Abstract

To carry out their roles, first responders need to have appropriate skills. It is important to identify and train in key skills appropriate for the tasks that first responders will perform. Once these skills have been acquired, they need to be maintained otherwise they will decay to the point where performance of the skill is no longer acceptable. This means that emergency services organisations need programs that appropriately maintain the skills of their volunteers and employees. To deliver cost-effective training, these organisations need a good understanding of what key skills are required for tasks that are regularly performed, why and how quickly these skills decay and how these skills can be maintained. To help emergency services organisations better understand these important concepts, this paper reviews relevant literature on skill decay and skill maintenance. Task decomposition methods and training needs analysis are introduced to assist organisations determine what key skills they require. This provides information to make sound, evidence-based decisions about recurrent training programs that can maintain the skills required by first responders and retain efficacy in the organisation.

Understanding skill decay and skill maintenance in first responders

Peer Reviewed

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Introduction

The acquisition and maintenance of personnel skills is a critical element in the effective performance of any organisation. However, skill acquisition and retention is more crucial for first responders where poor performance may result in adverse outcomes that may affect individuals, their colleagues, organisations and communities (Boyle & Eastwood 2018; Flin, O'Connor & Crichton 2008; Vaughan, Stoliker & Anderson 2020; Villado *et al.* 2013; Youngquist *et al.* 2008). The lack of skill maintenance opportunities and the resulting skill decay is a particular challenge when people are not able to practise skills on a regular basis, as is the case for many volunteers (Hughes *et al.* 2020, Vlasblom *et al.* 2020). This issue has become more evident since the arrival of COVID-19 and the resulting pandemic restrictions that have reduced the opportunities for personnel to undertake recurrent training. Programs to maintain skills typically occur within the context of broader organisational pressures, including changing priorities and limited resources. The costs of recurrent training, access to facilities, environmental constraints and a distributed workforce all present difficulties to skill maintenance programs. Examining current literature can help organisations improve their understanding of what the key skills are for tasks that are regularly performed, why and how quickly these skills decay and how these skills can be maintained.

Method

Relevant literature was identified using the search terms: 'skill decay', 'skill atrophy', 'skill maintenance' and 'skill acquisition'. Databases searched included Ebscohost, ScienceDirect (Elsevier SD Freedom Collection) and Science Database (ProQuest). The literature was explored for relevance and applicability to first responder organisations, then organised thematically to identify key theoretical areas.

Skills and tasks

According to Johnson and Proctor (2016) a 'skill' reflects complex learnt behaviour necessary to respond to some form of goal-oriented task. Skills are not innate, rather, they must be learnt and require careful coordination of perception, cognition and action to achieve the required task (Kluge *et al.* 2016). There are many skills in which first responders are trained so they can effectively undertake mission-critical operations. Understanding the range of skills necessary to perform the work of a first responder is an essential element of suitability of skill attainment and retention measures. Skills become the practical enabler of task achievement, enacted by individuals or teams to achieve goals.

Skills can be classified along different dimensions such as physical and cognitive, natural and synthetic (or artificial) and closed-looped and open-looped (Arthur *et al.* 1998). Physical tasks require manual effort or exertion (such as moving a patient), while cognitive tasks are characterised by perceptual input, mental operations, problem-solving and decision-making. The task environment will determine if it is natural or synthetic with natural tasks existing within an uncontrolled or 'real-world' environment while synthetic (or artificial) tasks occur in a controlled environment (Arthur *et al.* 1998; Driskell, Willis & Copper 1992). Closed-looped tasks capture those that are managed or controlled by process, often being a fixed set of tasks with a clear beginning and end. An example of a closed-looped task in firefighting is the donning/doffing procedure for compressed air breathing apparatus. Open-looped tasks are less process driven actions focused on problem-solving or similar considerations that are continuous in nature and do not have a clear start and end. Open-looped tasks may include incident size-up and ongoing management of safety at the incident. It is important to identify the different types of skills required for task performance because different types of skills decay at different rates (Arthur & Day 2013). Generally, cognitive tasks decay faster than physical tasks, synthetic tasks decay faster than natural tasks, open loop tasks decay faster than closed loop tasks and accuracy tasks decay faster than speed related tasks (Arthur *et al.* 1998).

Skill decay

Skill decay is defined as the loss or decay of trained or acquired skills (including knowledge) after periods of non-use (Arthur *et al.* 1998). Skill decay is a particular problem for volunteer first responders who may not use skills on a regular basis, although there is evidence that it can also be problematic for full-time employed first responders (Skelton & McSwain 1977, Zautcke *et al.* 1987). It is important for first responder organisations to understand how skills decay and how to maintain these skills so that appropriate and timely training can be provided.

Semb and Ellis (1994) demonstrate that while learners retain significant amounts of knowledge after learning and training, retention decreases as a function of time. Stothard and Nicholson (2001) display this as a forgetting curve or skill decay curve (Figure 1), which represents the declining nature of skill retention. Skill decay curves provide an effective method to predict the rate at which a skill is likely to decay (Vlasblom *et al.* 2020).

Skill decay curves vary as a function of task-type, cognitive demands, the conditions of learning the task and frequency and types of interference (Arthur & Day 2013, Gronlund & Kimbell 2013). This means that an organisation must have a good understanding of the critical skills that are required in first responder roles to assess and determine decay rates.

Arthur and co-authors (1998) identified factors that directly relate to and impact on skill decay. These factors provide a framework from which skill retention and decay can be explored and managed. Not all factors will be relevant to every skill and associated task, however, collectively they provide a comprehensive structure to determine the variabilities between skills that directly inform how skills decay. These factors include:

- type of skill
- methods of testing
- evaluation criteria
- the retention interval
- conditions of retrieval
- the degree of overlearning (Arthur *et al.* 1998).

The methods of testing and the evaluation criteria used to assess skills are of less interest for a general discussion of skill decay. Thus, the focus here is on the retention interval (which includes consideration of the different types of skills) and the conditions of retrieval. The degree of overlearning is relevant to skills maintenance and is considered in that section.

Retention intervals

Figure 1 shows that skills decline as time increases away from initial learning. Arthur and co-authors (1998) examined retention intervals relative to skill decay and found that as the length of time associated with a retention interval increases so does the extent of skill decay. Relative to one skill assessment they tested, they found that an average performance level of 92% below that of the original assessment level was produced after 365 days

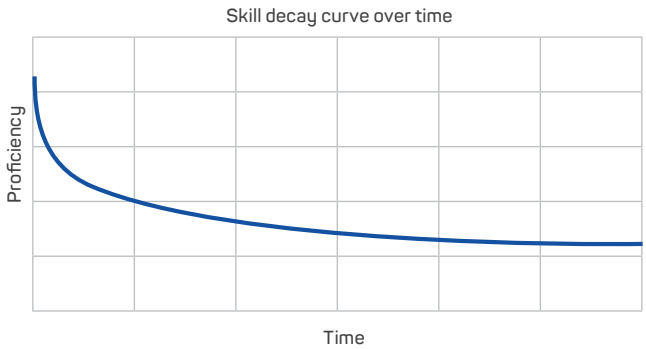

Figure 1: Skill decay curve showing the decline in skill proficiency is rapid soon after attainment if the skill is not maintained.

Source: Stothard and Nicholson (2001)

of non-use. Different types of skills will decay at different rates (i.e. they will be retained over a longer or shorter time interval). Generally, cognitive tasks decay faster than physical tasks, synthetic tasks decay faster than natural tasks, open loop tasks decay faster than closed loop tasks, and accuracy tasks decay faster than speed related tasks (Arthur *et al.* 1998).

Conditions of retrieval

Arthur and co-authors (1998) identified that skill retention is dependent upon 2 factors:

- how the information was initially encoded
- the types of cues present at retrieval.

How the information is encoded is largely based on the manner of training delivery and opportunities to compare the new skill to previously learned information (Arthur *et al.* 1998). When a skill is used after training, the cues present in the current situation that indicate the need to use the skill will affect whether the skill can be recalled and used. If the cues present in a situation are similar to the training scenarios, it is likely that the skill will be recalled. However, if they are very different, then it is likely that the skill will not be recalled. Higher fidelity training that accurately matches the cues and psychological demands that are likely to be experienced in real-world situations will result in better retention of skills (Stothard & Nicholson 2001). This is described by the concept of identical elements (Thorndike & Woodworth 1901) and can be framed in terms of improved transfer of training (Saks & Belcourt 2006, van der Locht *et al.* 2013).

Skill maintenance and refresher training

Figure 1 shows that the majority of skill decay occurs relatively soon after acquisition, with the loss stabilising over time (Stothard & Nicholson 2001). The rate at which a skill decays (represented by the skill decay curve) is important to understand when setting refresher training intervals. The use of refresher training is a method to break a retention interval and periodically increase skill performance relative to a standard or criterion. Figure 2 depicts a standard decay rate of a skill in dark blue with the impact of individual or team refresher training on performance in light blue. The required standard of performance for the skill is shown in orange. The upward gradient of the orange line highlights that operational environments continue to evolve across multiple dimensions (e.g. ongoing changes to technology and equipment, procedures and types of threat or risk). This aspect means that first responders whose skills have decayed significantly may suffer a larger gap between the skills they hold versus the skills required to perform their role effectively.

Figure 2 shows that the period associated with non-use of a skill is directly related to skill decay. However, the effective spacing or distribution of refresher training improves skill retention for a period of time before it again decays.

The period between training sessions is the 'interstudy interval' and is represented by the periodic increase in performance

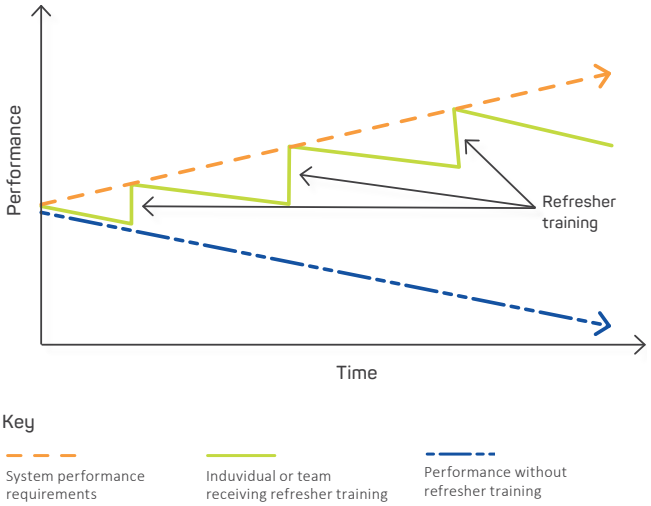

Figure 2: Performance, skill decay and the impact of refresher training.

Source: Hayes (2014)

associated with refresher training in Figure 2. The spacing of interstudy intervals has been explored by Arthur and co-authors (2010). Results showed that longer interstudy practice intervals can enhance performance and promote long-term skill retention in certain circumstances. While initially this may appear to act in opposition to the theory of skill decay, such considerations highlight the criticality of managing skills on an individual basis with knowledge of skill decay as a product of time and the benefits of carefully distributed practice.

Overlearning

One method often used to improve skill maintenance is overlearning. Overlearning is where additional training is provided in excess of that required for initial proficiency; reducing the likelihood that a response will decay and be forgotten (Arthur *et al.* 1998). A meta-analytic study investigating the effects of overlearning found that to demonstrate a reduction in skill decay required a threshold of at least 50% overlearning and that overlearning was more effective for reducing decay in cognitive than physical skills (Driskell, Willis & Copper 1992).

Kluge and co-authors (2016) examined the role of overlearning, specifically the benefits of retentivity and symbolic rehearsal. Skill retentivity refers to the maintenance or sustainment of skills in the absence of practice while symbolic rehearsal captures the imaginary practice of a skill without actually performing it (Kluge *et al.* 2016). The study indicated that symbolic rehearsal was unable to prevent skill decay, however, it was able to attenuate the severity of decay. As such, the role and function of symbolic rehearsal should not be overlooked within training systems, especially when other forms of more complex training may not be available or are unable to be performed.

Rohrer and Pashler (2007) explored the benefits of overlearning over time. They found that the effects of overlearning were clearly identifiable after one week, but the benefits were almost undetectable after 4 weeks. Similarly, Driskell, Willis and Copper (1992) found that the duration of the benefits from overlearning were somewhat limited (i.e. less than 38 days). While the benefits of overlearning may be short lived in some situations, where a critical skill needs to be carried out without error, overlearning may be useful if sufficient resources are available (Rohrer & Pashler 2007).

Individual differences

The level of skill performance attained by an individual is largely the result of training quality, practice and experience. This establishes the point from which skill decay commences (Johnson & Proctor 2016). However, for each individual there are likely to be large differences in the quality of training received, opportunities to practice skills and the experience they develop. Individuals also vary in their ability and motivation to learn and perform skills. These differences in the performance of skills need to be factored in to decisions about refresher training frequency (Stothard & Nicholson 2001). Determining the point at which individual or team refresher training is required means that the relevant performance standards (or criterion level of performance) are met with acceptable levels of competency. To support first responders who have differing access to high-quality training, large differences in practice opportunities and widely differing levels of expertise, it is sensible to build flexible systems that support the differences in skill performance that may exist within organisations.

Non-technical skills

Non-technical skills are cognitive and social skills (such as teamwork, decision-making, situational awareness, leadership, fatigue and stress management) that complement the technical skills required to carry out the work (Hayes *et al.* 2021). Non-technical skills play a critical role in first responder operations (Flin, O'Connor & Crichton 2008). First response is fundamentally a teamwork activity that coordinates technical skills in a time-constrained, dynamic environment.

In many first responder domains, training competency frameworks and operational guidelines have focused on technical skills relating to practical (technical) activities with a limited focus on the role, function and importance of non-technical skills (Civil Aviation Authority 2017, National Fire Protection Association 2015). Technical skills are activities such as effective application of medical procedures, pitching a ladder to make ready and haul-aloft equipment or undertaking a primary or secondary search in a smoke-obscured building. These technical skills will only be effective if they are supported by good teamwork, decision-making, situation awareness and leadership (i.e. non-technical skills).

The execution of non-technical skills may be implied in some existing technical competencies, for example, an officer's training in incident management and supervision may help them to undertake incident size-up (situation assessment) to inform decision-making about the initial action plan. However, this is not the same as being trained to recognise, interpret and anticipate events and to understand the limitations and pitfalls inherent in the process. Situation awareness is more than being aware of the external environment and becomes difficult to achieve as the complexity and dynamics of a situation increases (Endsley 1995). Situation awareness is developed and practiced through specific training and is a skill that benefits from increased competency development and maintenance programs.

Teamwork is set of non-technical skills that are critical for effective response. If first responders do not communicate effectively, cooperate and coordinate their activities properly, then the operational outcome will be poor; putting responders and the public in danger. Arthur and co-authors (2013) identified the criticality of teamwork relative to skill retention and the importance of differentiating between teamwork (facilitation of interaction among members in the accomplishment of team tasks) and taskwork (team effort to understand and perform the requirements of the task). Performing refresher training on taskwork does not necessarily mean that teamwork is sufficiently addressed relative to reasonable standards or criteria. Training systems should require non-technical skills as a component of the performance of technical skills and as a set of skills that need to be trained and maintained in their own right.

Task decomposition and training needs analysis

It is essential that first responder organisations have a thorough understanding of the skills and tasks that are required in any given activity. This helps to determine the particular skill requirements for each task based on how critical that task is (Arthur *et al.* 1998). Several techniques (such as job analysis and task analysis) exist that deconstruct work activities to understand the component parts (Frederiksen & White 1989, Johnson & Proctor 2016, Moore 1999). These methods are a systematic and reliable way to identify the key skills required to carry out tasks and provides information that directly informs instructional and training design (Fine & Wiley 1971, Moore 1999, Salmon *et al.* 2010). Principled task deconstruction can be used to order tasks based on how critical they are and identify mission-critical tasks compared to tasks aligned with lower-level goals (Johnson & Proctor 2016).

Training needs analysis can also be used to identify learning needs like course planning, delivery and evaluation (Gould *et al.* 2004). As a process, training needs analysis guides the collection, analysis and interpretation of data to define:

- when formal instructional actions are the best option (or not) to remedy gaps in competencies
- the profile of who needs to be trained
- what content should be taught (Kraiger *et al.* 2014).

Figure 3 shows a schematic of the role needs assessment and task analysis can play in holistically determining training needs for an organisation and highlights the information dependency

between needs assessment and task analysis. The process commences with organisational analysis to identify the areas that need improvement and the target groups within the organisation who can provide input and data relevant to the analysis. The areas requiring improvement inform the task analysis and also inform the redesign of policies and procedures required for training needs as determined by the task analysis. Once the areas needing improvement are identified, the target groups complete a gap-analysis of the difference between the knowledge, skills and attitudes needed compared with those that currently exist. The outcome of the analysis feeds into the redesign of policies and procedures and, collectively, indicate the training need as a final outcome.

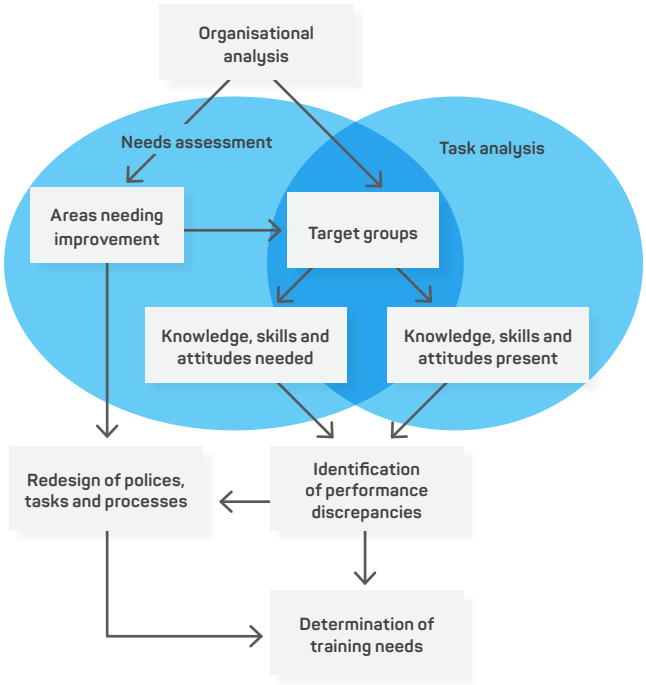

Figure 3: Determining training needs is a network of analysis and decisions based on Needs Assessment and Task Analysis.

Source: Johnson and Proctor (2016)

There are helpful tools and guides that can assist in completing task analysis including 'A guide to task analysis' by Kirwan and Ainsworth (1992), tools for the application of hierarchical task analysis by Hone and Stanton (2004) as well as a practitioner's guide to cognitive task analysis titled, Working Minds, (Crandall, Klein & Hoffman 2006). The selection of task analysis tools and processes should be considered carefully for their suitability for the contexts in which they might be applied.

Conclusion

Skill decay and skill maintenance present real challenges to the effective performance of first responders. This paper has highlighted some important concepts that first responder organisations need to consider and provided information on how to understand and manage skill sets for first responders. By considering the nature of skills, their decay rates and appropriate maintenance schedules, first responder organisations can make evidence-based, defensible decisions around investments in skill maintenance programs. This brings benefits to first responders who receive the best training possible at the most appropriate times so they can more effectively carry out their work in communities.

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