Generation after Next HMI in Defence: What might the future look like?

Victoria Steane[1], Katie Shepherd[1] & Erinn Sturgess[1]

[1]Research, Technology & Solution Innovation, Thales, Reading, United Kingdom

SUMMARY

Future systems in defence are likely to incorporate increasingly levels of automation and Artificial Intelligence. With data proliferation representing a significant challenge, alternative visualisation and presentation technologies may be needed to better support operators in completing tasks. This paper aims to provide a view of the current state of the art and future trajectory of visualisation and presentation technologies. Centred on the task of tactical picture compilation, this paper describes the findings of a scoping review and technology scan aiming to identify potentially suitable approaches to support the visualisation and presentation of a tactical picture in Generation after Next (GaN) systems.

KEYWORDS

Defence, generation after next, human machine interface

Introduction

Trend research indicates that future defence systems will make use of increasing levels of automation and use of Artificial Intelligence. It is widely anticipated that such approaches will have multiple benefits at varying levels (i.e., individual operator, team, and organisation). In a general sense, automation and AI aims to improve operational effectiveness and efficiencies contributing to improved lethality and survivability. It is anticipated that automation and AI will improve operator performance by enhancing their decision-making (making 'smarter' and 'faster' decisions), reducing workload and improving situational awareness. Despite the potential of such approaches, we know from the academic literature that significant Human Factors challenges remain with these approaches (e.g., issues relating to complacency, inappropriate trust calibration, misuse). Further, from a Human Computer Interaction perspective, significant issues remain that relate to dealing with increasing volumes of data; fusing and synthesising data from different sensors (both local and remote); dealing with uncertain and ambiguous data; and achieving a common understanding. Whilst user interfaces have evolved to meet current requirements, this approach may not be suitable for future requirements (Fay et al., 2020). In short, new Human Machine Interfaces (HMIs) may be required to maintain effective performance (Fay et al., 2020).

Imagining what the future may look like can be a difficult endeavour. This is because Generation after Next (GaN) capabilities often refer to things that are not yet available or fully understood. For HMI specifically, this may mean incorporating components yet to be made possible. Generating future-orientated solutions and innovations requires some degree of Strategic Foresight (SF; Gordon et al., 2019). SF requires researchers to use a structured and systematic approach to explore potential future ways of operating. For example, identifying trends and scenario planning are widely used and common methods that are used to help develop foresight (e.g., Schwarz, 2008; Vallet et al., 2020). Literature reviews, expert panels, Delphi studies, and use of visual artefacts to imagine future scenarios are also often used (Popper, 2008; Kimbell, 2011; Mozuni & Jonas, 2017).

Method

As the initial phase of developing strategic foresight, this paper will describe the findings of a scoping review and technology scan which intended to explore the current state of the art and trajectory of visualisation and presentation technologies. The review was intentionally broad to explore alternative ways of supporting and enhancing operator performance but also identified a number of tools, techniques and technologies that demonstrate potential. To contextualise the analysis, a use case surrounding tactical picture compilation was utilised. Tactical picture compilation was chosen because it is a process that is conducted across all defence domains to gain situational awareness about the surrounding environment. Tactical picture compilation is based upon the integration of data from local and/or remote sensors/sources (both human and non-human) to form a visual representation about your surrounding environment. It incorporates information relating to objects (i.e., identification, classification), that are displayed within a geographical context (i.e., in relation to own position, or the position of others/key points of interest). Generally, a tactical picture will be formulated using all available data sources (e.g., visual, aural, vocal) and is a coordinated endeavour, involving many people and systems – but can involve uncertain or contradictory information, depending on the sensors and situation. Further, in pursuit of multi-domain operations, there will need to be a shift from platform-centric approaches to domain-centric approaches. This will mean capitalising on fused data and multi-static processing. There is increasing emphasis on Multi-Sensor Data Fusion (MSDF) given its potential to improve decision-making and reduce cognitive workload (Kessler & White, 2017).

In order to understand specific challenge areas associated with tactical picture compilation, an empathy map was created with support from an ex-operator within the maritime domain. Empathy Mapping is a powerful tool within the solution innovation space as it enables you to build empathy and resonate with the intended user group allowing designers to consider how they may be better supported in fulfilling their role/task. They were first asked to consider how work is currently done and then, in light of potential future scenarios, consider how this may change. A number of challenge areas were identified using this approach (Figure 1).

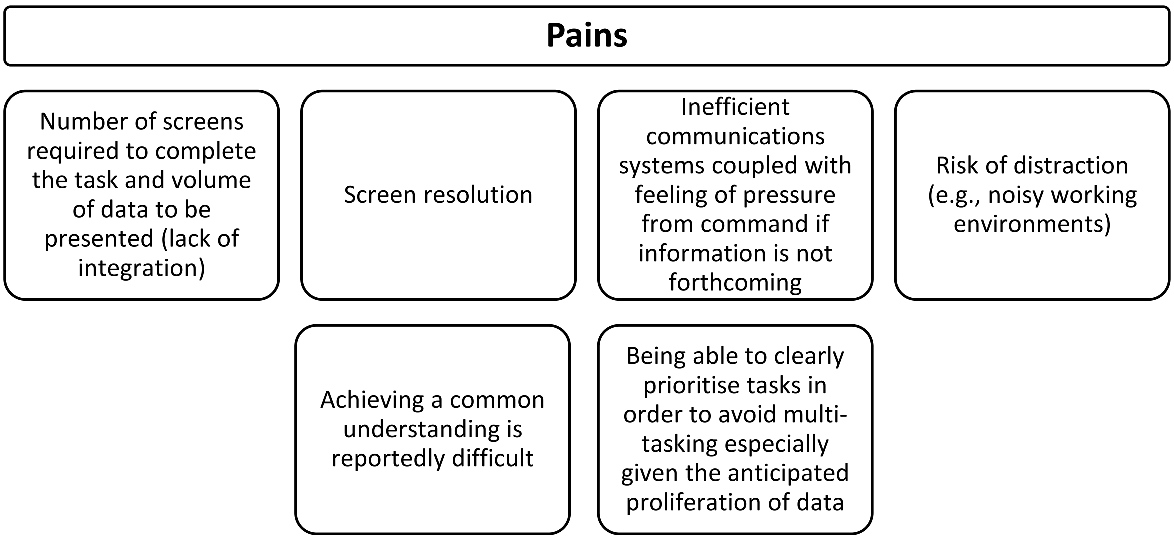

Figure 1: Challenge areas identified as relevant to tactical picture compilation

The suitability of alternative HMI approaches to this type of task were then explored further using a Red, Amber, Green (RAG) assessment – a robust approach offering Subject Matter Experts (SMEs) a way of identifying solutions that demonstrate most potential. The criteria used for assessment were broadly based on desirability, feasibility and viability metrics to allow for a holistic view to be taken (Figure 2), whilst also recognising the challenge areas identified above. For example, applicability to the task of tactical picture compilation and dissemination; integration with the system, training implications and safety.

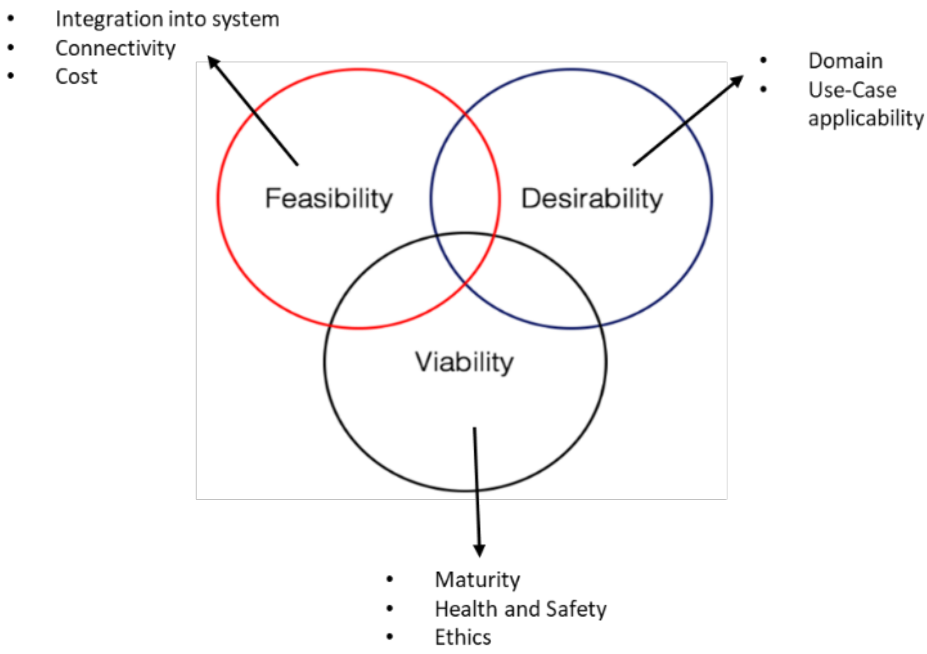

Figure 2: Connected nature of key assessment concepts

Findings

The RAG assessment identified a large volume of visualisation, presentation and decision support technologies as being of interest for future systems in which tactical picture compilation features. These included but were not limited to:

- 3D audio displays;
- Artificial Intelligence;
- Automation;
- Decision Support Systems; and
- Mixed Reality.

Despite the large volume of technologies identified, understandably not all were rated as being suitable for the task of tactical picture complication. For example, whilst 3D audio displays may be applicable to other roles within command teams, aural data is not used within target motion analysis. Some of the most promising technologies identified through the RAG assessment include:

Three dimensional (3D) displays

3D displays vary in size and the format of the display, yet provide the opportunity to present 360 degrees of information. Depending on the size and format of the display, 3D visual displays may be used to encourage co-location and collaborative working between team members and assist in the planning of operations. It is anticipated that the initial training burden for 3D visual displays will be moderate, as it represents a significant step change away from traditional 2D displays.

Whilst the detail on the technical development of 3D displays is beyond scope of the current work, it is important to acknowledge that images are presented to the eye using temporal or spatial interlacing. Temporal interlacing is prone to temporal artefacts (e.g., flicker, distortions in perceived depth) whilst spatial interlacing can be prone to poorer spatial resolution (Banks et al., 2016). However, in general, there is some evidence to suggest that 3D visual displays can improve operators situational awareness (e.g., Lager et al., 2019), user experience (e.g., Pitts et al., 2015) and improve overall system safety (e.g., Lager et al., 2019).

3D visual displays have been widely used within the civilian space for some time (e.g., mechanical design in the automotive and aviation sectors, medical imagery and architecture; Rousseau, 1994). In the context of tactical picture compilation, Rousseau (1994) argued that 3D visual displays would present informational components more intuitively, particularly for above and below water scenarios. Anti-Submarine Warfare displays, for example, could include the provision of high-resolution, computer generated imagery, pertaining to the environment (e.g., a representation of active, passive, location and environmental sensor information) and its relevance to the local bottom topography and water properties (Rousseau, 1994).

Augmented Reality (AR)

AR has been heralded as a technology that can be used to improve the ability of individuals to perceive information and performance in tasks leading to enhanced global awareness (e.g., Kim & Dey, 2016). Within the maritime sector, the use of AR technologies aim to support and improve operator situational awareness (Grundmann et al., 2022). However, it represents a relatively new technology for maritime operations meaning that the effects on operator performance are not yet widely understood (Van den Oever et al., 2023). Further, applications of AR within the maritime sector include ship navigation, construction, maintenance, inspection and training so more research is needed to fully establish the suitability of AR technologies to the task of tactical picture compilation. In the short term at least, AR may be suitable for training new operators (Patterson et al., 2010) or be used as a mechanism to overlay important information directly into an operator’s field of vision supporting the interpretation of real-time information. According to Lackey et al., (2014), simulation based training that emulates the real world is more likely to facilitate the transfer of learning to operational contexts. The utility of AR will be in part determined by the specific use case under scrutiny.

Holographic Displays

Unlike traditional 3D visual interfaces, holographic displays provide operators with the capability to move around and view different angles of the same image. It is anticipated that holographic displays will enable a more intuitive visualisation of the tactical picture as they enable assets and contacts to be visualised in their 3D positions and motion vectors. Within the marketplace, there are alternative forms of holographic displays. “Sandbox” implementations enable multi-person collaboration whilst “monitor” implementations are somewhat smaller but still enable up to three people to collaborate together (e.g. Urban Photonic Sandtable Display by the Defense Advanced Research Projects Agency); and has also been implied to aid situational awareness (Fay et al., 2019). In the context of command and control, both 3D and holographic HMI solutions may provide a platform in which a more open dialogue between team members may be achieved as they offer a means to view and plan in real-time, increasing the speed of decision-making.

Alternative visual HMI displays

Alternative HMI displays represent a significant step-change away from the traditional means of presenting data to tactical picture compilers. Touch foils and projection screens, for example, offer a way to enlarge the display area and permit greater collaboration amongst team members within control room environments. Other types of displays (e.g., mid-air displays and rollable displays) permit greater levels of flexibility in terms of the location in which tactical picture compilation may take place. Stanney et al., (2004) argued that graphics are better than text or auditory instructions when you are trying to communicate spatial information as they produce better comprehension of complex tasks. However, interfaces that allow for more active engagement or direct manipulation, as those identified above) are thought to lead to better comprehension of information, supporting users in dealing with and comprehending 'uncertainty' (Newton et al., 2017). Given that tactical picture compilation often involves handling ambiguous data, greater levels of embodied interaction with visualisations may support situational awareness and operator cognitive processing.

Discussion

Imagining the future can be challenging – particularly with a 2060 time horizon. However, technology scans provide the opportunity to explore the current state of the art and trajectory of visualisation and presentation technologies moving forward. This type of strategic foresight contributes to our understanding of future display technologies and their potential use in supporting and enhancing the work completed by tactical picture compilers in GaN systems remembering that "speculation unfettered by display constraints leads to some intriguing possibilities" Rousseau (1994, p.30). Whilst current technologies may not yet provide the level of sophistication required to fully realise its potential, the literature base points to many advantages of alternative HMI tools, techniques and technologies.

Moving forward, we must remain mindful that vision is the predominant sense used to convey information to humans yet there are many other senses that can be exploited to transfer information. For example, multi-modality interactions are likely to offer greater levels of enhancement than visual interventions alone in situations whereby operators are exposed to huge volumes of data. Multiple Resource Theory (MRT; Wickens, 2002) may offer a good foundation to guide the design of GaN HMI, particularly in situations whereby an operator is required to perform multiple tasks simultaneously. This is because MRT suggests that distributing tasks across different sensory modalities can reduce dual task interference, which should, in turn lead to more efficient information processing and better task performance (Wickens, 2002). Stanney et al., (2004) published a comprehensive set of guidance relating to optimal senses to convey different information types. Whilst this research is over twenty years old, the guidance still appears to be valid.

Future research will continue to use strategic foresight approaches in combination with Design Thinking approaches to further explore GaN HMI within the context of tactical picture compilation across a number of defence sectors (i.e., land, air, sea). Using Design Thinking provides a platform to co-create innovations that connect the needs of the intended end users with technical solutions. In this sense, it an alternative way of thinking about and approaching problems in a user-centred way. Inviting end users to be directly involved within ideation processes will provide further insight into "how" they may be better supported, "what" they might need and "when" they need it. This data can contribute significantly to the design of specifications for future systems.

References

Banks, M. S., Hoffman, D. M., Kim, J., & Wetzstein, G. (2016). 3D Displays. *Annual Review of Vision Science*, *2*(1), 397-435.

Fay, D., Stanton, N. A., & Roberts, A. P. J. (2019). All at sea with user interfaces: From evolutionary to ecological design for submarine combat systems. Theoretical Issues in Ergonomics Science, 20(5), 632-658.

Fay, D., Stanton, N. A., & Roberts, A. P. J. (2020). Designing future submarine control room HMIs. Contemporary Ergonomics and Human Factors 2020.

Gordon, A. V., Rohrbeck, R., & Schwarz, J. O. (2019). Escaping the 'faster horses' trap: Bridging strategic foresight and design-based innovation. Technology Innovation Management Review, 9(8), 30-42.

Grundmann, R., Hochgeschurz, S., Hohnrath, P., & Ujanki, A. (2022). White paper: Increasing maritime situational awareness by augmented reality solutions. Fraunhofer Center for Maritime Logistics and Services CML.

Kessler, O., & White, F. (2017). Data fusion perspectives and its role in information processing. In Handbook of Multisensor Data Fusion (pp. 35-64). CRC Press.

Kim, S., & Dey, A. K. (2016). Augmenting human senses to improve the user experience in cars: Applying augmented reality and haptics approaches to reduce cognitive distances. Multimedia Tools and Applications, 75, 9587-9607.

Kimbell, L. (2011). Rethinking design thinking: Part I. Design and Culture, 3(3), 285-306.

Lackey, S. J., Salcedo, J. N., Matthews, G., & Maxwell, D. B. (2014). Virtual world room clearing: A study in training effectiveness In Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC). Orlando, FL. 14045

Lager, M., & Topp, E. A. (2019). Remote supervision of an autonomous surface vehicle using virtual reality. IFAC-PapersOnLine, 52(8), 387-392.

Meshram, V. V., Patil, K., Meshram, V. A., & Shu, F. C. (2019). An astute assistive device for mobility and object recognition for visually impaired people. IEEE Transactions on Human-Machine Systems, 49(5), 449-460.

Mozuni, M., & Jonas, W. (2017). An introduction to the morphological Delphi Method for design: A tool for future-oriented design research. Journal of Design, Economics, and Innovation, 3(4), 303-318.

Newton, O. B., Fiore, S. M., & LaViola Jr, J. J. (2017). An external cognition framework for visualizing uncertainty in support of situation awareness. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 61, No. 1, pp. 1198-1202). Sage CA: Los Angeles, CA: SAGE Publications.

Patterson, R. E., Pierce, B. J., Bell, H. H., & Klein, G. (2010). Implicit learning, tacit knowledge, expertise development, and naturalistic decision-making. Journal of Cognitive Engineering and Decision-making, 4(4), 289-303.

Pitts, M. J., Hasedžić, E., Skrypchuk, L., Attridge, A., & Williams, M. (2015). Adding depth: establishing 3D display fundamentals for automotive applications (No. 2015-01-0147). SAE Technical Paper.

Popper, R. (2008). How are foresight methods selected? Foresight, 10(6), 62-89.

Rousseau, D. (1994). 3-D Displays and controls for sonar operators. Virtual Reality Systems, 1(2), 28-32.

Schwarz, J. O. (2008). Assessing the future of futures studies in management. Futures, 40(3), 237-246.

Stanney, K., Samman, S., Reeves, L., Hale, K., Buff, W., Bowers, C., & Lackey, S. (2004). A paradigm shift in interactive computing: Deriving multimodal design principles from behavioral and neurological foundations. *International Journal of Human-Computer Interaction*, *17*(2), 229-257.

Vallet, F., Puchinger, J., Millonig, A., Lamé, G., & Nicolaï, I. (2020). Tangible futures: Combining scenario thinking and personas-A pilot study on urban mobility. Futures, 117, 102513.

Van den Oever, F., Fjeld, M., & Sætrevik, B. (2023). A Systematic Literature Review of Augmented Reality for Maritime Collaboration. International Journal of Human–Computer Interaction, 1-16.
Wickens, C. D. (2002). Multiple resources and performance prediction. Theoretical Issues in Ergonomics Science, 3(2), 159-177.