Trust in Automation: how this is shaped by the human operator and the underwater domain

Abstract — High speciality and criticality domains categorise the most researched areas in the field of Trust in Automation. Few studies have explored the nuances of the psycho-social environment and organisational culture in the development of appropriate mental models on dispositional trust. To aid integration of human operators with emergent specialised systems, there is ambition to introduce Human-Human/Human-System analogies with AI Avatars and 3D representations of environments (MoD 2018, Human Machine Teaming Joint Concept Note) [1]. Due to the criticisms in the literature of Human-Human and Human-System teaming analogues this research has explored personal narratives of civilians and military personnel about technology, adaptability and how to facilitate beneficial attitudes and behaviours in appropriate trust, reliance and misuse. A subdivision of the research explored the socio-cultural idiosyncrasies within the different echelons of the military as variances in authority and kinship (most prominent in Subsurface Navy) provided insight on informing training targeted to unique domains.

1 Introduction

Trust in automation has been the subject of extensive research, in both civil and military domains over recent decades as increased technological capability has allowed for more sophisticated applications of automation [2] [3]. However, as automation has become more prevalent, so have the requirements and stressors placed both on the system agents (i.e. the capabilities of the automated subsystems and their human supervisors/interpreters) and on the pursuit of intuitive, transparent interface design. As systems become more advanced, the role of the operator has changed from active control (human-in-the-loop) to a more supervisory role (human-on-the-loop) [4]. Since the amount of human monitoring has changed, the amount of trust the human shares with the system becomes a metric of misuse and maladaptive reliance on systems [5] [6]. Furthermore, in this move towards increased levels of automation and human operators as supervisory support roles, this can impair appropriate reliance and support complacency due to their overreliance on the automation [7] [8].

Current research also indicates that there is a disconnect between perceived reliability and actual reliability, of an automated system, regardless of the system's fidelity [9] [10]. This cognitive dissonance between actual and perceived reality (such as the capability of the system, or situational awareness of the operator) and cognitive overload can impact trust facilitation, performance and lead to the subsequent degradation of the human's mental picture if operator behaviour is not framed accurately.

1.2 Objective

Trust formation with technology and automation is affected by several precursors, similar to how we trust each other. Features such as, prior knowledge, experiences with similar technology (or people) and how expectations, lack of transparency and failures can lead to mistrust. In critical environments, appropriate trust and reliance on decision making systems and automation is key for mission success, personnel, and safety. Our actions and behaviours are not formed in a '*cognitive vacuum*' – we are influenced by the context of tasks, environments, prior experiences and memories.

The amalgamation of thought patterns, behaviours, memories, culture and social demands all contribute to the formation of 'Mental Models' and how we frame the world around us. The research seeks to explore trust formation and human mental models, specifically how they can assist interaction facilitation between operators and future systems with high levels of automation in command, control, communication and intelligence (C3I).

2 Related Work

In this section, a brief overview of different approaches to trust in automation, concepts of trust and the use of mental models and cognitive framing to support the changing technical and warfare environment are discussed. The scope of trust and automation is vast and therefore the focus is on the general approaches which have been proposed in the literature. Furthermore, the interest of trust research has been shown to be a precedent for automation usage and reliance in both consumer-orientated and highly-specialised domains such as the military domain [11]. The impact of domain on user trust is an emerging area of interest and thus where the scope of the research originated.

2.1 Trust in Automation

Human factor accident analyses of automation failures in the literature have featured explicit conscious influences on user trust levels (e.g. over- and -under reliance) [12] and complacency [13]. However implicit attitudes towards automated systems is an emerging area of research which can provide insight into the risks that occur in increasing automation capability.

Trust in automation has been the subject of extensive research, in both civil and military domains over recent decades as technological capability has allowed for more sophisticated applications of automation [2] [3]. However, as automation has become more prevalent, so have the requirements and stressors placed both on the system agents (i.e. the capabilities of the automated subsystems and their human supervisors/interpreters) and on the pursuit of intuitive, transparent interface design. As systems become more advanced, the role of the operator has changed from active control (human-in-the-loop) to a more supervisory role (human-on-the-loop) [4]. It is with this changing amount of human monitoring, the amount of trust which the operator shares with the system is a key determinant of misuse and maladaptive reliance on systems [5] [6]. Furthermore, in this move towards increased levels of automation and supervisory roles can impair appropriate reliance and support complacency through reduced vigilance in human-system interaction [7, 8].

As previously mentioned, the fidelity of the system seemingly does not equal increased levels of trust with operators. The cognitive dissonance is a human factors and product design issue as this is imperative to operator use, experience and facilitation. Regarding user design of the human-automation interface, transparency between human and system interaction is vital for providing the operator with congruent information. The design elements should provide accurate and appropriate interpretations of the system's capability and reliability, thereby allowing for robust appropriate mental frameworks, or schema [14] [15]. As will be discussed in the next section, the facilitation of trust with operators is key for appropriate adaption and thus transitions to increasing levels of automation in future battlespaces, (specifically in submarines Ritchie (2017) [16]). Cook, Thody and Garrett (2017) [17] suggest "*the transition between perception and comprehension or projection is a reflection of the quality of mental models of the operator, which in turn may reflect the operators workload on the task they are attempting"* which is crucial for task management and decision making with human-system teaming.

2.1.1 Trust Facilitation and Mental Models

Previous work by the author investigated the use of mental models to explore trust in automation in a systematic scoping review [18]. The following are excerpts from the systematic scoping literature review on the topic.

Priming and prior training are positive influencers on operators trust in automation, through the reduction of mistrust or inappropriate behaviour with the system, and appropriate reliance and knowledge of limitations of the system capability. Olson, Fisk, and Rogers (2009) [9] Ososky (2013) [14] and Wilkinson, Fisk and Rogers (2007) [10] suggest distrust and incorrect estimations of automation accuracy were still apparent at 100% precision. Transparency supports an operator's appropriate interpretation of the system's capability and reliability, however, with distrust at the higher fidelity suggests there is an internal psycho-social factor affecting overall trust of the system.

Situational awareness is key for framing mental models, especially in environments with high levels of automation. The current literature indicates that incomplete or low quality mental models can increase inappropriate behaviour with the system, whereas robust mental models support improved interaction and facilitation [19] [20] [15] [21].

Deviations from strong and resilient mental model frameworks are associated with lower performance outcomes and error behaviour. Accident analysis has shown that robust models help the operators perceive the actual capabilities of a system. The current literature seeks to explore underlying psychosocial impacts affecting performance and interaction within complex socio-technical environments through exploring mental models and schema. The utilisation of mental models as a theoretical framework for inquiry, is an expanding field of research in the identification of the shifting limitations of trust in automation research as technology emerges at an ever-expanding pace.

2.2 Trust and Reliance

As discussed throughout the literature, the terms trust and reliance are often used interchangeably. Lee and See (2004) [8] attempt to define trust as a behaviour and reliance as an action. Therefore, it can be extrapolated that a significant amount of trust in automation research that use psychometric experimental design are oft exploring over- and under-reliance of operators on systems. Although this is important for analysis of decision-making sequencing, the assessment of behavioural elements for trust may look towards internal factors and dispositional trust in automation. These inter- and intra-personal factors include features such as culture and age. The research discussed in this paper specifically focuses on culture and the attitudes and behavioural idiosyncrasies in different echelons of the military. Research by Pak (2017) [22] observes the attitudes and behaviours of undergraduates and cadets, specifically addressing age as a factor influencing mental model schemata of trusting emerging technologies and automation.

2.3 Narratives in the Military

Military psychology is a unique field in and of itself due to the highly distinct psycho-socio-culture characterised by high level of discipline, robust social order through authority, rules and regulation [23]. Hoff and Bashir [6] approximate 80% of trust in automation studies are in high criticality domains such as military/security – this suggests that high consequence domains are over-represented and therefore there is debate on whether it can be generalisable. There are limited studies that have observed whether organisational structure, such as military culture, influences trust in automation [24]. Therefore, trust research is a hot topic in automation, however, the effect of culture which is intrinsic to the domain are underrepresented. Qualitative inquiry and the study of narratives is a topic not closely associated with military contexts [25] however, as a cognitive tool, it can be effective to execute strategic communications for vertical and horizontal knowledge integration. For example, the information can be packaged in a way so that the short contextual story, made up of a complex combination of actors and knowledge elements, can be understood by a wide range of people. Furthermore, narrative is inextricably linked with culture. Utilising narratives can provide benefits through understanding the beliefs and behaviours of personnel, as well as a method of knowledge transfer. This in turn can improve communication by cognitive amplification of action and event discourses. Such as, framing the context of the impact in a social way may provide ethical and human-centred context in an increasingly digitised battlespace. Additionally, the use of narratives in the complex and fluctuating decentralised forms of social organisation, information and communication may benefit decision making processes in chaoplexic warfare by providing a holistic view of the multiple levels in this sociotechnical system [26].

3 Method

3.1 Theoretical Framework

A theoretical framework uses existing concepts and definitions to support the theoretical assumptions of the researcher/s and to understand the broader knowledge base of the research ecosystem. This framework aims to strengthen the study through an explicit statement of theoretical assumptions used to critically evaluate the qualitative data, in addition to identifying limitations to generalisations about the phenomena discussed and examining key variables which may differ under different theoretical framing. The specific phenomenological paradigm informing these studies are social constructionist. The theoretical framework belies that the data is co-constructed by researcher and participant. So, for example, the research utilised semi-structured responsive interviewing of open-ended and exploratory questions to capture participant experiences, and thus were oft participant led. The research has implemented a phenomenological methodology with methods derived from constructivist grounded theory [27] to bolster methodological rigour.

3.2 Participants

The civilian cohort comprised of 7 participants of subject matter experts (SME) and Non-SME between the ages of 24-55 with an even gendered representation. The Military cohort included a voluntary selection of 20 participants from different branches of HM Forces (Army (4), RAF (2), Surface Navy (5), Subsurface Navy (9)) and varied occupation and length of service (from 7 to 36 years) within these echelons with a large predominantly male representation. However, many branches of the military remain male-centric in recruits thus this is representative of the wider group.

3.3 Materials

The design of the focus groups and interviews grouped (or separated) personnel into semantically similar or diverse groupings to incur in-depth discussion and shared lived experiences. These interviews were performed in secure rooms on site of the respective participants with a digital audio recording device. Transcripts from these files were subsequently inputted via computer assisted qualitative data analysis software (CAQDAS), primarily NVIVO [28] for coding and organisational analysis, in addition to Leximancer for visual concept mapping [29]. In order to develop a social theory grounded in the lived experiences of the participants, the research uses triangulation of Interpretive Phenomenological Analysis (IPA) and Hierarchical Content Analysis (HCA).

4 Procedure

The scope of the semi-structed responsive interviewing used a series of main questions to structure the interview through enquiries related to the research question of this paper [30]. These were prepared in advance but varied from interview to interview as to match the interviewees' experience.

The key topics explored are as follows:

- What are your opinions of automation?
- What are major changes you perceive in the implementation of increased levels of automation (LOA)?
- How would you describe trust and/or trust in automation/technology/systems?
- How do your peers/teammates feel about trust/technology/Levels of automation?
- Could you describe to me positive and/or negative impacts you foresee with increasing levels of automation?

These were supported by follow-up questions which seek to gather detail and nuance to substantiate diligence, in addition to exploration of further events, concepts and themes arising from the main questions. These are designed to be responses based on interactions within the conversation where they can reflect on previous statements.

The interview procedure utilised interview probes which are designed to manage conversation and to elaborate or provide more detail. They can also be used keep the interview on target and allow the researcher to ask for clarification, examples or evidence. Probes can also be used to reveal slant or bias through methods such as silent or echo probes which make use of uncomfortable silences or repeating quotes back to the interviewee.

4.1 Analysis of Transcripts

The methodology for the research is outlined more conclusively in Field (2019) [31]. To elaborate, the transcripts use interpretive phenomenological analysis for initial coding of raw themes and data units with supplementary analysis provided from hierarchical content analysis to classify categories, super- and sub-ordinate themes and underlying narratives. The method attempts to appraise themes to inform risk matrices and concern registers at both the sematic and latent thematic level [32]. The approach is a method of extrapolating data from large verbal protocol data sets that can be used across many system ergonomics applications, such as user experience trials, health and safety analysis and exploring relationships of inter- and intra- personnel in sociotechnical systems.

5 Findings

The principle generalisations from the primary trends insofar is that, if trust is defined as positive expectations [33] but negative experiences are oft used as example interactions in the data, can trust as a technology acceptance metric be appropriately used? A clear dissonance between verbalised sentiments and underlying expressions of trust attitudes was also observed across both civilian and military cohorts, more specifically exploring expressions of mistrust and distrust of technology which occur closer to category boundaries [34]. Category boundaries are concepts which are the grey area of between two phenomena – for example, in this case mistrust was higher in technology which blurs the lines between humans and robotics. An instance of this would be voice communication of directions from a satellite navigation device is closer to the category boundary than a visual display. Cases such as personal assistive smart devices, with personalisation, customisation and learning algorithms are further blurring these category boundaries. This is important when considering the aspiration to integrate human analogues or human-human teammate mimicry in future C3I control centres and Human-System Interfaces.

Furthermore, the research saw conflicting narratives within and between military subgroups whether that specific Military culture primes operators for technology adaptability. A number of participants expressed steadfast resolve in that, due to the unique basic and subsequent training members of HM Forces experience that propensity to trust is apportioned through command responsibility. Others conversely believe that trust adaptation is restricted through negative prior experiences and contravening feelings of self-autonomy which is high-lighted in these hierarchical authoritative domain environments.

The expressions of self-autonomy and the sentiment that human-automation interaction inherently violates or constricts independence and self-governance is a recurrent theme throughout. For example, there is the subconscious indication that the use of automation sharing or appropriating human-teammate tasks, that this intrudes on the sense of self- autonomy of the user/operator. This was more perceptible in those participants in sub-surface navy and submariners, who expressed differences in attitudes and behaviours between their individual subcultures and across the branches of the military, more clearly and confidently compared to participants in other echelons. The social structure and subculture in these narratives explores the disparity between trust, reliance and compliance in complex, high-risk systems in more detail than ground and air military personnel.

6 Conclusions

6.1 Discussion

The ‘fear’ of automation ‘taking away’ self-autonomy of operators, especially with the increasing levels of automation and the technology implemented in C3I, is a major human factor issue at both the inter- and intra-personal level and therefore holistic systems thinking may hold some solutions. As discussed in the work of Carr (2014) [35], self-determining factors associated with job satisfaction and engagement are often closely associated with job performance and interaction. Therefore, an unconscious bias against the facilitation of technology can be intrinsic to the mental models operators have constructed from their environment, peer interaction and the wider social framing of emerging technology. For example, human-teaming with automated systems can be hindered by the lack of mental schema or framing on how the automated system ‘thinks’ and therefore too much or too little reliance is placed on the technology. In other words, if the operator does not understand the machine, there is scope for the operator to trust it too much (higher perceived capability than actual capability of the system) or too little (for example, predisposed by prior experience, negative psycho-social narratives interfering with schema, inadequate training on the capability of the system).The future of autonomy and battlespace, the blurring of cyberspace and reality and ethics is discussed more broadly by Scharre (2018) [36] Furthermore, discussion on the ‘disruption of technologies’ [37] and the role of operators in increasingly automated battlespace is one that has been repeated over the centuries with each technological revolution, hence evolution and adaption is key for appropriate teaming, reliance and cooperation.

6.2 Study Limitations

The study is perspective based data construction and thus purely qualitative, it does have the limitation that statistical significance cannot be drawn from the data points. However, the analysis at a deeper richer level gains new insight into the behavioural patterns of the demographics explored and thus can provide information for future experimental study design in addition to providing exploring more personalised training vignettes and knowledge transfer.

Recontextualising is the main influence qualitative research can provide. Recontextualisation is the development of emerging theories so that they can be generalisable and more applicable to other settings and demographics where the research can be applied. [38, p. 34]. The research explored multiple echelons of the military with a focus on the idiosyncrasies of submariners, however, broader trends and narratives can provide a platform which can influence the domain at large.

6.3 Future Work

Future work will examine the concerns of Trust in Automation research regarding novel and emerging interface techniques, such as mixed reality and augmented avatars. There are trends in the analysis which endorse the multifaceted and complex psycho-socio-cultural issues observed with exploring mimicry of human responses in system communication and interaction. As implementation of these novel user interfaces are a goal of future human-machine teaming [1], further recommendations and requirements are vital for appropriate use in the ergonomics of future command and control centres.

The post-hoc analysis of the research will explore sensemaking via Data Frame Theory [39] to inform a mental model schemata in which maladaptive decision making and behaviours can be explored and modified. In addition, story based learning and training based upon the dominant narratives concluded from the research will also be explored through graphical narrative and storytelling techniques as alternative data visualisation for more inclusive data dissemination and knowledge sharing.

Acknowledgements

The author would like to acknowledge BAE Systems and EPSRC for sponsorship funding for the research discussed in this paper. The author takes responsibility for the content and opinions expressed in this project and these do not reflect those of BAE Systems. Furthermore, the author would like to thank Dr Dawn Wood for their constructive criticism of the manuscript.

References

[1] Ministry of Defence, "Human-Machine Teaming (JCN 1/18)," 21 May 2018. [Online]. Available: www.gov.uk/government/publications/human-machine-teaming-jcn-118. [Accessed 20 February 2019].

[2] P. A. Hancock, D. R. Billings, K. E. Schaefer, J. Y. Chen, E. J. De Visser and R. Parasuraman, "A meta-analysis of factors affecting trust in human-robot interaction.," *Human Factors: The Journal of the Human Factors and Ergonomics Society,* no. 53, pp. 517-527, 2011.

[3] K. E. Schaefer, D. R. Billings, J. L. Szalma, J. K. Adams, T. L. Sander, J. Y. C. Chen and P. A. Hancock, "A meta-analysis of factors influencing the development of trust in automation: Implications for human-robot interaction," US Army Research Laboratory, Aberdeen Proving Ground, MD, 2014.

[4] D. Atkinson, P. Friedland and J. Lyons, "Human-Machine Trust for Robust Autonomous Systems," in *4th IEEE Workshop on Human-Agent-Robot Teamwork*, 2012.

[5] J. D. Lee and N. Moray, "Trust, self-confidence, and operators' adaptation to automation," *International journal of human-computer studies,* vol. 40, no. 1, pp. 153-184, 1994.

[6] K. A. Hoff and M. Bashir, "Trust in Automation Integrating Empirical Evidence on Factors That Influence Trust.," *Human Factors: The Journal of the Human Factors and Ergonomics Society,* vol. 57, no. 3, pp. 407-434, 2015.

[7] R. Parasuraman and V. Riley, "Humans and automation: Use, misuse, disuse, abuse," *Human Factors,* vol. 39, no. 2, pp. 230-253, 1997.

[8] J. D. Lee and K. A. See, "Trust in Automation: Designing for Appropriate Reliance.," *Human Factors: The Journal of the Human Factors and Ergonomics Society.,* vol. 46, no. 1, pp. 50-80, 2004.

[9] K. E. Olson, A. D. Fisk and W. A. Rogers, "Collaborative Automated Systems: Older Adults' Mental Model Acquisition and Trust in Automation.," in *Human Factors and Ergonomics Society Annual Meeting*, 2009, October .

[10] B. D. Wilkison, A. D. Fisk and W. A. Rogers, "Effects of mental model quality on collaborative system performance," in *Human Factors and Ergonomics Society Annual Meeting* , 2007, October.

[11] R. Pak, E. Rovira, A. C. McLaughlin and N. Baldwin, "Does the domain of technology impact user trust? Investigating trust in automation across different consumer-oriented domains in young adults, military, and older adults.," *Theoretical issues in ergonomics science, ,* vol. 18, no. 3, pp. 199-220, 2017.

[12] S. M. Merritt, "Affective processes in human–automation interaction," *Human Factors*, vol. 53, no.

4, pp. 356-370, 2011.

[13] R. Parasuraman and D. H. Manzey, "Complacency and bias in human use of automation: An attentional integration.," *Human factors,* vol. 52, no. 3, pp. 381-410, 2010.

[14] S. J. Ososky, "Influence of Task-Role Mental Models on Human Interpretation of Robot Motion Behavior," University of Central Florida Orlando, Florida, 2013.

[15] P. P. Morita and C. M. Burns, "Understanding 'interpersonal trust' from a human factors perspective: insights from situation awareness and the lens model," *Theoretical Issues in Ergonomics Science,* vol. 15, no. 1, pp. 88-110, 2014.

[16] D. Ritchie, "Past, Present and Future Submarine Manoeuvring Control," in *Paper presented at RINA Warship 2017: Naval Submarines and UUVs*, Bath, UK, 2017.

[17] M. Cook, M. Thody and D. Garrett, "I Didn't See that Coming: The Perils of Underwater Automation," in *Warship 2017: Naval Submarines & UUVs*, Bath, 2017.

[18] M. Field, "Review of Mental Models as a Method of Trust Facilitation for Human System Interaction," in *Defence and Security Doctoral Symposium*, Swindon, 2018.

[19] R. Aydoğan, A. Sharpanskykh and J. Lo, "A Trust-Based Situation Awareness Model.," *Multi-Agent Systems,* pp. 19-34, 2014.

[20] B. Birkmeier, B. Korn and F. O. Flemisch, "First findings on the controller's mental model in sectorless air traffic management," in *Digital Avionics Systems Conference (DASC), IEEE/AIAA 30th*, 2011, October.

[21] B. &. E. J. Sætrevik, "The "Similarity Index" as an Indicator of Shared Mental Models and Situation Awareness in Field Studies.," *Journal of Cognitive Engineering and Decision Making,* vol. 8, no. 2, p. 119–136, 2013.

[22] R. Pak, E. Rovira, A. C. McLaughlin and W. Leidheiser, "Evaluating attitudes and experience with emerging technology in cadets and civilian undergraduates.," *Military Psychology,* vol. 29, no. 5, pp. 448-455, 2017.

[23] N. Stanton, Trust in military teams., Ashgate Publishing, Ltd., 2011.

[24] R. Pak, E. Rovira, A. C. McLaughlin and N. Baldwin, "Does the domain of technology impact user trust? Investigating trust in automation across different consumer-oriented domains in young adults, military, and older adults.," *Theoretical issues in ergonomics science,* vol. 18, no. 3, pp. 199-220, 2017.

[25] M. A. &. C. S. R. Finlayson, "The military interest in narrative.," *Sprache und Datenverarbeitung,* vol. 37, no. 1-2, pp. 173-191, 2013.

[26] A. Bousquet, "Chaoplexic warfare or the future of military organization.," *International Affairs,* vol. 84, no. 5, pp. 915-929, 2008.

[27] K. Charmaz, Constructing grounded theory: A practical guide through qualitative analysis., Thousand Oaks, CA: Sage, 2006.

[28] QSR International Pty Ltd, *NVivo qualitative data analysis Software,* Version 10 ed., 2012.

[29] Leximancer Pty Ltd., *Leximancer,* Brisbane.

[30] H. J. Rubin and I. S. Rubin, Qualitative interviewing: The art of hearing data., Sage Publishing, 2011.

[31] M. Field, "Building risk matrices from interview transcripts utilising HCA and IPA," in *[manuscript submitted for publication] Ergonomics and Human Factors Conference 2019*, Stratford-Upon-Avon, 2019.

[32] V. Braun, V. Clarke and G. Terry, "Thematic analysis," in *Qualitative Research in Clinical and Health Psychology*, Palgrave Macmillian, 2014, pp. 95-114.

[33] J. A. Colquitt, B. A. Scott and J. A. LePine, "Trust, trustworthiness, and trust propensity: A meta-analytic test of their unique relationships with risk taking and job performance.," *Journal of applied psychology,* vol. 92, no. 4, p. 909, 2007.

[34] K. F. MacDorman, S. K. Vasudevan and C. C. Ho, "Does Japan really have robot mania? Comparing attitudes by implicit and explicit measures," *AI & society,* vol. 23, no. 4, pp. 485-510, 2009.

[35] N. Carr, The glass cage: Automation and us., WW Norton & Company., 2014.

[36] P. Scharre, Army of none: Autonomous weapons and the future of war., WW Norton & Company, 2018.

[37] K. Morris, C. Schlenoff and V. Srinivasan, "A Remarkable Resurgence of Artificial Intelligence and its Impact on Automation and Autonomy.," *IEEE Trans Autom Sci Eng.,* vol. 14, no. 2, p. 407–409, 2017.

[38] J. M. Morse, Critical issues in qualitative research methods., Sage Publications, 1994.

[39] G. Klein, J. K. Phillips, E. L. Rall and D. A. Peluso, "A data-frame theory of sensemaking," in *Expertise out of context: Proceedings of the sixth international conference on naturalistic decision making*, New York, 2007.

Author/Speaker Biographies

Megan Field is a PhD Student at the University of Birmingham within the Human Interface Technologies Team. She specialises in qualitative research techniques with a focus on investigating limitations and barriers within complex sociotechnical systems through using her background in psychology, human factors (ergonomics) and Defence.

Paul Bass served for 33 years in the Royal Navy Submarine Service as a Weapon Engineer Officer before joining industry. Receiving 3* Commendations for operations and operational support, Alfie has managed and operated the Royal Navy's Submarine Command System through the transition from analogue, digital to the current drive for open architecture. His current role within BAE Systems Submarines tests the concepts of how to exploit technology and research in the next generation of submarine complex systems.