Human-Centred Assessment of Human Augmentation Technologies

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SUMMARY

Human Augmentation (HA) technologies have been identified as a key future technology to enhance human performance, which could be of benefit in a range of contexts, including defence and security. However, there are a wide range of HA technologies, and limited methods available to evaluate the benefits and risks associated with their use. This project tested an approach to evaluating HA technologies that involved a modified version of the Ministry of Defence (MOD) Early Human Factors Analysis (EHFA). The HA EHFA was tested by applying it to the use of telexistence for use in battlefield medical care. The HA EHFA was successful in being able to identify the operational benefits, capability vulnerabilities, and ethical considerations associated with the technology. It is recommended that the HA EHFA be used to evaluate HA technologies for use in a defence and security context.

KEYWORDS

Human Augmentation, Early Human Factors Analysis

Introduction

Human Augmentation (HA) technology has been defined by the Ministry of Defence (MOD) as "*the application of science and technologies to temporarily or permanently improve human performance*" (MOD, 2021). HA technologies seek to improve performance of the user to, or beyond, their biological potential. As this technology continues to develop, there is a need to understand the potential benefits of HA for defence and security, whilst considering the safety, wellbeing, and performance of the user. This understanding is necessary to allow constrained budgets to be invested in the most promising technologies, to de-risk the use of HA technologies, and maximise its intended impact.

Work undertaken by QinetiQ on behalf of the Defence Science and Technology Laboratory (Dstl) has explored the use of the MOD Early Human Factors Analysis (EHFA) Methodology (MOD, 2016) to assess HA technologies. EHFA is typically used in the early stage of a procurement process, and is a structured and systematic method to identify the human-related benefits and risks of a technology.

EHFA could provide a means of characterising the benefits and risks of HA technology, as it ensures human capabilities, needs and limitations are taken into account across all contexts of use. EHFA is also a broad approach, covering all elements of human system integration including the context, equipment, organisation, operation, maintenance, training, health hazards, and system safety. This breadth would be beneficial for HA, as HA covers a wide range of technology types which have a range of different impacts for users.

The initial work concluded that a modified EHFA could be used to assess the use of HA technologies in a specified military context, but that further testing and piloting was required to refine and validate the process (Clerici, 2023).

A follow on task was undertaken, also funded by Dstl, which aimed to refine and test the HA EHFA in the context of an ongoing research programme. The task set out to review and validate the HA EHFA, and develop an HA EHFA Methodology Guide. Accordingly, the project was structured into three phases as shown in Figure 1.

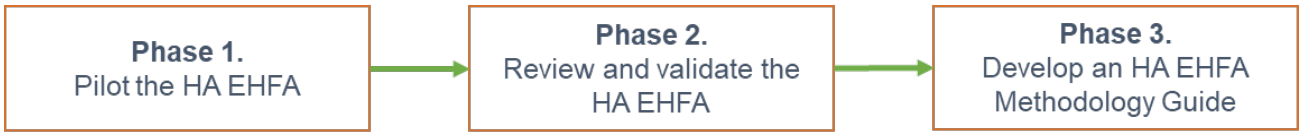

Figure 1: Project structure

This paper presents the outcomes from this project, with a focus on the development of the HA EHFA methodology.

Phase 1. Pilot the HA EHFA

The HA EHFA was piloted on the use of telexistence for battlefield medical care. Telexistence is the use of robotic avatars, operated remotely by a human in an immersive environment, to perform a task. Telexistence augments the human by allowing them to feel present in an environment other than the one they are currently in, allowing them to operate in that environment as if they were there. This use case was chosen to align with a Dstl research programme investigating the potential uses of telexistence. The pilot HA EHFA aimed to identify if telexistence could be applied to achieve competitive advantage in the context of battlefield medical care.

The first stage of the HA EHFA involved a review of telexistence documentation and interviews with two stakeholders. One stakeholder was an expert in telexistence the other in battlefield medical treatment. Two stakeholders was adequate for the pilot nature of the EHFA, and the emerging nature of the technology. A series of workshops were then used to establish, review, and score considerations associated with implementing telexistence in battlefield medical care. The considerations were documented in a Human Factors Integration Risks Assumptions, Issues, Dependencies, Opportunities, Ethical Concerns (HFI RAIDO-E) Register.

The HFI RAIDO-E Register for the use of telexistence for battlefield medical care contained 53 HFI considerations, of which there were 37 risks, 1 assumption, 6 dependencies, and 9 opportunities. No issues were identified. The HFI Considerations covered a range of technical areas. The majority related to equipment, process, and user integration. However, there were also HFI Considerations related to safety, social and organisational factors, training, and user characteristics.

Risks and opportunities were rated for their probability and impact, and this was used to generate an overall Probability-Impact Score between 1 and 6, using the scoring table in the MOD EHFA Methodology Guide (MOD, 2016). Assumptions and dependencies were not given a Probability-Impact Score, as they do not have a quantitative probability or impact. There was a spread of Probability-Impact Scores, as shown in Figure 2, indicating that the process was able to identify a subset of risks and opportunities as the most important for effective integration of the user. Examples of risks and opportunities with a high Probability Impact Score are:

- Reduced risk of harm to the Medic (opportunity);
- Trust (risk); and
- Casualty acceptance (risk).

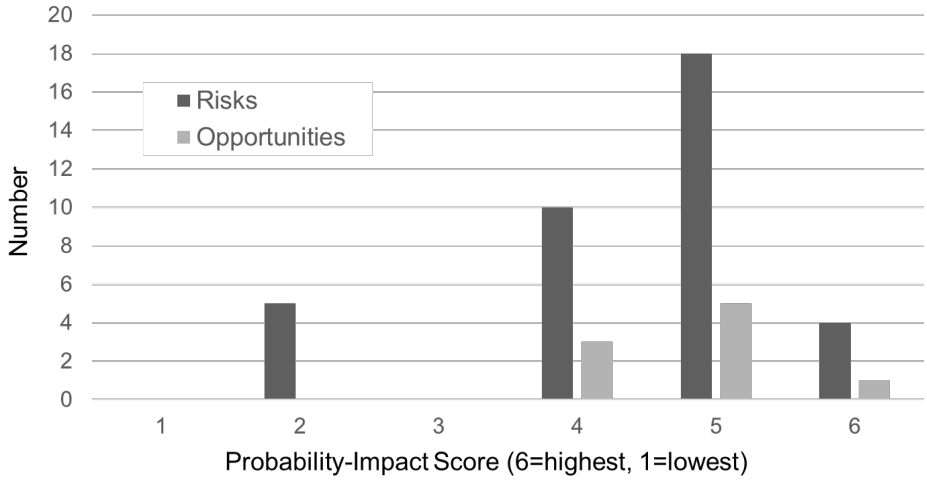

Figure 2: Number of risks and opportunities with each probability impact score

Using the HFI RAIDO-E Register, a Capability Evaluation was carried out. The Capability Evaluation involved determining an ethical stance and summarising the operational benefits, capability vulnerabilities, and HA technology development status. A summary of areas highlighted is shown in Table 1.

Table 1: Summary of the Capability Evaluation

	Operational benefits	**Capability vulnerabilities**	**Ethical issues**
Definition	Competitive advantage relative to the UK's existing capability and/or adversarial capability, by application of the HA technology in the specific context	Any weakness/issue that might lead to an enemy's enhanced ability to destroy, degrade, disrupt or deny a UK capability/advantage	Ethical concerns associated with the HFI Considerations identified.
Number identified in pilot EHFA	9	6	8
Examples from pilot EHFA	• Reduction in risk to medics • Remote monitoring • Equipment carriage	• Casualty acceptance • Disruption to communications • Loss of data	• Standard of medical care delivered • Importance of human contact • Medical confidentiality

Following the Capability Evaluation a decision point was reached where the team must determine, based on the ethical stance, operational benefits, capability vulnerabilities and technology development status, whether to continue with the final stages of the HA EHFA process. For the pilot EHFA, it was decided that the capabilities could outweigh the vulnerabilities but only with further development of the technology, and that further assessment was required in relation to the ethical issues. This meant that the response plans were developed with the goal of reaching the point at which a telexistence system could be procured for use in battlefield medical care.

Response plans were generated for each HFI consideration, often comprising of multiple actions. The actions were grouped into related tasks and an overall plan of activities generated showing the order in which the tasks would be performed, and how the tasks were linked. This sequence of HF activities is shown in Figure 3.

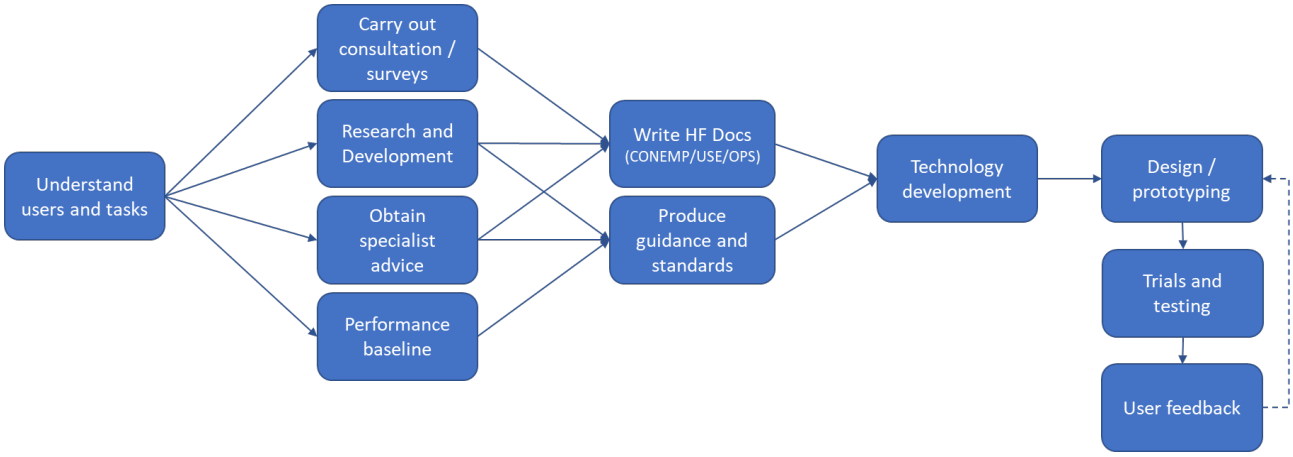

Figure 3: Sequence of HF activities

At the end of the pilot, the HA EHFA was documented in a report and a separate HFI RAIDO-E Register. The HA EHFA Report described the process applied and the HFI Considerations, presented the Capability Evaluation Summary, and detailed the response plans. The HFI RAIDO-E Register provided a full set of data on each of the individual HFI Considerations, and was designed to be a living document that could be used to manage the HFI Considerations through the future development of the HA technology.

Phase 2. Review and Validate the HA EHFA

Completing the pilot HA EHFA on using telexistence for battlefield medical care gave the team insight into the effectiveness of the process as originally devised. The team held an internal review to draw out these insights which:

- Evaluated the HA EHFA process, based on the experience of applying it to the potential use of telexistence for battlefield medical care;
- Reflected on the wider applicability of issues identified with the HA EHFA process; and,
- Identified further refinements to the HA EHFA.

The review concluded that the HA EHFA could be applied successfully in real world applications. The EHFA outputs were usable, addressed the aim of the EHFA, and were suitable to inform decision makers. A particularly valuable output of the HA EHFA was its ability to identify discrepancies between Technology Readiness Level (TRL) and Human Readiness Level (HRL).

A critique of the process was that the HA EHFA outputs were at a high level, but this was considered appropriate to the stage of telexistence development at which it was conducted. The most challenging part of applying the HA EHFA method was the ethical assessment process, and a number of updates to this aspect were recommended.

The results of the HA EHFA and internal team review were presented to external stakeholders in a validation workshop. The aims of the workshop were to:

- Gain initial validation of whether the proposed HA EHFA methodology is fit for purpose;

- Expose the work with communities who are likely to exploit and/or benefit from the modified process; and,
- De-risk and inform specifications for developing the HA EHFA Methodology Guide.

The workshop was attended by representatives from Dstl, Defence Equipment and Support (DE&S), MOD Front Line Commands (FLC), and ethics SMEs. The consensus at the workshop was that the HA EHFA provided a useful means of assessing HA technologies in a defence or security context. It was also highlighted that the methodology would benefit from further modifications to maximise its utility, particularly around ethics.

Phase 3. Develop a HA EHFA Methodology Guide

The findings from the internal review of the HA EHFA and the validation workshop were used to update the HA EHFA method and develop an HA EHFA Methodology Guide. The HA EHFA Methodology Guide was prepared in the same format as the existing MOD EHFA Methodology Guide to maximise its potential exploitation.

The HA EHFA Methodology Guide outlined five stages to the HA EHFA as shown in Figure 4. These five stages are the same as the MOD EHFA Methodology, but there are refinements to each stage that support the aims of the HA EHFA, and tailor the approach to the nature of HA technologies.

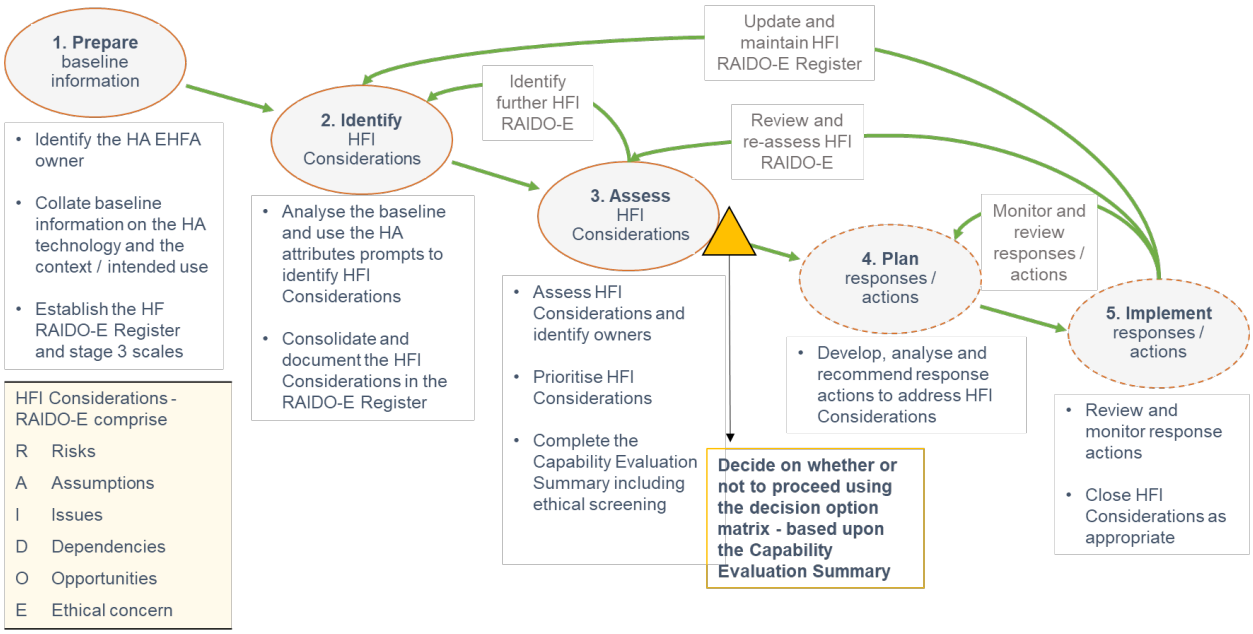

Figure 4: HA EHFA Process

The HA EHFA Methodology Guide also included resources to support the conduct of the HA EHFA including prompts to be used to gather information relevant to HA technologies, scales to assess the HFI Considerations, a table highlighting HA attributes for consideration during the EHFA, and a template for conducting the Capability Evaluation.

Conclusions

The pilot study of telexistence for battlefield medical care showed that the HA EHFA Methodology was effective in identifying ethical, safety, and other HFI considerations. The HA EHFA outputs were usable and suitable to inform decision makers. While the outputs from the pilot study were at a

high level, this was appropriate for the telexistence project for which it was conducted. The HA EHFA was also effective at producing a focused and manageable set of response plans, by setting a realistic goal state to be achieved by those actions.

It was concluded that the HA EHFA Methodology is suitable for use in assessing the use of HA technologies, at Research and Development (R&D) stage, in a defence context. The review and validation phase identified areas where modification of the HA EHFA as piloted were required to ensure that the outputs were representative and usable for its intended purpose. These changes were made and integrated into the HA EHFA Methodology Guide. The HA EHFA Methodology Guide can be obtained from the Dstl Human Augmentation team.

It is recommended that specific and more extensive ethical guidance be developed to support the evaluation and use of HA technologies in defence and security contexts. To support the exploitability of this work further, it would also be beneficial that the HA EHFA is integrated into the MOD EHFA Methodology Guide.

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