# Human factors training

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**Abstract**

The aim of this article is to introduce the concept of human factors training, illustrate the importance of human factors to safe surgical care, and clarify the relationship between human factors science and non-technical skills.

**Keywords** Human factors; non-technical skills; patient safety; simulation; training

## Introduction to human factors

Humans are fallible; even those who work in the operating room where the margins for success and error can be razor-thin. Human factors (HF) acknowledges the limitation of human performance and potential for avoidable error. It evaluates humans within systems and is concerned with the study and design of the environment and practices within a system to ensure safe, efficient human performance.[1–3] Whereas healthcare focuses on 'fixing' problems that arise and correcting errors, HF educates us to explore performance, how errors happen, the role the system plays, and how we can continually learn and improve. Human factors is rooted in high risk, heavily engineered industries such as aviation, aerospace, military, nuclear power and formula one, where humans interact with machinery or technology. These industries have developed clear safety policies to reduce risk, and strategies to enhance human performance and wellbeing of operators at the sharp end.[1–3]

In the aviation industry, HF research was triggered as a response to the fact that the majority of airline crashes in the 1970s–2000s were due to human error rather than a technical failure. Crew resource management emerged[1] in aviation to evaluate the factors that limit performance and stressed the impact of non-technical skills. Error and near-miss reporting is encouraged, when identified. The approach is to learn from these errors with task and incident analysis, not associate blame, understand the effect of non-technical skills such as communication, decision making, teamwork and situational awareness on performance, and develop tools to improve safety. HF stresses that unsafe situations are likely due to a combination or sequence of events rather than one main error – as illustrated commonly with the Swiss cheese model. HF acknowledges that some errors may be minor, with many going unnoticed and the majority benign or trapped by teams before resulting in harm. However, minor errors have the potential to turn into adversity.

## Human factors in surgery

Despite the benefit to health and cure of disease for the majority, healthcare itself poses significant risk to patients. Over 10% of admissions will have some degree of avoidable patient harm, with surgical patients at high risk of potentially suffering an iatrogenic injury. At least half of surgical adverse events occur in the operating room (OR) and a large proportion are deemed to be preventable. This has a clear impact on the health of our population and in a resource-strapped NHS, a considerable financial impact. Healthcare is a complex industry in comparison to the heavily engineered industries where HF originated. Healthcare has multiple goals, outcomes, outputs, procedures and systems, yet requires individuality for each patient, and is constantly changing and adapting to new treatments, procedures and even pathology. The OR is a very complex environment with coordinating teams of clinicians and healthcare professionals, patients, equipment and technology. Although the entire group will have a shared goal of patient care, each team will have their own priorities and skill set: the anaesthetist focusing on safely monitoring the patient and maintaining their physiology; the surgeon carrying out the procedure, reacting to an individual's anatomy, pathology and unexpected events; the scrub team concerned with equipment and patient advocacy, and other OR members conducting critical functions. Additionally, as humans in a busy healthcare system the teams are subject to influence by the environment, fatigue, burnout, noise, home stress, concurrent focus on unwell patients on the ward and a multitude of other demands that shape and in some cases limit performance.

However, despite the complex nature of healthcare and surgery, we can still look to the industry's error management culture to influence our own practice, such as the introduction of checklists, theatre briefs and standardization of procedures. HF methods are required to ensure these tools are effective, well-designed and correctly implemented.

## Analysing surgical systems

Complex work environments, like the OR, can be thought of as *socio-technical systems* comprising humans, technology and processes which all work together in synchrony. The Chartered Institute for Ergonomics and Human Factors (CIEHF) is the professional body for human factors specialists in the UK and it recently produced a white paper on 'Human Factors for Health & Social Care'. This sets out broad principles for delivering a patient safety strategy with three aims:

- human factors in healthcare should be systems focused
- improvements in performance are predominantly design led
- there should be an emphasis on improving the wellbeing of patients and staff.

Developing systems which support surgical teams to have long and successful working lives, and achieve their full potential has a huge upside for both clinicians and patients. One prominent model that can be used to understand these systems factors is the *Systems Engineering Initiative for Patient Safety (SEIPS)* model 2.0.[4] This is a framework for evaluating the complex and

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dynamic *systems and processes* within healthcare using HF concepts. The SEIPS model outlines the *parts* of a system and influencing factors. Figure 1 outlines the SEIPS 2.0 model and illustrates how interacting systems lead to processes and ultimately outcomes. This allows evaluation of how an outcome was achieved and target areas for improvement. It gives the bigger picture rather than associating blame to one issue or event.

The SEIPS model outlines how a person carries out tasks using tools/technologies within an environment and organization that is ultimately under the influence of a larger, external governing force (or external environment).[3] The 'work system' encompasses five interconnected elements: person, tasks, tools and technologies, physical environment and organizational conditions. These five interacting elements in turn influence care and other connected processes which in turn impact on patient, staff and organizational outcomes. Within the model, 'person(s)' at the centre of the model relates to both healthcare professionals and patients, individuals and teams. The SEIPS model demonstrates how systems interact and influence one another and we describe each of the main components in turn:

### The work system

- **Individual**: The individual at the centre of the work system could be any healthcare provider, or team performing patient care related tasks, or a patient receiving care, or their family and support system. System design must take into account person characteristics (including age, competence, preferences, ability to manage health information and wellbeing) as well as collective-level characteristics such as team cohesiveness or consistency of knowledge. The person carrying out the task is affected by the system and environment.
- **Tools and technologies**: These are the items required by the caregiver to do their work. They can range from paper and pencil to computers and include information technology, medical devices as well as physical equipment. These factors can be characteristics such as usability, accessibility, familiarity and automation.
- **Tasks:** These are those specific actions required by the caregiver to treat the patient, e.g. documenting results, talking with patients and team interactions. Task factors can also be attributes of the task such as complexity, variety and ambiguity.
- **Organizational factors**: Organization refers to the structures external to a person that impact activity, including time, resources allocation and hierarchy.[3,4] Within hospitals, organization factors can be characteristics of work schedules, management systems, organizational culture, training and resource availability.
- **Environment**: Internal environment refers to the physical environment in which staff work and includes characteristics of lighting, thermal environment (OR temperature), physical layout and protection from hazards. External environment incorporates macro-level societal, economic and policy factors out with an organization, e.g. the influence of regulatory, professional and patient groups and the effect of standards and legislation.

### Processes

These describe how a goal is actually achieved and the activity required. Professional work in surgery involves the patient preoperatively and postoperatively, but the majority of the focus is on the surgical team in the OR and processes of care during a surgical procedure. The patient work is their interaction with

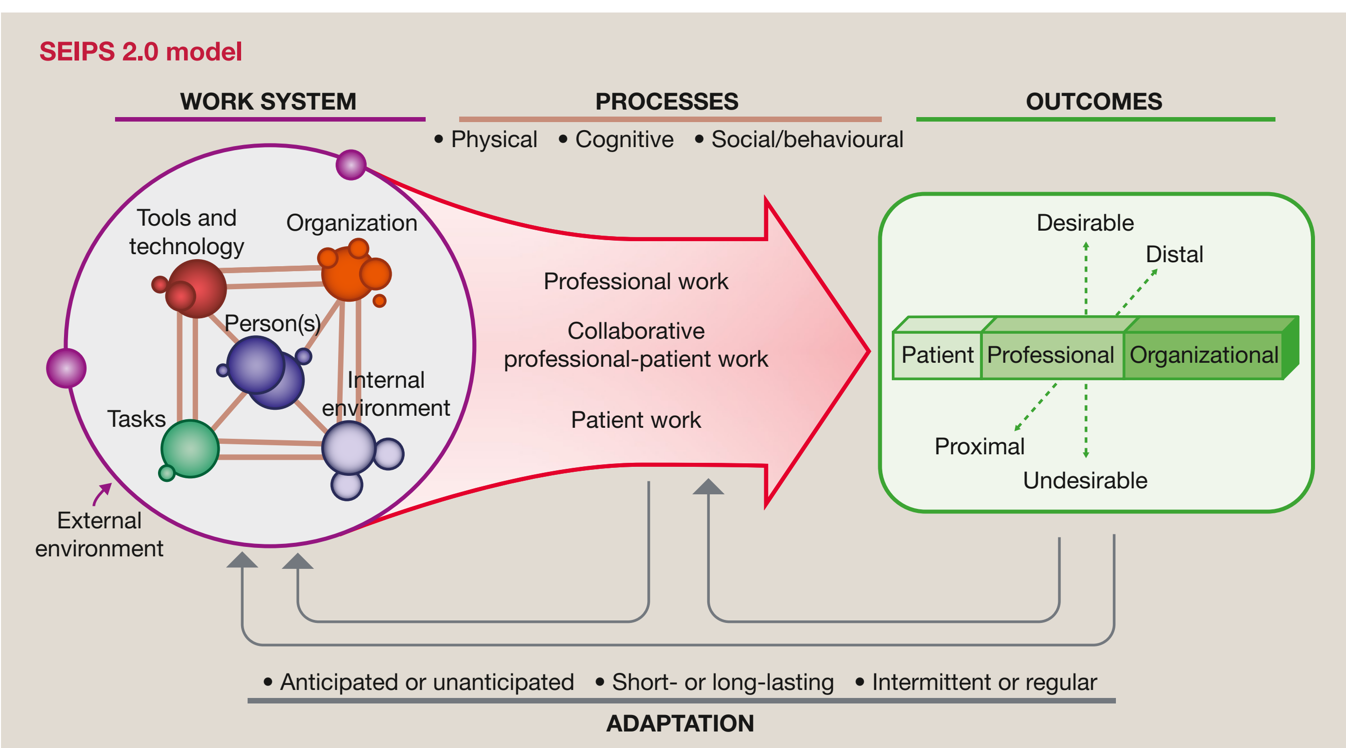


**Figure 1**

healthcare, and commitment to a healthy lifestyle, taking prescribed medications, and being an advocate for their own care in partnership with healthcare provider guidance. Collaborative work involves the patient and the healthcare professional working together, such as a stoma nurse taking a patient through stoma care. SEIPS 2.0 introduces the term ‘adaptation’, relating to feedback loops and highlighting that in the clinical setting things are dynamic, ever changing and not linear.

### Outcomes

Staff outcomes include safety, health, satisfaction, stress and burnout; organizational outcomes include rates of turnover, injuries and illnesses, and organizational health. We must also account for the potential interaction of outcomes for those involved, e.g. a poor health outcome for a patient might have psychological outcomes for the surgeon. Alternatively, success in high-demand surgery (e.g. living donor transplant) can transform patients’ lives, have a huge positive impact on families in the community and provide a source of professional fulfilment and joy for the operating teams.[4]

## Non-technical skills

Human factors and non-technical skills are often used interchangeably. This is not entirely accurate; non-technical skills can be seen as a subset of HF, focused on training knowledge awareness and skills in individual and team processes regarding cognitive factors (situation awareness, decision making), social factors, (communication, teamwork, leadership, task management) and limitations of human performance (dealing with stress, fatigue, rudeness, and burnout). As identified above in the SEIPS model, successful human factors training must address concepts beyond individual and team non-technical skills such as tools, technology, complexity, design and systems thinking. However, as the majority of available training for surgeons currently focuses on non-technical skills, in this section we will explore those skills and investigate why they are required for the complete surgeon.

Surgeons carry a lot of responsibility and accountability in the operating theatre but they do not work alone. Non-technical skills are defined as the cognitive and social skills that characterize high-performing individuals and teams. Optimizing team performance via enhanced non-technical skills can result in improved decision making, increased efficiency, higher adherence to safety standards, greater resilience and better outcomes. One method of achieving this is to use behaviour assessment tools such as the Non-Technical Skills for Surgeons (NOTSS) system to structure observation, assessment and improvement (Table 1) which incorporates situation awareness, decision making, communication and teamwork, and leadership.

### Situation awareness

Arguably the most critical non-technical skill, situation awareness, is required for accurate decision making, timely communication and appropriate leadership. For the operative environment, situation awareness is defined as ‘developing and maintaining a dynamic awareness of the situation in the operating theatre, based on assembling data from the environment (patient, team, time, displays, equipment); understanding what they mean, and thinking ahead about what may happen next’.

**The Non-Technical Skills for Surgeons (NOTSS) framework**

| Category | Elements |
| --- | --- |
| Situation awareness | • Gathering information<br>• Understanding information<br>• Projecting and anticipating future state |
| Decision making | • Considering options<br>• Selecting and communicating option<br>• Implementing and reviewing decisions |
| Communication and teamwork | • Exchanging information<br>• Establishing a shared understanding<br>• Co-ordinating team activities |
| Leadership | • Setting and maintaining standards<br>• Supporting others<br>• Coping with pressure |

**Table 1**

Situation Awareness comprises three distinct levels: (i) gathering information; (ii) interpreting the information (based on experience); and (iii) projecting and anticipating future states.

### Decision making

Surgical decision making can be defined as ‘skills for diagnosing a situation and reaching a judgement in order to choose an appropriate course of action’. Classical models of decision making propose that this is an analytical process: the relative features of options are compared in turn and an optimal course of action is selected. However, this is an effortful process, requiring both experience and time to come to an acceptable solution. Rule-based decision making can be used effectively by novices and experts alike; once a situation has been detected, a relevant rule can be applied, either by following national guidelines or local protocols. Experts tend to use a more heuristic-based style called recognition-primed decision making (RPD); a type of pattern matching used to make satisfactory decisions under times of high stress or time pressure. As there are not always prior experiences from which to work, surgeons may use creative decision making when a totally novel solution is required to treat patients or develop new processes of care.

### Team communication

Effective team dynamics are essential for rapid diagnosis, concurrent treatment, and containment of risk. They are also essential for the vast majority of surgical practice and essential for experienced and novice surgeons alike. Communication and teamwork are the skills required for working in a team context to ensure that the team has an acceptable shared picture of the situation and can complete tasks effectively. What is essential is that each member of the team has a ‘shared mental model’ of both what is happening and the planned outcome. There are many barriers to communication, which can be both internal and external. Closed loop communication can reduce communication errors by making certain that all members of the care team clearly and effectively share information with one another in a structured manner. Other structured communication tools will be described later.

### Leadership

In organizations exposed to hazards, there is widespread recognition that leadership is essential for efficient and safe team performance. Surgery is no different, and although surgeons are often leaders, the situation in the operating room is often not a clear hierarchy, with anesthetists, nurses, and other colleagues often taking leadership roles and displaying leadership behaviours. Surgeons may normally be used to autonomous practice, but can contribute to effective teamwork by demonstrating shared leadership or assuming followership in certain situations. A core function of leadership is demonstrating the standards that are expected from other team members. A key failing of leaders is to emphasize the importance of safety but then implicitly undermine those sentiments by breaking rules and not adhering to high standards of ethical and professional conduct themselves. For surgeons, examples of this are adhering to guidelines regarding antibiotic use, respecting sterility protocols, and being transparent regarding errors, even during surgical emergencies. Surgeons exert leadership by coping with pressure and by keeping composure even in the most difficult of times.

### Non-technical skills for pandemic response

It is important to emphasize that these non-technical skills are important during routine surgical care, and really come to the fore during emergency surgery and non-routine situations. See Box 1 for suggested best practices. Non-technical skills are also essential during a pandemic response and in rebuilding capacity for surgical care after major disruption, such as the COVID-19 global pandemic. A specific set of behavioural competencies for surgeons have been developed for pandemic responses, inspired by a study of surgical teams in low and middle income countries (LMICs) where resources including systems, personnel and communication can be variable.[5]

**Best practices in non-technical skills**

**Situation awareness**

- Check back important information
- Provide periodic status updates
- Share what will likely happen in the near future so others can plan
- Engage the team in 'mental simulations' regarding what may happen in the future

**Decision making**

- Gather sufficient data to make decisions
- Don't delay in order to have the complete picture
- Offer potential solutions
- Apply rule-based decision making where appropriate. When not practical, RPD works well for experts

**Communication & Teamwork**

- Introduce yourself and role to other team members
- Be clear and concise
- Express authentic curiosity
- Use names if you can and eye contact if culturally acceptable

**Leadership**

- Set expectations on roles, culture and norms of team behaviour to unite the team
- Listen to concerns of others and validate them
- Be aware of non-verbal communication
- Active engagement in conflict resolution

**Box 1**

## Technology advances

Human factors training can make use of rapid changes in artificial intelligence (AI) in surgery. In this section we describe two exciting new concepts (surgical sabermetrics and the OR Black Box) that have the potential to systematically highlight areas for HF improvement and democratize performance feedback.

### Surgical sabermetrics

Professional sports such as baseball use and analyse in-game data to evaluate performance in a *process* called 'sabermetrics'. Think of Brad Pitt in the film Moneyball. As surgeons we can use the same process to evaluate perioperative data as 'surgical sabermetrics', an exciting developing field that looks to provide advanced analytics of digitally recorded surgical procedures to enhance and support professional development, training and optimize clinical, safety and financial outcomes.[6] Technical and non-technical skill assessment can be integrated with diverse outcomes relating to surgeon health and wellbeing, team function and patient care. As technology develops, especially in the arena of AI combined with audiovisual, physiological, environment and device-related data, automated assessment of surgical performance can be discretely conducted for training, continuing professional development and optimizing HF in the OR and beyond. In the future, real-time analysis of digitally recorded data could predict potential for error and identify near misses that were otherwise missed by human observers, providing another avenue to improve patient safety. Data can be related to patient physiology, surgeon physiology and objective technical skill assessment with AI such as economy of movement in laparoscopic surgery, and non-technical skills including communication metrics and team situation awareness. Surgical sabermetrics may also provide insight into HF aspects of design and workflow through systematic analysis of performance patterns across procedures, and between different hospital settings.

### OR Black Box

The OR Black Box[7] is a highly innovative technological and analytical platform, developed by a pioneering surgical research group at University of Toronto, that allows unprecedented continuous collection of multiple streams of data (audiovisual, physiologic, environmental, device-related) from the operating theatre. This 'flight recorder' records performance of the operating surgeon, anesthesia team, nursing team and the patients' vital signs in a single integrated platform. Through a combination of machine-learning algorithms and human annotators, it is able to provide a comprehensive picture of the actual operating room performance. For adverse events, when performance has broken down, a HF approach should be applied to exploring the sequence of events and the complex interactions which contributed to the event happening at the particular time point. Focus should not be restricted to individual actions but on identifying which components of the system could be improved to give rise to sustainable change and prevent the event happening again. In a recent analysis of important safety factors with the OR Black Box,[7] video reviewers identified intraoperative errors, events, and distractions from videos of 132 patients undergoing elective laparoscopic general surgical procedures. A median of 20 errors (IQR 14–36), 8 events (IQR 4–12) and 138 auditory distractions were identified per procedure. Cognitive distractions were identified in 64% of procedures. Observation metrics for surgeons' non-technical skills, such as the NOTSS system have been developed and are in use for assessment, and training.[8] These have already been implemented in an initial study of 56 patients undergoing laparoscopic Roux-en-Y gastric bypass surgery using the OR Black Box,[9] demonstrating that technical and non-technical performances are related, on both an individual and a team level.[10]

## Conclusion

Although human factors in healthcare is a relatively new topic, there is a long and rich history of human factors science applied across industry sectors about how to improve performance and safety in high-demand work settings. It is now possible to study for a Masters degree in topics such as Patient Safety, Simulation, and Clinical Human Factors at several institutions around the world. For example, The University of Edinburgh offer a MSc in Patient Safety and Clinical Human Factors aimed at all healthcare workers entirely online.[11] Mentorship is provided by a diverse faculty with deep knowledge of performance at work across the healthcare sector and with expertise in human factors. The programme is innovatively delivered entirely online, and comprises video lectures, interactive discussion boards, simulated videos, reading and online activities.

Human factors training is in many cases voluntary for surgeons and teams who are motivated to enhance their own performance. In some contexts the training is part of the national curriculum, for example in Ireland all surgical trainees complete modules in human factors as part of core surgical training. The field is rapidly moving to provide similar training for all, and to achieve this, more practitioners are required, and human factors training needs to develop to be broader than non-technical skills.[12] The notion that surgical performance is solely about the technical ability of the lead surgeon is now outdated. Performance must also take into account the systems, design, tools, technologies and non-technical skills described. Furthermore, the next generation of surgeons and teams must be educated to be aware of these factors and the potential to enhance processes and outcomes for all clinicians and patients by viewing surgery through a human factors lens. ◆

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