



Investigation on the impact of human-automation interaction in maritime operations

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ABSTRACT

The level of automation around the world has grown significantly over the past few decades, and continues to do so. There are many reasons behind this trend, such as safety and potential economic benefits. However, when automation fails or behaves unexpectedly, the impact on the human operator can be severe. In a safety critical operation, such as on the bridge of a ship, the consequences could be catastrophic.

The research presented in this paper aims to improve understanding in this important area of study for the maritime industry. An experiment was conducted to assess the awareness of deck officer cadets in the recognition of a developing emergency situation due to failure of the autopilot. Using the results from this experiment and experiences from the aviation industry, the paper provides a potential strategy to improve automation monitoring and accuracy of situation awareness. This has led to the identification of opportunities to improve human-machine interaction.

1. Introduction

In safety critical industries the level of computerisation and automation has increased over the past few decades (Hadnett, 2008). In this context, automation has been introduced with the intention of increasing safety, efficiency, and productivity, and hence reducing operating costs (Harris, 2011). Commercial aviation was one of the leaders in this trend, with operations becoming increasingly automated in the 1980s (Sarter, 2008). Whilst this has been a mostly successful initiative, with automation handling routine operations well (Onnasch et al., 2014), automation has inadvertently created new accident pathways (Lützhöft and Dekker, 2002).

Automation limitations are commonly cited as issues such as degraded manual skills, ineffective monitoring, inaccurate situation awareness and over-reliance (Dhami and Grabowski, 2011). Recent aircraft accidents related to these issues are a cause of great concern in the aviation industry (FAA, 2013).

Maritime operations lag behind aviation in terms of technology introduction on the bridge (Schager, 2007), and so there may be scope to leverage experience from aviation to reduce the likelihood of similar occurrences in shipping. Alongside technology changes, the demographics of the deck officer population are also evolving. Over the

next 15–20 years, a significant number of masters and officers will be reaching the age of retirement (Department for Transport, 2014), to be replaced with crews who have only ever experienced heavily automated operations. Therefore, the trends associated with the negative impacts of automation could become even worse.

Research into the area of automation, and the interaction between human and machine, is relevant to current issues and future threats. This paper aims to improve understanding of automation limitations, as well as identifying current industry trends and ways to improve the human-automation partnership.

1.1. Automation technology

Automation has been defined as the mechanical or electrical accomplishment of work and in many cases it “involves the substitution of automation components for tasks that humans are capable of performing” (Wickens and Hollands, 2000). The levels of automation are typically split between (Balfe et al., 2015): information acquisition, information analysis, decision and action selection, and action implementation.

With the introduction of computerised systems, operators have become increasingly supervisory in their role (Meister, 1999), interacting

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Nomenclature

CAA	Civil Aviation Authority
SA	Situation Awareness

with systems through manual and automatic control (Lee and Moray, 1994) and for this reason human-computer interaction became a topic of significant research interest in the 1980s (Guastello, 2006).

Automation may be employed for a number of reasons, such as reducing workload, making up for human performance limitations, due to the operating environment being unsuitable for a human and/or reducing costs (Wickens and Hollands, 2000). Wiener and Curry (1980) and Balfe et al. (2015) considered increased capacity and productivity, reduced manual workload and fatigue, economical utilisation of machines, more precise handling of routine operations and reduced individual skills differences as benefits of automation.

However, these benefits are dependent on an automated system being of good design, and the operator receiving sufficient training in the effective use of the system (Parasuraman and Manzey, 2010). Despite the benefits, Wiener and Curry (1980) suggested that automation has limitations, which will contribute to accidents. These limitations are over-reliance and complacency, low alertness, low proficiency in manual skills, automation bias and automation induced failures. Bainbridge (1983) also discussed in “The ironies of automation” areas of manual control skills, cognitive skills and monitoring. Bainbridge mentioned that when automation was introduced, the operator was originally tasked to perform manual control, left to monitor the automation, and intervene when failure occurred. However, the net result led to deterioration of manual skills due to lack of practice. Although monitoring seems to be a straightforward task, most of the time the process or system works smoothly and there is very little to do. Therefore, the operator can find it difficult to maintain effective monitoring for more than half an hour, when information is largely unchanged (Bainbridge, 1983). Whilst automation can outperform human operators at routine tasks, when automation fails the effect on human performance can be catastrophic (Onnasch et al., 2014).

1.2. Review of accident caused by automation technology

Whilst intended to reduce human error, automation systems may result in larger errors (Wiener, 1989) and as a result new accident sequences have been inadvertently created through automation implementation (Lützhöft and Dekker, 2002).

Automation and its effects on the human operator in aviation has been studied for decades (Carr, 2015). According to the UK Civil Aviation Authority's (CAA) ‘Global Fatal Accident Review 2002–2011’ (CAP 1036), of the 205 accidents over that period, 62% had flight crew related factors as the primary cause, which could be related to degraded manual handling skills (CAA, 2013).

The problems associated with ineffective monitoring and degraded situation awareness were identified by Wiener and Curry (1980) and this issue continued to be a concern in the 1990s (FAA, 1990; Parasuraman and Riley, 1997). Into the 2000s, the common theme of over-reliance on the automation, in spite of the guidance issued, still remains. The 2002–2011 accident data from the CAA indicates that effective automation monitoring remains a key concern for the aviation industry today. Combining ineffective monitoring, with over-reliance on automation and consequently degraded situation awareness, can lead to a startled response when faced with sudden automation failure (Jarvis et al., 2014). This in turn can lead to poor performance from the crew, and the loss of the aircraft.

Similar situations could happen in the shipping industry and it is worthwhile to learn lessons from the aviation industry. A ship's

navigating bridge could be considered equivalent to the aeroplane cockpit. A ship's bridge has positions for navigation, traffic surveillance and manoeuvring, route planning, communications and safety operations, manual steering, and docking operations (Linna, 2005). On modern vessels, separate pieces of equipment, such as a Global Positioning System (GPS), electronic charts and depth sounders, are integrated into one main system (Belev, 2004). An integrated system must decide what information to display, and in some cases, what actions to take based on that information (Mills, 2006). A typical integrated bridge system is shown in Fig. 1.

However, the increased levels of technology and automation on the bridge have not been trouble free (Mills, 2006) (Schager, 2007). Hadnett (2008) states:

“The relentless drive within the shipping community to introduce electronic navigation aids to merchant ships had the principal stated objective of improving safety by enhancing situational awareness. However, some of the doubts expressed at the inception of these initiatives regarding their likely success have been realised, in that there is now a commonly held view that the general standard of bridge watch-keeping has been eroded, leading to several collisions and groundings.”

In light of accidents due to automation failure, the Short Course Programme in Automated System in Shipping (SURPAS), an EU funded project, provided specialist training to seafarers to understand the automation systems and enable them to comprehend the weaknesses and limitations of such systems. In the initial stage of the project, in reviewing sea accident investigations, it was found that 60% of shipping accidents are due to human error. In this study it was concluded that better education and training is one of the solutions to potentially reduce such accidents. They also proposed cooperation between users and producers of automated systems to create a platform for transfer of knowledge and ultimately eliminate man-machine interface problem (SURPASS Project, 2012).

1.3. Human factors related to accidents

Human Factors, as a research topic, is a “multifaceted subject drawing on psychology, sociology, physiology and medicine, engineering and management science” (Harris, 2011). As 80% of accidents in high risk industries can be attributed to human error (O'Connor et al., 2008), there is a clear benefit to understanding the human-machine interaction.

Both technical and human action barriers are built into a well-designed system, with a view to improving resilience. This is in order to protect both humans and machines from each other's weaknesses (Re and Macchi, 2010). Human and machine related errors need to line up to create a pathway for an accident sequence to propagate and pass through what should have been barriers. Human factors in relation to the automation technology that contribute to the occurrence of an accident are human error, lack of situation awareness, automation complacency and automation bias.

1.3.1. Human error

Consistent definitions of human error are summarised by (Wickens and Hollands, 2000), who suggest that error can occur if the operator interprets the situation incorrectly, the action decided upon is incorrect, or the action decided upon may not be carried out correctly. The performance of a particular individual, and so the likelihood of error, can be influenced by many factors such as skill, experience, age, fatigue, humidity and noise (Park, 2011). Hetherington et al. (2006) reviewed the literature on safety in shipping and addressed human error failures at design, personnel and organisational levels. In their review, they highlighted the most common human error factors were due to misjudgement and improper lookout or watch keeping. In another related study, Turan et al. (2016) presented the outcome of the SEAHORSE project focused on safety in marine transport and addressed human and organisational

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