

Handoff strategies in settings with high consequences for failure: lessons for health care operations

EMILY S. PATTERSON^{1,3}, EMILIE M. ROTH², DAVID D. WOODS³, RENÉE CHOW⁴ AND JOSÉ ORLANDO GOMES⁵

¹Veteran's Administration Getting at Patient Safety (GAPS) Center, Cincinnati, OH, ²Roth Cognitive Engineering, Boston, MA,

³Institute for Ergonomics, The Ohio State University, Columbus, OH, USA, ⁴University of Toronto, Toronto, Canada,

⁵Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

Abstract

Objective. To describe strategies employed during handoffs in four settings with high consequences for failure.

Design. Analysis of observational data for evidence of use of 21 handoff strategies.

Setting. NASA Johnson Space Center in Texas, nuclear power generation plants in Canada, a railroad dispatch center in the United States, and an ambulance dispatch center in Toronto.

Main measure. Evidence of 21 handoff strategies from observations and interviews.

Results. Nineteen of 21 strategies were used in at least one domain, on at least an 'as needed' basis.

Conclusions. An understanding of how handoffs are conducted in settings with high consequences for failure can jumpstart endeavors to modify handoffs to improve patient safety.

Keywords: coordination, fatigue, grounded theory, handoff, human factors, patient safety, nursing, physician

Information needs to be accurately communicated during patient handoffs to meet quality and safety goals. For example, one contributing factor to the 1995 amputation of the wrong leg of Willie King in Tampa was that the handoff from the surgery pool nurse to the surgery shift nurse did not include the information that the incorrect leg had been input by the clerk for amputation [1]. In this paper, we describe a set of coordination and communication strategies, observed in settings with the potential for high consequences for failure, which might prove useful in a variety of initiatives to modify handoffs to improve patient safety.

The primary objective of any patient handoff is the accurate transfer of information about a patient's state and care plan [2–4]. In nursing shift change updates, other objectives, including increasing team cohesion [5], training, socialization, and emotional catharsis [6] have also been identified.

Research in space shuttle mission control has identified some of the potential costs of failing to be told, forgetting, or misunderstanding information communicated during a shift change handoff [7]:

1. having an incorrect or incomplete model of the system's state;

2. being unaware of significant data or events;
3. being unprepared to deal with impacts from previous events;
4. failing to anticipate future events;
5. lacking knowledge that is necessary to perform tasks;
6. dropping or reworking activities that are in progress or that the team has agreed to do; and
7. creating an unwarranted shift in goals, decisions, priorities, or plans.

In addition to being a recognized point of vulnerability [8], there are potential benefits to handoffs. During a handoff, the person who is accepting responsibility has a fresh perspective, which has been shown to increase the detection of fixation errors [9,10]. For example, during 16 observed shift change handoffs between NASA mechanical systems personnel, eight out of 75 questions were asked to detect errors (e.g. 'Do you know that for sure?'). The remaining questions were to initiate an update or a new topic, to obtain more details, and to confirm understanding [7].

Therefore, in order to ensure system robustness during handoffs, effective communication and coordination strategies are needed [11]. An understanding of how strategies are used

Address reprint requests to Emily Patterson, Veteran's Administration Getting at Patient Safety (GAPS) Center, 210 Baker Systems, 1971 Neil Avenue, Columbus, OH 43210, USA. E-mail: patterson.150@osu.edu

during handoffs in settings with high consequences for failure may provide insight, particularly for efforts to redesign how handoffs are conducted given that residents are now mandated to work fewer hours. To this end, we investigated how 21 handoff strategies were employed during personnel changes in space shuttle mission control, nuclear power generation, railroad dispatching, and ambulance dispatching.

Materials and methods

Direct observations were conducted at the NASA Johnson Space Center [7], two Canadian nuclear power plants [12], a railroad dispatch center in the United States [13], and an ambulance dispatch center in Toronto [14]. Although the original handwritten ethnographic data were collected for other purposes, sufficient observations of personnel change handoffs and opportunistic interviews were conducted to characterize how routinely the 21 strategies were employed. Summary data about the original studies are shown in Table 1.

A list of handoff communication and coordination strategies was generated from prior research on shift change updates in space shuttle mission control [7]. In addition, strategies were brainstormed based on comparisons between handoffs in non-medical and medical settings, including inpatient nursing shift changes and surgery [15]. The resulting list of strategies and their inferred objectives is shown in Table 2.

During analysis, the original observers reviewed the previously collected data. For all four settings, the data were originally collected as detailed, unstructured, handwritten capture

of activities and verbalizations ‘in situ’ that were then transcribed into electronic text files. Evidence relevant to each of the 21 strategies was summarized and interpreted by the original observer, and discussed among the analysts. A summary description of how the strategy was used in each domain as well as information regarding how routinely the strategy was used was then provided for each strategy.

Because observation is guided by study objectives, performing data analysis on data originally collected for another purpose can decrease the validity and reliability of inferences [16]. For example, evidence for a particular strategy might not be available in the collected data that might have been available if the observer had been focused on that aspect (i.e. evidence supporting a strategy is missed). Alternatively, existing data might be interpreted as evidence that a particular strategy exists, but contradicting data might have been missed (i.e. evidence for a strategy is given too much weight because evidence refuting a strategy is missed). Several steps were taken to address these issues, thereby increasing the validity and reliability of our findings. Firstly, we only investigated strategies that were relatively unambiguous to observe, particularly compared with internal cognitive strategies such as mental simulation [17]. Secondly, in order to take advantage of information that was not contained in the original handwritten data, the original observer conducted the analysis of the strategies for their setting. Then a second individual familiar with the setting verified that they concurred with the interpretations of the primary analyst. Finally, several discussions with the analysts were held to identify and resolve discrepancies in interpretation about the definition of the strategies and interpretations of the evidence.

Table 1 Summary data of original observational studies

Setting	Study objective	Hours of observation	Number of observed handoffs and personnel	Typical handoff update time
Space shuttle mission control	To investigate what it means to update a supervisory controller on the status of a continuous, anomaly-driven process in a complex, distributed environment	67	16 shift change handoffs Five personnel	10 minutes
Nuclear power	To identify and model the monitoring strategies employed during normal operations	177	27 personnel, all interviewed on handoff strategies, most observed during shift change handoff	10–15 minutes
Railroad dispatching	To understand how dispatchers plan and manage track use in order to inform the design of advanced visualization, communication and decision-support systems	60	Seven shift change handoffs 15 personnel	5–10 minutes
Ambulance dispatching	To inform the design of human–computer interfaces to support real-time decision making	118	Multiple break handoffs on 11 shifts 22 personnel Three interviews on handoff strategies	1–5 minutes

Table 2 Handoff coordination and communication strategies and objectives

No.	Inferred objectives	Strategy
1	Improve handoff update effectiveness	Face-to-face verbal update with interactive questioning
2	Improve handoff update effectiveness	Additional update from practitioners other than the one being replaced
3	Improve handoff update effectiveness	Limit interruptions during update
4	Improve handoff update effectiveness	Topics initiated by incoming as well as outgoing
5	Improve handoff update effectiveness	Limit initiation of operator actions during update
6	Improve handoff update effectiveness	Include outgoing team's stance toward changes to plans and contingency plans
7	Improve handoff update effectiveness	Readback to ensure that information was accurately received
8	Improve handoff update efficiency and effectiveness	Outgoing writes summary before handoff
9	Improve handoff update efficiency and effectiveness	Incoming assesses current status
10	Improve handoff update efficiency and effectiveness	Update information in the same order every time
11	Improve handoff update efficiency and effectiveness	Incoming scans historical data before update
12	Improve handoff update efficiency and effectiveness	Incoming reviews automatically captured changes to sensor-derived data before update
13	Improve handoff update efficiency and effectiveness	Intermittent monitoring of system status while 'on call'
14	Improve handoff update efficiency and effectiveness	Outgoing has knowledge of previous shift activities
15	Increase access to data	Incoming receives primary access to the most up-to-date information
16	Increase access to data	Incoming receives paperwork that includes handwritten annotations
17	Improve coordination with others	Unambiguous transfer of responsibility
18	Improve coordination with others	Make it clear to others at a glance which personnel are responsible for which duties at a particular time
19	Enable error detection and recovery	Overhear others' updates
20	Enable error detection and recovery	Outgoing oversees incoming's work following update
21	Delay transfer of responsibility during critical activities	Delay the transfer of responsibility when concerned about status/stability of process

'Incoming', personnel arriving to begin their shift; 'outgoing', personnel ending their shift; 'readback', verbal repeat of information that was just heard to verify accuracy; 'on call', personnel who are assigned responsibility to be available to provide support on an 'as needed' basis during a scheduled time.

Results

All observed handoff updates were interactive, verbal, face-to-face interactions between the outgoing and incoming person. With the exception of the ambulance dispatch center, where a relief dispatcher would relieve a primary dispatcher once every 3 hours during a 12-hour shift for a brief time, the outgoing person had worked the entire previous shift. With few exceptions, the outgoing person was inaccessible following the update, and so there was no question that a transfer of responsibility had occurred at that time.

With the exception of strategy 7 (having the incoming person read back information to the outgoing person to verify

accuracy) and strategy 10 (updating information in the same order every time), every strategy was found in at least one setting on at least an 'as needed' basis. An overview of how the strategies were used in each setting is provided in Table 3. All of the strategies were routinely used, except where indicated. For example, strategy 20, having the outgoing personnel oversee the incoming personnel's work following the update, was routinely used in space shuttle mission control but was rare, only occurring if perceived necessary, in the other three settings.

As shown in Table 3, six of seven strategies were employed to improve the effectiveness of the handoff update, even though they likely reduced the efficiency of the update.

Table 3 Data on handoff strategies for all settings

Strategy	Setting-specific details
1. Face-to-face verbal update with interactive questioning	All: rarely employ other means
2. Additional update from practitioners other than the one being replaced	SSMC: updates from incoming supporting personnel during handoff and everyone to flight director after handoff NP, RDC: not observed ADC: updates from paramedic crews, update to supervisor after handoff
3. Limit interruptions during update	SSMC, NP, RDC: interruptions limited by protocol or convention ADC: interrupted by crew and dispatch center communications
4. Topics initiated by incoming as well as outgoing	SSMC: common (except for update after takeoff) NP, RDC: common ADC: if outgoing perceived to have missed standard topics
5. Limit initiation of operator actions during update	All: other activities, with the exception of monitoring the visual or audio channels, were postponed to end of update ADC: dispatchers are scheduled to change shifts 10 minutes before ambulance crew
6. Include outgoing team's stance toward changes to plans and contingency plans	SSMC: routinely observed, not a formal procedure NP, RDC, ADC: not observed
7. Readback to ensure that information was accurately received	All: not observed during handoff updates
8. Outgoing writes summary before handoff	SSMC: one paragraph summary of shift written in log before handoff NP, RDC, ADC: not observed
9. Incoming assesses current status	SSMC: glance at displays, listen to audio system NP: review control panel displays and alarms ("walk the board") RDC: glance at large wall-mounted displays and local screen displays, listen to audio system ADC: glance at Global Positioning System (GPS) display, tailor screen, displays to user-preferred default settings, listen to audio system
10. Update information in the same order every time	All: not observed
11. Incoming scans historical data before update	SSMC: scan recent log entries, flight plan NP: scan recent log entries RDC: scan recent log entries ADC: review log entries for unusual incidents (after update)
12. Incoming reviews automatically captured changes to sensor-derived data before update	All: not observed, reported done on 'as needed' basis
13. Intermittent monitoring of system status while 'on call'	SSMC: daily updates required for 'on call' personnel NP, RDC, ADC: not observed
14. Outgoing has knowledge about previous shift activities	SSMC, NP, RDC: outgoing person providing handoff held position in the previous shift ADC: outgoing person providing handoff held position in the previous shift, with the exception of periodic breaks
15. Incoming receives primary access to the most up-to-date information	All: incoming receives primary access to tools, paperwork, up-to-date information following (or before) the update
16. Incoming receives paperwork that includes handwritten annotations	SSMC: handwritten entries in logs and annotations to flight plans NP, RDC: handwritten record in logs of significant activities that have occurred during a shift ADC: annotations to unit availability and meal break forms

continued

Table 3 *continued*

Strategy	Setting-specific details
17. Unambiguous transfer of responsibility	SSMC: incoming takes responsibility for answering audio system NP: incoming replaces outgoing in seat at desk RDC, ADC: incoming replaces outgoing in seat at desk and takes responsibility for answering audio system
18. Make it clear to others at a glance which personnel are responsible for which duties at a particular time	All: transfer of duties after update unless negotiated
19. Overhear others' updates	SSMC: always hear updates to flight director and related positions through audio system NP, RDC: not observed ADC: often hear others' updates
20. Outgoing oversees incoming's work following update	SSMC: 1 hour overlap for handoff NP, RDC, ADC: rare, but occurs if perceived necessary
21. Delay transfer of responsibility during critical activities	All: short activities completed before transfer of responsibility; long delays rare, but employed 'as needed'

ADC, ambulance dispatching center; All, all settings; NP, nuclear power; RDC, railroad dispatching center; SSMC, space shuttle mission control.

- The update was verbal, face-to-face, and included interactive questioning so that much could be quickly communicated using non-verbal cues (e.g. gesturing) and questions could immediately be asked to clarify the understanding of the incoming person (strategy 1).
 - Additional updates from other personnel were conducted around the time of the handoff update to verify that the information had been communicated accurately and to synchronize ongoing plans distributed across interacting teams (strategy 2). For example, the incoming space shuttle mission controller responsible for the mechanical systems received updates not only from the outgoing controller, but also from three supporting incoming personnel, after which he updated the incoming Flight Director. Note that all of these updates were heard by the outgoing shift so that misunderstandings could be immediately corrected.
 - Interruptions were limited during the update in order to minimize the possibility that information would fail to be conveyed or be forgotten (strategy 3).
 - Topics were initiated by the incoming person, in addition to the outgoing person, to reduce the chances that topics would be missed (strategy 4).
 - Actions initiated by the personnel were delayed until after the handoff update was complete, with the exception of peripherally monitoring the visual displays and/or audio 'voice loop' channels (strategy 5).
 - The team's stance toward changes to plans and contingency plans were provided in every observed handoff update in space shuttle mission control. For example, the stance of an outgoing person was that an Auxiliary Power Unit (APU) with a hydraulic leak should be turned off during entry in order to avoid relying upon a potentially faulty system. By including this stance in the update, the incoming controller was positioned to provide and defend a recommendation in the event that the decision to leave the APU on during entry was reconsidered (strategy 6).
- Secondly, six of seven strategies were observed that were inferred to improve both the efficiency and the effectiveness of the handoff updates.
- In space shuttle mission control, the outgoing person wrote a one-paragraph summary of the shift in the handwritten log in preparation for the verbal handoff (strategy 8).
 - In all the settings, the incoming person assessed the current status of the monitored system before or during the update. Note that this was made easier by 'at a glance' overview visual displays [18] (strategy 9).
 - The incoming person scanned historical data immediately before the update to enable a more efficient and informed update, or immediately following the update in order to reinforce and extend the learned information (strategy 11).
 - The incoming person was expected to review automatically captured changes to sensor-derived data ('automated logs') before the update in situations where there were known problems or instability (strategy 12).
 - In space shuttle mission control, two personnel designated 'on call', one for the first 12 hours in a day, one for the second 12 hours in a day, were required to receive daily, 15 minute updates so that they would be better prepared to accept responsibility quickly if needed (strategy 13).
 - The outgoing person providing the handoff briefing was the individual who held the position in the previous shift. He or she was thus highly knowledgeable of the activities that occurred during that shift, increasing the chance that the information transmitted was correct and complete (strategy 14).

Thirdly, the handoff included the transfer of supporting tools, documents, and information that were not mentioned during the verbal updates. The inferred objective of these strategies is to reduce the time and effort needed for the incoming person to search for information if events occur while they are responsible for intervening. Specifically, the incoming person received primary access to tools, paperwork, and up-to-date information following (or before) the update (strategy 15). In addition, the incoming person gained access to forms that were left at the desk that were informally annotated in a systematic way (strategy 16). The annotations contained information that was not considered critical enough to be maintained in the 'official record', but which helped to prevent a discontinuity in the flow of activities. For example, when ambulance personnel took meal breaks, dispatchers noted this on a paper form, which became available to the incoming dispatcher because it was physically located at the desk.

Fourthly, two strategies were employed that rendered observable and unambiguous which individual (incoming or outgoing person) was currently responsible for the position. The first strategy (strategy 17) included physical positioning (e.g. proximity to the control desk) and control of tools (e.g. jack for the audio 'voice loop' [19]). For example, an ambulance dispatcher reported that it is 'almost insulting' to plug in headphones before the outgoing person has handed over responsibility because it is 'a sign of taking over'. In addition, all settings employed the social norm that the outgoing person maintained responsibility for the position until the handoff update was complete (strategy 18).

Fifthly, two strategies were employed to enable detection and recovery from erroneous interpretations following the handoff update. Firstly, in space shuttle mission control and ambulance dispatching, it was common for operators to overhear others' updates (strategy 19). Therefore, discrepancies with their own understandings could easily be identified. In addition, the personnel could better anticipate others' requests with the information gleaned from overhearing the update. Secondly, in space shuttle mission control, two people were scheduled to work side by side for 1 hour, which allowed the outgoing person to correct misunderstandings of the incoming person (strategy 20). Although mission control was the only setting to employ this strategy formally, personnel in the other three settings reported that they informally stayed to watch the incoming person begin his or her work if an unusual situation or a training need merited it.

Finally, personnel delayed transferring responsibility until the completion of a critical activity was routinely observed for short periods of time (strategy 21). Although rare, this delay was observed to be several hours long in one exceptional circumstance in space shuttle mission control when an anomaly on an Auxiliary Power Unit (APU) had not yet been definitively diagnosed.

Discussion

The use of 21 handoff coordination and communication strategies was described based on an analysis of existing ethnographic observational data from NASA mission control, nuclear power, railroad, and ambulance dispatching.

The four investigated settings have similar characteristics to many health care settings. For example, they are made up of complex, interconnected systems, and are event-driven, time-pressured, and resource-constrained, while having the potential for high consequences for system failure. In addition, work is distributed across multiple people in dedicated roles with specialized knowledge and expertise, who are all supported in accomplishing their objectives by computerized tools. Given these similarities, it is likely that a better understanding of strategies employed to make handoff updates in these settings more robust could provide insight into endeavors to redesign handoffs to improve quality and patient safety.

Nevertheless, patient handoffs have some unique characteristics. For instance, health care personnel do not have 'at a glance' overview status and historical displays, and therefore have to convey more information during their updates. For example, in ambulance dispatching, the outgoing person does not normally convey ambulance locations because there is a map-based display that automatically displays ambulance locations from Global Positioning System (GPS) data. Updates about locations generally focus on situations where the displayed information is inaccurate, such as if the GPS data is incorrect, or when the display does not include information such as a broken stretcher. In addition, health care providers rely upon different communication systems, normally pager and phone systems, than most of these settings. In space shuttle mission control, for example, personnel primarily use a 'voice loops' audio technology [19]. This technology allows them to listen to multiple 'channels' at once. A social norm is to listen in on another person's communications before initiating an interaction. When the personnel are engaged in important communications such as handoff updates, they will usually delay the interaction, thereby reducing interruptions.

In health care, there are numerous types of patient handoffs, each of which will likely require tailoring of these strategies to their specific constraints and needs. A non-inclusive list of handoffs in health care are nursing shift changes for complete and coverage responsibility, physicians transferring complete responsibility for a patient, physicians transferring 'on call' responsibility, temporary acceptance of responsibility for patients of a nurse who leaves a ward, nursing and physician handoffs between emergency departments, surgical to postoperative care, different inpatient settings, different hospitals, nursing homes, and home health care. Many handoffs are between individuals within the same discipline, but there are also interdisciplinary handoffs such as from an operating room anesthesiologist to a nurse in postoperative recovery. Within these specific types of handoffs, there are many variations, including differences in the use of supporting tools such as audio tape players, fax machines, and written summaries, and differences in the frequency of trainee or substitute (e.g. 'agency') staffing.

To illustrate how the identified handoff communication and coordination strategies might apply to a health care setting, consider the example of a nursing shift change on an acute care ward where an outgoing nurse verbally summarizes information about each of the patients under his or her responsibility near the end of the shift onto an audiotape. When the nurses

for the next shift arrive, the audiotape with all of the verbal summaries are played for everyone to hear, but only the nurse assigned responsibility for each individual patient takes handwritten notes while listening to the taped update.

Although this is overall a fairly systematic process with some clear benefits, we feel that modifications might be made to improve the quality of the handoff process based on our findings. It is unlikely that all of the identified strategies can be directly applied, however. For example, the first strategy of a face-to-face verbal update with interactive questioning (strategy 1) would be challenging to use in this setting for several reasons, most notably an efficiency cost from locating the appropriate nurses and interrupting ongoing tasks to provide an update that might be longer with the interactive questioning. In addition, other nurses would lose the benefit of overhearing the updates. For example, the charge nurse schedules which nurses accept incoming patients and when nurses leave the ward for breaks and patient transfers. By overhearing all the updates, the charge nurse can do a better job with these tasks. In addition, if a patient has an urgent need such as resuscitation, by overhearing all the updates, nurses other than the primary caregiver would be more likely to be aware if the patient is HIV positive or has ordered that no attempts be made to resuscitate. Nevertheless, by only listening to the audiotaped summary, incoming nurses have no ability to ask questions about topics that were not covered or to clarify their understanding, particularly if a portion was difficult to hear. A modification of strategy 1 might be implemented that yields some of the benefits of a 'face to face' handoff without incurring excessive costs or losing the benefits of the 'shared' update. For example, an explicit final face-to-face 'check out' of the outgoing nurse with the incoming nurse might be implemented to provide this opportunity. A forcing function for this interaction could be that the outgoing nurse needs to transfer a marker of responsibility for the patients such as a cellular phone, pager, or index card that represents the patient, which could also serve as an unambiguous transfer of responsibility for the patients (strategy 17). Ideally, this 'marker' would be observable to all health care workers and perhaps even the patient, so that it is easier to know which nurse is responsible for particular patients.

Additional strategies might be considered for the nursing shift change handoff. When the outgoing nurse records the verbal update on the audiotape, perhaps he or she could 'flag' portions of the patient chart, such as changes to a critical laboratory value, for the incoming nurse to review before listening to the update (strategy 9). If paper charts are not available, perhaps flagging functions could be added to the electronic chart or the nurse could ask a clerk to print out particular portions of the electronic chart for the incoming nurse (strategy 11). To reduce interruptions while recording and listening to the updates, other health care workers could be restricted by protocols or social norms from interrupting except in urgent circumstances (strategy 3), and a dedicated communication system, such as pagers or call lights, could be used to identify requests from patients so that nurses can queue the requests until after the handoff (strategy 3). Similarly, calls from families could be eliminated during the shift change (strategy 3).

Finally, all patient actions initiated after the taped handoff update could be required to be communicated during the 'check out' process (strategy 5).

The strategies described above are designed for the typical nursing shift change as it is currently configured. New technologies might be used to reduce some of the costs associated with trade-offs such as efficiency, the ability to overhear others' updates, and handing off the most accurate, up-to-date information. For example, the use of a single audiotape recorder requires the nurses giving updates to wait to give their report until the tape player is available. In order to avoid waiting, nurses have been observed to give updates well before the shift change, increasing the uncertainty about the status of their patients and their activities. If personal devices, either personal audiotape players, digital recorders, or personal digital assistants (PDAs), were employed, the update could be done much closer to the end of the shift. Nurses have also been observed to tape their report in rooms with few people in them to improve the sound quality of the tape. Often, these rooms do not contain computers or patient charts, precluding the ability to access these resources during the taping of the handoff update. Technologies that improve taping quality, such as digital recorders, would reduce the need to do this. With the current system, the nurses coming onto the next shift often listen to the audiotape player in a central location that does not allow them easy access to patient charts or computers while they listen. If the updates are digitized, they can be downloaded to computer files and listened to while doing other tasks, particularly for the patients that are not under their responsibility. Technologies that allow variable playback speeds would enable nurses to more quickly hear updates for patients not under their responsibility. Finally, if devices that made it easier to begin the playback at the beginning of each patient update were used, information that other nurses would benefit from hearing, such as do-not-resuscitate (DNR) orders, could be entered first, followed by information that only the primary caregiver needs to hear. In this way, the incoming nurses would only need to hear the beginning portions of the updates for the patients that were not under their primary care.

Automated logs might also be used to aid the handoff process. When the medical record is in electronic format, it is possible that automated records could be created that would enable incoming nurses to have the ability to scan information quickly. In space shuttle mission control, automated logs are used to detect and represent changes in sensor-derived data [20]. Nevertheless, the current capabilities of automated logs do not enable highlighting of significant changes, unexpected events, non-routine plans, and urgent priorities. Therefore, we suggest that they may be useful as a supplement to a human-human update, but not as a replacement.

This study has several limitations. Our objective was to describe handoff strategies used in four settings with high consequences for failure. Our findings, as in any analysis of complex, interacting, multi-faceted field data, are dependent upon our conceptual frameworks, and so we likely did not find all strategies that are in use. The analysis was conducted on existing field data mainly collected for other purposes, and so data regarding which specific strategies were observed during particular individual handoffs are not available. Therefore,

evidence supporting a strategy might have been overlooked or evidence for a strategy might have been given too much weight because evidence refuting a strategy was missed. We did not evaluate the effectiveness of any of the identified strategies. This study did not explore how important and effective each strategy is in the observed setting or could be for the health care setting. Finally, whether any of the strategies can be generalized to health care settings remains a question to be addressed by future research.

In this paper, we described how coordination and collaboration strategies were employed during shift change handoffs in space shuttle mission control, nuclear power generation, railroad dispatching, and ambulance dispatching. An understanding of the 'state of the art' in how handoffs are conducted in settings with high consequences for failure can be used to jumpstart endeavors to design handoffs in health care.

Acknowledgements

This research was supported by the Department of Veterans Affairs (VA). The views expressed in this article are those of the authors and do not necessarily represent the view of the Department of Veterans Affairs. Emily Patterson was supported by a VA HSR&D Merit Review Entry Program Award and José Orlando Gomes was supported by the Capes Foundation of Brazil. We thank Kim Vicente, Nicholas Malsch, and Jennifer Perotti for reviewing our findings and providing helpful comments.

References

1. Cook RI, Woods DD, Miller C. *A Tale of Two Stories: Contrasting Views on Patient Safety*. National Patient Safety Foundation, April 1998. Chicago, IL: National Patient Safety Foundation: <http://www.npsf.org/exec/toc.html> Accessed 22 October 2003.
2. Parker J, Gardner G, Wiltshire J. Handover: the collective narrative of nursing practice. *Aus J Adv Nurs* 1992; **9**: 31–37.
3. Liukkonen A. The content of nurses' oral shift reports in homes for elderly people. *J Adv Nurs* 1993; **18**: 1095–1100.
4. Sherlock C. The patient handover: a study of its form, function and efficiency. *Nurs Stand* 1995; **9**: 33–36.
5. Lally S. An investigation into the functions of nurses' communication at the inter-shift handover. *J Nurs Manage* 1999; **7**: 29–36.
6. Wolf Z. Nursing rituals. *Can J Nurs Res* 1988; **20**: 59–69.
7. Patterson ES, Woods DD. Shift changes, updates, and the on-call model in space shuttle mission control. Computer supported cooperative work. *J Collab Comput* 2001; **10**: 317–346.
8. Barden CB, Specht MC, McCarter MD *et al.* Effects of limited work hours on surgical training. *J Am Coll Surg* 2002; **195**: 531–538.
9. Guerlain S, Smith PJ, Obradovich JH *et al.* Interactive critiquing as a form of decision support: an empirical evaluation. *Hum Factors* 1999; **41**: 72–89.
10. De Keyser V, Woods DD. Fixation errors: failures to revise situation assessment in dynamic and risky systems. In: Colombo AG, Saiz de Bustamante A (eds). *Systems Reliability Assessment*. 1990, pp. 231–251.
11. Keyes C. Coordination of care provision: the role of the 'hand-off'. *Int J Qual Health Care* 2000; **12**: 519.
12. Mumaw RJ, Roth EM, Vicente KJ, Burns CM. There is more to monitoring a nuclear power plant than meets the eye. *Hum Factors* 2000; **42**: 36–55.
13. Roth EM, Malsch N, Multer J. Understanding how train dispatchers manage and control trains: results of a cognitive task analysis. US Department of Transportation/Federal Railroad Administration (DOT/FRA/ORD-01/02). Washington, DC: Federal Railroad Administration, 2001: <http://www.fra.dot.gov/> Accessed 22 October 2003.
14. Chow R, Vicente KJ. *A Field Study of Emergency Ambulance Dispatching: Implications for Decision Support*. Proceedings of the 46th Annual Meeting of the Human Factors and Ergonomics Society 2002, pp. 313–317. Human Factors and Ergonomics Society, 2002: <http://www.hfes.org/publications/2002proc.html> Accessed October 22, 2003.
15. Roth EM, Christian CK, Gustafson M *et al.* Using field observations as a tool for discovery: analyzing cognitive and collaborative demands in the operating room. Submitted for publication.
16. Strauss AL, Corbin J. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Newbury Park, CA: Sage, 1990.
17. Ericsson K, Simon H. *Protocol Analysis: Verbal Reports as Data*. Cambridge, MA: MIT Press, 1993.
18. Vicente KJ, Roth EM, Mumaw RJ. How do operators monitor a complex, dynamic work domain? The impact of control room technology. *Int J Hum Comp Stud* 2001; **54**: 831–856.
19. Patterson ES, Watts-Perotti J, Woods DD. Voice loops as coordination aids in space shuttle mission control. Computer supported cooperative work. *J Collab Comput* 1999; **8**: 353–371.
20. Schreckenghost D, Thronesbery C, Bonasso P, Kortenkamp D, Martin C. Intelligent control of life support for space missions. *IEEE Intell Sys* 2002; **17**: 24–31.

Accepted for publication 19 November 2003