Human Factors in general practice – early thoughts on the educational focus for specialty training and beyond

John McKay[1]
GP Assistant Director (Safety, Improvement and Performance)[1]

Laura Pickup[2]
Research Fellow

Sarah Atkinson[2]
Senior Research Fellow

Duncan McNab[1,3]
GP Associate Adviser (Safety and Improvement)[1] and PhD Student[3]

Paul Bowie[1,3]
Programme Director and Honorary Senior Lecturer

[1]Medical Directorate, NHS Education for Scotland, Glasgow, UK
[2]Human Factors Research Group, University of Nottingham, Nottingham, UK
[3]Institute of Health and Wellbeing, University of Glasgow, UK

Corresponding author:
Dr P Bowie
Programme Director (Safety and Improvement)
Medical Directorate
NHS Education for Scotland
2 Central Quay
GLASGOW, Scotland, UK
G3 8BW

Email: paul.bowie@nes.scot.nhs.uk
Telephone: 0141 223 1450
Twitter: @pbnes

ABSTRACT

In the third article in the series, we describe the outputs from a series of roundtable discussions by Human Factors experts and GP Educational Supervisors tasked with examining the GP training and work environments through the lens of the systems and designed-centred discipline of Human Factors and Ergonomics (HFE). A prominent issue agreed upon proposes that the general practice setting should be viewed as a complex sociotechnical system from a care service and specialty training perspective. Additionally, while the existing GP specialty training curriculum touches on some important HFE concepts, we argue that there are also significant educational gaps that could be addressed (e.g., physical workplace design, work organisation, the design of procedures, decision-making and human reliability) to increase knowledge and skills that are key to understanding workplace complexity and interactions, and supporting everyday efforts to improve the performance and wellbeing of people and organisations. Altogether we propose and illustrate how future HFE content could be enhanced, contexualised and integrated within existing training arrangements, which also serves as a tentative guide in this area for continuing professional development for the wider GP and primary care teams.

INTRODUCTION

In the previous article in this series [1} we described the discipline of Human Factors (also known as Ergonomics) and how it can potentially make a significant contribution to improving safety, performance and wellbeing in primary care [2-4]. To recap, Human Factors and Ergonomics (HFE) is the application of scientific evidence to understand how human performance varies in relation to the working environment and design of work within the systems that people interact with [5-6]. HFE takes a holistic approach to the evaluation of human work and aims to consider all interactions within a system e.g. between individuals and the tasks they perform, the technologies they use, and their physical, social and cultural environments [7-8]. Its primary workplace purpose is to jointly optimise the performance (e.g. productivity, efficiency and effectiveness) and wellbeing (e.g. health, safety and satisfaction) of people and organisations [6].

In terms of service and educational policy, a recent NHS Concordat strongly suggests that HFE understanding and techniques can inform patient safety and quality improvement, as well as support change management and emphasise the importance of the design of equipment, physical environments, and procedures [9]. It also acknowledges the need for HFE to be viewed as 'a way of thinking' that should be incorporated into the design of processes and jobs as well as being integrated within clinical education and training. In general practice and wider primary care we have been slow to embrace and integrate the potential conceptual and practical benefits of this discipline.

A possible sticking point is that HFE is a very broad discipline which covers many different concepts, principles, contexts and approaches. Admittedly, this is a difficult challenge when striving to focus on, for example, those issues of potentially greatest value to enhancing human performance and wellbeing in primary care - and which should, therefore, be considered for inclusion on a specialty training curriculum or in support of continuing professional development. Against this background, we present the agreed outcomes of a series of broad ranging roundtable discussions on the HFE discipline and its relevance to the GP training environment and wider workplace by a small 'expert' group of GP educational supervisors, safety and improvement researchers and human factors specialists. As part of this process we also examined the RCGP curriculum [10] and GMC guidance documents in

detail [11] to fully understand the job roles and goals of a GP trainee and qualified GP within this context. Specifically, our express purpose during discussions was to take the first small steps in attempting to understand the following from the HFE perspective:

- The relationship between the contexts, interactions, complexities and constraints associated with the full range of clinical and organisational work activities typically performed by the GP trainee in preparation for independent medical practice.
- How expected educational and work goals and activities during training and beyond relate to the existing content of the specialty training curriculum and identify potential educational gaps that may need to be addressed.

In doing this, we surmised that we can take the first steps in identifying specific HFE issues, concepts and approaches that may have direct relevance to the safe, effective and efficient functioning of everyday general practice from a service delivery and specialty training perspective – and so inform the future direction of education and training in this area.

DISCUSSION ISSUES

GP training context and goals

It is self-evident that in the work and educational context of the GP trainee the primary system is the GP surgery, therefore, any future HFE-related education and training should be designed to reflect their role and the structure of the wider system within which they function and interact. In HFE terms the GP training environment (and general practice more broadly) can be considered as a complex socio-technical system i.e. the identified care services and training goals can only be achieved through the interactions between technical, human, social and organisational components of the system [12]. The term complex socio-technical system refers to a particular set of qualities typical to a workplace, not all of which might be present but can include: a large number of potentially relevant factors or solutions to problems requiring decisions; many people are required to communicate within the system; the time for a reaction to a clinician's decision or actions may vary from minutes to hours and requires careful consideration to avoid catastrophic consequences; there is uncertainty in the

information received due to imperfections in the source of the information; and there is a requirement to deal with unpredicted events to maintain system safety and efficiency. The heterogeneity and everyday workload, complexity, uncertainty and adaptability of general practice is a testament to this type of complex system for which specialty training prepares future GP doctors and leaders.

A 'systems approach' is considered an essential feature of the integration of HFE principles and approaches in the workplace and as part of education and training [6]. The term fundamentally implies a need to recognise that a work system should first be defined, complex interactions understood, and the context or current climate recognised as an influencer of system behaviour. A system can be broken down into individual elements that reflect the physical, cognitive, social and organisational characteristics specific to the system - taking a holistic view of these interacting properties is a core HFE principle. The diagram illustrated in Appendix 1 provides a representation of the GP system to highlight the high level values and goals of the system drilling down to the functions, activities and artefacts relevant to the GP training environment.

Activities, interactions and constraints

It is also axiomatic that GP training aims to provide a trainee with the skills to manage a patient caseload but also to understand how the practice works in relation to the goals of patient care and the safety and financial wellbeing of the system as a whole. The typical activities of the GP trainee include patient consultation, interpreting the communication and information received from the patient, completing physical examinations and coordinating information from investigations or previous consultations to develop a working hypothesis to inform their decision making (Box 1). The time pressure for patient consultations and decision-making is initially reduced and supported as a GP trainee, but once qualified the expectation is to self-manage a dynamic workload, personal stress and fatigue while achieving accurate and appropriate levels of communication and clinical decision-making to ensure patient safety.

A core team of support staff is normally present to ensure the system can achieve its service delivery and training practice goals - typically the team includes a Practice Manager, GP,

Practice Nurse and administrative staff (as well as key staff in the wider community), all of whom will interact with, support, advise and teach GP trainees to help them demonstrate competencies and pass examinations (Figure 1). Within any system there will be constraints that influence what, how, when and why a person completes the work they do – for example, in general practice there are, amongst other factors, constraints on time, access to appropriate working environments, available expertise, work patterns and safety and financial commitments of the practice (Box 2).

[Insert Figure 1 about here]

Box 1. High level goals of GP training and independent practise

1. To promote good health;
2. To deliver end of life care;
3. To manage complex health problems;
4. To engage/ communicate within the NHS team to manage and deliver patient care;
5. To manage patient care for acute and chronic conditions;
6. To deliver emergency care as required;
7. To request, receive, interpret and act upon diagnostic investigations;
8. To deliver patient treatment;
9. Prioritise and direct patient care;
10. To propose diagnoses;
11. To communicate appropriately and effectively with patients; written and verbally;
12. To safely prescribe medication;
13. To manage, access and analyse clinical and health related data;
14. To deliver education to patients/community, relevant health professionals;
15. To ensure cost efficiency of patient care;
16. To maintain competences;
17. To maintain patient safety, dignity, confidentiality and trust;
18. To document patient interactions clearly and timely;
19. To recognise, manage and report on patient/staff concerns and adverse events affecting safety, dignity and confidentiality;
20. To commission services for patient care.

Box 2. Typical system constraints in general practice

- Availability of appointment times;
- Duration of appointment;
- Review of chronic conditions – surgery targets;
- Review of patients receiving repeat prescriptions;
- Availability of consultation/treatment rooms;
- Gender of GPs –chaperones may be required;
- Patient preference for a particular GP due to sensitivity about a condition;
- Continuity of care – aim to see same clinician for each appointment;
- Sample collection times – deadline for bloods/samples to be gained;
- Arrival and access to results from investigations;
- GP with specialist/extended knowledge – expertise;
- GP trainer time allocated to trainee supervision/training;
- Organisational financial/quality measures;
- Prescription of medication – legislation and guidelines;

The GP surgery relies heavily upon multiple Information Technology (IT) support systems to communicate internally and externally, and also to store, retrieve, update and transfer clinical information on patients, consultations, specialist referrals and investigations. They also inform how quality of care performance is demonstrated and contractual payments are made. Confidentiality, ease of use, individual technical abilities, and compatibility between these IT systems are some of the HFE issues of high relevance (in terms of design, complexity and usability) to influencing the work and workload [13] of the trainee and wider GP team, and therefore the quality and safety of patient care.

Enhancing HFE education and training

In reviewing the relevant documentation and analysing the GP training and working environments it is clear there are potential gaps in existing HFE education and training which would be considered essential for those working in similar complex and safety relevant settings in other high hazard industries. Given the earlier classification of the GP surgery as a complex socio-technical system, the application of a related conceptual model (Figure 2) helps highlight these educational gaps and guide how these HFE concepts may be integrated into aspects of the specialty training curriculum (Figure 3) - and also potentially inform continuing professional development for the wider GP team. Understanding how the performance of a GP trainee may be influenced while working within a complex system requires an appreciation of many HFE concepts [3, 6]. Such a model can help demonstrate the breadth of HFE evidence, methods and education that should be considered for future GP training. The following were identified as of high relevance to the main activities and goals of the GP trainee (and the wider GP team):

[Insert Figures 2 and 3 about here]

Complex Sociotechnical Systems

There needs to be an appreciation that the interpretation of HFE as a discipline should be from a systems and design perspective [6]. A high level understanding should be provided of what this means and why a GP practice should be considered as a complex sociotechnical system. This approach is considered an appropriate way to reflect how a healthcare environment generally works well, but sometimes fail.

Human cognition

Understanding the evidence underpinning 'mental work' may provide a base level of knowledge to appreciate the HFE issues associated with, for example, problem solving, mental workload, decision making, vigilance and information processing concepts [14]. Human performance where cognitive tasks are involved will always vary, hence an appreciation of human capabilities, limitations and influencing factors associated with our perception, attention, working memory, long term memory and actions can assist in predicting and analysing risks associated with cognitive clinical work.

Work-related stress

Stress is a term that has different meanings depending upon the context where it is used. In the workplace context stress is intended to refer to the physical or psychological response/defence to the demands placed upon individuals [15]. In the HFE context a stressor may also come from the wider environment e.g. heat, time pressures, unfriendly IT systems, workload, unsupportive colleagues/management or Government targets. The outcome implies a level of stress or strain on the individual will result in reduced productivity, poor performance and be associated with ill-health or injury. A systems approach is necessary to fully appreciate how organisational structure, interactions and goals can influence the perception of control and stress experienced and impact on the health and wellbeing of a GP team and the performance of the practice system as a whole.

Fatigue

Our appreciation of types of fatigue (physical and mental) may vary but we generally understand that it implies a reduction in physical and mental capabilities which can impair our ability to complete safety relevant activities due to reduced levels of alertness [16]. Fundamental knowledge of these issues is important for assessing and managing risks associated with the causes of fatigue, which may be work related (e.g. shifts, extended hours, excessive/conflicting task demands) or related to home life (e.g. children, personal circumstances) or related to personal individual factors (e.g. age, fitness, stress, sleep disorders).

Workload

'Workload' has an intuitive meaning yet there is variability in what we understand by the term. Physical workload may imply the physical demand and strain imposed upon our bodies by repetitive or sustained movements. Cognitive workload cannot easily be observed and reactions by different individuals will influence the experience of mental efforts. Workload can be considered as a spectrum ranging from high to low, with performance deteriorating at both ends of the spectrum. The term also varies between referring to the amount of work to be completed within a period of time, the complexity of the work to be completed, the risk associated with poor performance and the compatibility or interference between multiple tasks [13-14]. In managing the workload for all staff groups, there is a need, therefore, to define it within the intended context and recognise the sources of demand and effort associated with the work and goals to be achieved.

Decision-making

The core work of the GP trainee is to learn how to elicit and interpret information they receive or observe about a patient's problem – a high frequency activity that often involves managing and coping with risk and uncertainty. This informs the decision-making processes adopted by the trainee and the relevance and success of the plan they then initiate to alleviate or solve a problem or manage a patient's symptoms. The cognition required will differ between individuals, relative to their general experience, specific knowledge or competence in recognising and managing certain conditions. Furthermore, different types of decision-making may occur in different contexts depending upon time pressure, multiple demands or the risk associated with the decision [17-18]. An appreciation of how we make decisions can assist individuals to develop related skills while also appreciating the factors that may bias their decision or vary the effectiveness of the process e.g. stress, fatigue, and unnecessary distractions or interruptions. Errors common to decision-making need also to be considered in the context of GP training e.g. tunnel-vision, reduced working memory, confirmation biases, and retrieval from memory of simple strategies. HFE can provide the evidence to appreciate how human performance may vary depending upon the nature of the work completed e.g. the type of work, its familiarity and context will influence whether we adopt skill-based, rule-based or knowledge-based behaviours to inform our choices and decisions to achieve the desired level of performance.

Non–technical skills

These are considered as the relevant cognitive, social skills and behaviors that complement the technical skills [19] exhibited by individuals to promote safe and efficient performance within their particular work contexts, with many already a focus of the existing curriculum e.g. management and leadership. The significance and training of non-technical skills should be covered within any future HFE education – a recent study involving GP trainers has highlighted the most important (and trainable) non-technical skills that are perceived for a 'safe' general practitioner [20]. The top three skills/attributes deemed most important were honesty, technical clinical skills and conscientiousness, while the least trainable were humility, honesty and patient awareness/empathy.

Physical workplace

Currently there is limited evidence that the use of good design principles, standards or HFE evidence relating to working environments is widely applied within a GP surgery [14]. The design of a workplace can have a large impact on human performance, the safety and efficiency of an organisation. Consideration to anthropometric dimensions, visual, auditory and thermal factors within an environment is relevant to understanding the workplace, its safety and influence as a stressor [21]. Knowledge of human-centred design principles should inform the process to adopt when reviewing, designing or modifying the physical working environment [2,5]. This is a process that should include the opportunity to understand the context and variability in the use of the environment/equipment, understand all users' requirements (physical and cognitive), develop human-centered solutions and evaluate the design against the original set of requirements.

Equipment and technology

HFE can provide the tools for future GPs to consider how to ensure they develop a safe and productive working environment. The procurement of equipment requires a fundamental understanding of human-centred design principles and product evaluation methodology to address associated 'usability' issues- a term that is considered relevant to understanding the introduction of new equipment or systems to establish if they are fit for purpose or compatible with existing equipment [2,5,21]. Usability in the context of a GP surgery would

have implications for the procurement, evaluation and application of relevant IT systems and medical equipment e.g. treatment beds, blood sampling equipment, communication support systems.

Teamwork

The concept of a 'team' may vary between workplaces as teams can exist closely or remotely but are generally defined as any group with a common goal. The job roles that exist within a GP surgery will differ between practices and this will determine the nature of the 'local team'. The 'distributed team' infers interactions with teams within different organisational settings e.g. secondary care and social services. The barriers or facilitators to interactions may differ from those relevant to a local team [22]. The GP trainee forms part of the team but is also learning to become a leader within a future team. A general appreciation is required to appreciate interactions between teams and the significance of how local and distributed teams can achieve safe and efficient patient care. Team working can reduce the stress of individuals and improve the safety and performance of the system. Therefore, GP trainees should be made aware of the importance of teamwork and how HFE can assist in understanding teamwork in the context of wider primary care, to recognise related strengths and weakness within a practice and to assist effective team interactions within the work system.

Communication

Communication is a vital ingredient in ensuring the goals of the GP surgery are achieved and is currently covered by the competences to be achieved during training e.g. consulting with patients and relatives. HFE can help understand where in the system all forms of communication are necessary and identify variability, constraints and the hazards and associated risks or potential for error [23]. Appreciating the significance of 'mental models' (i.e. how you think something works in the real world) is highly relevant to communication system design and mitigating potential errors. However, over-reliance upon system automation or prompts can erode mental skills. For example, human-computer interaction may influence how GP trainees (and others), communicate and interact with technology which ultimately influences system performance. Simulation training can consider, for

example, scenarios where technology fails and the knowledge and skills of staff are tested to determine if tasks can successfully continue and be completed [24].

Work Organisation

The term 'work organisation' refers to the way that jobs are designed and performance is measured and both are factors which can influence the efficiency, productivity and wellbeing of employees and the organisation. There are models of work that can inform how work is organised within a system to maximise the motivation and wellbeing of employees [5]. These aim to reduce risk of injury and maximise job satisfaction with the long-term aim of retaining staff and reducing sickness and absence. Factors that can influence individual perception relating to the work performed within a job role and potential for mismatches that may induce stress and dissatisfaction include skill variety, job rotation, and autonomy. Work organisation must be considered as part of any implementation of change to reduce risk factors at work [5, 13, 23]. Organisational changes can provide an opportunity to gain greater involvement and autonomy for the workforce, who in turn can then contribute more directly to improving the work situation (known as participatory ergonomics) for efficiency and productivity as well as for health and safety.

Safety Culture

This term is used to describe the way safety is perceived within an organisation and hence the value and priority that is placed upon safety when the organisation defines and expresses its goals and targets [25]. A prevailing safety culture may be positive, negative or neutral and reflects what the people within the organisation perceive the level of importance placed upon maintaining and improving safety in everyday work. Safety culture can be considered to be 'the way things are done around here' or 'what motivates us'. An organisation may have many safety initiatives in place but a safety culture is a reflection of the reality of how those initiatives are prioritised by a workforce and those in management and leadership positions. An appreciation of the properties of a positive safety culture is necessary to understand this concept fully, while the evaluation of the prevailing safety culture may assist local care teams to learn collectively about those cultural domains (e.g. systems of communication or team working) that may need to be improved – the Scottish Patient Safety Programme in Primary Care is one example of where this concept has been tested nationally [26].

Procedures

Procedures such as protocols, checklists, briefings, incident investigation processes and safety huddles are fundamental to most high reliability organisations [27]. It is suggested that their consistent application in healthcare may increase safety as they allow for the appropriate simplification and standardisation of work activities that may be considered as safety relevant or which promote the efficiency and capacity of a system [7]. However, the approach to developing and applying procedures in healthcare has been challenging. The compliance with existing safety procedures can be considered as a major contributor to incidents within the workplace. Development of *effective* procedures needs to consider the working environment, constraints and resource limitations to ensure they are realistic and achievable and requires an understanding of the way work is *really* done within a workplace. This requires an organizational approach that actively seeks the participation of all relevant front line staff groups in the design, testing and refinement of these types of procedures [28-29].

Safety, human reliability and risk assessment

The concept of safety is frequently considered to be the absence of things that go wrong. When an accident or incident occurs people (erroneously) are generally considered as the unpredictable component and one of the greatest hazards or contributing factors. Incident investigations and risk assessments focus to identify 'causes', consequences and the likelihood of unsafe outcomes and then eliminate or install barriers to minimise occurrence or impacts. An important part of risk assessment is to understand the hazards present within the GP surgery and the risk that these hazards present to patients or staff in the context of the way people normally work there [30]. Individual responsibility, a willingness to highlight incidents and a reporting system that recognises the whole sociotechnical system and associated hazards is necessary to create a proactive approach to safety management. The evaluation of safety within the whole system and the interactions of humans with all levels can contribute to ensuring the safety and performance of the system and a number of tools can help here. However, applying safety management comes in different forms. The recent introduction of Resilience Engineering [31] proposes that variability in human performance is normal and that the design, monitoring and responsiveness of the system may counter

unwanted variability, while identifying and harnessing positive system elements to support risk management in complex systems.

Social and Cultural Pressures

Society and political influences typically search for the best value, and the most efficient and safest form of healthcare service. 'Best practice' is often cited as ensuring all of these goals can be achieved, however, the reality is that there is always a trade-off between these types of goals which need to be balanced [32]. In frontline practice, the influence on choice for efficiency over safety or vice versa needs to be considered alongside the related impact on the prevailing safety culture and system resilience within the organisation. A recognition of how these high level influences impact the functions and goals of the GP work system and how frontline staff adjust performance to accommodate these decisions as part of everyday work is an important HFE concept which provides, for example, an appreciation of how these factors can inform workload and prevailing culture.

DISCUSSION

We have highlighted to some extent how the GP trainee works and interacts within the context of a complex socio-technical system (the GP training and work environments) and, therefore, which areas of HFE are of most relevance in integrating within a future training curriculum. The suggestion is that HFE education for GP trainees (and the wider GP team) should provide sufficient breadth to highlight concepts and approaches that reflect the whole sociotechnical system and its goals of delivering high quality, safe and efficient patient care, whilst protecting the wellbeing of the workforce required to achieve this. Embracing this approach may ensure a comprehensive understanding of how the context and the design of the working environment and technologies are key to influencing human behaviour and performance in the workplace [12, 31]. The high level aim should be to integrate [5, 33] this type of fundamental HFE knowledge within related areas of the existing curriculum (not add the topic as a bolt-on), rather than to create 'experts' which is not feasible for most given the academic training and experience necessary; but also have fundamental knowledge and insight into the existence of HFE expertise as required.

The rationale for these tentative recommendations is multi-factorial. GP trainees are future health and social care managers and leaders, decision-makers, resource allocators and commissioners of services. A broad understanding of care system complexities, sociotechnical interactions and constraints is fundamental to understanding system hazards and designing effective solutions for improving the performance and wellbeing of people and organisations. For example, currently there is a political drive to improve healthcare buildings and workspaces [34] – senior clinical leaders, including GPs, are becoming involved in the purchasing of technology and equipment and in contributing to the physical design of buildings and workspace layouts. Additionally, although some important HFE issues are touched upon in the existing training curriculum, a more comprehensive and holistic approach is necessary to properly reflect the system and design centred purpose of the discipline and fully extract the potential benefits to be accrued in terms of improving care efficiency, productivity and safety. In this regard, arguably the failure to fully embrace and integrate HFE concepts and approaches in healthcare is a key reason why patient safety and quality improvement efforts have not been as successful as anticipated [2-5,35]

In wider educational terms there will be a clear learning need for most GP trainers. Workshops and materials would be required for them to gain a better understanding of the principles of HFE in order to cascade these to not only the trainee but also to develop the educational and workplace culture of the whole practice team. For those aspiring to become GP Trainers, faculty development programmes should include basic HFE understanding as a core competency. Work-placed based assessment could also be developed through the core competency requirements and curriculum coverage to ensure an underpinning of HFE principles within GP training.

While there is now wide-spread acceptance of the need for HFE thinking and approaches in healthcare to mirror implementation in other high hazardous industries, its development is slow in comparison and unfortunately narrow in scope [24]. As previously stated [1], its introduction to some acute hospital specialties (e.g. anaesthetics, surgical practice and emergency medicine), and in many postgraduate training curricula [37], has often led to a focus on person-level behavioural safety issues (important though they are) which was largely

based on a very limited 'crew resource management' model of 'human factors' imported from aviation [35].

CONCLUSION

In general practice education and service delivery we have an important and timely opportunity to embrace broader system and design-centred approaches to enhancing the overall performance and wellbeing of people and organisations, which is the true hallmark of HFE as a discipline. A more comprehensive appreciation of HFE will provide future GPs and existing GP teams with the knowledge and skills to contribute to further developing their working environments to optimise performance and wellbeing, with the ultimate goal of creating a system that will facilitate safe and efficient care for patients.

REFERENCES

[1] Bowie P and Jeffcott S. Human factors and ergonomics for primary care. *Education for Primary Care* 2016:27; 2: 86-93

[2] Karsh B-T, Holden RJ, Alper SJ, et al. A human factors engineering paradigm for patient safety: designing to support the performance of the healthcare professional. Qual Saf Health Care 2006;15:i59–65.

[3] Carayon P, Wetterneck TB, Rivera-Rodriguez AJ, et al. Human factors systems approach to healthcare quality and patient safety. Appl Ergon 2013.

[4] Carayon, P. 2010. "Human factors in patient safety as an innovation". *Applied Ergonomics* 41, 657–665.

[5] Gurses, A.P., A.A. Ozok, and P.J. Pronovost. 2012. "Time to accelerate integration of human factors and ergonomics in patient safety". *BMJ Quality & Safety* 21 (4), 347–351

[6] Wilson JR. Fundamentals of ergonomics in theory and practice. Appl Ergon 2000;31:557–67.

[7] Norris BJ. Systems human factors: how far have we come? BMJ Qual Saf 2011;21:713–14.

[8] Chadwick L, Jeffcott S. A brief introduction to human factors engineering. *Transfusion* 2013; 53:1166-1167.

[9] National Quality Board. 2013. *Human Factors in Healthcare: a Concordat from the National Quality Board.* http://www.england.nhs.uk/wp-content/uploads/2013/11/nqb-hum-fact-concord.pdf (Accessed 25th January 2016).

[10] Royal College of General Practitioners Curriculum (2010). Revised 14th Aug 2013. http://www.rcgp.org.uk/gp-training-and-exams/gp-curriculum-overview.aspx.

[11] General Medical Council. *Good Medical Practice* http://www.gmc-uk.org/static/documents/content/Good_medical_practice_-_English_0414.pdf Accessed 5th March 2016

[12] Vicente, K. J. (1999) Cognitive Work Analysis, New Jersey, Lawrence Erlbaum Associates.

[13] Beasley JW, Escoto KH, Karsh BT. *Human Factors and Ergonomics in Primary Care*. Chapter 51, 921-935. In Handbook of Human Factors and Ergonomics in Health Care and Patient Safety [edited by Pascale Carayon] Lawrence Erlbaum Associates, 2007: NJ

[14] Moray, N., 1979, Mental Workload Its Theory and Measurement (New York: Plenum Press).

[15] Folkman,S. (1984). Personal Control and Stress and Coping Processes: A Theoretical Analysis. Journal of Personality and Social Psychology 1984, Vol. 46, No. 4, 839-852

[16] Health and Safety Executive (1999). 'Validation and Development of a Method for Assessing the Risks Arising from Mental Fatigue'. Contract Research Report 254/1999. ISBN 0 7176 1728 9

[17] Hutton,R.J.B and Klein,G (1999).Expert Decision Making. *Systems Engineering* 2;1 32-45.

[18] Kahneman,D (1991) Judgement and Decision Making: A Personal View. Psychological Science, 2, 3. P142-145.

[19] Flin,R., O'Connor,P and Crichton,M (2008). Safety at the Sharp end – A guide to Non-Technical Skills. Ashgate Publishing company, Surrey.

[20] Maria Ahmed, Sonal Arora, John McKay, Susannah Long, Charles Vincent, Moya Kelly, Nick Sevdalis and Paul Bowie. Patient safety skills in primary care: a national survey of GP educators. *BMC Family Practice* 2014; 15:206 DOI: 10.1186/s12875-014-0206-5

[21] Corlett, E N, and Clark, T S, (1995). The Ergonomics of Workspaces and Machines. A Design Manual. (Second Edition) London: Taylor & Francis.

[22] Sevdalis,N (2013). Non-technical skills and the future of teamwork in healthcare settings. The Health Foundation, London: UK.

[23] Carayon P, Hundt AS, Karsh B-T, et al. Work system design for patient safety: the SEIPS model. Qual Saf Health Care 2006;15:i50–8.

[24] Russ A, Fairbanks RJ, Karsh BT, et al. The science of human factors: separating fact from fiction. BMJ Qual Saf 2013 22: 802–808.

[25] De Wet C, Spence W, Mash B, Johnson P & Bowie P. The development and psychometric evaluation of a safety climate measure for primary care. *Quality and Safety in Health Care* 2010, 19(6):578-584

[26] Scottish Patient Safety Programme in Primary Care.
http://www.scottishpatientsafetyprogramme.scot.nhs.uk/programmes/primary-care
[Accessed 1st March 2016]

[27] Health and Safety Executive (2011). High reliability organisations – A review of the literature. Health and Safety Executive Research Report RR899; UK

[28] Woods,D.D., Johannesen,L.J., Cook,R.I and Sarter,N.B (1994). Behind Human error: Cognitive Systems, Computers and Hindsight. Wright-Patterson Air Force, OH: Crew Systems Ergonomics Information Analysis Centre.

[29] Dekker,S (2003). Failure to adapt or adaptations that fail: contrasting models on procedures and safety, Applied Ergonomics, 34: 233-238.

[30] Bowie P, Ferguson J, Macleod M, et al. Participatory design of a preliminary safety checklist for general practice. Br J Gen Pract 2015; 65: e330–e340.

[31] Hollnagel E, Woods DD, Leveson N.. Resilience engineering: concepts and precepts. Ashgate, 2006.

[32] Hollnagel,E (2009). The ETTO Principle – Efficiency: Thoroughness Trade-Off. Ashgate, Surrey.

[33] Catchpole K. Spreading human factors expertise in healthcare: untangling the knots in people and systems. BMJ Qual Saf 2013 22: 793–797

[34] Department of Health (2009). Primary and community care Health Building Note 11-01: Facilities for primary and community care services. https://www.england.nhs.uk/mids-east/wp-content/uploads/sites/7/2014/07/health-build-pc.pdf [Accessed 4th April 2016]

[35] Hignett, S., E. Jones, D. Miller, L. Wolf, C. Modi, W. Shahzad, J. Banerjee, P. Buckle, and K. Catchpole. 2015. "Human Factors & Ergonomics and Quality Improvement Science: Integrating Approaches for Safety in Healthcare". *BMJ Quality & Safety* 24, (4), 250-254.

[37] Greig PR, Higham H, Vaux E. Lack of standardisation between specialties for human factors content in postgraduate training: an analysis of specialty curricula in the UK. BMJ Qual Saf 2015;0:1–3.

Figure 1. Examples of GP trainee interactions with colleagues and settings
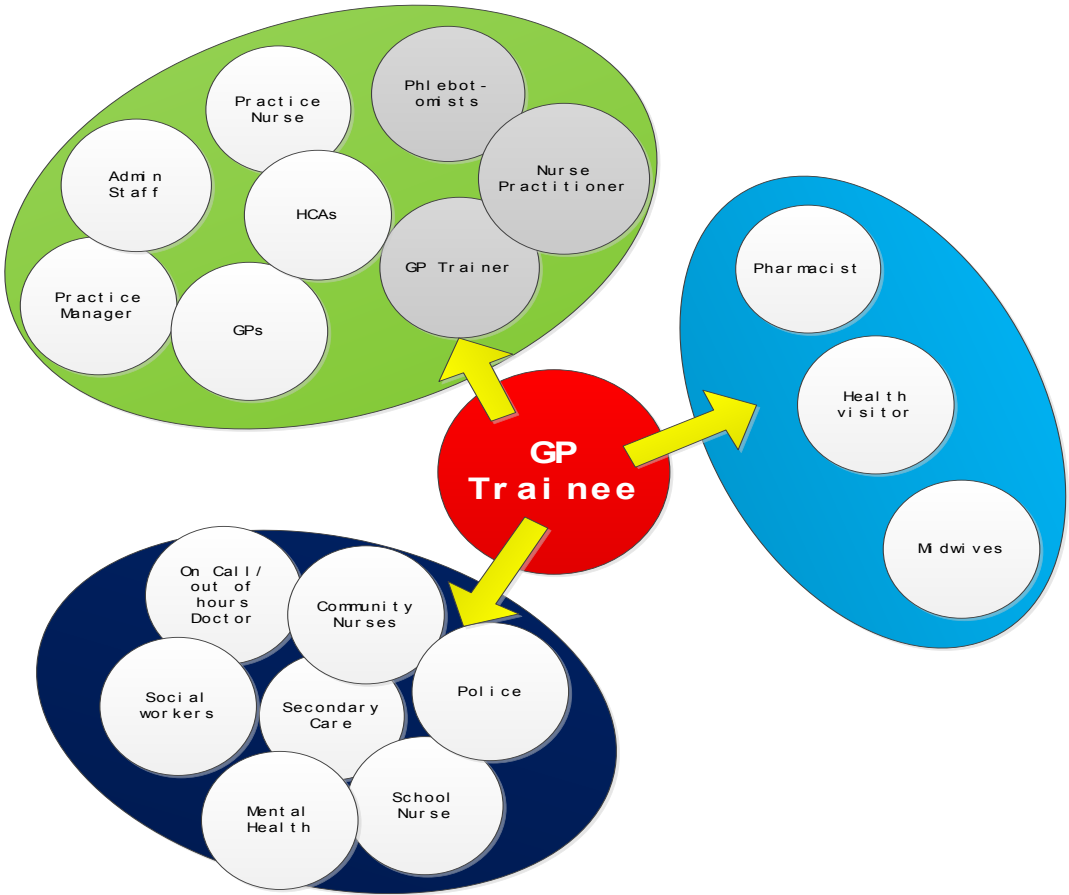
Figure 2. Interacting systems model for HFE (Wilson, 2000)
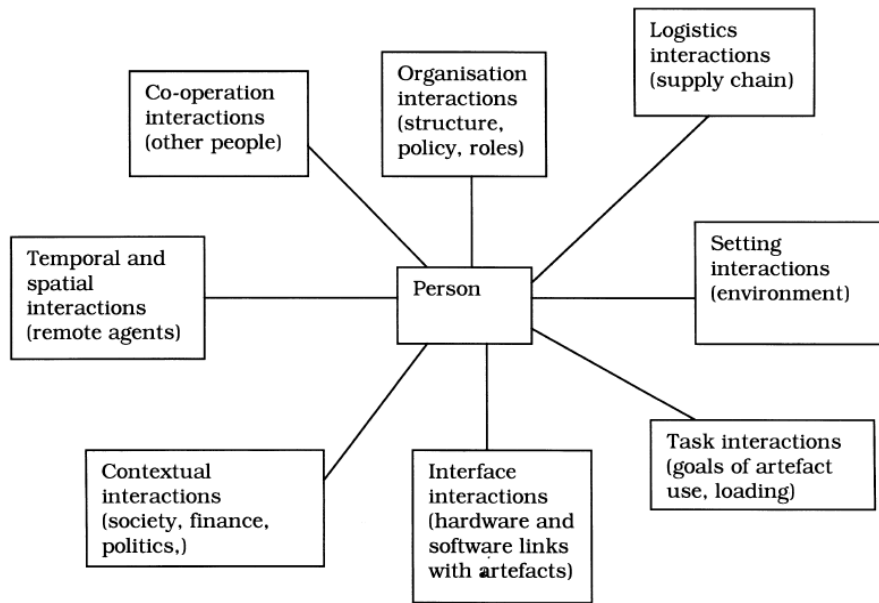
Figure 3. Possible integration of HFE concepts and approaches within existing RCGP training curriculum

HFE Concept	QI and SEA	Reflective log entries	CBD	COT	MSF	PSQ	ESR
Complex sociotechnical Systems	●	●	●				
Human cognition	●	●	●	●			
Work-related stress	●	●					●
Fatigue	●	●					●
Workload	●	●	●				
Decision-making	●	●	●	●		●	
Non–technical skills	●	●	●	●	●	●	
Physical workplace	●	●					
Equipment and technology	●	●	●	●			
Teamwork	●	●	●		●		
Communication	●	●	●	●	●	●	
Work Organisation	●	●					
Safety Culture	●	●	●		●		
Procedures	●	●	●				
Safety, human reliability and risk assessment	●	●	●				
Social and Cultural Pressures	●	●	●				

CBD - Case based discussion; COT - Consultation Observation Tool; MSF - Multi-source feedback; PSQ - patient satisfaction questionnaire; ESR - Educational Supervisor's Report

Online Appendix 1. Example of Abstraction Hierarchy of an accredited training practice

Accredited GP training surgery

Functional Purpose

Provide holistic medical care	Gatekeeper to secondary care	Optimise local community health	Commission local health services	Manage demand and cost of general NHS – ensure 'value for money'	Education

Values and Priority

Interpretation of patient requirements - patient satisfaction	Best practice, effective, high quality & safe patient management – NICE/SNC, Never events, reports of adverse events	Community health metrics – D.O.H	Confidential & accurate documentation – audit/legislation	Efficiency and sustainability of GP surgery – patient care, & QOF/17C/2C performance, prescribing audit	Competence of staff – patient complaints/ incidents/pass rate of trainees	Staff wellbeing – sickness and absence/staff turnover

Purpose Related Function

Triage	Patient consultation	Propose diagnosis	Treat patient	Prescribe	Refer patient	Investigate patient	Communicate patient information	Evaluate practice performance	Educate	Evaluate competence	Support

Object Related Function

Match patient : clinician	Communicate with patient	Identify patient symptoms	Physically examine patient	Propose differential diagnosis	Check results	Request investigations	Obtain relevant samples	Supervise	Evaluate competences Scenario/patient cases	Consult educational/ professional resources

Identify patient — observe patient — Classify stability of condition — Perform clinical decision making — Issue prescription — Record consultation — Administer treatment — Dictate referral — Provide/attend tutorials — Deliver emergency care — Provide pastoral care

confirm patient identity — Obtain` past/current medical history — Perform Clinical reasoning — Evaluate cost :effectiveness of intended treatment — Maintain patient trust — Manage patient's expectations — Identify patient preferences

Physical Objects

EMIS/ VISION — DOCMAN — SCI gateway — Digital dictation system — Stethescope — laryngoscope — Prescription papers — Administrative staff — GP trainers — Nurses — GPs — Telephone — IT training

Oxygen — Couch — Consultn room/ patient's home — Treatment room — Tendon hammer — Thermometer — Sphygmom anometer — Swabs — Sample receptacle — Domestic staff — Practice manager — Printers — Admin collection points — Surgery policies/ procedures

Tuning fork — Desk — Emergency bag — Reception — Pulse oximeter — auriscope — Needles — Blood Vials — Phlebotomist/ HCAs — Defibrillator — Emergency trolley — Medical resources e.g. books, websites, journals

Patient — Blood pressure monitor — Nebulisers — Chairs — Peak flow meter — Toungue depressor — Blood glucose monitor — Request forms — Appointment time — National guidelines