Heavy metal: reflections on practice in military vehicle human factors

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Abstract. *This paper discusses what it is like to practice in the development and assessment of military land vehicles. It presents a number of cases of practice and the key learning points, including reflections on requirements, systematic approaches and expert-based approaches to HF engineering for military land vehicles. Military vehicles are becoming increasing sophisticated, and so require more complex human factors methods to adequately understand and improve the. Future trends are also identified.*

Keywords. Human Factors Practice, Vehicle Ergonomics, Military Vehicles

The views expressed in this paper are the author's own and do not represent official government policy.

1. Introduction

1.1 Why Heavy Metal?

Heavy metal is a term used by the British Army's Royal Armoured Corps (RAC) to refer to Armoured Vehicles (AVs) such as tanks, infantry fighting vehicles, support engineering and self-mobile artillery platforms. In truth the variety of military land vehicles is far wider, including a wide array of other tracked platforms of various ages, design pedigrees as well as a number of purposed built wheeled and tracked vehicles, amphibious vehicles and commercial-off-the-shelf trucks and engineering vehicles. The purpose of this paper is to share my personal reflections as a government HF practitioner with experience of working on a range of vehicles over the past ten years. The reason for putting pen to paper was my move from the land area to the air sector, so a good point at which to stop and reflect on the challenges of working in this area of human factors. The paper is, therefore, offered as an example of practitioner reflective practice (Schön, 2011).

1.2 Historical Context

HF practice in the land domain has steadily improved from the baseline assessed in 2007 (Tutton et al., 2007). In part this has been principally due to the large number of Urgent Operational Requirement (UOR) platforms acquired by the UK Ministry of Defence for operations in Iraq and Afghanistan that has raised the profile of HF in military and acquisition communities. During these operations, core vehicle projects such as AJAX have also been matured, building on the investment in research made by the UK MOD, as well as HF practice developed collaboratively between the UK MOD and industry. The UK is still a global player in military vehicles, with the UK and US being the main English speaking nations to invest in land vehicle development. It should be noted, however, that better practice is still far from being adopted universally, and some projects still face some considerable technical challenges, let alone some of the HF-related legislative issues faced by the Army. In this paper I hope to discuss what better practice should ideally consist of, and if it cannot be applied, how HF practitioners can at least have some influence on a land vehicle project.

1.3 Government HF engineering perspective

In doing this paper, I was influenced by Shorrock and Williams lecture to the EHF Conference 2016, arguing for discussion about practitioner reflection on what it is to practice HF as a research output in its own right. In my organisation, the principal science and technology body in the UK MOD, we have begun to work on improving the opportunities to reflect on what we do, since as practitioners we rarely get the chance to look at how to improve the influence of HF on engineering projects. Part of the challenge for us is that as government staff we rarely get to actively design land vehicles, but are often called on to generate requirements, review contractors commercial offerings and technical designs, assess vehicles for compliance with requirements, and to tackle urgent operational problems encountered by UK Armed Forces personnel. From this perspective some of the activities that we do are simply not done by anyone else. It's also important to note that within our team, by the end of operations in Afghanistan most staff had experience of at least five vehicle projects; a much wider variance of experience compared to most industry practitioners according to industry contractors embedded in our group. So from this perspective it was important to capture some of the lessons we had identified from the large number of projects we had been involved with.

2. Methods

This paper will present a picture of what it can be like to practice in the land vehicle domain, discuss some of the lessons identified from my (and others) experience as well as offer some heuristics that we have found effective in getting HF adopted on projects. This paper does not cover any of the intendant inadequacies of organizational practice that HF engineers typically deride. Norman's (2010) view that we should not blame others for HF having a lack of influence on projects is of relevance here, and there are lessons that are reflected on that led the author to ask whether HF professionals should be focused on what value we contribute and take responsibility for managing our specialist skills alongside other engineering disciplines.

To help explain this perspective in the context of land vehicles this paper is in two principal parts; 1) the presentation of several case studies of practice areas and the issues identified, and 2) a discussion of possible practice orientated recommendations. The focus is on how we as HF professionals can enable development of land vehicle systems from socio-technical perspective; in that these systems are a part of a wider system of systems.

3. Findings

Three case studies are presented reflecting three areas of HF practice in land vehicle development, from the perspective of government practitioners.

3.1 Core vehicle project

This case comes from experience of working as HF Manager in the UK MOD acquisition team supervising the mid-phase of development of the AJAX AV. AJAX is a capital acquisition project, currently nearing its Initial Operating Capability (IOC) thus about to go into service, focused on development of a medium weight (note this is a relative term in land vehicles, being somewhere between 30 to 40 plus tonnes!) armoured reconnaissance vehicle.

AJAX is a demanding vehicle for its RAC operators since it is a flexible platform that is required to operate at long distances from support, to fight for the intelligence and information it seeks to gain, and at times operate in close support with other vehicles and infantry.

AJAX's human-related properties benefited, in part, from early human factors integration work conducted on a partner programme, the Utility Vehicle (UV) project that demonstrated

the benefits brought by a thorough human factors approach (conducted by Atkins and Dstl). Key to the success of AJAX has been the people-related requirements, which have enabled the MOD to conduct progressive human factors assurance, as well as act as a clear contractual requirement for the designer and manufacturer. From this perspective the physical characteristics of AJAX will be a step change compared with other AVs and should set a new benchmark for physical accommodation of armed forces personnel. Another element to this success has been the expression of the requirements in a form that other engineers can recognise and understand their relative importance. In my view one of the most critical requirements has been to specify anthropometric ranges in association with task performance, though a task analysis.

AJAX has also benefited from an active and ongoing Human Factors Integration (HFI) (MOD 2015) process that has been the principal conduit for the military to actively track and resolve user integration issues. The strength of this process has varied, but the consistent involvement and importance put on it by the military has certainly helped influence the design. The relationship between human factors engineers, both on the government and industry side, has also enabled development tests to be more effective and to be of high quality, and avoided the inevitable 'design by committee' which can happen with an unstructured user involvement approach.

The key lesson identified from AJAX, however, is to improve the approach for developing Human Computer Interfaces (HCI) and specifying cognitively-related requirements. AJAX took full cognizance of the development of Generic Vehicle Architectures standards which while not contracted for, were used to outline design for AJAX's HCI. The challenge with AJAX, however, was that may of the functions required were considerably more complex than previous vehicles, and so additional interface design was needed. From this perspective the use of HCI specifications and generic HCI requirements could have been improved; through the use of a specified test regime (and fidelity of test facilities) specified in the contract.

3.2 UOR vehicle projects

The UK has bought many vehicles direct from manufacturers with some or no modification to meet urgent operational needs in the last ten years, of which the majority have had some form of human factors applied. The example used here is Warthog, a semi-amphibious tracked vehicle. Warthog was bought off-the-shelf to provide additional mobility over existing wheeled vehicles, and was assessed by Dstl HF Engineers shortly before it went to theatre, to inform safety activities. The assessment highlighted a number of minor deficiencies from what would be ideal with respect to UK HF requirements, from which Dstl prepared a HF Consideration Register (HFCR) to enable the UK acquisition organization (Defence Equipment and Support) to track a monitor any issues. The HFCR enabled the various issues to be prioritised and appropriate mitigations to identified and costed, through the Safety Working Group. The main concern with the vehicle was the difficulty in accommodating the range of sizes of UK soldiers when equipped with modern protection equipment such as the newer types of body armour. Since this was a multivariate anthropometry and posture problem, resolution may impact on multiple vehicle systems and physical architecture (e.g. bulkheads, support struts and so forth). So, a design study to be conducted by the manufacturer (ST Kinetics) was commissioned by DE&S, with oversight from Dstl. This was a highly useful piece of work, which enabled the Project Team to understand what could be done to mitigate the risk in the short-term (during operations), and what would be longer term solutions. Critical to this activity was getting costed options from the manufacturer so that the Project Team could submit business cases with specific HF justifications as evidence, alongside conventional engineering and military rationales.

The impact on the vehicle by conduct of the tailored HF interventions was considerable, with

several physical modifications made to the vehicle, including the removal of seated positions in order to re-design the front cab.

Of the ten or so UOR projects looked at by Dstl HF engineers, the principal critique was the lack of consistent and thorough HF requirements. In some regard the absence of, or poorly articulated requirements was understandable, given the short-timescales with which most UORs were acquired. However, to say that there was no time to incorporate HF requirements, is in my view arguable since HF requirements have been established on vehicles like AJAX, and could be translated to UOR projects without difficulty, and indeed for latter UORs they were used. In discussion with the military - who are usually responsible for requirements formulation - the reason for this is due to training and access to appropriate subject matter experts. To partially address this gap, Dstl commissioned a Land Vehicle Design Guide which incorporates many generic requirements and guidance points on the factors to take into consideration in vehicle requirement development.

3.3 Policy advice to Army Headquarters

The examples used to date are principally focused on two individual land vehicle development or acquisition projects. This is not to say that there are themes of human factors that span most land vehicles. An example of this is a survey of the anthropometric and postural qualities of land vehicles conducted by Dstl in order to support survivability assessments. This work was carried out extremely rapidly to respond to a policy decision to be made by MOD Headquarters. The findings from this work cannot be formally released, but it highlighted the cramped nature of many land vehicle crewstations. Through an investigation of these issues, it then also transpired that many vehicles also had possible vibration issues that allied to the cramped position in some crew stations may increase the health risk for some military roles. This work has subsequently instigated a large ongoing research project, led by Dstl, to support Army Headquarters formulate the appropriate policies to manage these issues. This work is in its early stages, and has already led to a change in Army career structures and the way in which vehicles are assessed for compliance with vibration regulations.

The salutatory lesson from this work however, was that it highlighted that many vehicles did not have up to date HF Consideration Registers (HFCRs) and that few people had a good understanding of some of the physical risks endured by those operating land vehicles. It should also be mentioned that the Army, as the principal Duty Holder, were highly responsive to this issue when it arose, and have been actively pursuing it as a high priority.

4. Discussion

A discussion on this topic would not be complete without a brief word on personal behaviours in projects: For without the confidence of the customer, usually a project manager in DE&S, and military stakeholders, HF does not stand a chance of making a difference. In the 16 or so land vehicle projects I've worked on, once my personal monologue of 'wow I didn't realise it was that bad!' had calmed down, the principal approach has always been to rationally explain the impact on military operations of a specific issue before then moving to possible solutions. From bitter experience, unless the customer understands the impact of an issue, they will not be willing to act. While this is common in all domains, the land vehicle world is no different to others, HF has had a relatively small role in military vehicle development until now, so many of the issues raised will probably be new to the customer and stakeholders.

4.1 Recommendations for Practice

Ideally all projects should be systematically assessing and tracking the human-related considerations for their vehicles, as per MOD HFI directives in JSP 912. The reality is that

many Project Teams do not: They focus principally on the Human Factors Engineering (HFE) aspects (the HFI domain concerned with the direct human-related influences on the vehicle design) and the operators manage to make those vehicles work reasonably effectively. Although one will doubt the efficiency of what it takes to make some vehicles effective, (and as the recent issues with vibration and posture have illustrated) it is possible for fairly straightforward human-related issues to go unnoticed. Part of the difficulty is the overt focus of acquisition on HFE aspects since this has a demonstrable impact on time, cost and quality for which the acquisition community is responsible, with other domains such as manpower, organizational and social arguably not being as well considered. Again this can be demonstrated through the vibration and posture work where some of the direct mitigations were related to career structures, rather than engineering changes to vehicles. However, as illustrated by the Warthog case, it is possible to construct an HF Considerations Register (HFCR) while a vehicle is in-service - to support systematic prioritization of the human-related considerations (i.e. risks, issues, assumptions, opportunities and so forth), so the message at first is: do HFI if you can.

4.1.1 What to do first?

The question then comes back, what if we cannot get a customer to do HFI? In this instance I personally think one is then back to some form of 'non-systematic' more expert-based principles, such as taught to me by my mentor, David Streets. David's advice when looking at whole vehicle assessment, which I believe still stands, is to look at physical ergonomics first, principally anthropometrics and posture, then the environmental conditions, before moving to look at cognitive interfaces. The principal reasons for this, are that for land vehicle crews to perform adequately they must be in a physical position to be able to interact with interfaces, and in land vehicles that can actually be quite difficult to achieve in an adequate manner. Finding adequate physical position and environmental conditions for sustained performance can be problematic, particularly in legacy vehicles. As a result there may well be an impact on the quality of the interface across the user range, so attempting to get some understanding of this at the outset is essential.

4.1.2 Effective Human Factors methods / techniques

An aspect that I have not touched on, allied to understanding the physical and cognitive qualities of land vehicles is the importance of getting some idea of the military role of the vehicle and its crew, and then of the specific tasks conducted by a crew. This knowledge is essential since it can underpin so many different technical activities; from issue identification, prioritisation and mitigation (including vehicle re-design). To aid this Dstl have published an outline framework of possible methods that HF engineers can apply to land vehicles. Essentially military vehicles can be assessed using well-known automotive techniques (Bhise 2012, Walker et al. 2015), such as vehicle walkthroughs (this does take some domain knowledge to set up), anthropometric / postural assessment, and visibility assessment. In my experience there are few cases where land vehicles require any form of specialist methodology, bar those questions that need some form of formal experimental design to effectively answer.

4.2 Future Trends

It should be noted that in the UK, the take up of HF in the land vehicle domain has increased substantially from when I started to practice. There are sufficient physical ergonomic tools available to generally make a difference to land vehicle development, bar some relative minor, but important developments to be done to support postural assessment in automotive vehicles. Moving to cognitive ergonomics, an area which does need improvement, (born out

of experience on nearly all projects) is the need for better task performance metrics to enable accurate assessment of performance. It should be noted that this is not just an aspect to watch during development, it is also a concern during the early in-service phases of a vehicles use, as the military learn how to use the vehicle and so adapt and change their procedures, training and indeed selection of personnel.

An area which is gaining more interest is the improvement of the cognitive performance aspects of land vehicle operation. To date there are very few studies of cognitive performance, although some work has been done using simplistic predictive modeling and experimentation (Fidock et al., 2016). Since land vehicles are now becoming increasing complex, in part driven by the military's experience with complex sensors in recent operations, this is a critical area of investigation. In my view, this has to start with some scoping studies and baselining of the cognitive performance of land vehicle crews during a range of different military scenarios. My personal suspicion will be that, like aviation and other sectors, that there may be a bigger impact of task type, rather than specific types of HMI or HCI. In the long term, if it is proven that task type has a bigger effect on task performance in land vehicles, it may be that the MOD strategy should move towards task design, rather than technological design as a first priority.

5. Conclusion

This paper has shown that while military land vehicles are agricultural in nature, they are becoming increasingly sophisticated, and so require more complex human factors methods to adequately understand and improve them. The paper has briefly outlined some case studies that the author has been involved with and provided some thoughts on the key lessons identified from them. The paper has concluded that in the future land vehicle assessors and developers should focus most of their attention to the task performance aspects of land vehicles, and to ally this investigation to other domains, since there is much that the land vehicle domain could learn from other areas of HF practice.

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Much of my personal practice has been in this domain, having worked on more than 16 vehicle programmes in the past ten years. I could not have operated as effectively without the support of a mentor (David Streets). I have also been lucky to work with some highly committed and able engineers from many disciplines on these projects, and have seen some very inexperienced staff thrown in at the deep end. I hope this paper gives those unfortunate to be in that position to pick up on the rules of thumb that have helped me in sticky situations!

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Practitioner Summary

"Little has been published about human factors practice in the development and assessment of military land vehicles. This paper outlines a number of cases of practice and presents the key learning points, including reflections on requirements, systematic approaches and expert-based approaches to HF engineering for military land vehicles. Since military vehicles are becoming increasing sophisticated, and so require more complex human factors methods to adequately understand and improve them future trends are also identified."