Identified Handover Tools and Techniques in High-Risk Domains:

Using distributed situation awareness theory to inform current practices

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**Abstract**

In high-risk domains, poor shift handover has been identified as a key contributing factor in many incidents. This raises the question of: how can personnel collaborate effectively during shift changes? The vast majority of handover literature relates mainly to healthcare, aviation, energy generation and distribution domains. This review identified 19 distinct handover tools/techniques (HTTs) that domains employ to improve handover communication. The most prevalent HTT is standardisation in the form of a structured checklist, followed by the bidirectional exchange of information. This review assesses and summarises HTTs using ‘distributed situation awareness’ theory, and provides a comprehensive review on what is currently practised in high-risk domain handover, as well as a discussion around their potential contribution to raising distributed situation awareness.

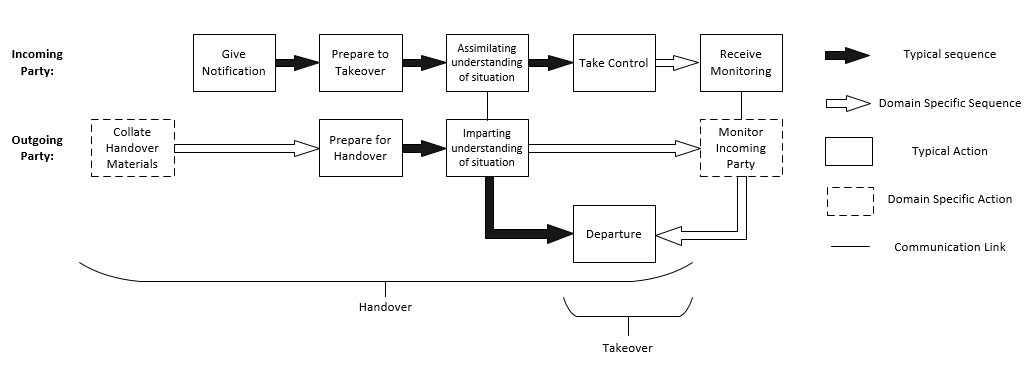
*Keywords:* handover, handoff, communication, distributed situation awareness

**Introduction**

**1.0 The handover of control and responsibility**

In work environments requiring continuous human-to-human activity (for example, air traffic control (ATC), healthcare, military, maritime, energy generation and distribution, logistical boundaries dictate the need for a handover of control and responsibility between personnel (Stanton, Salmon, Jenkins and Walker, 2010). Boundaries may include high levels of operator fatigue, an imminent breach of operational capabilities or the requirement of a specialist. The handover task creates issues for safety, as incidents disproportionally occur directly following handover (e.g. Thomas, Schultz, Hannaford, & Runciman, 2013). These incidents are typically attributed to inadequacies in the transfer of ‘situation awareness’ (SA; Stanton, Salmon, Walker, Hancock, & Salas, 2017) during the handover period. The challenge that many domains must face is how outgoing personnel can effectively encourage compatible SA for incoming personnel and foster a seamless and safe handover of control and responsibility. This review identifies and summarises the handover tools and techniques (HTTs) that high-risk domains involving human-human handover employ to achieve better communication during shift-change, and discusses these HTTs through the lens of Distributed Situation Awareness theory (DSA; Stanton et al., 2006). This is with the intention for current practitioners to evaluate their own, potentially new domain, and identify which HTTs may be suitable for their domain’s unique requirements.

Throughout the literature, many terms have been used to represent the handover process and the variety of steps involved. The terms identified by the authors were: handover, handoff, takeover, sign-out, shift-change, shift-to-shift report, transition of care, exchange of control, and position relief briefing (Andorre & Quiennec, 1996; Eurocontrol, 2007; Fassert & Bezzina., 2007; Federal Aviation Administration, 2010; U.S. Department of Transportation, 1995; Riesenberg, 2012; Wilkinson & Lardner, 2013). Many of these definitions have their own applications to the specific domain in which their used (e.g. transition of care in healthcare settings). Given that all of these terms relate to the process of an incoming agent taking responsibility/control from an outgoing agent, we use the term ‘handover’ to apply to the collection of these terms.

A number of authors have attempted to create structure for application to the handover task. Grusenmeyer’s (1995) phases of shift change outline that the handover occurs over four stages: the end of shift, the arrival of the incoming operator, the meeting and the taking of post. Mccall, Mcgee, Meschtscherjakov, Louveton, & Engel (2016) have provided a simpler interpretation of two phases, the ‘notification’ and ‘the event’. One common misunderstanding is the distinction between ‘handover’ and ‘takeover’, as both have been used interchangeably in the research literature (Walch, Lange, Baumann, & Weber, 2015). Recent reviews have clarified that ‘takeover’ refers to the moment of the incoming party regaining control, and the outgoing party has relinquished control (Eriksson, & Stanton. 2017; Merat & de Waard, 2014; Morgan, Alford, & Pankhurst, 2016). Following this framework, we define the ‘handover’ as the entire process beginning with the ‘notification’ from either party, and ‘takeover’ as the moment that control is relinquished. As a result of this review, optional steps during the handover are also presented in figure 1.

*Figure 1.* Flowchart outliningthe handover process definitions adapted from definitions in Merat & de Waard, 2014. Dashed boxes and white arrows indicate optional stages.

Domains typically have a protocol when it comes to the handover. Many make use of unique HTTs to guide the handover task. For the purpose of this review, the authors define HTTs as encompassing communication strategies, handover aids, and any other action/method adopted to attempt to improve communication during the handover process.

* 1. **Applying Distributed Situation Awareness to the handover task**

During its inception, and its emergence in the literature, situation awareness has had a central focus on the individual – the human in which a task is concerned (Endsley, 1995; Stanton et al., 2006; 2017). The most influential SA model outlines perception, comprehension and projection as being the constructs that make up situation awareness. As systems become more complex, this approach is becoming limited in its scope, as it does fails to address how information is stored, distributed, and can interact with its networked components (Stanton et al., 2006; 2017).

Due to the complexity of the handover task and the numerous artefacts involved, situation awareness should be addressed via a systems-approach and view the handover task as a collection of transactions in SA between components within a system (Stanton et al., 2006; 2017). DSA suggests that to ensure that a system works effectively, a system must acknowledge that each individual and component (e.g. interfaces, sensors, and automation) has its own perception the situation, and for humans, a unique understanding of the situation viewed through their own experience. Therefore, rather than merely share information about the situation, SA should be made compatible between components through means of transactions related to the task and roles in which individuals experience (Stanton et al., 2006; 2017). DSA implements a cyclical approach inspired by the Perceptual Cycle Model (Neisser, 1976; consisting of world, perception and schemata) where the system has overall SA that is dynamically changing in line with environmental cues – perhaps as a result of actions taken by the components within the system (Salas, Dickinson, Converse & Tannenbaum, 1995; Stanton et al., 2017). Schemata, as defined by Neissar (1976), comprises both genotype and phenotype schemata. These are described as consisting of schemata that are already present as a result of previous experiences, and schemata that are dynamically created as a response to the activity and interactions, respectively.

In regards to the handover task, there has been much discussion regarding raising SA. Studies typically address the perception of situation elements (e.g. de Carvalho, Benchekroun, & Gomes, 2012; Durso, Crutchfield, & Harvey, 2007; Le Bris et al., 2012). This feature of SA has been discussed in practical settings in the form of ‘information transfer’ (IT), which relates to the effective sharing of information between groups of individuals within and between organisations (see. Borowitz, Waggoner-Fountain, Bass, & Sledd, 2008; Bulfone, Sumathy, Grubissa, & Palese, 2012; Stanton et al, 2017; van Wijk, Jansen, & Lyles, 2008). The DSA approach describes IT as providing the receiver with ‘transactions’ that can be integrated with their own schemata (Sorensen & Stanton, 2016). Further, transactions are bidirectional as both the receiver and deliverer become aware of each other’s awareness (Salmon et al., 2009; Sorensen & Stanton, 2016). This view focuses on each agent building their own SA for application to their own particular tasks and goals, whilst relating to their own experience and training.

As a result of work exploring the role of DSA in team-work, Salmon et al. (2009) outline sixteen guidelines (see table 1).

|  |  |
| --- | --- |
| Table 1. *Distributed Situation Awareness Design Guidelines* | |
| Guideline No. | Guideline |
| 1 | Clearly define and specify SA requirements |
| 2 | Ensure roles and responsibilities are clearly defined |
| 3 | Design to support compatible SA requirements |
| 4 | Design to support SA transactions |
| 5 | Group information based on links between information elements in DSA requirements analysis |
| 6 | Support meta SA through training, procedures and displays |
| 7 | Remove unwanted information |
| 8 | Use customisable/tailored interfaces |
| 9 | Use multiple interlinked systems for multiple roles and goals |
| 10 | Consider the technological capability available and its impact on SA |
| 11 | Ensure that the information presented to users is accurate at all times |
| 12 | Ensure information is presented to users in a timely fashion that and that the timeliness of key information is represented |
| 13 | Provide appropriate and explicit communication links |
| 14 | More information is not exclusively better |
| 15 | Use filtering functions |
| 16 | Present SA-related information in an appropriate format |

For an in-depth discussion regarding these guidelines, see Salmon et al (2009). These guidelines provide practitioners with a way of improving system performance, where need-to-know information is displayed appropriately for that individual and their role. How well these guidelines can be applied to current handover practice is yet to be determined, a recurring issue cited across the literature is ‘how much is too much?’ with regards to information exchange (transactions).

**1.2 Purpose of the review**

Past reviews in handover protocol have been limited in scope, either by: interpreting strategies for their application to a specific field of practice (Lardner, 2006; Lawrence, Tomolo, Garlisi, & Aron, 2008; Morgan, Alford, & Pankhurst, 2016; Patterson, Roth, Woods, Chow, & Gomes, 2004; Plocher, Yin, Laberge, Thompson, & Telner, 2011; Riesenberg, 2012; Thomas et al., 2013), focusing on a narrow set of studies (Patterson et al., 2004; Raduma-Tomás, Flin, Yule, & Williams, 2011), exploring the domains rather than comparing and contrasting the protocols implemented (Wilkinson & Lardner, 2012), or are becoming out-dated (Patterson et al., 2004). Further, no review has yet applied the theory-base of DSA (Stanton et al., 2006) to the handover task.

This review aims to collate, compare and contrast literature regarding the handover tools/techniques (HTTs) used in a variety of domains during handover, and discuss them in light of DSA, and summarise them based on the design recommendations made by Salmon et al. (2009).

**Method**

**2.0 Search methods and source selection**

Many key terms such as ‘handover’, ‘handoff’, and ‘shift change’ relate to radio technology, chemistry, biology and physics. Where possible, search terms were filtered to hone in on relevant handover literature. Sources were searched for with the terms displayed in table 2 using Web of Science, Google Scholar and Scopus. The titles of the first 1000 results from each search were reviewed, ordered by relevance on Google Scholar, citation count on Web of Science and all results from Scopus to ensure that as many key papers were captured as possible. Subsequent search terms were then adapted to target specific domains based on keywords found in previously identified articles.

Many industries report their protocol in large organisational reports; therefore, a wealth of information regarding an industries practice can be gleaned from a handful of these reports. To supplement search, the bibliographies of four key papers and reviews of major domains were reviewed, selected for their breadth of knowledge and their relevance to hard-to-access areas (i.e., Catchpole et al., 2007; Plocher et al., 2011; Lardner, 1996; Patterson & Woods, 2001).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table 2. *Syntax used during literature search* | | | | |
| Syntax | Search Tool | Result Count | Action | Unique identified articles |
| Intitle: handover(s) OR "hand over(s)" OR handoff(s) OR "hand off(s)" OR signout(s) OR "sign out(s)" OR signover(s) OR "sign over(s)" NOT radio(s) NOT network(s) NOT mobile(s) NOT wireless *AND*LANGUAGE:(English) | Web of Science (filtering out telecommunication related fields) | 1,884 | Titles of top 1000 most cited reviewed | 528 |
| Google Scholar | ~17,200 | Titles of top 1000 most relevant reviewed | 134 |
|  | Scopus (filtering out telecommunication related fields) | 378 | All titles reviewed | 96 |
| Intopic: “shift handover” | Web of Science | 45 | All titles reviewed | 9 |
| Intopic: “shift change” OR “shift changes” OR “shift changeover” | Web of Science Filtered for relevant handover domains | 129 | All titles reviewed | 9 |
| Intopic: handover AND oil | Web of Science | 30 | All titles reviewed | 4 |
|  | Identified from key papers | - | All titles reviewed | 19 |

In total, 799 sources were identified. The vast majority of sources were related to the healthcare domain (698, 87.36%), followed by aviation (40, 5%), energy manufacturing (35, 4.38%) and other domains such as military and railroads (7, 0.87%). The remainder of sources were classified as being unaffiliated (19, 2.37%). The representation of handover in the domain of healthcare is likely due to the importance of patient safety, resulting in higher amounts of research attention and funding. Consequently, in some domains, the handover process is more likely to be mentioned in papers or books related to human cooperation or the causes of specific accidents rather than having articles or books dedicated to the issue.

All 799 titles, and where necessary, abstracts, were reviewed on their contribution to the handover strategy literature in their relevant domain, either by discussing or proposing handover strategies to be implemented. 419 sources met this criterion. From these, 376 papers were related to healthcare handover. To create a platform for equal representation across domains, only medical sources that mentioned handover ‘strategies’ in their abstracts were included in the final review. 40 medical sources were carried over to the review, alongside the 43 from the other domains totalling 83 sources. The final sources were comprised of a range of source types: 28 literature reviews, 19 quantitative studies, 16 qualitative studies, 11 organisational documents, 4 mixed methods documents, 4 design papers, and 1 discussion paper.

**Results and Discussion**

**3.0 Overview of Handover Tools/Techniques**

In total, 19 HTTs were identified within the literature. Table 3 outlines the frequency at which HTTs were discussed, in each domain, as a viable tool in aiding the handover of responsibility.

Commonalities include the demand for standardisation, vocal communication, and making use of technology during handover. However, domains appear to differ in many aspects regarding the handover procedure. The healthcare domain focuses on training programmes and the use of contextual information (e.g Anderson, Malone, Shanahan, & Manning, J, 2015; Haig, Sutton, & Whittington, 2006; Iedema et al., 2009; Bost, Crilly, Patterson, & Chaboyer, 2012), whereas energy manufacturing focuses on the accumulation and review of accurate past information (e.g. Adamson, Lardner, & Miller, 1999). Aviation pays a particular emphasis on clarifying control and overlapping responsibility through monitoring the operation of their counter-part (e.g. FAA, 2010).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3.  *Authors’ count of sources discussing each HTT as a viable method* | | | | | | | | |
| No. | HTT | Healthcare | Aviation | Energy | Military | Maritime | Unaffiliated | Total |
|  | [Total number of sources] | 40 | 20 | 17 | 1 | 1 | 4 | 83 |
| 1 | Standardisation | 31 | 13 | 7 |  | 1 | 2 | 54 |
| 2 | Vocal Communication | 16 | 9 | 9 | 1 | 1 | 2 | 38 |
| 3 | Use of past information | 12 | 6 | 14 | 1 | 1 | 1 | 35 |
| 4 | Training programmes | 19 | 3 | 5 |  |  | 2 | 29 |
| 5 | Bidirectional exchange | 13 | 7 | 8 |  |  | 1 | 29 |
| 6 | Use of technology | 12 | 7 | 4 | 1 |  | 1 | 25 |
| 7 | Face-to-face | 10 | 3 | 6 | 1 |  | 2 | 22 |
| 8 | Adaptation | 11 | 3 | 4 |  |  | 1 | 19 |
| 9 | Compatible mental model | 7 | 6 | 4 | 1 |  | 1 | 19 |
| 10 | Preparation | 5 | 3 | 7 | 1 |  | 2 | 18 |
| 11 | Contextual handover | 13 | 1 | 1 |  |  | 1 | 16 |
| 12 | Read-back | 8 | 1 |  |  |  | 1 | 10 |
| 13 | Clarify control | 2 | 7 |  |  |  | 1 | 10 |
| 14 | 3rd parties | 7 | 1 |  |  |  | 1 | 8 |
| 15 | Overlap of vigilance | 1 | 6 | 1 |  |  | 1 | 8 |
| 16 | Assess handover | 3 |  | 2 |  |  |  | 5 |
| 17 | Shared responsibility | 4 | 1 |  |  |  |  | 5 |
| 18 | Multiple media |  |  | 3 |  |  | 1 | 4 |
| 19 | Walkthrough |  |  | 1 |  |  |  | 1 |

*Note.* HTTs are ordered by total number of mentions as a viable HTT across all domains

During this review, it was found that most HTTs, in some way, have been discussed in an empirical framework, whether that be through interpretations of case studies or measurements during controlled trials. The most cited HTTs have been assessed using both objective and subjective approaches. Other HTTs, such as ‘clarify control’ and ‘contextual handover’, appear to have been developed in response to domain constraints or vulnerabilities. Finally, a minority are poorly represented in the literature (e.g. guided walkthrough) so appear to have no explicit findings to show that they are effective. It is important for domains to validate their approaches to their handover tasks to ensure that they are effective for their specific situations.

**3.1 Standardising handover protocol (1)**

With two thirds of the sources including some discussion around the standardisation of handover protocol, it can be safely concluded that the majority of research attention has been paid towards establishing a domain-wide approach to handover protocol. Many authors from across the domains agree that a standardised handover protocol reduces the likelihood of critical information being omitted (e.g. Adamson et al., 1999; Brazier & Pacciti, 2008; Dawson, King, & Grantham, 2013; Norris, West, Anderson, Davey, & Brodie, 2014; Riesenberg, Leitzch, & Little, 2009a), whilst also ensuring that critical information is not subject to any bias or misinterpretation (Gross et al., 2016). By far the most favoured strategy towards standardisation is the adaptation of a structured checklist or mnemonic to the specific domain/setting in which it is to be applied. Forty-seven of the fifty-two identified sources discuss their application.

It is of no surprise that the content of checklists is vastly different between domains. Domains differ on the type of information as well as the content, for example, Patterson et al. (2004) notes that the healthcare domain cannot assess patient status ‘at a glance’ and require a holistic view on the patient’s condition. Whereas ATC operators can take advantage of transmitting information in a predictable fashion (e.g., air pressure will always be required and either be referred to as high/low/min stack; Fassert & Bezzina, 2007).

An example of the most discussed case of standardisation comes from the medical domain, with 18 sources discussing SBAR (situation, background, assessment and recommendation) as a viable structure for handover. SBAR was designed to ensure the transmission of a mental model, as well as reduce cognitive demands during handover meetings (Arora, Johnson, Meltzer, & Humphrey, 2008; Cheung et al., 2010; Haig et al., 2006; Riesenberg et al., 2009b; Riesenberg, Leitzsch, & Cunningham., 2010). SBAR addresses SA sufficiently, as it gives the individual a sense of the previous events and the rationale behind actions to allow for them to perform the task effectively following the handover (Haig et al., 2006).

Previous studies indicate that structuring information during handover has the capability to reduce absolute medical errors made (see. Horwitz, Moin, & Green, 2007; Starmer et al., 2014a; Starmer et al., 2014b). These structures address SA by presenting relevant information at the perceived correct timing (Salmon et al., 2009). Many of the structures found for the clinical domain within this review focus on a holistic interpretive account of the situation, whereas those used in air traffic control appear to be more descriptive. An example comes from the National Air Traffic Services (NATS) in the UK who make use of mnemonics such as PRAWNS in the approach environment, outlined below (Walker, Stanton, Wells, & Gibson, 2010, Wilkinson & Lardner, 2012):

* P – Pressure (Barometric)
* R – Runway currently in use
* A – Area sector information and how they are organised
* W – Weather conditions
* N – Non-Standard Priority Information
* S – Strip data for aircraft status

The mnemonics within air traffic control typically include information about the current situation that will affect future decisions without explicitly transmitting past information or current goals, but rely on the operator’s decision-making and schemata to interpret this information. The content of these mnemonics are specific, and do not involve the same encompassment of a mental model as checklists like SBAR. However, air traffic controllers make use of other HTTs to supplement handover, such as monitoring radars prior to and after handover, which will be discussed in the relevant section.

Energy production and distribution control room operators favour longer and more detailed checklists to ensure that physical checks have been complete prior to takeover (Lardner, 2006). In this domain, leaving out one detail can lead to disastrous consequences. Examples include that of the Buncefield fire incident in 2005 caused in part by a miscommunication of which pipeline was filling which tank. This has since been attributed to many deficiencies in shift changeover protocol including a lack of handover structure resulting in uncertainty around whether key information had been transmitted; in doing so, operators collectively lost SA in relation to the current operational status (Brazier & Pacitti, 2008; Gordon, 1998; Wilkinson & Lardner, 2012; Stanton et al., 2010; Wilkinson & Lardner, 2013). To avoid incidents such as Buncefield, checklists are used to cover risk factors related to handover, and ensure that all information related to previous, current and future work has been included (Adamson et al., 1999; Department of the Army, 2007; Lardner, 2006; Wilkinson & Lardner, 2012; Wilkinson & Lardner, 2013).

From a DSA perspective, checklists allow domains to identify ‘need-to-know’ information and ensure that it is delivered at the appropriate time. Unwanted information can be addressed, and reduce inefficient information exchange. However, the authors suggest that problems may arise during the implementation stage. For example, SBAR is applied to a range of arguably contrasting circumstances across healthcare. A rigid checklist that is generally applied loses the specification factor as it may not be tailored to that individual role/task. Providing shift-workers with standardised approaches to the handover tasks may ensure that schema, and SA, is compatible amongst agents prior to the handover task. Further, it may allow for the domain to implement what they believe is necessary information during this time leading to an optimisation in the amount of information transferred (Sorensen, & Stanton, 2016; Stanton et al., 2006).

As a final note on this HTT, there is a warning to be made regarding strict overreliance on standardisation. Cohen, Hilligoss, & Amaral (2012) contest the use of checklists by stating that the implementation of a rigid checklist can result in a bias towards one-way transmission of information. Further, if a checklist is to be used, it is important that the checklist be tailored for the specific domain and sub-domain in question (Staggers and Blaz, 2013) - a poorly constructed checklist can result in longer handover times and increase the amount of irrelevant content transmitted - in line with the DSA guidelines put forward by Salmon et al. (2009).

**3.2. Vocal communication, face to face and bidirectional exchange of information (HTTs 2, 5 & 7)**

Throughout the literature, HTTs 2, 5 and 7 were discussed either on their own or as a collective. This section will discuss them together as they all relate to exchanges made from one operator to another.

Written information has been described as being insufficient for handover when used as the singular stream of IT (Adamson et al., 1999; Brazier & Pacitti, 2008; de Carvalho et al., 2012). Research over recent years has focused on the importance of the vocal exchange of information during handover. Sources typically distinguish between written and verbal handover, where verbal relates to the use of voice rather than text. These sources have been classified as ‘vocal’ in our review for clarity. In nursing, it has been suggested that rather than replacing the current flexibility of handover with ‘over-rigid standardisation’, vocal communication skills can be developed to enhance the handover and is applicable to all nursing situations (Randell, Wilson, Woodward, & Galliers, 2011). Further, in space mission-control, it is common for operators to refuse to take control unless a vocal update has been given (Patterson & Woods, 2001).

Research in healthcare settings suggests that vocal communication directs attention towards priority information more readily than written information (Chui & Stone, 2012). Other suggestions from healthcare, aviation and energy domains suggest that vocal communication provides a platform for feedback on how well information is being received (Adamson et al., 1999; FAA, 2010; Parke, Hobbs, & Kanki, 2010; Parke & Mishkin, 2005; Walker et al., 2010). From a DSA perspective, face-to-face and vocal communication provides an explicit avenue of communication which allows for immediate two-way feedback to be given, and ensures that the shift taking over can receive the information that they require through the use of questioning. Such advantages should be taken advantage of, as this provides domains with the support required for transactions in SA to take place.

The healthcare domain mentions face-to-face interaction more so than other domains, likely due to the enhanced capability of the environment. Other domains are more likely to conduct tasks at a workstation, thereby hindering face-to-face interaction. Hobbs (2008) notes that in aviation maintenance face-to-face interaction can be used to transmit non-verbal communication to gain additional information using gestures and emphasis (Philibert, 2009). Further, face-to-face interaction is less effortful and immediate (Lebie, Rhoades and MacGrath, 1996).

Research also suggests that one-way information transmission is not as effective as two-way interaction (Cohen et al., 2012). The role of questioning has been a major focus of handover literature, placing a requirement for the incoming staff member to engage in cooperative interaction to facilitate the handover procedure (Drach-Zahavy & Hadid, 2015; Parke & Kanki, 2008; Rayo et al., 2014). As an example, Parke and Mishkin (2005) illustrate that during NASA’s Mars Exploration Rover (MER) mission, featuring the rovers ‘Spirit’ and ‘Opportunity’, three major handovers took place. These involved lengthy face-to-face meetings involving two-way interactions so that questions could be asked. Through asking questions, gaps in the knowledge of the incoming operator can be filled, and rather than relying on the transfer of a descriptive account, the receiver can create their own mental-model (Bost et al., 2012; Revell & Stanton, 2012). This is done through the access of additional information that may not have been transmitted originally.

Errors and incidents may occur when a culture of questioning is not permitted (Sutcliff, Lewton, & Rosenthal, 2004; Wachter & Shojania, 2004). Many organisations have written this into their official protocol (e.g. Eurocontrol, 2012; Lardner, 2006; The Royal College of Surgeons of England, 2007) noting that the handover should be a two-way process, giving the person about to take responsibility an opportunity to ask questions.

**3.3 Use of past information (3)**

In air traffic control, space-shuttle operations and energy manufacturing control rooms, knowledge of what has happened is suggested to be important in the process of raising SA in individuals, as this allows operators to understand current and future operation and goals (Adamson et al., 1999; Kontogiannis & Malakis, 2013; Patterson & Woods, 2001; Stanton et al, 2017). Twelve of the fourteen (86%) energy-manufacturing domain sources reviewed in this paper discussed reviewing logs, making this their top priority during the handover.

In energy manufacturing and distribution, the handover of correct and accurate information is conducted to avoid scenarios such as the major incidents such as the Buncefield explosion mentioned in HTT 1 (see, Wilkinson & Lardner, 2013). Another example of this is the Piper Alpha explosion (Lardner, 1996; Paté-Cornell, 1993) that has been partly attributed to the failure to transmit information about a removed safety release valve for a condensate pump during shift changeover. The next shift encountered an issue with a second condensate pump and made the decision to restart the (unbeknownst to them) compromised pump, giving way to the resulting explosions that occurred shortly after. Knowledge of such consequences may be why more experienced operators are more likely to check previous trends and information when coming onto shift (Li, Mckee, Horberry, & Powell, 2011). However, relying heavily on personalised logs and notes has been criticised as being under-structured, and should include structures to ensure priority information is transmitted (Plocher et al., 2011). If this HTT is to be adopted, thought should also be paid to the structure and the layout of handover logs, alongside trials to assess their effectiveness.

The DSA approach favours such an HTT, as it allows for information to reside in the system, without relying heavily on one-to-one communication (Stanton et al., 2006). However, this approach does not provide an immediate explicit communication, although it may serve as a safety net should the incoming shift require information without having to establish communications with the previous shift.

**3.4. Training programmes (4)**

Errors that occur during handover may be due to insufficient training (Li, Powell, & Horberry, 2012). When implementing a structured handover, providing individuals with the appropriate training has been reported to be an effective HTT (Gordon & Findley, 2011; van Sluisveld, Zegers, Westert, van Der Hoeven, & Wollersheim, 2013; Pucher, Johnston, Aggarwal, Arora, & Darzi, 2015; Weikert & Johansson, 1999). This has been achieved in a number of ways including giving guidance on an implemented structured tool, enhancing communication skills, building trust between staff members and taking part in simulations of handover scenarios (Drach-Zahavy & Hadid, 2015; Gordon & Findley, 2011; Horwitz et al., 2012; Pucher et al., 2015). Under the DSA guidelines providing such training programmes may allow for individual schema to be addressed, and ensure that agents are compatible during their transactions (Neisser, 1976, Stanton et al., 2006).

Many organisations across domains note the importance of training and practice on handover effectiveness (Eurocontrol, 2007; Fassert & Bezzina., 2007; Patterson et al., 2004; Weikert & Johansson, 1999). An example of a programme comes from the healthcare domain is the ‘HELiCS programme’. This programme makes use of video playback of real-time scenarios so that personnel can develop their handover communication through discussion and in-depth analysis (Bost et al., 2012; Iedema et al., 2009).

**3.5 Use of Technology (6)**

The DSA theory base places an emphasis on the use of technology and its role in SA. Information residing in displays, sensors and automation is no longer supplementary to humans, but rather forms an element of the system as a whole (Stanton et al., 2006). In current day operations, technology plays a central role in team communication. Bolstad, Endsley, & Hill (2003) explored the ways in which SA can be raised during army operations. Their review recommended aspects such as video conferencing, file sharing, networked radios and programme sharing to exchange information. All reviewed domains make use of technology in the form of either electronic handover tools, electronic logs/health records or video data to handover more effectively (Cheung et al., 2010; Hannaford et al., 2013; Parke & Kanki, 2008).

Literature has repeatedly outlined the importance of designing human-machine interfaces with the human operator in mind (Hopkin, 1989; Stanton, 1993). In air traffic control, this has been particularly important as the development of technologies such as sensing devices, computer assistance, and prediction services, all of which have changed the landscape of how humans interact with their work setting over time (see, Nolan, 2010). These interfaces can be optimised to foster a smoother handover (Brazier & Pacitti, 2008; Hopkin, 1989). Today’s air traffic controllers use radars and electronic flight strips at their workstations to raise situation awareness during the handover period (Durso, Crutchfield, & Harvey, 2007; Kontogiannis & Malakis, 2013; Walker et al., 2010).

Lawrence et al. (2008) discussed technological possibilities for coordinating handover in a chaotic emergency department involving colour changes of screens 2 hours before handover and a blinking 40 minutes prior. The use of electronic time tracking allows staff to pre-empt the handover with enough time to prepare. Further, studies have explored the benefits of using electronic systems rather than paper systems to handover shifts, and they report improvements to the continuity of care, likely due to the increased accessibility of information (Cheah, Amott, Pollard, & Watters, 2005; Raptis, Fernandes, Chua, & Boulos, 2009). Allowing for information to be distributed across the system in computer, as well as human agents, ensures that the system keeps high SA, without requiring the transmission of unnecessary information during handover (Stanton et al., 2006).

**3.6. Adaptation of task or setting (8)**

Situational factors, such as the timing and location of the handover, may affect handover. The location of handover is deemed as being important due to distractions such as noise or staff interruptions posing a threat to the effective transmission of information (Cheung et al., 2010; Spooner, Corley, Chaboyer, Hammond, & Fraser, 2015). In healthcare settings, the location of handover significantly varies between institutions (Street et al., 2011). A call to standardise the location for handover has been made over the years, as this ensures access to data-systems, be away from distractions and allow confidential information to be passed on (Chui & Stone, 2012; Singer & Dean, 2006). Douglas, Raban, Walter, & Westbrook (2016) also discuss multi-tasking in healthcare and include the handover as one of their considerations. They draw upon van Rensen et al.’s (2012) findings that conducting vocal handover after monitoring equipment had been prepared was more effective and no more time consuming than doing both concurrently.

The timing of handovers is also important so that individuals are well prepared for the handover (Eurocontrol, 2007). In domains such as energy manufacturing, the incoming operator must be aware of the upcoming handover so that that no attention-critical events are managed during this time. Setting timetables for the handover allows personnel to plan time effectively for tasks such as checking records. Further, this allows them to make an early arrival to ensure handover goes smoothly (Wilkinson & Lardner, 2012; Wilkinson & Lardner, 2013). A tactical example of adaptation comes from air traffic control. By conducting the handover during a low workload period, the deterioration of control can be avoided (Durso et al., 2007; Walker et al., 2010). ATC tasks are shifted towards achieving short-term goals, whilst putting requests on hold to ensure that the incoming operator can handle the issues in their own way (Durso et al., 2007).

**3.7. Compatible Mental Model (9)**

Being able to synchronise goals and establish a narrative has long been regarded as the goal of the handover. This is facilitated through understanding how humans process information (Grusenmeyer, 1995). A large focus in some of the identified sources is specifically related to how raising situation awareness is not done through receiving information alone, but rather being able to relate information to schemata, tasks and temporal features of the environment (Stanton et al, 2017). A mental model is defined as a mental representation of how the real world operates, and can be applied to a given task (Revell, & Stanton, 2012). Every individual possesses a mental-model regardless of if it is accurate or not (Revell, & Stanton, 2012), in line with the DSA approach of compatible SA between agents (Stanton et al., 2017). Therefore, by assuming that the outgoing operator’s mental model of the situation is correct, the goal of the handover is to transfer SA and ensure that the incoming party has an adequate mental model of the situation.

With the popularity of SBAR in healthcare settings, the focus on a shared mental model has been successful in the healthcare domain. Cohen et al. (2012) outline that individuals have mental models as a summary of the information available to them so they can pass on to the following shift. They describe how similar mental models during handover allows for slight differences to approaches that may not have been considered previously. LeBaron et al.’s (2016) recent exploratory analysis of how Intensive Care Unit (ICU) physicians coordinate their actions by communicating a mental image of *“where we were, where we are, and where we’re going”* (p. 520).

**3.8. Preparation (10)**

Setting time aside to handover is important to ensure that materials are in place, although in areas such as energy distribution, this appears to be commonplace (Stanton & Ashleigh, 2000). This is likely due to less pressure on time limits and more detailed information to read through (Adamson et al., 1999; Wilkinson & Lardner, 2012; Wilkinson & Lardner, 2013). A period for preparing and reviewing handover material was also utilised in the Mars exploration rover handover procedure (Parke, 2005).

**3.9. A Contextual Handover (11)**

Our review found that domains differ greatly on the likelihood that a specific set of information will be required for handover. Domains like air traffic control involve predictable information types, whereas in healthcare settings the need to adapt to different patient statuses, needs and requirements requires a flexible handover procedure. Due to many sub-domains in healthcare settings being present, some researchers have made it clear that a domain-wide standardisation may not be possible (Anderson et al., 2015). If handover is overly structured, details regarding the patient’s unique condition may be omitted and the capability for medical staff to make up for this through use of previous experience may have an impact on the quality of the handover (Staggers & Blaz, 2013).

Patterson (2008) warns against the unintended consequences of standardising a domain-wide rigid checklist. In reality, trade-offs have to be made due to external pressures, and staff must use their intuition by deviating from the template. Consequently, they may be criticised by authorities for any failure that may occur due to their deviation, even if they are fully justified in their deviation due to the contextual aspects involved. Therefore, HTTs that are resilient to these environmental pressures should be favoured (Drach-Zahavy, Goldblatt, & Maizel, 2015), as well as HTTs that take into account a range of local factors (Bulfone et al., 2012). As an example, the energy production domain favours allocating more time to handover if the incoming staff have been absent for a longer period of time (Adamson et al., 1999). This approach better ensures that situation awareness is raised to the required level based on the current state of the incoming shift.

**3.10. Other Handover Tools and Techniques (HTTs 12-19)**

A number of additional HTTs were also identified. These HTTs have been grouped into two distinct groups: those related to handover techniques, and those concerned with handover quality. The handover techniques are read-back, clarification of control, use of multiple media, and walkthroughs. Those concerning handover quality are the presence of a third party, overlap of vigilance, assessments of handover quality and shared responsibility. Each following paragraph in this session outlines a given HTT.

**Additional techniques.**

* The use of read-back involves the receiver repeating back to the sender information that they receive. This approach can be used as a way of ensuring the accurate transmission of information and correct any errors. This HTT may have an additional benefit, reviewed by Macleod, Gopie, Hourihan, Neary, & Ozubko, (2010), who refer to the improvement of memory simply by saying a word aloud. This technique has shown to improve the handover procedure in the healthcare domain (Boyd et al., 2014; Brown, 2004; Patterson et al., 2004).
* In a plane’s cockpit, who is in control of the aircraft can be unclear at times. In these scenarios, verifying who has control during handover can be useful. Some crews state “you have control” with the person taking control instantly replying “I have control” to ensure that both parties are aware of the transition of control (U.S. Department of Transportation, 1995).
* Arora et al. (2008) describe how a culture of shared responsibility can help manage the negative effects of the handover. By working as a team with shared goals and mental models, handover can be made more effective compared to doctors treating their patients as ‘their own’. Air traffic control also practices this, as both the outgoing and incoming operators are tasked with the effective transmission of information (FAA, 2010).
* The energy-manufacturing domain make use of guided walkthroughs during handover to ensure that incoming operators have seen the status of the facility. This is conducted alongside a vocal talk-through, and allows the outgoing operator to remind himself or herself of all information required for handover and allow incoming operators to see first-hand the status of their environment (de Carvalho et al., 2012).

**Handover quality.**

* Many sectors find that conducting the handover with the presence or monitoring of a patient or an authoritative figure can have a positive influence on information transfer. Particularly, errors can be corrected and logistics can be better managed (Flink et al., 2012; Patterson et al., 2004; Tobiano, Chaboyer, & McMurray, 2013).
* In ATC, it is common for operators to monitor one-another’s task handling prior and after the takeover (FAA, 2010; Kontogianni & Malakis, 2013; Walker et al., 2010). During the arrival stage of the handover, the incoming operator scans the radar to familiarise themselves with the airspace and the strategies taken by the current operator. They achieve this by plugging in his or her headset into a communications port to listen to outgoing and incoming transmissions. After the takeover of control, the outgoing operator oversees the new operator for a brief period to ensure the tasks are being dealt with appropriately (Durso et al., 2007; Walker et al., 2010).
* Many sources have noted that finding methods to measure the quality of handover is important to ensure that current HTTs and factors related to staffing are adequate (Brazier, & Paciti 2008; Lardner., 2006).
* Multiple media is also used to provide information in a variety of ways helps to encompass a range of information types. Sources claim that supplying handover information vocally and written information concurrently is a viable method for improving handover communication (Brazier, & Pacitti, 2008; Lardner, 1996).

**3.11 HTTs and the DSA guidelines**

In regards to the HTTs generated in this review, many have been identified as being of importance within DSA research (e.g., training programmes, standardised protocol, assessing performance; Salmon et al., 2009). From this review, there are notable insights that could be drawn upon. HTTs that focus on the availability of accurate information for accurate representations of the situation (e.g. standardisation, technology, contextual handover) can be applied to the DSA approach of transactions of information regarding the situation when, and where, it is necessary (Stanton et al., 2006; 2017). For example, training programs can be utilised to foster suitable schemata for better comprehension of these cues, and address an individual’s schema, in line with the perceptual cycle model and DSA (Neisser, 1976; Plant, & Stanton, 2017; Stanton et al., 2006).

Techniques such as overlap of vigilance rely on individual SA representations within each operating pair, so that if SA is not compatible (perhaps in the form of missing cues or not comprehending/projecting the scenario sufficiently), then the outgoing operator has the opportunity to correct this if they detect a danger in the current operation. Assitionally, standardising information to understand what is ‘need-to-know’ may also provide practitioners with a way to reduce the amount of unwanted information present, and allow for an efficient delivery of information. By extension, following protocol may also allow individuals to know what is expected of them, who knows what, and who needs to know what and when. This can be aided by the use of technology through addressing a number of guidelines related to the presentation of information, and storing information within electronic sources.

HTTs such as bidirectional exchange and implementing a ‘contextual handover’ may allow for shifts to tailor information to their own individual needs/roles. By doing so, unwanted information can be filtered, allowing incoming shifts to retrieve only the information that is required.

Domains have a variety of human-factors analysis techniques (such as Task Analysis; Annett, 2003, or Cognitive Work Analysis; Vicente, 1999) to refine their protocol, checklists and training programmes to facilitate transactions and improve system performance. It would no doubt be beneficial to a domain to implement a combination of HTTs into a handover protocol in order to address all of the recommendations made by Salmon et al. (2009) for raising DSA.

**4.0 Conclusion**

Nineteen Handover Tools/Techniques (HTTs) were identified in a range of high-risk domains such as healthcare, aviation, and energy manufacturing/distribution. Domains differ on their approaches to the handover procedure, although many similarities exist. Popular HTTs include the use and adaptation of checklists, two-way interaction with questioning, and the use of past information. This review has provided a discussion of these HTTs in relation to distributed situation awareness (DSA) and provides a unique perspective on the handover task. Many of the HTTs identified address DSA in a variety of ways - the authors believe that to maximise benefits, multiple HTTs should be adopted so that guidelines presented by Salmon et al. (2009) can be addressed in their entirety.

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