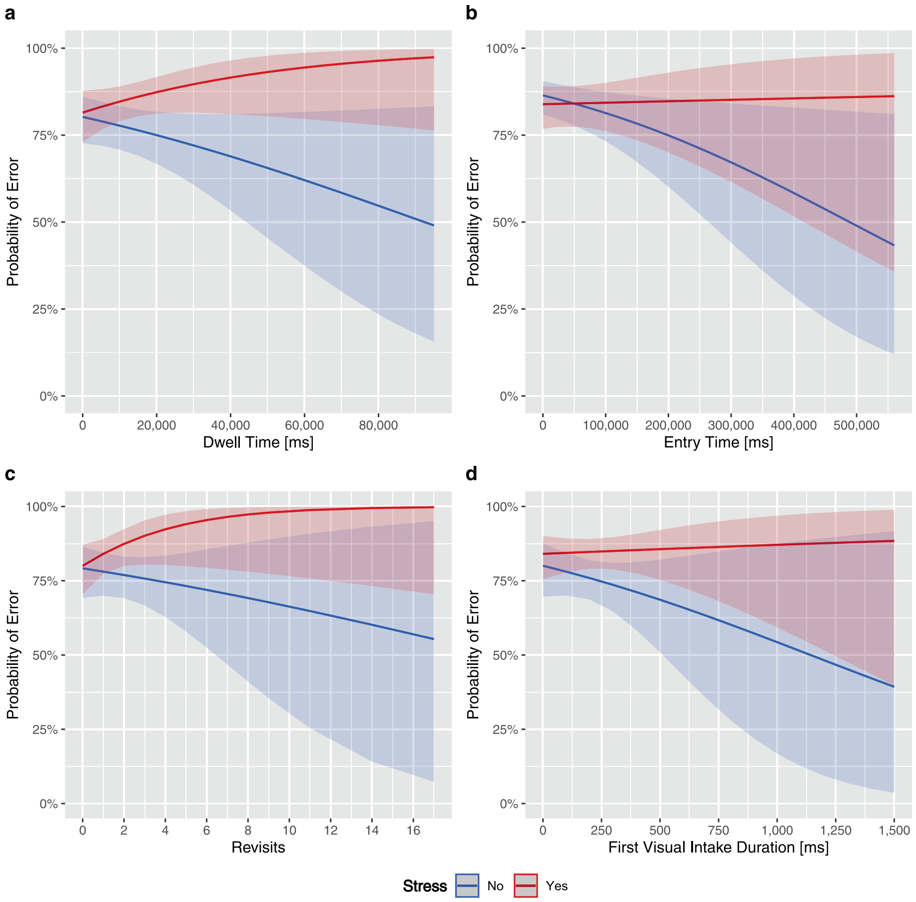

Fig. 2. Probability of error for groups with and without time pressure exposure. Panel a: dwell time (ms), Panel b: Entry time (ms), Panel c: Revisits (n), Panel d: First visual intake duration (ms).

could offer learning opportunities, allowing practice in decision-making, error detection, and teamwork without risk to real patients.

In contrast, error detection in the checklist groups was similar to the control group. Standardized handovers and checklists have long been advocated to mitigate errors [2,3]. Of 91 participants, 89 supported implementing a checklist. Although not routinely used, checklists can be effective in ICU settings and handovers by improving information retention [26–31] and contributing to continuity of care [32]. The lack of advantage in our checklist group may reflect inadequate training or limited acceptance, which was presented without prior training. Only 9 of 45 participants found it useful. Despite benefits, checklist uptake remains low, highlighting the need for training and engagement [33–36]. Notably, all 91 participants were willing to engage in checklist training. Future studies should examine whether different checklist designs or implementation approaches yield different results. Eye-tracking enables precise assessment of visual patterns and may support developing user-friendly checklists.

Our previously published study demonstrated that error recognition during handover checks is linked to distinct gaze metrics [17]. Here, we observed a correlation between specific gaze metrics and time pressure. Participants under time pressure had shorter dwell times, meaning they spent less time on a given area of interest (AOI), which resulted in more missed errors. Additionally, they had fewer revisits, making them less likely to recheck an AOI, further contributing to error omission. Revisits serve as a surrogate for rechecking and control glances [37,38], explaining the negative correlation between revisits and error detection. We were able to add to emerging evidence that the probability of committing or missing an error was dependent on distinct eye tracking metrics. We used eye-tracking to observe ICU nurses' visual attention during handover aiming to better understand whether the addition of time pressure or checklist use influences their gaze behaviour. While conventional observations are prone to bias due to the Hawthorne effect, where individuals alter their behaviour when aware of being observed [39], eye tracking provides objective insights into gaze patterns [40,41]. Whether it is in the care of ICU patients, complex procedures such as airway management, interaction with medical devices or medication verification processes [15–17,20,41], eye tracking offers advantages that can be used in future studies.

Our study has several strengths, including a large sample size and scenarios based on real events, creating conditions close to clinical reality. However, limitations must be acknowledged. First, the simulated setting may have reduced perceived realism [42], although introducing hidden errors in real patients would have been unethical and impractical. Second, only time pressure was examined as a stressor. Oher factors such as noise, interruptions, and fatigue were excluded due to difficulties in standardization and measurement. Despite differing gaze patterns, self-reported time pressure did not differ between groups, likely reflecting the highly subjective nature of stress perception, which may be influenced by factors such as prior clinical experience and baseline stress tolerance. As these were not controlled for, inter-individual variability may have attenuated group differences. In addition, subjective ratings of time pressure might not fully capture task-related cognitive load or momentary stress experienced during critical phases of task execution, also in simulated settings.

Future studies should identify stressors that affect both performance and subjective stress perception.

Although the head nurse contributed to checklist development, acceptance was very low, likely due to limited training and short preparation time, which may have reduced familiarity, usage and perceived usefulness, indicating insufficient implementation. Moreover, participants were unaware of the potential checklist use before they took part in the study and the checklist might not have been very user-friendly, all limiting familiarity with the checklist. Especially low familiarity thus might have mainly contributed to low checklist uptake. Future research should evaluate strategies for effective checklist or guideline implementation to maximise uptake and utility. Finally, the checklist used in this pilot study was not formally validated. The results derived from the checklist should thus be interpreted with caution, as they might not be generalizable and necessitate further validation.

In conclusion, our findings indicate that error detection during shift handovers of ICU nurses were adversely affected by time pressure. The use of our checklist did not appear to have an impact on error detection. Eye-tracking data indicated that time pressure was associated with distinct gaze behaviour patterns.

Declarations

Data sharing statement: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics: The local competent Ethics Committee approved the study protocol (Ethikkommission Ostschweiz, BASEC Nr. 2023–01130, approval date 21.09.2023). The study was performed in accordance with the Declaration of Helsinki and its later amendments or comparable ethical standards.

CRediT authorship contribution statement

Ivan Chau: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Carina Graf:** Writing – review & editing, Methodology, Formal analysis. **Patrick Zinsli:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Yael van der Geest:** . **Pedro David Wendel-Garcia:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Philipp K. Buehler:** Writing – review & editing, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Urs Pietsch:** Writing – review & editing, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Daniel A. Hofmaenner:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2026.104394.

References

[1] Spooner AJ, Aitken LM, Chaboyer W. Implementation of an evidence-based practice nursing handover tool in intensive care using the knowledge-to-action framework. Worldviews Evid Based Nurs 2018;15:88–96.

[2] Dutra M, Monteiro MV, Ribeiro KB, Schettino GP, Kajdacsy-Balla Amaral AC. Handovers among staff intensivists: a study of information loss and clinical accuracy to anticipate events. Crit Care Med 2018;46:1717–21.

[3] Zakrison TL, Rosenbloom B, McFarlan A, Jovicic A, Soklaridis S, Allen C, et al. Lost information during the handover of critically injured trauma patients: a mixed-methods study. BMJ Qual Saf 2016;25:929–36.

[4] Dusse F, Pütz J, Böhmer A, Schieren M, Joppich R, Wappler F. Completeness of the operating room to intensive care unit handover: a matter of time? BMC Anesthesiol 2021;5:21–38.

[5] Drews FA, Markewitz BA, Stoddard GJ, Samore MH. Interruptions and delivery of Care in the Intensive Care Unit. Hum Factors 2019;61:564–76.

[6] Kowitlawakul Y, Leong BSH, Lua A, Aroos R, Wong JJ, Koh N, et al. Observation of handover process in an intensive care unit (ICU): barriers and quality improvement strategy. Int J Qual Health Care 2015;27:99–104.

[7] Salulee R, Ramirez MM, Al-Qaqaa YM, Chakravarti SB, McKinstry J. Safety checklist implementation did not reduce central venous catheter duration in pediatric cardiac ICU patients. Pediatr Qual Saf 2020;5:253.

[8] Barman A, Pradhan D, Bhattacharyya P, Dey S, Bhattacharjee A, Tesia SS, et al. Diagnostic accuracy of delirium assessment methods in critical care patients. J Crit Care 2018;44:82–6.

[9] Starmer AJ, Sectish TC, Simon DW, Keohane C, McSweeney ME, Chung EY, et al. Rates of medical errors and preventable adverse events among hospitalized children following implementation of a resident handoff bundle. J Am Med Assoc 2013;310:2262–70.

[10] Krimminger D, Sona C, Thomas-Horton E, Schallom M. A multidisciplinary QI initiative to improve OR-ICU handovers. Am J Nurs 2018;118:48–59.

[11] Gardiner TM, Marshall AP, Gillespie BM. Clinical handover of the critically ill postoperative patient: an integrative review. Aust Crit Care 2015;28:226–34.

[12] Sirgo Rodríguez G, Chico Fernández M, Gordo Vidal F, Garcia Arias M, Holanda Pena MS, Azcarate Ayerdi B, et al. Handover in intensive care. Med Intensiva 2018;42:168–79.

[13] Bergs J, Hellings J, Cleemput I, Zurel O, De Troyer V, Van Hiel M, et al. Systematic review and meta-analysis of the effect of the World Health Organization surgical safety checklist on postoperative complications. Br J Surg 2014;104:150–8.

[14] Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat AHS, Dellinger E, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med 2009;360:491–9.

[15] Hofmaenner DA, Buehler PK. The impact of eye-tracking on patient safety in critical care. J Clin Monit Comput 2022;36:1577–9.

[16] Hofmaenner DA, Klinzing S, Brandi G, Hess S, Lohmeyer Q, Enthofer K, et al. The doctor's point of view: eye-tracking as an investigative tool in the extubation process in intensive care units. A pilot study. Minerva Anestesiol 2020;86:1180–9.

[17] van der Geest Y, Chau I, Wendel-Garcia PD, Buehler PK, Hautz W, Filipovic M, et al. Eye tracking during a simulated start of shift safety check: an observational analysis of gaze behavior of critical care nurses. J Intensive Care Soc 2024 Aug 2;25(4):383–90.

[18] Kadhim B, Khairat S, Li F, Gross IT, Nath B, Hauser RG, et al. Implementation of eyetracking technology to monitor clinician fatigue in routine clinical care: a feasibility study. ACI Open 2023;7:e1–7.

[19] Hofmaenner DA, Herling A, Klinzing S, Wegner S, Lohmeyer Q, Schuepbach RA, et al. Use of eye tracking in analyzing distribution of visual attention among critical care nurses in daily professional life: an observational study. J Clin Monit Comput 2021;35:1511–8.

[20] Buehler PK, Herling A, Bienefeld N, Klinzing S, Wegner S, Wendel Garcia PD, et al. Differing visual behavior between inexperienced and experienced critical care nurses while using a closed-loop ventilation system – a prospective observational study. Front Med 2021;8:681321.

[21] Hollnagel EFRAM. The functional resonance analysis method: modeling complex socio-technical systems. Ashgate Publishing Limited England 2012:142 p.

[22] Clay-Williams R, Hounsgaard J, Hollnagel E. Where the rubber meets the road: using FRAM to align work-as-imagined with work-as-done when implementing clinical guidelines. Implement Sci 2015 Aug;29(10):125.

[23] Garrouste-Orgeas M, Perrin M, Soufir L, Vesin A, Blot F, Maxime V, et al. The Iatroref study: medical errors are associated with symptoms of depression in ICU staff but not burnout or safety culture. Intensive Care Med 2015;41:273–84.

[24] Robertson JJ, Long B. Suffering in silence: medical error and its impact on health care providers. J Emerg Med 2018 Apr;54(4):402–9.

[25] Salam A, Segal DM, Abu-Helalah MA, Gutierrez ML, Joosub I, Ahmed W, et al. The impact of work-related stress on medication errors in Eastern Region Saudi Arabia. Int J Qual Health Care 2019 Feb 1;31(1):30–5.

[26] Wu J, Feng M, Liu Y, Fang H, Duan H. The relationship between chronic perceived stress and error processing: evidence from event-related potentials. Sci Rep 2019 Aug 12;9(1):11605.

[27] Erikson EJ, Edelman DA, Brewster FM, Marschall SD, Turner MC, Sarode VV, et al. The use of checklists in the intensive care unit: a scoping review. Crit Care 2023;27:468.

[28] Graan SM, Botti M, Wood B, Redley B. Nursing handover from ICU to cardiac ward: standardised tools to reduce safety risks. Aust Crit Care 2016;29:165–71.

[29] Milby A, Böhmer A, Gerbershagen MU, Joppich R, Wappler F. Quality of post-operative patient handover in the post-anaesthesia care unit: a prospective analysis. Acta Anaesthesiol Scand 2014;58:192–7.

[30] Keller N, Bosse G, Memmert B, Treskatsch S, Spies C. Improving quality of care in less than 1 min: a prospective intervention study on postoperative handovers to the ICU/PACU. BMJ Open Qual 2020;9:e000668.

[31] Salzwedel C, Mai V, Punke MA, Kluge S, Reuter DA. The effect of a checklist on the quality of patient handover from the operating room to the intensive care unit: a randomized controlled trial. J Crit Care 2016;32:170–4.

[32] Malekzadeh J, Mazluom SR, Etezadi T, Tasseri A. A standardized shift handover protocol: improving nurses' safe practice in intensive care units. J Caring Sci 2013; 27:177–85.

[33] Turner CJ, Haas B, Lee C, Brar S, Detsky ME, Munshi L. Improving communication between surgery and critical care teams: beyond the handover. Am J Crit Care 2018;27:392–7.

[34] Marschall AP, Tobiano G, Murphy N, Comadira G, Willis N, Gardiner T, et al. Handover from operating theatre to the intensive care unit: a quality improvement study. Aust Crit Care 2019;32:229–36.

[35] Segall N, Bonifacio AS, Schroeder RA, Barbeito A, Rogers D, Thornlow DK, et al. Can we make postoperative patient handovers safer? a systematic review of the literature. Anesth Analg 2012;115:102–15.

[36] Jigajinni S, Sultan P. The intensive care unit handover: the most stressful part of the shift. Br J Hosp Med 2010;71:M25–7.

[37] Jaarsma T, Jarodzka H, Nap M, van Merrienboer JJG, Boschuizen HPA. Expertise in clinical pathology: combining the visual and cognitive perspective. Adv Health Sci Educ Theory Pract 2015;20:1089–106.

[38] Zimmermann JM, Vicentini L, Lohmeyer Q, Taramasso M, Maisano F, Meboldt M. Visual behaviour strategies of operators during catheter-based cardiovascular interventions. J Med Syst 2019;44:12.

[39] McCarney R, Warner J, Iliffe S, van Haselen R, Griffin M, Fisher P. The Hawthorne effect: a randomised, controlled trial. BMC Med Res Method 2007;7:30.

[40] Bodet-Contentin L, Szymkowicz E, Delpierre E, Chartier D, Gadrez P, Muller G, et al. Eye tracking communication with intubated critically ill patients: a proof-of-concept multicenter pilot study. Minerva Anestesiol 2022;88:690–7.

[41] Kang D, Charlton P, Applebury DE, Robinson EJ, Merkel MJ, Rowe S, et al. Utilizing eye tracking to assess electronic health record use by pharmacists in the intensive care unit. Am J Health Syst Pharm 2022;79:2018–25.

[42] Bokka L, Ciuffo F, Clapper TC. Why simulation matters: a systematic review on medical errors occurring during simulated health care. J Patient Saf 2024;20: 110–8.