Ergonomics
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/terg20

State of science: human factors and ergonomics in healthcare

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Published online: 08 Aug 2013.

Ergonomics, 2013
Vol. 56, No. 10, 1491–1503, http://dx.doi.org/10.1080/00140139.2013.822932

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(*Received 8 February 2012; final version received 1 June 2013*)

The past decade has seen an increase in the application of human factors and ergonomics (HFE) techniques to healthcare delivery in a broad range of contexts (domains, locations and environments). This paper provides a state of science commentary using four examples of HFE in healthcare to review and discuss analytical and implementation challenges and to identify future issues for HFE. The examples include two domain areas (occupational ergonomics and surgical safety) to illustrate a traditional application of HFE and the area that has probably received the most research attention. The other two examples show how systems and design have been addressed in healthcare with theoretical approaches for organisational and socio-technical systems and design for patient safety. Future opportunities are identified to develop and embed HFE systems thinking in healthcare including new theoretical models and long-term collaborative partnerships. HFE can contribute to systems and design initiatives for both patients and clinicians to improve everyday performance and safety, and help to reduce and control spiralling healthcare costs.

Practitioner Summary: There has been an increase in the application of HFE techniques to healthcare delivery in the past 10 years. This paper provides a state of science commentary using four illustrative examples (occupational ergonomics, design for patient safety, surgical safety and organisational and socio-technical systems) to review and discuss analytical and implementation challenges and identify future issues for HFE.

Keywords: patient safety; medical devices; socio-technical systems; occupational health and safety

1. Introduction

Medicine is an imperfect science and an uncertain art (Jewson 1976, 13).

The need for human factors and ergonomics (HFE) in healthcare has been recognised since the inception of the profession and discipline, but development and growth have been slow (Carayon 2010; Norris 2012; Gurses, Ozok, and Pronovost 2012). The first conference on healthcare (hospital) ergonomics was held in Paris in 1991 (Estryn-Behar, Gadbois, and Pottier 1995). This was followed by the foundation of the International Ergonomics Association (IEA) Technical Committee on Healthcare Ergonomics and Patient Safety (HETC9) by François Daniellou in 1997. Since 2005 there have been regular conferences on healthcare and patient safety ergonomics as well as sessions and papers at clinical (patient safety) conferences.

The healthcare sector is a very complex industry and has multiple stakeholders for clinical and non-clinical work in acute, ambulatory (combination of hospital outpatient and out-of-hospital services, USA) and community care settings. Hignett (2003a) identified some of the characteristics and challenges for HFE practice in healthcare as organisational, staff (gender), physical and emotional subcultures, and implementation barriers. The size, complexity and structure of organisations providing healthcare can result in multiple hierarchical lines for administrative, professional and clinical decision making. In the UK National Health Service (NHS), there are more than 1.3 million employees (Health and Social Care Information Centre 2012), of these more than 75% are women with nurses accounting for 50% (Dargie 1999), making the NHS a major employer in the labour market for women. This presents a challenge for HFE to access data about female workers as a population group.

Caring for patients often involves heavy physical, dirty, cognitively difficult and challenging emotional work in situations in which the patient can be both physically and mentally vulnerable (Fox 1989). There are physical and emotional professional subcultures to allow the handling of other peoples' bodies linked to a coping attitude by which staff may put patient needs and well-being before their own.

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Implementing change is often a key part of HFE projects. It has been suggested that 80% of the effort when working in healthcare would be needed to progress the project because of the complexity of the industry with only 20% on understanding/solving the problem. For example, evidence-based recommendations for patient handling are not universally implemented, and improved interface design may not be incorporated in healthcare products, devices and information technologies because manufacturers have not adopted HFE design principles and purchasers have not demanded them. The reverse is a more usual model for HFE in other industries.

As a professional discipline, HFE focuses on systems and design to improve performance and well-being, whereas in healthcare, the focus has been on either the caregiver (occupational ergonomics) or care receiver (patient safety) rather than looking at interactions across the system. This complexity has led to the generation of new theoretical models, including the Systems Engineering Initiative for Patient Safety (SEIPS, Figure 1). This provides an analytical framework to consider how system components can influence human behaviour at the organisation, employee (caregiver) and patient (service user) levels (Carayon et al. 2006). The input data are both complicated and complex with the *Person* representing a wide range of physical and cognitive abilities for all stakeholders, including clinical and non-clinical staff, patients, families, visitors, volunteers and contractors (clinical and non-clinical service providers not directly employed by the organisation).

This paper provides a state of science commentary using four illustrative examples to review and discuss analytical and implementation challenges. The examples include two domain areas (occupational ergonomics and surgical safety) to illustrate a traditional application of HFE and the area that has probably received the most research attention. The other two examples show how the core principles of systems and design (IEA 2000; Dul et al. 2012) have been addressed in healthcare with theoretical approaches for organisational and socio-technical systems and design for patient safety.

2. Occupational ergonomics

In 2009–2010, Health and Safety Executive (UK) received 18,030 reporting injuries, diseases and dangerous occurrences regulations notifications from health and community care duty holders, the highest number across all industrial sectors (http://www.hse.gov.uk/healthservices/riddor.htm, 19 December 2011). These regulations require employers, the self-employed and those in control of premises to report specified workplace incidents. Occupational hazards included:

- Musculoskeletal disorders (MSDs) – associated with animate and inanimate load handling and static postures.
- Environmental – fire, security, lighting, temperature and workplace.
- Equipment – design for usability, maintenance, electrical and protective.
- Biological – radiation, infectious diseases and needle stick (cuts and blood borne).
- Chemical – cytotoxic drugs, mercury, waste anaesthetic gases, latex allergy and cleaning fluids.

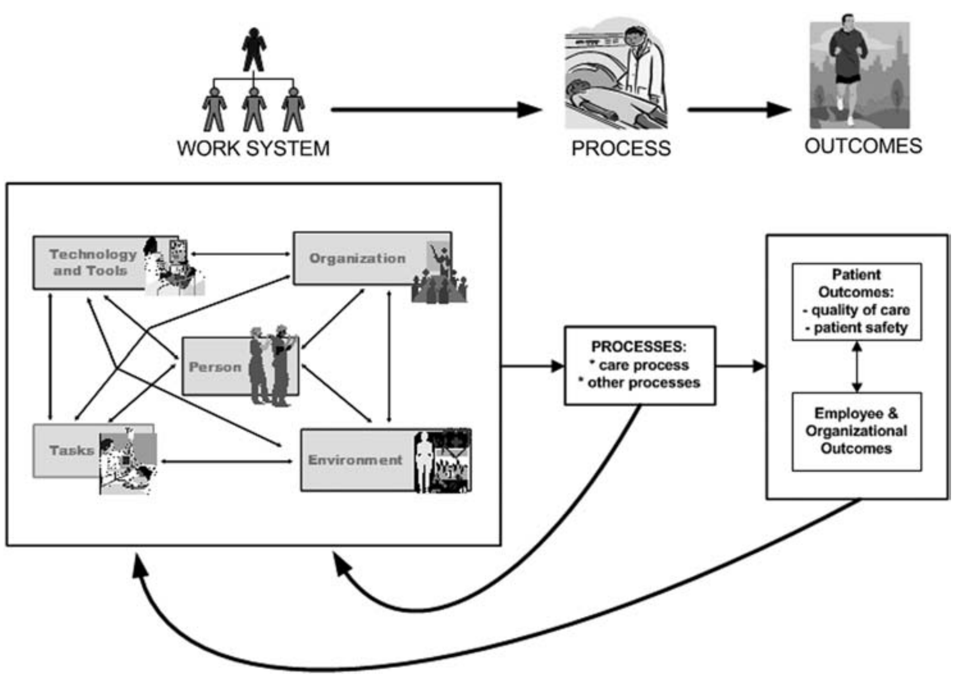

Figure 1. Conceptual model for ergonomics in the healthcare industry (Carayon et al. 2006).

- Violence – psychiatric patients, alcohol/drug related, especially for front-line staff in ambulance, emergency department, maternity and community settings.
- Shift work – unsociable hours to provide 24-h care, 7 days per week and 365 days per year.
- Stress – work demands, burnout and organisational changes.

MSDs are reported in most professional groups and disciplines in healthcare workers, with nursing listed as one of the highest MSD-risk occupations (Buckle 1987; Smedley et al. 1995; Estryn-Behar et al. 2003). The Nurses Early Exit Study (NEXT) concluded that nurses are still exposed to a high risk of back injury associated with their working activities including awkward positions, prolonged standing and lifting patients (Estryn-Behar et al. 2003; Simon et al. 2008).

Over the past 20 years, there have been a multitude of recommendations for improvements in working conditions and product design to reduce the risk and severity of manual handling activities in healthcare (patient handling) and at least four systematic reviews of patient handling interventions (Hignett 2003b; Amick et al. 2006; Dawson et al. 2007; Martimo et al. 2008). The key findings are the following:

- Strong evidence that interventions predominantly based on technique training have no impact on working practices or injury rates (Hignett 2003b).
- Moderate evidence that training in isolation was not successful and that multi-dimensional interventions were effective (Dawson et al. 2007).
- Moderate evidence that multi-factor interventions, based on a risk assessment programme, are most likely to be successful in reducing musculoskeletal injuries related to patient-handling activities (Hignett 2003b).
- Moderate evidence for the effect of occupational health and safety interventions on MSDs in healthcare settings (Amick et al. 2006).
- Moderate evidence for multi-component patient handling interventions and physical exercise interventions (Amick et al. 2006).
- No evidence that training with or without lifting equipment was effective in the prevention of back pain or consequent disability. They suggested that either the advocated techniques did not reduce the risk of back injury or that training did not lead to adequate change in lifting and handling technique (Martimo et al. 2008).

These interventions included many HFE applications (Table 1) from systems level changes (national and local) to building and product design and personal well-being (occupational health) programmes.

Professional groups other than nursing have also been involved in HFE interventions, for example hospital orderlies (Evanoff, Bohr, and Wolf 1999), laboratory workers (Estryn-Behar et al. 2000), home healthcare workers (Pohjonen, Punakallio, and Louhevaara 1998) and ambulance staff (Hignett and Jones 2007).

The physical environment of the ward, clinic or department and equipment have been identified as two of the seven main types of performance obstacles experienced by intensive care unit (ICU) nurses (Gurses and Carayon 2009) and can affect nurses' quality of working life and their perceptions of quality and safety of care (Gurses, Carayon, and Wall 2009). The provision of adequate and functional space to care, diagnose and treat has been associated with risks for both employee and patient safety (Stanton 1983; Hignett and Richardson 1995). Recommendations for an individual hospital bed space width (in single or multiple occupancy accommodation) have increased by 1.2 m over 44 years, from 2.4 m in 1961 to 3.6 m

Table 1. Intervention strategies for patient handling (Hignett, 2003b; Fray 2010).

Audit working practices/risk assessments	Medical examination and lifting skill assessment
Change/introduce patient risk assessment system	National regulation/guidance
Change in uniforms	Peer leader, local risk assessment facilitator or patient handling supervisor
Discussion of goals with clients (patient)	Physical fitness training
Equipment design/evaluation	Review and change of policies and procedures/ safe systems of work
Equipment maintenance	Review staffing levels, increase staffing levels
Equipment provision and/or purchase (including training on new equipment)	Risk assessment
Education and training	Stress management
Group problem solving/team building	Task analysis, job design analysis
Injury monitoring, treatment, e.g. return to work	Work environment redesign, spatial constraints addressed
Introduction of hazard register	Work organisation/practices changed
Introduction of lifting team programmes	Feedback
Management systems, change management and organisational structures	

in 2005 (Hignett and Lu 2009). These increases in space are likely to benefit those who deliver the care but may introduce difficulties for patients due to the increased distance to the toilet or to get assistance. For example, Morse, Tylko, and Dixon (1987) found that patients (with no confusion) had difficulty with distance perception, leading to underestimation of distances between objects due to the greater size and distance between hospital fixtures compared with domestic environments. Other environmental factors include noise, air quality, lighting, toxic exposures, temperature humidity and aesthetics. Although it is likely that there are direct links between environmental factors and reduced patient health and employee well-being, there is relatively little high-quality research to confirm negative effects (van den Berg 2005).

2.1 Future issues

There is an increase in the provision of out-patient (ambulatory) and community-based care with less hospital and residential care (Talbot-Smith and Pollock 2006), which will bring new HFE challenges (Hignett 2001; NRC Committee 2010; Zayas-Caban and Valdez 2012; Szeto et al. 2013). Implementation of improvements will be more complex for non-residential healthcare, and many services may be provided by solo (lone) workers or small teams. This may lead to more complicated working systems with multiple service providers contributing to a care package. The increased use of information technology (IT) to provide advice and monitoring for service users may offer interface design opportunities to contribute to the usability of remote services.

There is a growing literature on the effects of work-related fatigue in nursing associated with turnover (Hayes et al. 2012), performance (Barker and Nussbaum 2011) and compassion fatigue (Hooper et al. 2010). These will be important areas for future HFE input. For example, the demographic changes in developed countries will impact on both the service demands and provision with older service users cared for by older employees (care givers), and increasing populations of people with dementia, mobility problems and obesity (Hignett and Griffiths 2009).

3. Design for patient safety

Patient safety was, until the start of the twenty-first century, an under-researched area for HFE. Key publications from health institutions in the USA (Kohn, Corrigan, and Donaldson 1999) and the UK (Department of Health 2000) then empowered researchers and practitioners to start to unravel the extent of patient safety issues and their possible causes. A number of countries, when faced with the prevalence of reported incidents and the apparent complexity of the emerging causes, sought to develop centres of excellence and of practice. The challenges that emerged from these centres soon provided opportunities for HFE experts to transfer their knowledge from other sectors directly to the healthcare industry. It became apparent very quickly that there was a need for systems approaches.

The extent of problems and the limited resources for research have often been reflected in patterns of research that do not truly represent a systems approach (Waterson 2009). Thus, there is evidence of over-reliance on technological solutions that, subsequently, are shown not to meet user needs. Similarly, behavioural solutions are frequently advanced, but these rarely consider what else in the system might need to be redesigned to enable and encourage such changes. Many healthcare professionals have adopted the systems rhetoric without really understanding what a system is, or how to approach understanding/analysis/improvement from a systems perspective. This leads to healthcare giving little or no regard for concepts such as partnerships with engineering or systems.

Much research over the past decade has helped develop an improved understanding and knowledge base for HFE in patient safety. However, the complexity of the challenges, the difficulty of implementing and sustaining interventions, and the constrained economic climate in many countries continue to stretch the ability of researchers to deliver better systems and provide evidence of improved practice.

The publication of ‘Design for Patient Safety’ in 2003 (Department of Health/Design Council 2003) marked a huge step for systems HFE thinking to be incorporated into the development of safer healthcare systems. The report, written by the University of Surrey, jointly with the Engineering Design Centre at Cambridge University and the Royal College of Art demonstrated how design can be used to cut the risk of medical errors and accidents, making hospitals safer for patients and improving environments for healthcare workers. The researcher group (Clarkson et al. 2004) considered that design was best seen as a *structured process for identifying problems and developing and evaluating user-focused solutions.* They also indicated that when the design thinking was appropriate with respect to the end-users (e.g. where products or services are simple or intuitive to use), then accidents and misuse were less likely to occur. If this were not the case, then designs were potentially dangerous to healthcare staff and/or patients (Bates et al. 1997). The report found that the NHS was *seriously out of step with modern thinking and practice* on design, leading to avoidable risk and error. It also found that design practice and understanding was less advanced in the NHS than in other safety-critical industries, and that not only did the design of individual devices and products need to be improved, but also the way the NHS views the potential of design thinking and methods to help organisations as a whole. It demonstrated that design initiatives need to be seen in the light of the *big picture* of the healthcare system (Carayon et al. 2006) and in relation to patients. This research, primarily limited to device design and medication packaging/labelling, provided an important direction for others based on the need to focus on users as part of complex socio-technical systems.

Recently, Norris (2012) concluded that HFE principles and approaches are still under-used in medical device development in contrast with the focus on the importance of the user in other design domains such as consumer products and occupational environments. In particular, limited advice was available for developers on the issues to consider during design and development and recommendations for the methods and approaches needed to capture the full range of user requirements (Martin et al. 2008). Although literature (Weinger et al. 1998; Carayon 2007; Weinger, Wiklun, and Gardner-Bonneau 2011) and standards (e.g. ISO 14971:2007 and ISO 62366:2008) do exist, there is still only relatively limited evidence that these are being widely applied or that the design outcomes are evaluated systematically.

The 'Design for Patient Safety' model (Figure 2) provides a simple representation of how and where knowledge can be used to better inform the design process and serves as an excellent starting point for helping those who design physical or organisational contributions or those who procure or commission to understand the role of design. It also enables rapid assessment of how and where existing systems in healthcare may be prone to failure. Understanding the process and context (or environment) of use is essential to aid this assessment.

In most healthcare systems, there has been an emphasis on designing products in isolation from the full operational system (Clarkson et al. 2004; Buckle et al. 2006). In effect, the product is then delivered into the existing system without fully understanding how that system will now behave. For example, the introduction of a new model of infusion pump, perhaps with enhanced functions, may run into difficulties if appropriate training is not available for all those who may have need of it.

Similarly, procurement based on purchase cost alone may result in problems of maintenance or servicing, resulting in hidden costs or failed services, both of which, either directly or indirectly, may compromise patient safety and quality. The need for a systematic approach that includes an understanding of HFE impact is evident.

A vital starting point for improving the design of systems is the evaluation of the existing systems. Appropriate evaluation can generate a vastly improved knowledge base on which design requirements can be more clearly specified. Indeed, one criterion that might to be used is that any innovation should not significantly degrade the performance of other systems. This would require a significant effort to ensure that risk assessment was undertaken at the earliest stages of innovation.

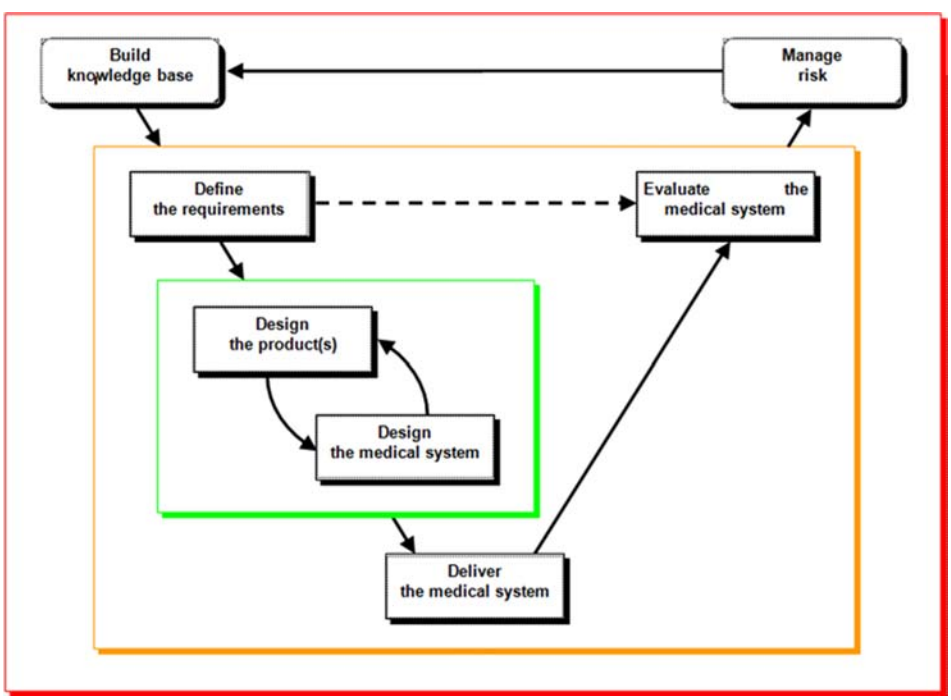

Figure 2. Design for patient safety. *Source*: Adapted from Department of Health/Design Council (2003) and Clarkson et al. (2004).

One recent research study (Ward, Buckle, and Clarkson 2010) has provided some simple tools to enable the healthcare industry to better assess risk in existing systems or in innovation (i.e. the trigger). The steps involved are then to:

- articulate the purpose of the assessment,
- define the requirements for the assessment,
- describe the system to be assessed,
- identify system hazards,
- assess the system risks and
- propose actions based on a detailed evaluation of the risks.

The assessment then provides designers with a clear description of potential risks within the system. It also enables an assessment of the resultant risks associated with the hazards (and their defences and mitigation) and a representation of the results of the risk assessment. These data then become an integral part of the knowledge base from which improved design criteria can be developed (Anderson, Buckle, and Hanna 2012; Ward et al. 2010).

3.1 Future issues

There need to be many more examples of design using the HFE approach of healthcare systems; scientific, evidence based and sustained. Norris (2012) advocates continuing to integrate the work on device usability, human error, team work and safety culture into an approach that includes work design and systems analysis.

4. Surgical safety

Surgery has been fundamentally influenced by HFE research in the past decade. Following the Bristol enquiry (Walsh and Offen 2001), work in paediatric cardiac surgery linked process to mortality and morbidity rates (de Leval et al. 2000). This linkage brought about a plethora of observational studies investigating process, teamwork, errors and safety practices with attention focused on disruptions that increase the chance of more serious problems. These studies provided a window on the performance shaping factors within the surgical system, including communication and information flow, teamwork, distractions, equipment, training, lack of resources and conflict (Christian et al. 2006; Catchpole et al. 2007b; Undre et al. 2007; Wiegmann et al. 2007). These system deficiencies potentially increase risk for the patient in three ways: through delays and longer operating times, by increasing the chance of an error cascade and by creating unpredictability and escalation of the cognitive demands that predispose surgeons to make technical errors. Given the dynamic, technical and team-based processes in the operating theatre, there has been an emphasis on applying non-technical skills (Fletcher et al. 2004; Yule et al. 2006, 2008) and teamwork models (Healey, Undre, and Vincent 2006). Checklists have also shown to be particularly successful with influential work leading to mandated changes in practice (Haynes et al. 2009). This work has built on the recognised successes achieved in improving safety in anaesthesia over many decades (Botney 2008), which needs to be extended to the wider team in the operating room, and to patient care both before and after surgery.

Despite the potentially limited value of behavioural change, training solutions, often based on aviation crew resource management principles, have also been popular. There is growing evidence that such courses may deliver a range of improvements, and systematic reviews have generally found positive effects (McCulloch, Rathbone, and Catchpole 2011). There has also been a huge increase in the use of simulation both for technical training and for teamwork training which has yielded evidential benefits (Cook et al. 2011). The success of this type of intervention contrasts with the billions spent on developing new drugs, new surgical techniques or the equivocal evidence of the value of surgical robotics (Weissman and Zinner 2013).

Unfortunately, the dominance of HF training has led many clinicians to the mistaken belief that aviation-style training is training in HFE, despite a lack of systems theory, human factors integration, human-centred design or HFE analysis techniques within these courses (Saleem et al. 2011). Thus, this training may inappropriately focus on behavioural safety solutions to the exclusion of systemic problems. Indeed, effective and sustainable solutions to risks in surgical care have proven to be less than straightforward. It is, therefore, an achievement that HFE now has a presence in surgery and surgical science. In fact, the understanding that the HFE perspective can bring to understanding the complexity and interdependence of the components of surgical safety and performance improvement is only just beginning to be acknowledged (Catchpole 2011; Wiegmann et al. 2010). Though comprehensive multi-dimensional HFE interventions are still few and far between, and behavioural change remains a focus, some studies have begun to develop and a few have garnered considerable attention (Catchpole et al. 2007a). The challenge for the future is to deliver demonstrably better standards of safety and quality of care. Following are the key findings:

- Observational and behavioural methods have been deployed to understand teamwork, socio-technical complexity, the effect of interventions, performance shaping factors and the effects on patient outcomes (Carthey 2003; Undre et al. 2007; Schraagen et al. 2011).
- Communication is frequently cited as a major source of error (Greenberg et al. 2007; Karsh et al. 2009).
- Dynamic models of adverse error causation have been suggested in high-risk surgeries by which small, seemingly innocuous events concatenate to create errors, near-misses or injuries in the operating room (de Leval et al. 2000; Catchpole et al. 2006; Schraagen et al. 2011).
- Teamwork, training and behavioural change have been dominant in intervention considerations, with generally positive results (Fletcher et al. 2004; Yule et al. 2006, 2008; McCulloch, Rathbone, and Catchpole 2011).
- Checklists, briefings and debriefings have also been explored with success (Lingard et al. 2008; Berenholtz et al. 2009; de Vries et al. 2009; Haynes et al. 2009).
- There is some confusion over what HFE is and who should be doing it (Leonard, Graham, and Bonacum 2004; Gurses, Ozok, and Pronovost 2012).

4.1 Future issues

The future holds a number of key goals. There needs to be a better theoretical underpinning to understand the complexity of work in surgery. This includes better:

- understanding of the healthcare system and the roles and effects of different components,
- task/activity analysis to develop a library of well-researched surgical procedures,
- methods to observe and measure human and process behaviour in surgery,
- ways to analyse events and incidents,
- solutions that rely less on behavioural safety and more on systems analysis and
- recognition that expertise in HFE (and the particular nature of that expertise) can have value in addressing socio-technical problems for the direct benefit of patients.

Given the focus on safety incidents, there is currently a unique opportunity to examine the effects of HFE-based interventions on patient care. Clinicians will want to see that evidence, even though developing it is an exceptionally difficult challenge. Alternatively, there will be considerable resistance in moving the clinical mindset to process-oriented outcomes from the deeply ingrained view that clinical outcomes are the best evidence for efficacy. Finally, of course, clinicians do not change their behaviour uniformly in response to evidence or top-down interventions (Gurses et al. 2010), so HFE professionals will need to continue to work carefully at the sharp end to understand and influence behaviour.

5. Organisational and socio-technical systems

Studies have extensively documented the numerous quality problems in healthcare delivery across the world. According to the US Institute of Medicine (2001), healthcare quality covers six domains: (1) safety, (2) effectiveness, (3) patient-centred care, (4) timeliness, (5) efficiency and (6) equity. The Institute of Medicine has published a series of reports that document evidence of medical errors (Institute of Medicine 2001; Kohn, Corrigan, and Donaldson 1999), medication errors (Institute of Medicine 2006) and more recently patient safety problems related to the design, implementation and use of health IT (Institute of Medicine 2012). Healthcare experts and professionals have recognised the value of HFE models and methods to improve healthcare quality (Leape 2004), in particular in the areas of patient safety culture/climate (Itoh, Andersen, and Madsen 2007), health IT design, implementation and use (Institute of Medicine 2012; Karsh 2004; Karsh et al. 2010) and transitions of care (Carayon et al. 2011a). Other HFE issues in the design of socio-technical systems for healthcare quality are reviewed elsewhere, for example Morrow, North, and Wickens (2005), Carayon et al. (2011a) and Carayon (2012).

Reviews of research on patient safety culture/climate emphasise the following findings and HFE issues (Itoh, Andersen, and Madsen 2007; Halligan and Zecevic 2011):

- It is important to distinguish between patient safety culture and safety climate (Halligan and Zecevic 2011). Safety culture refers to the patterns of values, beliefs, attitudes and behaviours that shape an organisation's commitment to patient safety, whereas safety climate represents organisational members' perceptions of safety culture at a given point in time (Schein 1992; Halligan and Zecevic 2011).
- Several survey instruments have been developed and tested and can produce valid, reliable measures of safety culture and climate (Hutchinson et al. 2006; Singer et al. 2009; Nieva and Sorra 2003; Halligan and Zecevic 2011). For

instance, the US Agency for Healthcare Research and Quality (AHRQ) has developed different versions of a survey to assess patient safety culture in hospitals, physician offices and nursing homes (http://www.ahrq.gov/qual/patientsafetyculture/). The AHRQ Surveys on Patient Safety Culture cover multiple dimensions of safety culture such as supervisor/manager expectations and actions promoting safety, feedback and communication about error as well as management support for patient safety.

- There is some evidence for the link between safety climate and patient safety. In a study of 1033 nurses and 78 nurse managers in 78 units of 10 hospitals, perceptions of safety organisation (e.g. *We talk about mistakes and ways to learn from them*) were related to lower levels of medication errors (Vogus and Sutcliffe 2007).

Another socio-technical issue of importance for healthcare quality and HFE relates to the design, implementation and use of health IT. Although health IT is often described as a major solution for improving quality of care, the evidence for the benefits of health IT applications such as Electronic Health Record is limited (Wu et al. 2006). Usability of health IT (Bastien 2010; Kushniruk et al. 2005), acceptance of health IT by healthcare professionals (Carayon, Hundt, and Wetterneck 2010; Carayon, et al. 2011b; Holden and Karsh 2010), workarounds associated with health IT (Koppel et al. 2008) and implementation of health IT (Karsh 2004) are HFE issues that have received significant attention. Lack of attention to these HFE issues may actually explain the limited success of health IT in producing quality of care benefits (Karsh et al. 2010). Enhanced collaboration between healthcare and HFE professionals and academics is necessary to understand clinical work and to design health IT that supports clinical work (Karsh et al. 2010). This research as well as other HFE research in healthcare face numerous challenges (Carayon 2010) such as cultural differences between HFE engineering approaches and healthcare (Carayon and Xie 2011) and the belief that HFE is 'common sense' and consists of tools that can be easily learned and applied (Xiao and Fairbanks 2011).

The interface between health and community care continues to change. With increasing fragmentation of the healthcare system, the number of care transitions has increased, and often led to a range of information flow, communication and coordination problems (Horwitz et al. 2009; Schultz et al. 2007; Clancy 2006). Care transitions occur when patients move from one care setting to another care setting (e.g. patient discharged from the hospital to their home), when patients are handed off from one unit to another within a hospital (e.g. surgical patient handed off to the recovery room and then to the ICU) or when healthcare professionals hand over patients to each other (e.g. nursing shift change). Transitions of care have been identified as contributing to healthcare quality problems such as hospital re-admissions within 30 days (Naylor et al. 2011) and medication errors (Bell et al. 2006). However, transitions of care can also be unique opportunities for error detection, correction and recovery. For instance, Cooper et al. (1982) found that intra-operative breaks between anaesthesiologists allowed a 'fresh second pair of eyes' to review patient anaesthetic care and make necessary changes for the safety of patients. Wears, Perry and colleagues (Perry 2004; Wears et al. 2003) have also demonstrated safety benefits in transitions of care that occurred when emergency physicians hand over patients at shift change. HFE research on care coordination and transitions of care faces various difficulties because of the need to look at work processes across time, space and organisational entities. In addition, measuring the impact of interventions aimed at improving care coordination and transitions can be challenging because of the time necessary for the intervention to have an effect and the range of other factors that can affect the impact of the interventions.

5.1 Future issues

Significant efforts have occurred in the measurement of patient safety culture and climate. For instance, the measurement of safety culture in Danish healthcare was explored by Madsen and Anderson (2005), and a safety climate questionnaire was evaluated in UK healthcare by Hutchinson et al. (2006). We need to continue developing the emerging evidence for the link between patient safety culture and climate and safety outcomes, as well as understanding the work system factors that contribute to both patient safety and worker safety. Research should also be conducted to evaluate the impact of various HFE interventions on patient safety culture and climate (Halligan and Zecevic 2011).

The recent report on health IT and patient safety by the Institute of Medicine (2012) identifies major areas of research for HFE, such as the design of health IT to support clinical work, the design of alarms and alerts to provide meaningful information and the design of health IT to support cooperative healthcare work. That research requires HFE research aimed at developing a deep understanding of healthcare work (Cook 2003; Karsh et al. 2010).

The following key areas of HFE research in transitions of care have been identified (Carayon et al. 2011a):

- Identification of HFE hazards in transitions of care; see, for example Gurses et al. (2012).
- Design and evaluation of HFE interventions to improve quality of transitions of care.
- Teamwork and coordination across transitions of care (e.g. coordination of care between ICUs and floor units).

6. Discussion and conclusion

There are common threads across the four examples of HFE described in this study, for example the need for systems thinking to understand how changes may impact elsewhere in the system through linear and ripple effects. However, systems thinking is still relatively immature in healthcare, and there are major opportunities for new HFE theory and practice with HFE experts immersing themselves in the complexities, opportunities and challenges. For example, Hignett et al. (2013) proposed a new theoretical model (DIAL-F) to represent the human elements of staff (care givers) and patients (care recipients) separately rather than combined as the ‘Person’. The DIAL-F model changes the patient role from predominantly passive in a process model (SEIPS, Carayon et al. 2006) to an active role in which the patient is both transient (for both short-term care and long-term care with repeated visits) in the system and independent to choose when (and if) they engage with the system (as a voluntary member of the system rather than an employee). It is suggested that this model is closer to Miller and Gwynne’s (1972) *horticultural model of care* (active, risk-taking) than a minimum-risk environment or *warehousing model of care* (passive).

The past decade has seen a slow and gradual increase in the application of HFE techniques to healthcare delivery across a broad range of contexts. This expertise is beginning to be valued and more widely understood across the healthcare system. The challenges should not be underestimated, but nor should the benefits. As the importance and relevance of HFE in healthcare has grown, there are examples of bright and action-oriented healthcare professionals interested in safety and quality rushing off to *do human factors* with only a superficial understanding of the fundamental concepts (Saleem et al. 2011), resulting in *do it yourself* HFE. In response to this, there are examples of HFE re-claiming the term human factors to separate the ‘fact from fiction’ and highlight that HFE is a scientific discipline with accredited training courses leading to professional graduate skills (Russ et al. 2013). Although we recognise and respect that it will still be doctors, nurses and other caregivers who have to make difficult decisions and perform increasingly complicated procedures, we agree with the suggestion by Kneebone (2002) that medical [clinical] education does not necessarily provide a good preparation to understand the ideas and the literature of other fields, for example engineering, psychology and design.

The focus of healthcare research traditionally has been on efficacy of treatments and practices, cost containment and more recently provision of user information. These pressures have led to an emphasis on randomised control trials with an associated ‘retarded development of a broader view of evaluation’ (St Leger and Walsworth-Bell 1999) of how health services are managed, organised and delivered (Fulop et al. 2001). In order to leverage sustained and increasing focus on the value of HFE in healthcare, there is a need for HFE to demonstrate benefits (Carayon, Xie, and Kianfar 2013). This can be achieved with safety cases (Health Foundation 2012) and by working with executive boards, commissioning services and insurance companies to embed HFE in the assurance (governance) metrics (including patient satisfaction/experience) and reimbursement schemes.

Recently, there have been initiatives to move clinical audit from a quality assurance to quality improvement process (Dixon and Pearce 2011). Although this is not a new phenomenon, it offers an opportunity to revisit safety initiatives from the 1980s and 1990s which were based on total quality management and risk management. Furthermore, it is becoming apparent through the increased interest in protecting both patients and practitioners from accidental injury that many everyday performance and efficiency benefits may be found through system improvement. What began as a hunt for errors now signals a major means by which spiralling healthcare costs might be reduced, controlled or at least better understood. This is an opportunity for HFE experts to take a central role and help to avert future systematic safety problems (Flin et al. 2013). We suggest that HFE experts need to work closely with clinicians, to understand the complex world of healthcare and to shape and grow the application and understanding of clinical HFE with an infrastructure to support meaningful long-term partnerships.

Notes

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