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The Chartered Institute of Ergonomics and Human Factors at 75: perspectives on contemporary challenges and future directions for Ergonomics and Human Factors

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ABSTRACT

As the UK's Chartered Institute of Ergonomics and Human Factors (CIEHF) celebrates its 75th anniversary, it is worth reflecting on our discipline's contribution, current state, and critical future endeavours. We present the perspectives of 18 EHF professionals who were asked to respond to five questions regarding the impact of EHF, contemporary challenges, and future directions. Co-authors were in agreement that EHF's impact has been only limited to date and that critical issues require resolution, such as increasing the number of suitably qualified practitioners, resolving the research-practice gap, and increasing awareness of EHF and its benefits. Frequently discussed future directions include advanced emerging technologies such as artificial intelligence, the development of new EHF methods, and enhancing the quality and reach of education and training. The majority felt there will be a need for EHF in 75 years; however, many noted that our methods will need to adapt to meet new needs.

Practitioner statement: This article provides the perspectives of 18 Ergonomics and Human Factors (EHF) professionals on the impact of EHF, contemporary challenges and critical future directions, and changes that are necessary to ensure EHF remains relevant in future. As such, it provides important guidance on future EHF research and practice.

Abbreviations: CIEHF: Chartered Institute of Ergonomics and Human Factors; CWA: Cognitive Work Analysis; EAST: Event Analysis of Systemic Teamwork; EHF: Ergonomics and Human Factors; FRAM: Functional Resonance Analysis Method; HMI: Human Machine Interaction; HTA: Hierarchical Task Analysis; SQEPs: Suitably Qualified and Experienced Persons; STAMP: System-Theoretic Accident Model and Processes; SWARM: Schema World Action Research Method

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Ergonomics and human factors; impact; contemporary challenges; future directions

1. Introduction

Since its inception 75 years ago, the UK Chartered Institute for Ergonomics and Human Factors (CIEHF) has become a cornerstone within our discipline, helping to advance the science of EHF, providing a platform to connect, develop, and support researchers and practitioners, and acting as a thought leader on several critical societal issues. With the world changing considerably over the past seven decades, the CIEHF has played an instrumental role in the evolution of EHF, facilitating the development and refinement of EHF practice, helping address societal challenges impacting work, health, and well-being, and expanding our reach into novel domains and problem spaces.

But what of the discipline it serves? With EHF now well over 100 years old (Moray 2008), the discipline is

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arguably at a critical juncture. Despite much endeavour, there are a set of longstanding societal issues that remain unresolved. These include issues that have been at the forefront of EHF research and practice for many years, such as workplace harm, road trauma, and patient safety to name only a few. Further, society faces a growing set of global level risks that are highly complex, hard to predict, and extremely difficult to manage (e.g. World Economic Forum 2023). Some of these are existential in nature, threatening both our future and that of our habitat. The role of humans in future work is unclear, and the technologies that humans interact with on a daily basis are becoming so advanced that a future where technology surpasses human intelligence is increasingly likely (Salmon et al. 2023). Questions can quite rightly be posed regarding what EHF has achieved to date, what challenges it faces moving forward, and how the discipline will need to change to stay relevant. This special issue celebrating the 75th anniversary of the CIEHF is the perfect place to pose such questions.

In this commentary article we present the perspectives of a cohort of EHF professionals based on their responses to five questions concerning the impact of EHF, contemporary challenges for the discipline, critical future directions, changes required moving forward, and the need for EHF in future. Eighteen current EHF researchers and practitioners were invited by the first author to contribute. Co-authors were invited based on the lead authors collaborative relationships and current membership of the UK Chartered Institute of Ergonomics and Human Factors. In addition, the invitations were designed to ensure an equal split in terms of gender and researchers versus practitioners. Finally, given that each co-author was given a limit of 500 words to respond to the questions, a limit of 18 co-authors was imposed to ensure that the paper length did not go beyond journal requirements.

The co-authors comprise EHF researchers and practitioners with expertise and experience in a diverse set of EHF concepts, methods, areas, and problem domains (see Appendix A). They include a mix of early, mid-career, and senior professionals (9 male, 9 female), with nine identifying as researchers, six as practitioners, and three as both researcher/practitioner. The co-authors currently work in EHF-related roles in the UK, Australia, USA, Canada, and Europe and have on average 23.13 years' experience (SD = 8.99) working in EHF. Co-authors were asked to report their top 3 areas of EHF expertise, domains in which they have applied EHF, and their most frequently applied EHF methods. The most frequently reported areas of expertise were cognitive ergonomics (12, e.g. workload, situation awareness, decision making, human error), systems HFE (10, e.g. systems HFE, systems thinking, systems analysis and design, and sociotechnical systems), design (9, e.g. design, human-centred design, participatory design, interface design), and safety (6, e.g. safety, accident investigation and analysis, safety science). The most frequently reported domains of application were transport (26, e.g. road, rail, aviation, maritime), healthcare (9, e.g. healthcare, medical, health and social care), and defence (4). The most frequently reported EHF methods were Cognitive Work Analysis (CWA; Vicente 1999) and Hierarchical Task Analysis (HTA; Annett, et al. 1971), both reported by seven co-authors, followed by AcciMap (Svedung and Rasmussen 2002) (5), and interviews (4).

Each co-author was asked via email to provide a written response to the following questions:

1. On a scale of 1 (*Not having any impact at all*) to 10 (*Achieving its full desired impact)*, how would you rate the impact that EHF is currently having on the world?
2. What do you see as the top three most important contemporary challenges for the discipline of EHF?
3. What do you think are three critical future directions for EHF research and/or practice?
4. What changes are required to ensure that EHF can fulfil its potential impact over the next 75 years?
5. Will there be a need for EHF in 75 years' time? Why?

Summaries of the most frequently discussed responses are presented for each question. A summary of the co-author responses to all five questions is presented in Table 1.

2. On a scale of 1 (*not having any impact at all*) to 10 (*achieving its full desired impact),* how would you rate the impact that EHF is currently having on the world? Please explain why you gave the rating you did

The co-author ratings for the impact of EHF are presented in Figure 1. The mean rating of the impact of EHF was 4.95 (SD = 1.65).

Example co-author responses for the lowest, middle, and highest ratings are presented below.

Broadbent: Impact score 2 out of 10. The impact can be great but the influence we have I think is about 2. Certain industries are held up as shining examples of where EHF is accepted and integrated, but even in those areas getting EHF fully incorporated can be a challenge, let alone in other, less familiar industries.

Table 1. Summary of co-author responses.

Author	Impact	Contemporary challenges	Future directions	Necessary changes	Need for EHF in 75 years
Broadbent	2	1. Increasing awareness of EHF 2. A lack of Suitably Qualified and Experienced Persons (SQEPs) 3. Rapid advances in technology	1. Advanced emerging technologies 2. Healthcare 3. Development of new EHF methods	1. Enhanced collaboration between researchers and practitioners 2. Enhanced collaboration with other disciplines 3. Development of new EHF methods	Yes
Burns	6	1. The need for inclusive EHF methods 1. Rapid advances in technology 2. Loss of discipline expertise	1. Development of new EHF methods 2. Encouraging deep technical expertise (e.g. AI) 3. Developing participatory research and design frameworks	1. EHF needs to be part of the core curriculum for engineering and computer science programs 2. Improved EHF training and education	Yes
Chari	3	1. Increasing complexity of work and societal systems 2. Rapid advances in technology 3. Global risks	1. EHF's identity crisis 2. Under-utilisation in certain areas 3. Long-term large-scale collaborations	1. Maintaining a consistent and coherent identity 2. Improved EHF training and education	Yes
Clay-Williams	5	1. Rapid advances in technology 2. Increasing complexity of work and societal systems 3. Increasingly dynamic nature of work and societal systems	1. Advanced emerging technologies 2. Facilitating the adoption of EHF solutions 3. Increasing awareness of EHF	1. Development of new EHF methods	Yes
Hancock	3	1. Increasing awareness of EHF 2. Lack of integration of quantitative and qualitative methods 3. Naïve realism	1. Advanced emerging technologies 2. Exception processing 3. Machine psychology	1. Involvement in work focused on human-machine intimacy	Yes
Jenkins	5	1. A lack of SQEPs 2. Research-practice gap 3. Non-regulated fields	1. Global risks 2. Increasing the number of SQEPs 3. Enhanced collaboration between researchers and practitioners	1. Expanding the reach of EHF beyond highly regulated fields 2. Increasing the number of SQEPs 3. Improved EHF training and education	Yes
Mills	8	1. Rapid advances in technology 2. Increasing automation 3. Ageing workforce	1. Increasing automation and human-machine interactions 2. Changing workforce demographics 3. Sustainability	1. Increasing awareness of EHF and its benefits 2. Development of new EHF methods	Yes
Parnell	6	1. Conveying the value of EHF 2. Moving beyond human error 3. A lack of SQEPs	1. Trustworthy human-automation relationships 2. Development of new EHF methods 3. Equity, diversity, and inclusivity	1. Increasing the number of SQEPs 2. Improved EHF training and education 3. Rebranding	Yes
Plant	7	1. Increasing awareness of EHF 2. Ensuring that EHF methods are fit for purpose 3. 3. Research-practice gap	1. Global risks 2. The automation paradox 3. Equity, diversity, and inclusivity	1. Development of new EHF methods 2. Increasing awareness of EHF and its benefits	Yes
Read	5	1. Rapid advances in technology 2. Automation and its impacts on worker health and wellbeing 3. The interconnectedness of societal risks	1. Theoretical development 2. Gathering evidence on the utility of EHF 3. Research-practice gap	1. Increasing awareness of EHF and its benefits 2. Increasing the number of SQEPs	Yes
Salmon	5	1. Gathering evidence on the utility of EHF 2. Research-practice gap 3. A lack of SQEPs	1. Advanced emerging technologies 2. Global risks 3. Systems thinking	1. Enhanced collaboration with other disciplines 2. Gather evidence on the utility of EHF 3. Remove the research-practice gap 4. Increasing the number of SQEPs	Yes
Sharples	7	1. Maintaining the importance of humans in systems 2. A lack of SQEPs 3. Collaboration with other disciplines	1. Advanced emerging technologies 2. Future of work 3. Development of new EHF methods	1. Increasing awareness of EHF and its benefits 2. Evolution of the discipline 3. Enhanced collaboration with other disciplines 4. Improved EHF training and education	Yes

(*Continued*)

Table 1. Continued.

Author	Impact	Contemporary challenges	Future directions	Necessary changes	Need for EHF in 75 years
Shorrock	4	1. Staying relevant 2. A lack of SQEPs 3. Convincing key decision makers to recruit EHF professionals	1. Distinguishing Human Factors and Ergonomics 2. Getting practitioners in senior positions 3. Advanced emerging technologies	1. Attraction of personnel from other disciplines 2. Work on the biggest issues the most influential people	No
Stanton	3	1. Rapid advances in technology 2. Increasing awareness of EHF 3. Reliability and validity of EHF methods	1. Theoretical development 2. Development of new EHF methods 3. Development of predictive methods	1. Growing the size and influence of EHF 2. Improved EHF training and education 3. Increasing the number of SQEPs	Yes
Walker	3	1. Rapid advances in technology 2. Industry 4.0 3. An increasingly interconnected and data-rich world	1. Advanced emerging technologies 2. Systems thinking 3. Big data	1. Rebranding 2. Remove the distinction between researcher and practitioner 3. Clarifying our value proposition 4. Gathering evidence on the utility of EHF	No
Waterson	7	1. Climate change and the environment 2. Mutual respect between practitioners and researchers 3. Development of EHF courses	1. Advanced emerging technologies 2. Healthcare 3. Many model thinking	1. Less self reflection 2. Learning from the past 3. Opening out our discipline to others	Yes
Williams	5	1. Asserting the need for system design to be human centred 2. Rapid advances in technology 3. Clearly articulating EHF problems and solutions	1. Continuing core EHF activities 2. Revisiting assumptions in techniques and approaches 3. Allocation of functions	1. Improved EHF training and education	Yes
Young	5	1. Research-practice gap 2. Reliability and validity of EHF methods 3. The need to establish cost benefit ratios for EHF methods	1. Sustainability 2. Ageing population 3. Advanced emerging technologies	1. Increasing the number of SQEPs 2. Improved EHF training and education	Yes

Chari: Impact score 3 out of 10. At one level, EHF has been profoundly impactful in society. We can trace design features within virtually any human-oriented technology today to earlier contributions from cognitive systems and physical ergonomic concepts. Equally, as a formal discipline, EHF is vastly underutilised except in a very small number of sectors. Based on this – I would say HFE has had widespread impact but is vastly underutilised.

Hancock: Impact score 3 out of 10. We remain a small and esoteric part of the academy and insufficiently well-known or even acknowledged in the professions upon which we ought to have greatest impact. Our name recognition issue persists and 'ASPIRE' is not the solution to this challenge.

Stanton: Impact score 3 out of 10. I would say that the impact of EHF is patchy at best. That's not because of a lack of good research or practice, rather it is due to the lack of understanding by potential consumers of all that EHF has to offer together with competition over limited financial resources. EHF is often seen as a nice-to-have, rather than essential, and can sometimes be traded out of projects (or its input reduced to the bare minimum).

Walker: Impact score 3 out of 10. This is in no way a reflection of some truly excellent work – and equally excellent EHF colleagues – but an indication of the unmet potential of the discipline. The world needs EHF more than ever before but its impact seems to lessen with every passing year.

Shorrock: Impact score 4 out of 10. There is a lack of EHF practitioners to integrate into settings that could benefit such as healthcare, road transport, and agriculture. There is also confusion about what EHF is, the difference between Ergonomics and Human Factors, how it differs from Human and Organisational Performance (HOP) and safety differently, and the benefits.

Read: Impact score 5 out of 10. EHF has strong impact in the domains in which it is recognised (particularly where mandated by regulation or by industry standards), however it is not universally recognised in all relevant areas. I think the discipline has the potential to provide broader benefits to the world.

Salmon: Impact score 5 out of 10. If we think about our mission statement and what the discipline aims to do then it is clear we are not having the impact we desire. A key issue is our lack of evidence for the impact of EHF – even in domains where we have had a significant impact; we do not have robust evidence to show this.

Williams: Impact score 5 out of 10. First because the *full desired impact* of EHF is so ambitious. Balancing human flourishing and technical optimisation is a heady goal and one which is regularly missed. Second,

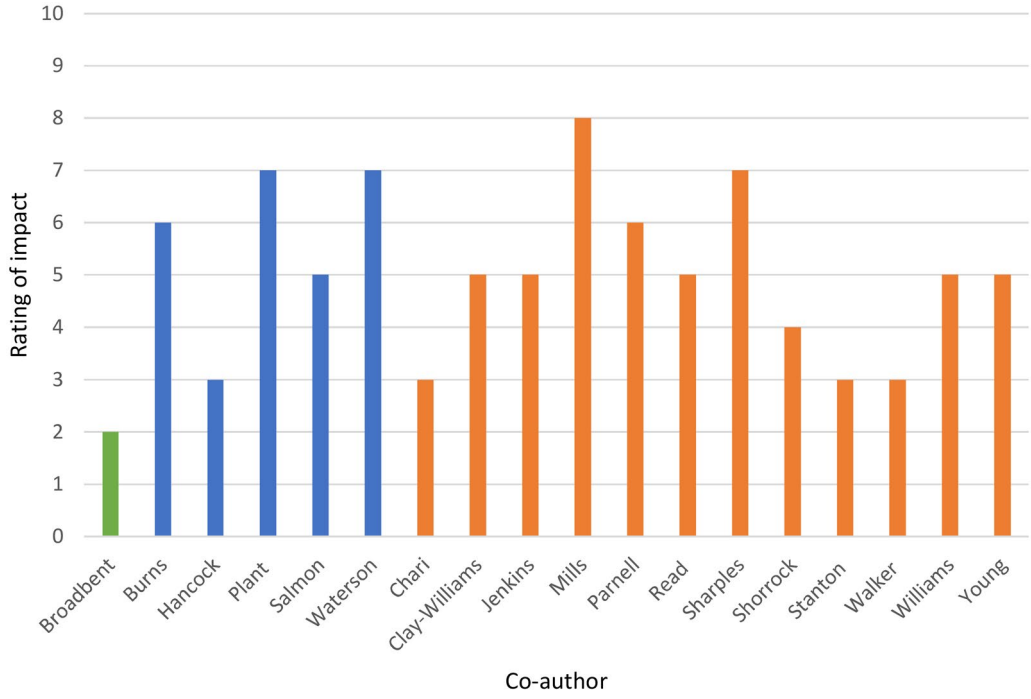

Figure 1. Co-author ratings of EHF's impact. Participants who identified as a researcher only are represented in blue, as a practitioner only in green, and as both researcher and practitioner in orange.

because there are still too few EHF professionals to have a place at all the tables where we are needed.

Young: Impact score 5 out of 10. Whilst our discipline has made much progress in 75 years, with its importance recognised across sectors such as defence, transport and healthcare, we still have a long way to go in terms of integrating EHF early in design processes, as well as better communicating the (socio-technical) nature of EHF: it is not just 'human error'.

Plant: Impact score 7 out of 10. Although this does seem to vary by domain. Overall, the impact is growing and what the discipline is capable of is more widely understood and valued. But there is still a way to go to close the research-practice gap and reduce misunderstandings around the scope of EHF.

Sharples: Impact score 7 out of 10. I think EHF specialists are having an impact on the world, but their work is not always recognised as being EHF. As a discipline, we develop people with fantastic multidisciplinary skills and an ability to deliver systems thinking in context. Those people can and do make a real difference.

Waterson: Impact score 7 out of 10. I'd probably split this – research 8, practice 6. Practice tends to lag behind research and whatever we may think we have a tremendous body of knowledge build up in what Karl Popper (1972) called 'world 3' (knowledge stored in books, libraries and now more online, electronic information). A lot of that knowledge stays on the shelf and I'm not clear as a researcher how I can best reach out to practitioners. I'm sometimes amazed by some of the brilliant things going on in practice (just hard to find out sometimes).

Mills: Impact score 8 out of 10. The importance of understanding interactions between humans and other elements of a system to influence performance, safety, useability etc is well understood in most safety critical industries – definitely in rail. Where it was once the preserve of aerospace and the military all our major engineering projects have EHF at their heart, our industry standards integrate EHF, and the development of new technologies and processes consider the humans that interact with them – a very different picture from when I joined the railways just after Ladbrook Grove!

3. What do you see as the top three most important contemporary challenges for the discipline of EHF?

The most frequently discussed contemporary challenges are presented in Figure 2. A summary of author responses relating to each theme is presented below.

3.1. Rapid technological advances

Broadbent: With new software, hardware and threats such as cyber creating new challenges to ensure the human is considered in the design and application.

Burns: Not a new challenge but the less EHF engages with our colleagues developing new

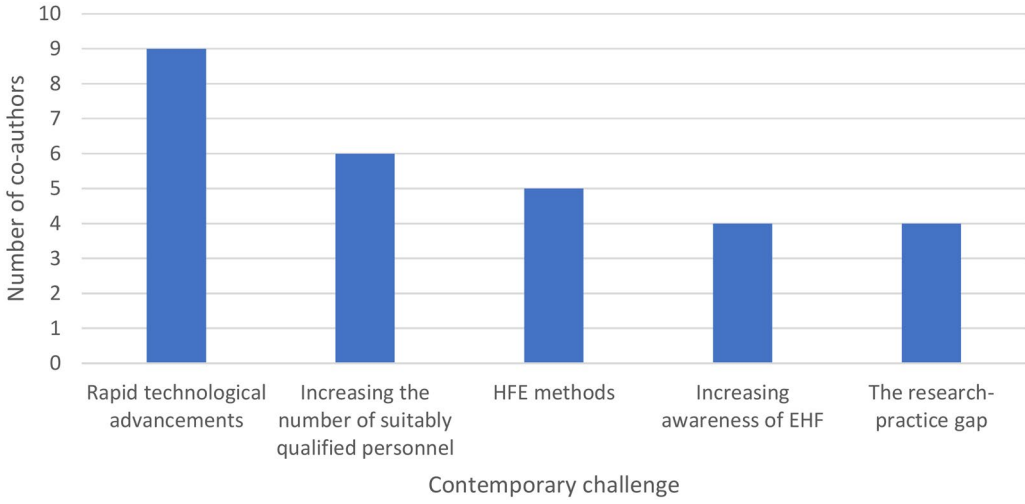

Figure 2. Most frequently discussed contemporary challenges for EHF.

technologies, the more likely it will be that EHF is considered only at the end of the design cycle. There is a need for EHF teams and researchers to join technology innovation at the start.

Clay-Williams: The obvious one is artificial intelligence (AI), which is going to change the context of work and requires new ways of thinking, doing and evaluating.

Mills: The increase in automation and the emergence of AI – how to embrace and distribute work to elements of the system best place to undertake the task. How do we manage this change and support our workforce during the change?

Read: EHF has a vital role to play in addressing the challenges associated with increasing advancements in AI. A key challenge relates to the urgent need for more EHF involvement in understanding and controlling the risks of future AI, especially the evolution towards artificial general intelligence/superintelligence. A related challenge is the current uptake of AI tools and resultant impacts on worker health, wellbeing, job satisfaction and sense of meaning in work. EHF is founded on notions of meaningful work and designing technology to match to human needs and ways of working (rather than the reverse). This is our core expertise and I believe we can have a stronger involvement in the design and integration of AI systems.

Stanton: Typically, EHF has chased technological developments rather than predicted them, although that is not always the case. Given the rapid rate of technological change, there is a significant challenge to be ready with the solutions for EHF problems that will be forthcoming (such as with highly automated vehicles – see Stanton, Revell, and Langdon 2021).

Williams: At a high level, we face the same challenge now as we ever have – making life better for people by resisting the primacy of technology, asserting the need for system design to be human-centred. I think huge strides were made in this over recent history, with human centred design becoming a wide-spread approach amongst many other professions, as well as our own. However, it seems that recent developments in AI have undone some of this progress – once again positioning technology in the driving seat (no pun intended). But this provides us with an opportunity. It seems our contemporary culture has noticed this slide towards the technological imperative and is looking for an alternative approach such as ours. The threefold challenge, then, is for us to articulate the problem clearly, outline our alternative well and then to provide practical advice about what to do.

3.2. Increasing the number of suitably qualified persons

Broadbent: The Ergonomist recently highlighted demand for our skillset growing across existing and novel industries, yet there is no undergraduate route to this and finding and developing Suitably Qualified and Experienced Persons (SQEPs) is a challenge. If we had one EHF specialist in every NHS trust (arguably nowhere near enough, but certainly better coverage than we have today), this would take up approximately half the current population of CIEHF members.

Burns: Many other fields are developing their own expertise in design and evaluation in parallel with, and sometimes in isolation from, our discipline. Generally this a good thing, as it shows more people are interested in safe effective human-centred design. But it does dilute the need for disciplinary expertise in EHF.

Jenkins: EHF is now mandated as part of the design process of many key sectors (e.g. medical devices, rollingstock, nuclear facilities). Combined with huge demand in adjacent fields (Fintech and tech), this has resulted in shortage of SQEP people. At the same time, supply has not kept up – there are very few undergraduate courses. Roles are often filled by people who are not really SQEPs.

Parnell: There is a lack of skilled EHF practitioners across organisations. This stems, in part, from a limited number of educational platforms and academic courses. Training those from other related fields could also help to increase awareness of EHF and its value.

Salmon: I am EHF's biggest fan, but there are some serious questions about our credibility as a scientific discipline. A major issue is the lack of SQEPs, which is linked to a lack of EHF courses. To be taken seriously it is critical that the people working in EHF roles are suitably qualified – this is clearly not the case in many areas.

Sharples: We need to ensure that we have enough people trained in an understanding of the holistic nature of EHF. This can be through dedicated courses but can also be on the inclusion of EHF as a topic in training for engineers and other professionals.

Shorrock: There are few courses – and almost none at undergraduate level – and so researchers and practitioners in the areas of system performance and human wellbeing will be attracted to other disciplines yet ultimately work in the same fields, whether in research or practice.

Waterson: Educational courses such as MSc courses – these are under threat worldwide and are vulnerable to cuts and cancellation. We are in danger of dying out as a profession.

3.3. EHF methods

Burns: EHF needs to evolve its methods to be inclusive of a wider range of different populations. We are learning that there are a lot of designs that would benefit from modern approaches that recognise sex and gender-based analysis to inform design.

Chari: EHF has an enviable tradition of innovation at the level of ideas and tools. As the nature of systems has changed over the past five decades, so has the discipline.

Clay-Williams: Increasing complexity means we will need to apply systems thinking to a greater degree and develop (or adapt) methods that can be applied at a system level.

Hancock: We have a lexicon of methods, but they remain a mish-mash between some mathematical models and many subjective assessment instruments. The two remain unintegrated. Hard sciences largely abhor subjective dimensions (still). One great issue is that many 'hard' scientists feel free to engage in unbound speculation about human behaviour (i.e. they are amateur experimental psychologists). The disapprobation they received for this is minimal. Should an experimental psychologist wander into a physics conference and then start speculating upon physics-based phenomena (especially well-established ones), they would be laughed out of court. We thus still face the 'naïve realism' challenge where all consider themselves quite expert at understanding human capabilities predicated upon their own naïve assumptions. This fallacy remains at the heart of our lack of recognition, or even dismissal.

Plant: Ensuring that our methods are fit for purpose in the truly digital age we find ourselves in is crucial. Many EHF methods are unsuitable for fully considering human-machine teaming and under (or cannot) represent the complexities of sociotechnical systems interaction and emergence.

3.4. Increasing awareness of EHF

Broadbent: As technology advances the need is greater than ever, but the basics of good EHF integration are still not present in many areas. Richard Bye talks of us being at the stage of EHF Infiltration rather than Integration.

Hancock: We are still the poor or even invisible cousin of most impact areas (even those focusing upon extensional challenges, e.g. sustainability). Our name recognition remains poor, especially in the quarters where it should be most evident. Diffuse efforts such as HIS, Aspire, Usability, etc., also don't hack it.

Parnell: To realise its full impact, the importance of EHF must be conveyed to other practitioners and members of the public who may not understand its benefits or have an incorrect understanding of its remit. This requires more awareness and visibility of EHF practises.

Plant: Perhaps more pervasive than contemporary is the challenges of ensuring the scope of EHF is fully understood; it is regularly equated to non-technical skills, rather than a discipline concerned with sociotechnical system interaction. In doing so, its value is misunderstood and status as a discipline in its own right reduced.

Shorrock: The discipline has become so broad and all-encompassing that it may be hard to differentiate from other disciplines both old (e.g. psychology, industrial engineering) and new (e.g. resilience engineering). The 'discipline' element may be stripped out by areas of practice such as HOP which are not disciplines.

3.5. Research-practice gap

Plant: We still have a way to go with closing the research-practice gap; all sectors bring unique contributions to the discipline, often with different priorities and metrics of success, but there is scope to better align these to reduce duplication of effort, to equip practice with cutting-edge approaches, and ensure impactful academic outputs.

Salmon: Differences in the theories and methods used by researchers and practitioners is a critical issue (Salmon et al. 2022; Shorrock and Williams 2016). There is no doubt we need far more consistency across researchers and practitioners as well as agreement on what methods and theories are state-of-the-art.

Young: One is bridging the research-practice gap (Chung and Shorrock 2011), which should be achievable for such an applied and practical field, yet in many areas there remains a mismatch between the work produced in academia and the needs of industry.

4. What do you think are three critical future directions for EHF research and/or practice?

The most frequently discussed critical future directions are presented in Figure 3. A summary of author responses relating to each theme is presented below.

4.1. Future advanced technologies

Broadbent: Human-autonomy teaming, adaptive autonomy, and trust should be tackled in research and practice. A recent paper on human augmentation stated, 'Future wars will be won, not by those with the most advanced technology, but by those who can most effectively integrate the unique capabilities of both people and machines'. This is as true in defence as it is in healthcare, rail and other safety critical industries.

Clay-Williams: There is an opportunity to lead in the adoption of AI, both in work but also in communities, rather than just being around to mop up the problems when things go wrong.

Hancock: Integration with Artificial General Intelligence (AGI): We have to be to the forefront of these developments. Most especially our knowledge of decision-making and memory mean we should be able to help lead in the distillation of the utility and shortfall of differing forms of Artificial Narrow Intelligence (ANI) and burgeoning AGI. Like many other areas, people assume they understand AI in the same way they believe they comprehend human abilities (somewhat by osmosis). We need to prove our value especially in human AI developments. The growing indeterminacy of AI-related processing also means that to understand the nuances and variations created by these systems we will need to understand their 'affordances' for action. This will be a new EHF area of focus (either us or an allied discipline).

Mills: The changing nature of work – greater automation and increased human-machine interaction modes the changing demographics of the workforce impact the way and where we work – the pace of change means we need to proactively understand the new hazards this brings such as more social isolation and emerging health impacts.

Parnell: The future will see increased integration of automated systems within society which will need to be trusted and trustworthy. Trust is a multidisciplinary

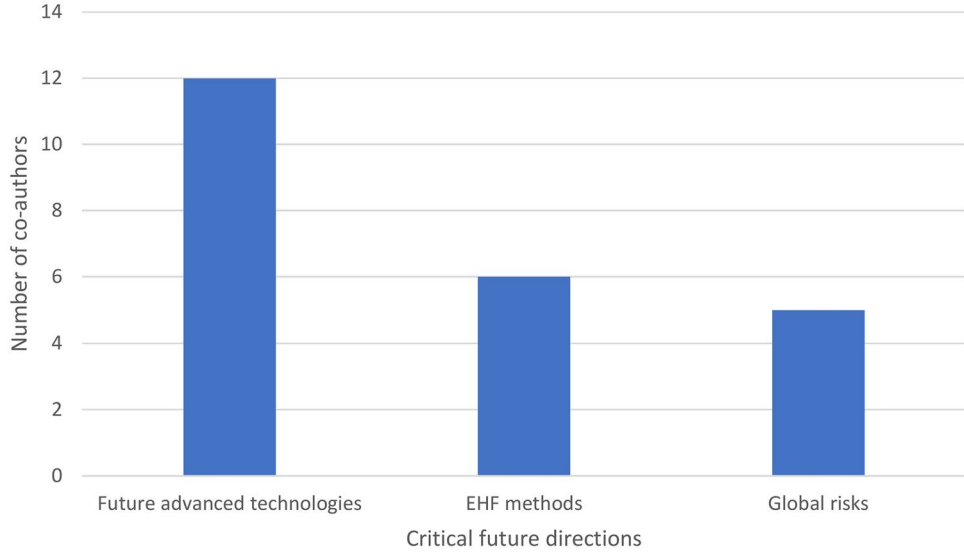

Figure 3. Most frequently discussed critical future directions.

issue, relying on effectively designed automation and appropriate user information. EHF has a significant role to play in the design of trustworthy automated systems and their effective integration into society. EHF will also need to adapt and develop methodologies that can keep pace with developments in technology, including automation and AI.

Plant: Uncertainty also comes from the exponential progress of 'intelligent machines', making the automation paradox more relevant than ever and bringing the need for EHF to design, deploy, regulate, and legislate trustworthy autonomous systems.

Salmon: AI is an obvious area where EHF should be taking centre stage to ensure that technologies are safe, ethical, and beneficial to humanity. Our inability to sufficiently impact the evolution of ANI is arguably our most significant failure as a discipline. With AGI the stakes are far greater – a similar failure could spell the end of humanity (Salmon et al. 2023).

Sharples: EHF knowledge and expertise must feed into design of complex sociotechnical systems that include an increasing amount of AI. The nature of many types of jobs is also changing rapidly as a result of novel technology. We need EHF to be influencing the wider discussion of the future of work. I'm disappointed that EHF is not seen as leading this discussion yet.

Shorrock: AI and Machine Learning: We risk being locked out of this because of the sheer speed of change and almost total lack of embedded EHF practitioners. We can only probably sound warning bells and more usefully seek influence at the most senior levels of organisations and governments.

Walker: The first future direction is simply to catch up with trends such as AI, agent-based modelling, and the panoply of tools and techniques needed to cope with an increasingly data rich environment.

Waterson: Some things are obvious future directions – I'm thinking of AI, data science and robotics – I see these as positive directions and not necessarily something to be feared (Waterson 2019).

Young: Most contemporary debates centre around the future of artificial (general) intelligence. There is clearly a need for EHF input in managing the risks associated with these developments, but recent calls (Salmon et al. 2023) have highlighted that we are not yet stepping up to the plate.

4.2. EHF methods

Broadbent: I'd like to see more adaptation of the new technological tools we have available to us as a discipline. Subjective measures remain very important but with objective data from psychophysiological methods we can strengthen evidence. Learning from industries such as gaming and UX is also key.

Parnell: EHF will need to adapt and develop methodologies that can keep pace with developments in technology, including automation and AI. Current methods may not be sufficiently complex, or they may not be able to account for new threats. Methods must be reviewed as the discipline evolves.

Sharples: We need to continue to develop methods and approaches that are usable in practice. Too many methods are strong theoretically, but difficult to apply in a real world context, or without significant training or expertise. If we are to truly embed EHF thinking, we need to enable more people to engage with EHF concepts and tools. Systems are complex, and therefore the methods to analyse them are also complex. Developing accessible methods to handle complexity in real world problems is key.

Stanton: In comparison with other Engineering disciplines, EHF is short on theory and long on methods (Stanton et al. 2005, 2013, 2014), but there is very little by way of integration (Stanton, Salmon, and Walker 2019). This can make EHF look very disparate. Typically, the seasoned researcher follows their favourite theory and the experienced practitioner uses their favourite methods. To the newcomer, it can seem rather bewildering and daunting. For this reason, I see the three critical future directions as the following:

1. Development and validation of sociotechnical systems theory, that draws all of the EHF domains and topics into an integrated framework;
2. Development and validation of a methodological framework that supports the sociotechnical systems theory; and
3. Development and validation of diagnostic and predictive methods that integrate into the methodological framework.

If it were possible to have a more systemic and systematic approach in the application of EHF, it could result in more consistent application across projects and domains.

Walker: At the time of writing the majority of EHF methods are still completed with MS Office tools or pen and paper. This is becoming archaic to the point of embarrassment. Data is also no longer the problem it used to be. Data is everywhere. EHF methods could be game changing in their ability to generate insight from this data, but there is little evidence it is happening currently.

Waterson: I'd like us to give up our obsession with building new methods – we make have reached 'peak

method'. There is a lovely book on adhocism in design and architecture written in 1972 which argues we need to reuse methods, tools and techniques in order to tackle problems (Jencks and Silver 1972, 2013). Something like this is also underway in the term 'many model thinking' (Salmon and Read 2019), but it could be taken much further.

Williams: I do think it is critical that we re-visit our assumptions for some of our key techniques and approaches, though. For example, the assumptions we have about which part of a system is allocated which function needs to be regularly reviewed as technology changes. Of course, we must do that whilst bearing in mind that, fundamentally, people do not change much; and therefore their needs, desires and capabilities must not be side-lined, even as we reconsider what technology is 'good at'.

4.3. Global risks

Jenkins: As a disciple we need to have a larger impact on largest challenges. The world is facing some huge, arguably existential, challenges (e.g. climate change, rising inequality, an ageing population). To have meaningful impact on these challenges, societies around the world need to rethink the way we live, the tasks we perform, and the artefacts that we interact with. These systems, tasks, and artefacts all need to be designed and EHF people should be at the centre of this design task. To be effective we need (1) the supply of SQEP people (2) the methods and tools (3) the influence that makes us heard (the seat at the table).

Plant: We find ourselves in uncertain times, whether through climate change, global inequalities, and international conflicts, EHF needs to demonstrate its value at contributing to the understanding of global challenges and how we might advance the (re)design of foundational systems of society; finance, work, healthcare, to ensure they are capable of optimising well-being and overall performance of our planet.

Salmon: Society faces a growing set of global risks that are complex, uncertain, and extremely difficult to manage. As a systems science and the discipline that has the core focus of enhancing human and health and wellbeing, EHF should be at the forefront of efforts to manage global risks (Salmon et al. 2021; Thatcher et al. 2020). Unfortunately we are not.

Young: The most important challenge must be sustainability, particularly with respect to the climate emergency. EHF has much to contribute at a socio-technical level and across all walks of life (see e.g. Thatcher and Yeow 2016), from consumer products (e.g. Combe et al. 2012), through transport (e.g. Young, Birrell, and Stanton 2011) to energy (e.g. Hamer, Waterson, and Jun 2021).

5. What changes are required to ensure that EHF can fulfil its potential impact over the next 75 years?

The most frequently discussed required changes are presented in Figure 4. A summary of author responses relating to each theme is presented below.

5.1. Improved EHF training and education

Burns: To have impact, EHF must seek to be part of the core curriculum of engineering and computer science programs, and education in EHF required for professional licencing in these other fields.

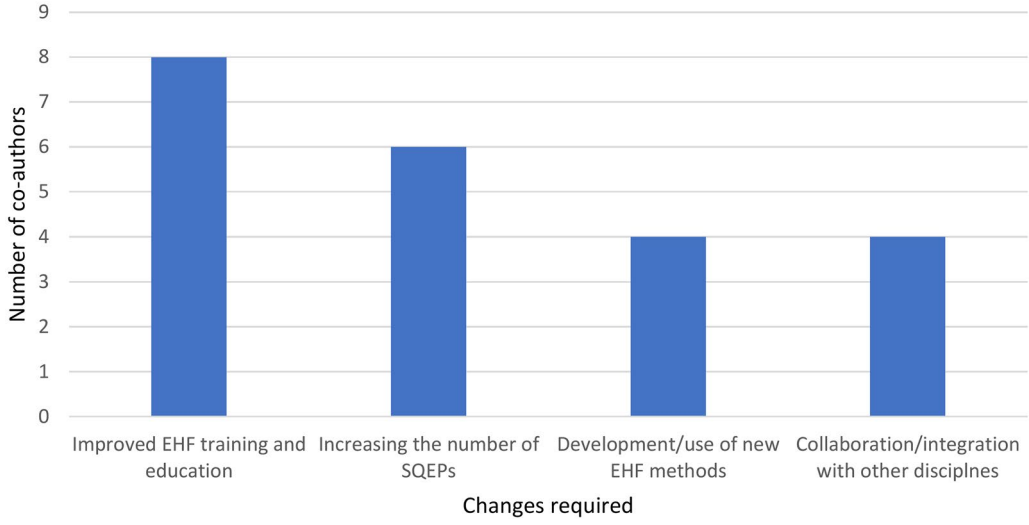

Figure 4. Most frequently discussed changes.

Jenkins: In the short term, we need to ensure that HFE practitioners can reach wider beyond highly regulated fields. To do this we need more SQEP people and we need to ensure that those we have, in the industry, are as efficient and effective as they can be. We need to address supply, the quality of training, and the quality of the tools.

Salmon: We need to remove the research-practice gap. It simply isn't acceptable for researchers and practitioners to be using different theories and methods – particularly when some of the theories and methods have been shown to be out of date and no longer fit for purpose. One obvious way to do this is through improved training for the future EHF workforce.

Sharples: We need to ensure that EHF education is as focused on new and emerging technologies as it is on fundamentals of the discipline.

Stanton: We need to attract many more people into the discipline, educate and train them appropriately, as well as proving that EHF is essential to the other disciplines. The variability in success of EHF projects can, to some extent at least, be due to the fact that different researchers and practitioners will tackle challenges in quite different ways (depending upon the theory and/or methods they ascribe to). Often there are many different paths that could be taken, although some are more likely to end in success than others.

Williams: One change that I think would be of huge benefit is to build in additional education in ethics and philosophy to our EHF programmes. I think the emergence of AI has encouraged lots of thinking about what it means to be human and also what human flourishing really is. Whilst ours is a scientific discipline, our craft as professionals should be informed by a wider understanding than only what we can learn from our science. Dr Joan Cahill's Human Factors and Ethics Canvas (HFEC) is a really helpful tool for this, I think.

Young: We need to bolster the training and education of the next generation not just to fulfil the potential impact of EHF, but merely in order for it to survive.

5.2. Increasing the number of SQEPs

Chari: The sub-fields that make-up the EHF 'diaspora' has been shaped considerably by the niches they occupy. Today, depending on which sector you pick, EHF can look like engineering, creative design, clinical biomechanics, or even computational modelling. While this speaks to its incredible inherent flexibility, how does EHF continue to project a consistent identity with the steady outward migration of the various circles that comprise the EHF 'Venn diagram'? How do we train for an increasingly speciated EHF workforce? These will be questions to contend with over the next 75 years alongside the potential impacts of rapid societal disruptions.

Parnell: More skilled EHF practitioners are required to fill the current skills gap and allow more industries to increase their EHF competency within their workforces. This requires more educational platforms to train up EHF practitioners, as well as allowing those from other professions to gain an understanding of EHF and how it plays a role within their field.

Read: I don't have much to add here that goes beyond what has been discussed at numerous HFE conferences, discussion panels and society board meetings. Of course, the more well-known HFE becomes, the more we will need to grow the discipline to meet demand. Finding ways to fast-track expertise while ensuring that quality HFE work is produced will be an important way forward.

Shorrock: Since we cannot attract large numbers of young people, we need to attract people with experience in other roles (e.g. in healthcare, transport, banking). But if full time jobs are not available, they remain educated in EHF but do not practice in any meaningful way.

Stanton: EHF needs to grow in size and influence, to at least that of other engineering disciplines. This means that we need to attract many more people into the discipline, educate and train them appropriately, as well as proving that EHF is essential to the other disciplines.

Young: There is great concern at the moment (in the UK, at least) about the pipeline of EHF specialists to meet future demands. In some respects, we have become a victim of our own success, in that many industries now recognise the importance of EHF and are seeking support, but the supply is not forthcoming. We need to bolster the training and education of the next generation not just to fulfil the potential impact of EHF, but merely in order for it to survive.

5.3. Development and use of new EHF methods

Broadbent: We have long been precious about our methods but we need to adapt and apply our own advice by using relevant language and approaches to be able to interact with other related areas such as wellbeing, systems engineering and AI. The use of modelling tools such as Model-based Systems Engineering (MBSE) and digital twins have long ignored the human component and we need to bend our traditional methods to fully integrate in these areas to ensure we make the impact required early on in design.

Clay-Williams: We need to invest further in research to develop and test new methods that are effective in complex and dynamic contexts. Unfortunately, a lot of our methods are still very linear in their approach and can lead the unwary in the wrong direction. We also need to develop simplified methods that can be used by non-HF professionals in their workplace, and a mentoring system to help workers apply them, as we will never have enough experienced HF professionals to complete the work that will be needed.

Mills: Undoubtedly our tools and techniques will need to evolve as the world of work does.

Plant: As a discipline we need to consider how our suite of methods is adapted to optimise them for application in the fully integrated sociotechnical systems of today. Digital technologies in almost every aspect of human activity are blurring the boundaries and changing the transactions that occur in these systems, can our methods truly represent human-machine teaming or the emergent properties of adaptable and resilient safety critical systems?

5.4. Collaboration and integration with other disciplines

Broadbent: Researchers and practitioners should be working closer together, not only in EHF but with related disciplines.

Burns: To have impact, EHF must seek to be part of the core curriculum of engineering and computer science programs, and education in EHF required for professional licencing in these other fields.

Salmon: We need to collaborate better with other disciplines – we tend to be seen as an insular discipline that doesn't play nicely with others. AI is a great example where we should be heavily involved but are not, simply because those developing AI do not know who we are or what we do.

6. Will there be a need for EHF in 75 years?

The authors responds are presented verbatim below.

Broadbent: Undoubtedly. The challenges of the next 75 years, from climate change to future transportation, space exploration, healthcare, the built environment and the rise of AI – all have clear requirements for the human considerations. Whether we are still labelled as EHF, the need for our skillsets will continue to grow.

Burns: Yes. Human innovation follows a pattern of exuberant innovation, followed by failure that results in the refinement of design to a stable and effective state of net progress. EHF is a field that is part of that process, particularly the latter stages. (I highly recommend Petroski's To Engineer is Human: The Role of Failure in Successful Design).

Chari: Absolutely (and perhaps not). If there is anything Sci-Fi teaches us it is that human-systems issues follow us to galaxies far away and near. Thus, EHF is needed for as long as there is human endeavour. Unfortunately, humanity could destroy itself within this time span and obviate any need for EHF.

Clay-Williams: The bucket of problems that can be improved with an EHF approach is bottomless and likely to increase in size with increasing complexity of the world in which we live. Wherever there are people, there will be a need to optimise their wellbeing and an EHF approach will provide a valuable contribution.

Hancock: Predicated upon the above, yes. But if disparate rates of development persist, probably not. It remains nice to believe in the centrality of human begins, but that may well be a false and failing assumption.

Jenkins: Undoubtedly yes! Humans will continue to innovate – new products and services will need to be developed, and these products and services should be designed based on solid EHF principles. Hopefully, more of these products and services, of the future, will be addressing meaningful challenges – climate change, inequality, an ageing population…

Mills: Of course – even with increased automation there is a human somewhere in the system! And of course the end user of the system and its outputs will be a human!

Parnell: Yes, I believe there will continue to be a need for EHF for many years to come, and this need may become even more important over time. Continual developments in automation and AI will not (and should not) leave the human redundant, instead the ways in which humans interact with systems will adapt, and this adaption will require EHF support and assessment. This work should aim in increase equality within society.

Plant: If we are still here, then yes. It remains to be seen whether complete digitisation or a return to more analogue choices will be the norm, but either way EHF principles and approaches will be essential to optimise the design of the sociotechnical systems we will live and work in.

Read: Assuming that humans have not become extinct or completely irrelevant, HFE will still be needed into the future. I suspect we will be addressing challenges we haven't yet thought of, and be working in new ways with AI collaborators, but the world will continue to need our expertise and values to inform future system design.

Salmon: If humans are still the dominant species then yes undoubtedly; however, if AI usurps us, then it

may not be needed or even permitted. It depends on what the AI decides to do with us…

Sharples: I describe EHF as 'Humans are fallible, and humans are brilliant'. Our job is to minimise the impact of human fallibility and maximise the value of human brilliance. I believe that the brilliance of people will still be critical in 75 years' time – and that EHF is key to ensuring that brilliance delivers the best possible sociotechnical systems.

Shorrock: No. The whole notion of disciplines and professions will change. There will be a need to solve design problems, system performance problems, and wellbeing problems, and manage complexity, but we will see transdisciplinary approaches and more competing approaches with added domain knowledge and skills. We will be subsumed into other areas.

Stanton: EHF will always have relevance, as long as there are humans in interacting with each other, systems, technology and their environment. As technological systems become more integrated and connected with our lives (such as smart homes and mobile technology), EHF has even greater relevance. This trend is extremely likely to continue.

Walker: There will be a critical need, but whether our niche discipline is up to the challenge is another question. I predict we will be swallowed up by a branch of human-centred big data analytics or AI. So for me, it is farewell EHF…it was nice knowing you.

Waterson: Yes, I certainly hope so. Maybe not in the form that we currently know it. I have positive and optimistic feelings for CIEHF, the International Ergonomics Association and the Human Factors and Ergonomics Society for example, but EHF is so much more than a Professional Society. It is very much in vogue to talk about transdisciplinarity in subjects such as design and the creative arts (Ozkaramanlia, et al. 2022). Aside from slight confusion about what that means I'd argue that EHF was one of the first to cross disciplinary boundaries. That won't change in the future and is worth celebrating in itself.

Williams: Yes. As long as there are people interacting with technological systems, EHF will have an important place. Those interactions will always need to be designed and, no matter how well designed, they will need regular revisiting as contexts and activities change.

Young: There will always be a need for EHF wherever humans are involved in a system. Nevertheless, given its interdisciplinary nature and the need for EHF integration in systems, there could be successful future where it no longer exists as a standalone discipline, but is just business as usual in engineering and design.

7. Summary

This commentary presents the perceptions of current EHF researchers and practitioners regarding the impact of EHF, contemporary challenges, critical future directions, changes required moving forward, and the need for EHF in future. It should be noted that the perspectives presented in this article represent only a small cohort of EHF professionals and therefore appropriate caution is urged when interpreting the findings. Future research should explore the views of a far larger and more representative cohort of EHF professionals via survey and a more formal analysis approach. As the CIEHF celebrates its 75th anniversary, it was our intention to initiate further discussion in terms of where we are as a discipline and where we need to go in future to ensure that EHF fulfils its mission statement of optimising human health and wellbeing across the broad spectrum of problem spaces it serves. Whilst each co-author perspective provides useful insight, to close we discuss recurring themes that, in our view, represent critical areas for further discussion and exploration.

The perceived impact of EHF was relatively low compared to its potential, although impact in certain sectors and contexts was recognised. Concerns over EHF's lack of impact have been raised previously, and there have been calls to gather more valid and robust evidence (Dul et al. 2012; Hendrick 1996; Koningsveld et al. 2005; Stanton and Young 1999). Future work should therefore seek to gather valid evidence on the impact of EHF in different areas and also explore the development of appropriate measures of impact. Concerns were raised regarding a lack of SQEPs, the current research-practice gap, and a lack of awareness of EHF and its benefits (both within our potential customer base and in other scientific disciplines). These issues are not new and have been previously discussed (Buckle 2011; Chung and Shorrock 2011; Dul et al. 2012; Karwowski 2005; Oakman et al. 2020; Read et al. 2021; Salmon et al. 2022; Shorrock and Williams 2016: Waterson and Sell 2006). Ongoing work should explore the development and implementation of appropriate solutions, with the CIEHF and other societies no doubt playing a key role.

The emergence of advanced technologies such as AI and eventually AGI was frequently cited, both as a contemporary challenge and a critical future direction for EHF. As noted elsewhere in the literature, there is a pressing and critical need to embed EHF within AI development programs worldwide, for EHF professionals to enhance our collaborations with those responsible for AI development and AI safety, and to consider what changes advanced AI will necessitate in our theories, methods, and practices (Salmon et al. 2023).

EHF methods were frequently discussed, which aligns with previous calls in the literature including the need to gather evidence to demonstrate that our methods work as intended (e.g. Stanton 2016), and the need to develop new methods that are more suited to the design and evaluation of advanced technologies (e.g. Salmon et al. 2023). Also discussed was the need to explore integration of our own tools with those used in other disciplines – an area not yet well explored in the literature. This represents an interesting area for further exploration, alongside vital work to examine whether contemporary EHF methods will remain fit-for-purpose given advances in technology, automation, and increases in the complexity, dynamicity, and interconnectedness of sociotechnical systems.

A final recurring theme related to the need for improved EHF training and education and the concomitant need to increase the number of SQEPs. Both have long been cited as key issues for EHF (e.g. Dul et al. 2012; Oakman et al. 2020; Read et al. 2022; Waterson and Sell 2006) and their frequent discussion here should serve as a reminder that they have not yet been resolved. Recommended actions included increasing the number, quality, and availability of academic and professional EHF courses, establishing EHF as part of the curriculum in other fields such as engineering and computer science, and ensuring that training courses focus on relevant societal issues such as advanced emerging technologies. As with the other issues identified the CIEHF will no doubt play a critical role in initiating and supporting the suggested responses.

To close we would like to congratulate the CIEHF on its 75th anniversary and acknowledge the significant role that it has played in the development, evolution, and impact of EHF. We wish it a long and successful future and hope this articles presents useful information to focus their future activities.

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Appendix A. Co-author demographics

Author	Current position	Researcher or practitioner	Institution / Organisation	Years experience applying EHF	Core areas of EHF expertise (Top 3)	Domains in which you have applied EHF (Top 3)	Most frequently applied EHF methods (Top 3)
Suzy Broadbent	Human Factors Specialist	Practitioner	Independent HF Specialist	*Researcher*: 0 *Practitioner*: 21	HMI design Cognitive workload Human autonomy teaming	Defence Healthcare Rail	Eyetracking Workload rating scales End user engagement
Catherine Burns	Professor	Researcher	University of Waterloo	*Researcher*: 30 *Practitioner*: 0	Work analysis Interface design Human-ai interaction	Healthcare, vehicles/automated vehicles, defence	Cognitive Work Analysis (CWA) Contextual design Functional Resonance Analysis Method (FRAM)
Satyan Chari	Program Director – Bridge Labs	Practitioner	Queensland Heath	*Researcher*: 12 *Practitioner*:19	Systems thinking and human-centred design Participatory ergonomics Organisational ergonomics	Health and social care	Participatory methods Everyday work exploration methods Systems-based tools
Robyn Clay-Williams	Associate Professor	Researcher	Macquarie University, Australia	*Researcher*: 16 *Practitioner*: 8	System/process evaluation and design Usability Cognitive/team skills training and evaluation	Healthcare Aviation	CWA FRAM Usability testing
Peter A. Hancock	Provost Distinguished Research Professor	Researcher	University of Central Florida	*Researcher:* 40 *Practitioner*: 0	Human-Machine Interaction Stress & Workload Trust	Aviation, Ground Transportation, Robotics	Meta-Analysis Experimental procedures Modelling and simulation
Daniel P. Jenkins	Research lead	Practitioner	DCA Design International	*Researcher*: 5 *Practitioner*: 15	Design Complex systems Use error	Medical Transport Consumer goods	Hierarchical Task Analysis (HTA) User studies CWA
Ann Mills	Deputy Director of System Safety and Health	Practitioner	Rail Safety and Standards Board	*Researcher*: 7 *Practitioner*: 23	Fatigue Culture Human performance/competency	Rail Aviation Oil and Gas	HTA Questionnaire/Interviews User trials
Katie Parnell	Senior Research Fellow in Human Factors Engineering	Researcher	University of Southampton, UK	*Researcher*: 8 *Practitioner*: 1	Sociotechnical Systems Human attention Interface design	Road transport Aviation Automation	AcciMap Perceptual Cycle Model Qualitative interviews/ workshops
Katie Plant	Associate Professor in Human Factors Engineering	Researcher	University of Southampton	*Researcher*: 15 *Practitioner*: 0	Decision making User centred design Application of methods	Aviation Road safety Defence	HTA AcciMap Schema World Action Research Method (SWARM)
Gemma J. M. Read	Associate Professor Psychology	Researcher	University of the Sunshine Coast, Australia	*Researcher*: 7.5 *Practitioner*: 9	Systems EHF Cognitive EHF Participatory design	Rail Road Healthcare	CWA STAMP AcciMap
Paul M. Salmon	Professor Human Factors	Researcher	University of the Sunshine Coast, Australia	*Researcher:* 22 *Practitioner*: 0	Accident analysis and prevention Systems analysis Situation awareness	Road transport Sport and outdoor recreation Workplace safety	CWA Event Analysis of Systemic Teamwork (EAST) AcciMap
Sarah Sharples	Chief Scientific Adviser, DfT and Professor of HF, University of Nottingham	Both	DfT and UoN	*Researcher*: 29 *Practitioner*: 5	Systems thinking Cognitive ergonomics EHF methods	Transport Manufacturing Healthcare	Structured observation Physiological monitoring Performance analysis
Steve Shorrock	Senior Team Leader Human Factors	Practitioner	EUROCONTROL	*Researcher*:4 *Practitioner*: 22	Culture (organisational, just, safety) Communication of EHF Human error	Aviation Rail Healthcare	Interviews (group and individual) Questionnaires Error analysis

(*Continued*)

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Author	Current position	Researcher or practitioner	Institution / Organisation	Years experience applying EHF	Core areas of EHF expertise (Top 3)	Domains in which you have applied EHF (Top 3)	Most frequently applied EHF methods (Top 3)
Neville A Stanton	Professor Emeritus in Human Factors and Director	Both	University of Southampton Stanton Psychological Services Ltd	*Researcher*: 38 *Practitioner*: 38	Systems HFE HFE methods Safety	Automobiles Aviation Maritime	HTA CWA EAST
Patrick Waterson	Professor	Researcher	Loughborough University (15 years)	*Researcher*: 25 *Practitioner*: 0	Safety science Accident investigation and analysis	Healthcare and many other safety critical industries	Task analysis AcciMap Other systemic accident analysis methods
Guy H. Walker	Professor	Both	Heriot-Watt University	*Researcher:* 24 *Practitioner:* 21	Systems ergonomics Sociotechnical systems Methods	Transport Accident analysis Defence	HTA EAST CWA
Claire Williams	Technical Director	Practitioner	CWC Ltd.	*Researcher*: 10 *Practitioner*: 19	Systems Thinking User centred design Ethics	Transportation Utilities Retail	Qualitative data gathering (interviews, deliberative techniques) Idealised design workshops Systems mapping
Mark S. Young	Professor of Human Factors in Transport	Researcher	Transportation Research Group, University of Southampton, UK	*Researcher*: 17 *Practitioner*: 11	Cognitive performance Accident analysis Sociotechnical systems	Automotive Rail Aviation	AcciMap Task analysis Workload measurement