

**HS 1.004 Skill Fade Competence Retention Analysis Handbook**

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**Acronyms & Abbreviations**

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
| AV | Air Vehicle |
| ARI | Army Research Institute |
| BIMS | Battlefield Information Management System |
| BNG | British National Grid |
| CF | Competence Framework |
| CRA | Competence Retention Analysis |
| CRA-T | Competence Retention Analysis Technique |
| CTA | Cognitive Task Analysis |
| DIF | Difficulty, Importance and Frequency |
| DSAT | Defence Systems Approach to Training |
| Dstl | Defence Science and Technology Laboratory |
| EO | Enabling Objective |
| HMI | Human Machine Interface |
| HSSRC | Human and Social Sciences Research Capability |
| JSP | Joint Service Publication |
| KLP | Key Learning Point |
| KSA | Knowledge, Skills and Attitudes |
| PPE | Predictive Performance Equation |
| RAF | Royal Air Force |
| RFI | Request for Information |
| RPS | Role Performance Statement |
| SME | Subject Matter Expert |
| TDA | Trainers Decision Aid |
| TGA | Training Gap Analysis |
| TNA | Training Needs Analysis |
| TO | Training Objective |
| TPS | Training Performance Statement |
| UAS | Un-crewed Air System |
| UDA | User Decision Aid |
| US | United States (of America) |

**Definitions**

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Adaptive cognition | The ability to adapt existing Knowledge and Skills to meet the demands of a new and unfamiliar situation, where the context changes completely. |
| Competence Retention Analysis -  Technique (CRA-T) | Predictive skills retention model that involves the identification of different psychological knowledge and skill domains and corresponding indicative  retention intervals. |

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| Complex decision- making | Iteration of stepped information processing cycles involving situational assessment, analysis and evaluation that continue until a decision is reached. Execution of a decision will often initiate further cycles.  Multiple assumptions/hypotheses and evidence have to be considered resulting in options/courses of action from which the decision-maker has to select the most optimal. The processes involved can be articulated by the decision-maker. |
| Component complexity | The number of subtasks and their underpinning task elements, along with the underlying type of skill (i.e., simple or complex cognitive). The higher the number of subtasks/task elements and the more these are  underpinned by complex cognitive skills, the greater the component complexity. |
| Conceptual Relationships | Interconnections between subtasks within a task. There are two types of conceptual relationship. The first type is coordinated but not integrated (i.e., where the subtasks are not performed concurrently). The second type is integrated i.e., where the subtasks are performed concurrently. |
| Continuous psychomotor skills | The ability to perform well-trained and practised motor actions that do not have distinct beginnings or endings. |
| Coordinative complexity | The nature of the conceptual relationships between subtask inputs and outputs. The higher the number of conceptual relationships, the greater  the coordinative complexity. |
| Cognitive Task Analysis (CTA) | Supplements traditional task analysis techniques to enable training designers to identify the conceptual relationships that underpin complex task performance. CTA involves the use of knowledge elicitation techniques, for example, the application of verbal protocols with experts thinking aloud while performing a task. |
| Discrete  psychomotor skills | The ability to perform well-trained sequences of actions with a distinct  beginning and end. |
| Dynamic complexity | The expected increase in unpredictable input/output changes to one or more subtasks that may impact whole task performance. The higher the number of expected input/output changes to one or more subtasks, the  greater the dynamic complexity. |
| Explicit knowledge | Declarative knowledge about basic facts, principles and theories, and  procedures to be followed. |
| Integrative domain | A mental ‘meta-skill’ which sits above the other psychological skill domains and represents the ability of an individual to manage their attention in order to integrate and coordinate two or more concurrent psychological skill domains. It is required for integrated tasks/subtasks, where two or more coordinated components of a task must be performed concurrently. As a psychological skill, it is trainable. |
| Implicit Knowledge | Non-declarative knowledge of actions to complete a task. Tacit, unconscious knowledge about ‘doing’ that cannot be articulated. |
| Mental model | An internal representation of a task, which captures how it is understood or conceptualised and performed. A task mental model can be specified explicitly by developing an external representation, which can be captured graphically to enable visualisation of complexity. |
| Procedural skills domain | The ability to remember a sequence of steps and their order to execute a task. It relies on the working memory capacity of an individual, and hence the procedural aspect of the execution of the task is inherently cognitive in nature. Different from discrete psychomotor skills, which have greater  motor demands combined with the recall of a sequence of actions. |

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| Scaffolding | An instructional approach, where learners complete manageable tasks which progress in difficulty. Trainers demonstrate the task at each stage and explain the steps. Learners are provided with the opportunity to  practise at each stage. |
| Simple decision- making domain | Executing a series of processes involving analysis and evaluation with discrete outputs that have a definite beginning and end and result in a decision. The options available during a simple decision-making process are usually binary (e.g., 'Yes'/'No, 'A' or 'B'). The processes involved are declarative (can be articulated). |
| User Decision Aid (UDA) | A survey-based rating method, which allows Subject Matter Experts (SMEs)  to rate ten task characteristics known to influence skills retention in order to generate a skill decay curve. |

* 1. **Introduction**

# 1 Competence Retention Analysis

For the purpose of this handbook, competence retention is defined as ***“the knowledge, skills and underpinning attitudinal dispositions that must be acquired and maintained by individuals in order to effectively perform tasks to a pre-defined standard of proficiency”***.

Competence Retention Analysis (CRA) is a scientific methodology developed as a practical approach to predicting the retention of different knowledge and skills that underpin military tasks at the workforce level. CRA is intended to assist Defence to reduce the impact of skill fade and enhance competence retention. It is relevant to two audiences as follows:

1. Training analysts can use the outputs of CRA during the Training Needs Analysis (TNA) process to justify training solutions and the training budget; and
2. Training designers can use the outputs of CRA during the design phase to inform the scheduling of refresher training or practice intervals, and during the development of training to mitigate knowledge and skills fade. CRA can also be used retrospectively to improve training design and to inform decision- making about the specification of training priorities (initial and refresher), where issues are identified during the TNA evaluation process.

This CRA handbook replaces the Defence Human Capability Science and Technology Centre (DHCSTC) Task Identification Number (TIN) 2.057 CRA User Guide (Cahillane, MacLean & Webb, 2015) to incorporate new insights into the retention of different types of current and future knowledge and skills over time. These insights were established during a programme of research commissioned by the Defence Science and Technology Laboratory (Dstl), through the Human and Social Sciences Research Capability (HSSRC) framework (Cahillane et al., 2020).

A summary of what has changed within the Competence Retention Analysis Technique (CRA-T) and why, is presented in Section 1.2. Gaps in the science related to the CRA-T are covered in Section 1.3.

Section 2 provides step-by-step guidance on how to conduct CRA, along with an overview of influencing factors that can be considered in training design to improve knowledge and skills retention.

Further detail on competence retention key concepts, including new insights is provided in Section 1.

## What Has Changed and Why?

This section summarises the updates made to the CRA-T and the rationale for these changes.

The terms ‘skill’ and ‘task’ that were introduced in the original CRA User Guide, often caused confusion because they were considered interchangeable. In order to avoid this confusion, the terms, as used in this handbook, are defined as follows:

* + - Task refers to what needs to be done, i.e., performed, or executed mentally or physically; and
    - Skill refers to the psychological capability that supports performance or execution of the task. These psychological capabilities are organised into domains.

The taxonomy of psychological knowledge and skill domains has been updated to include complex cognitive skills and implicit knowledge. The original taxonomy in the User Guide only considered simple cognitive skills and explicit knowledge. Simple cognitive skills are known to decay more rapidly, whilst the science to date indicates complex cognitive skills are better retained.

The updated taxonomy of psychological knowledge and skill domains in this handbook aligns with advances in the science and reflects the knowledge and skills considered important by Defence, today and in the future, given emerging roles. Understanding the retention of knowledge and skills is important to Defence because

knowledge and skills are retained at different rates over time. These insights can inform training design and delivery and the setting of refresher training intervals.

The CRA-T approach has been updated to allow combinations and integrations of knowledge and skills to be considered. The original approach involved decomposing a task into subtasks and identifying the ‘predominant psychological domain’ for each subtask. This approach failed to acknowledge that the predominant domain is not always that which is most susceptible to skill fade. It also prevented identification of where combinations of two or more domains underpin subtasks or where skills are integrated. In this handbook, CRA now requires decomposition of a task/Training Objective (TO) into subtasks/Enabling Objectives (EOs) and task elements/Key Learning Points (KLPs). Decomposing tasks down to the task element/KLP level enables a detailed identification of the knowledge and skills needed for an adequate understanding of the task. By doing so, it becomes possible to identify the psychological domain most susceptible to decay and map that to the subtask/EO, rather than the predominant domain.

The CRA-T considers other factors, including task frequency, which may affect the retention of the knowledge and skills that underpin task performance. These additional factors have been updated to include those known to moderate the acquisition and retention of complex cognitive skills and implicit knowledge.

Guidance for training designers and trainers on competence acquisition and retention have been updated to include those relevant to complex cognitive skills and implicit knowledge. Guidance on factors known to influence the acquisition and retention of complex cognitive skills and implicit knowledge is included, along with relevant training strategies that improve their acquisition and retention. This will enable more efficient and effective training to be developed for complex tasks.

## What is Not Known?

While complex cognitive skills and implicit knowledge are now included in the updated taxonomy of psychological knowledge and skills domains, their retention levels cannot be included in this handbook due to insufficient scientific evidence being available. However, guidance is provided in a Top Tips document for the Planning, Conduct and Analysis of Future Skill Fade research (Cahillane & Anderson, 2021), to support the collection of longitudinal empirical evidence if required.

## Guidance – What is the Competence Retention Analysis Technique For?

The CRA-T provides an indicative model of knowledge and skill retention, which may be exploited to give practical, usable advice and quick wins to optimise competence retention. It also provides training design and delivery options for competence acquisition and retention.

The early development of the CRA-T was underpinned by best practice from the scientific literature and an existing predictive model of skills retention known as the User Decision Aid (UDA) (Rose, Radtke et al., 1985; see Appendix B for background on competence retention key concepts). The CRA-T process has since been updated with reference to new insights from the science and from Defence and Security case studies (Cahillane et al., 2020).

The CRA-T can be used to indicate the percentage of a workforce (e.g., a unit) which will remain competent after a specified period of non-practice or application, based on the types of skills and knowledge that are characteristic of their job or task. This allows the operational readiness of a workforce to be estimated.

The CRA-T is flexible in that it can be applied as part of the Defence Systems Approach to Training (DSAT) TNA (JSP 822, 2021) and/or training design stages, or independently. It also complements Difficulty, Importance and Frequency (DIF) analysis.

Steps 1 to 4 of the CRA-T are required if individuals wish to know more about the retention of knowledge and skills within subtasks/EOs and wish to specify evidence-based refresher training intervals and priorities.

Step 5 is relevant if individuals wish to apply the CRA-T output to identify relevant training design and delivery options to improve competence acquisition and retention. This step is most appropriate for those responsible for the design of a training pipeline, or in the delivery of training, for those with an interest in understanding training design and delivery approaches for optimal acquisition and retention of knowledge and skills. Using the

output of Step 2, Step 3 and Step 4, it is possible to consider training design and delivery options for optimising both the acquisition and retention of the knowledge and skills required.

## Guidance – What the Competence Retention Analysis Technique Does Not Do

The CRA-T provides a method to identify how long knowledge and skills will be retained if they are not applied or practised, but it does not consider attitudes because these do not decay over time.

The CRA-T does not indicate retention beyond 12 months of non-practice or application.

The CRA-T can be applied to individual tasks at the workforce level but cannot indicate retention for individual tasks at an individual level. Therefore, the CRA-T cannot be used to identify the point at which an individual’s task performance would fall below a set level. ‘The Predictive Performance Equation (PPE)’, is a potential alternative to CRA (Peebles, 2020). The PPE can predict individual performance over periods ranging from days to months and can therefore support training designers in tailoring refresher training to an individual’s particular requirements. Application of the PPE is likely to be most suitable for specialised training courses, where an understanding of individual requirements for refresher training is needed. See Peebles (2020) for information on the type of training or performance data that is required to make use of the PPE.

The CRA-T cannot indicate retention for collective tasks since it does not consider the full range of factors that moderate the retention of collective skills.

## Revised Competence Retention Analysis Technique Process

This section summarises the structure of the updated CRA-T process, which comprises five steps as depicted by the presence of arrows shown in Figure 1.



**Figure 1 – Updated CRA-T process steps**

Each step in the updated CRA-T process is briefly described below:

* + - Step 1: Develop a clear understanding of the task. The level of analysis is at the whole task level, starting with the task/ TO and decomposing it into the subtasks/ EOs and task elements/ KLPs;
    - Step 2: Match task elements/KLPs and subtasks/EOs to psychological domains. This step looks at the task elements/KLP psychological domain mapping first and then maps the subtask/EO to a psychological domain;
    - Step 3: Consider frequency of application and assign retention level at the subtask/EO level of analysis;
    - Step 4: Consider subtask/EO criticality; and
    - Step 5: Use the CRA-T output in training design and delivery. This step considers additional influencing factors that can affect acquisition and retention. It supports the identification of training design and delivery options for very critical and/or moderately critical subtasks/EOs.

A dark blue arrow, similar to the example in Figure 2, is used in this handbook to indicate your location within the CRA-T process.



**Figure 2 – Indication of your current location within the process of CRA**

There is stand-alone guidance in Section 1 on ‘Competence Retention Key Concepts’ which the reader may choose to refer to at any point during the CRA-T process. This section provides background information on how the indicative competence retention model, which is used in the CRA-T process, works. It also summarises background information on the new insights from the science that led to the revised CRA-T process.

The output of each step of the CRA-T can be recorded using the template provided at Appendix A.

# The Revised Competence Retention Analysis Technique

## Step 1 – Establish a Clear Understanding of the Task



Step 1 of the CRA-T involves establishing a clear understanding of the task. The term ‘Task’ refers to what needs to be completed (i.e., performed, or executed), to meet the operational requirement. This understanding can be achieved when the available training documentation presents a clear description of the task, and the requisite knowledge and skills can be identified.

### Step 1 Guidance – How Do I Know If I Have Enough Information of the Right Quality?

The type of training documentation available will depend on the current stage of the DSAT process. Training analysts will have access to, or will develop, the Task Scalar, Role Performance Statement (RPS), and early Knowledge, Skills, and Attitudes (KSA) analysis outputs, generated as part of the Training Gap Analysis (TGA). These provide training analysts with a suitable input to CRA. The Task Scalar provides an understanding of the skills and decomposes high-level tasks into subtasks and task elements. The KSA analysis, which is updated during the design phase of the DSAT process, provides an understanding of the knowledge and skills required to perform the task/job.

For the training designer, in addition to the Task Scalar, RPS and early KSA analysis outputs, other relevant training documentation could include the Training Performance Statement (TPS), a Competence Framework (CF), and the Learning Scalar. A DSAT-compliant Learning Scalar decomposes the TO into EOs and KLPs. As more than one type of knowledge and/or skill can underpin an EO, the KLPs will provide the granularity needed to perform CRA and articulate the knowledge and skills required to complete the EOs.

Now proceed to perform Step 1.

### Perform Step 1 – Establish a Clear Understanding of the Task

The template in Appendix A can be used to record the output of Step 1 of the CRA-T.

Step 1 involves establishing a clear understanding of the task. The level of granularity required is determined by that information which provides the clearest understanding of the task or job, in terms of the requisite knowledge and skills.

In order to demonstrate the CRA-T process, an illustrative example of a DSAT-compliant Learning Scalar is used throughout this handbook. A clear understanding of the task is achieved by reviewing the scalar, which enables identification of the supporting knowledge and skills needed for the task.

Table 1 shows an example of a DSAT-compliant Learning Scalar for the pseudo military task – ‘Plan an Uncrewed Air System (UAS) Mission’. It decomposes the task/TO (presented in brown text) into subtasks/EOs (shown in green text) and task element/KLPs descriptions (displayed in blue text). This type of scalar is sufficient to proceed to Step 2. For training analysts, a Task Scalar with subtasks and task elements would also be sufficient to proceed to Step 2.

**Table 1 – Example Learning Scalar**

|  |  |
| --- | --- |
| Ref | Description |
| 1 | Plan an Uncrewed Air System (UAS) mission |
| 1.1 | Set up the mission planner |
| 1.1.1 | Power up |
| 1.1.2 | Create a new mission |
| 1.1.3 | Open a previously saved database |
| 1.1.4 | Create a mission for a previously saved database |
| 1.1.5 | Update mission security classifications |
| 1.2 | Manipulate the Sceptre map view |
| 1.2.1 | Describe the Sceptre application |
| 1.2.2 | Manage the plan perspective |
| 1.2.3 | Use the ruler tool |
| 1.2.4 | Explain the British National Grid (BNG) reference system |
| 1.2.5 | Identify features on the 1:50:000 map |
| 1.2.6 | Identify the BNG grid reference and height of a point on the Sceptre display |
| 1.3 | Develop the mission plan |
| 1.3.1 | Describe UAS performance details |
| 1.3.2 | Describe UAS Standard Operating Procedures |
| 1.3.3 | Describe the Tactical situation considerations |
| 1.3.4 | Select optimum Air Vehicle (AV) height and stand-off range |
| 1.3.5 | Describe airspace deconfliction methods |
| 1.3.6 | Calculate safety altitude |
| 1.3.7 | Evaluate the airspace constraints |
| 1.3.8 | Evaluate the intelligence picture |
| 1.3.9 | Analyse UAS constraints |
| 1.3.10 | Prioritise mission tasks |
| 1.3.11 | Develop the optimum mission plan |
| 1.4 | Enter a flight plan into Sceptre |
| 1.4.1 | Plot Request for Information (RFI) locations |
| 1.4.2 | Create a new mission task using a pre-prepared template |
| 1.4.3 | Enter the mission waypoints |
| 1.4.4 | Plan the inbound and outbound route |
| 1.4.5 | Review the plan using the Nav Card view |
| 1.5 | Manage the mission database |
| 1.5.1 | Archive mission date at the end of the mission |
| 1.5.2 | Manage archived imagery data |
| 1.5.3 | Back up archived mission data to external media |

## Step 2 – Match Task Elements/KLPs and Subtasks/EOs to Psychological Domains



This step involves matching the task elements/KLPs and subtasks/EOs to the psychological domain that best represents the knowledge or type of skill required to perform the task component.

### Step 2 Guidance – What Are Psychological Domains and How Do I Match Them to Task Elements/KLPs and Subtasks/EOs?

A skill refers to the psychological capability that supports performance or execution of the task. These psychological capabilities, along with knowledge, are organised into domains.

The psychological domains are higher-level categories against which Joint Service Publication 822 (JSP 822, 2021) job-related KSA analysis can be mapped. They reflect the human psychological processes known to underpin the acquisition and retention of job/task-related knowledge and skills. There are differences in retention between these psychological domains and consequently they influence the extent to which skilled performance of tasks is retained over time.

The psychological knowledge domains are Explicit Knowledge and Implicit Knowledge (see Table 2 for definitions and examples).

**Table 2 – Psychological Knowledge Domains with descriptions and task examples**

|  |  |  |
| --- | --- | --- |
| Psychological Knowledge Domains | Description | Examples |
| Explicit  (knowing 'what') | Declarative knowledge about ... | Basic facts.  Principles and theories.  Procedures to be followed, etc. |
| Implicit (knowing 'how') | Non-declarative, procedural knowledge of actions to complete a task. | Tacit, unconscious knowledge about 'doing' that cannot be articulated.  Pattern recognition, such as a firefighter ordering other firefighters to evacuate a burning building because they recognise situational cues that match previous experience of a burning building just before it collapses.  A driver knowing to slow down because they recognise cues in the flow of traffic ahead, etc., well before the severe road traffic  accident comes into view. |

Physical skills fall within the Continuous Psychomotor and Discrete Psychomotor domains. Simple cognitive skills fall within the Procedural and Simple Decision-making domains, whilst complex cognitive skills fall within the Complex Decision-making, Adaptive Cognition, and Integrative domains. The Integrative domain is a meta-skill involving the integration of two or more coordinated psychological skill domains that are performed concurrently rather than separately, along with underpinning explicit and/or implicit knowledge (see Table 3 for definitions and examples).

**Table 3 – Psychological Skill Domains with descriptions and task examples**

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Skill Domains | | Description | Examples |
| Physical | Continuous psychomot or | A combination of higher motor and lower cognitive demands.   * The ability to perform well-trained and practised motor actions that do not have distinct beginnings or endings. | * Driving. * Target tracking. * Flying and manoeuvring an aircraft. |
| Discrete psychomot or | A combination of higher motor and moderate cognitive demands (i.e., following a procedure).   * The ability to perform well-trained sequences of motor actions with a distinct beginning and end. | * Weapon handling drills. * Strip and reassemble equipment components e.g., vehicle engines, electrical equipment. * Pressing buttons on a control panel or touch screen in a required sequence. |
| Simple Cognitive | Procedural | A combination of moderate cognitive demands and minimal motor demands.   * The ability to remember a sequence of steps and their order to execute a task. It relies on the working memory capacity of an individual, and hence the procedural aspect of the execution of the task is inherently cognitive in nature. * Different from discrete psychomotor, which have greater motor demands combined with the recall of a sequence of actions. | * Navigating through menus and submenus on a digital Battlefield Information Management System (BIMS) to execute a command. * When using a BIMS to create map overlays, the motor component constitutes using a mouse and is of minimal complexity, and the procedural aspect dominates. |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Skill Domains | | Description | Examples |
|  | Simple Decision- making | Processes with moderate cognitive demand and no motor demands. Executing a series of processes involving analysis and evaluation with discrete outputs that have a definite beginning and end and result in a decision. The options available during a simple decision-making process are usually binary (e.g., 'Yes'/'No, 'A' or 'B'). The processes involved are  declarative (can be articulated). | Templated diagnostics. Vehicle fault finding.  Following a decision tree/flow  chart e.g., combat casualty drills. |
| Complex Cognitive | Complex Decision- making | Processes with high cognitive demand and no motor demands.   * Iteration of stepped information processing cycles involving situational assessment, analysis and evaluation that continue until a decision is reached. * Execution of a decision will often initiate further cycles. * Multiple assumptions/hypotheses and evidence have to be considered resulting in options/courses of action from which the decision-maker has to select the most optimal. The processes involved can be articulated. | * Performing   planning tasks e.g., the Combat Estimate.   * Pattern recognition among multiple options (e.g., vehicle recognition, behaviour patterns, acoustic and radar patterns). * Carrying out a medical diagnosis. * Threat analysis and assessment. * Carrying out an intelligence estimate. |
| Adaptive Cognition | Processes with high cognitive demand and either high, moderate, or no motor demands.   * The ability to adapt existing knowledge and skills to meet the demands of a new and unfamiliar situation, where the context changes completely. * Does not necessarily involve declarative processes. | * Problem- solving tasks requiring the ability to identify desired goal states (i.e., the need for a solution) and to apply and/or adapt existing strategies (derived from knowledge and   experience) to |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Skill Domains | | Description | Examples |
|  |  | * Involves iterative and   ongoing mental processing (e.g., what is happening and what needs to happen) until the desired results are achieved.   * Can be applied to many cognitive and/or physical tasks as it relies on feedback from the environment or feedback that is self- generated. | arrive at a solution.   * The United States of America (US) Airways Flight 1549 Hudson River plane crash provides an illustration. The pilot, ‘Sully’ had to consider all of the conceptual components of the landing task and their relationships within a new context and adapt his existing learnt strategies to successfully land the plane in the Hudson River. |
| Integrative | Two or more concurrent skill domains | Processes with high cognitive demand and either high, moderate, or no motor demands.   * A mental ‘meta-skill’ which sits above the other skill domains and represents the ability of an individual to manage their attention in order to integrate and coordinate two or more concurrent psychological skill domains. It is required for integrated tasks/subtasks, where two or more coordinated components of a task must be performed concurrently. As a psychological skill, it is trainable. * Note that procedural skills and discrete | Example tasks requiring this skill domain:   * Mission planner making complex decisions whilst using a planning support software application requiring procedural skills. * Armoured Fighting Vehicle commander managing their crew (simple decision- making), whilst receiving   information |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Skill Domains | | Description | Examples |
|  |  | psychomotor skills  cannot be integrated (i.e., performed concurrently). This is because discrete psychomotor skills involve the recall of a sequence of motor actions - hence, higher motor demands are combined with moderate cognitive demands (i.e., following a procedure). | from multiple  sensors/inputs, etc., on which complex decisions are made.   * A pilot applying procedural skills to remotely manage a swarm of UAS whilst having to making simple decisions. * A firefighter responsible for responding to an incident (simple decision- making) and deciding what and how information should be communicated to multiple agencies (complex decision- making) whilst managing events immediate to the scene of a fire (procedural skills). |

The mapping of knowledge and skills, represented by the task elements/KLPs and subtasks/EOs, to one of these psychological domains is important because the ability to retain these types of knowledge and skills varies. Figure 3 presents the levels of retention for the different psychological domains, which are underpinned by the science (see Appendix B for more detail). The retention levels are categorised into a practical traffic light system of three retention levels: GREEN (High Retention: 12 months), AMBER (Moderate Retention: 5 months) and RED (Low Retention: 2 months). GREY (Not Known) is used for implicit knowledge and the complex cognitive psychological skill domains, as a retention level cannot yet be assigned due to insufficient scientific evidence. Although insufficient, the available evidence suggests implicit knowledge and complex cognitive skills are retained for 6 months.

|  |  |
| --- | --- |
| **Retention Level** | **Psychological Domain** |
| High  G | * Explicit Knowledge * Continuous Psychomotor skills |
| Moderate  A | * Discrete Psychomotor skills * Simple Decision-making skills |
| Low  R | - Procedural skills |
| Not Known | * Implicit Knowledge * Complex Decision-making skills * Adaptive Cognition * Integrative |

**Figure 3 – Retention Levels for each of the nine psychological domains**

In order to match each task element/KLP and subtask/EO to the psychological domain whic h best represents the knowledge or type of skill required to perform it, it is important to read and understand the psychological knowledge domain definitions in Table 2 and the psychological skill domain definitions in Table 3.

Note that for complex tasks, all or some of the subtasks/EOs may involve two or more psychological skill domains at the task element/KLP level that are activated at the same time. That is, the task elements/KLPs are performed concurrently, rather than separately, and must therefore be coordinated and integrated. Where this is the case, these subtasks/EOs should be mapped to the Integrative domain.

### Perform Step 2 – Match Subtask/EOs to Psychological Domains

The output of CRA-T Step 2 should be recorded using the template in Appendix A.

When performing Step 2, look at the scalar and the psychological knowledge and skill domain definitions (see Table 2 and Table 3) and match the task elements/KLPs and the subtasks/EOs to the psychological domains.

Considering the action verb used to describe the task elements/KLPs and subtask/EOs will help in mapping to the correct psychological domains. For example, the action verb ‘Describe’ indicates the Explicit Knowledge domain underpins performance. However, the action verb may not always provide a clear and practical indication of the psychological knowledge or skill domain being applied in the conduct of the task element/KLP or subtask/EO. For example, ‘Manage’ could indicate the Procedural skills or Simple Decision-making skills domain. Therefore, Subject Matter Expert (SME) knowledge of the task/job role is needed in order to best match task elements/KLPs and subtasks/EOs to the psychological domains. In some cases, it may also be necessary to look at the steps (i.e., the next level of granularity below the task element/KLP) to better inform understanding of the domains required at the task element/KLP level.

Mapping should start with the task elements/KLPs, as this provides the necessary granularity to inform the subsequent mapping of the subtasks/EOs and, where appropriate, tasks/TOs. Table 4 – Table 6 provide examples of how this mapping should be conducted.

Where all task elements/KLPs (i.e., the blue text) are mapped to the same psychological domain, then this domain should also be mapped to the subtask/EO (i.e., the green text) (see Table 4).

**Table 4 – Example of matching a subtask/EOto a psychological domain when the same psychological domain is matched to all task elements/KLPs**

|  |  |
| --- | --- |
| Ref | Description |
| 1.1 | Set up the mission planner |
| 1.1.1 | Power up |
| 1.1.2 | Create a new mission |
| 1.1.3 | Open a previously saved database |
| 1.1.4 | Create a mission for a previously saved database |
| 1.1.5 | Update mission security classifications |

|  |
| --- |
| Psychological Domain |
| Procedural |
| Procedural |
| Procedural |
| Procedural |
| Procedural |
| Procedural |

Where task elements/KLPs are mapped to a combination of psychological domains, but they are performed *separately*, then the psychological domain that is most susceptible to decay should be mapped to the subtask/EO. For example, although Explicit Knowledge is the predominant domain in the example at Table 5, it is the Procedural skills domain required for the 1.2.3 and 1.2.6 tasks elements/KLPs that is the most susceptible to skill fade. As can be seen in Figure 3, procedural skills have a low (RED) level of retention. Therefore, the subtask/EO is mapped to the Procedural skills domain.

**Table 5 – Example of matching a subtask/EO to a psychological domain where a combination of psychological domains are matched to task elements/KLPs that are performed *separately*. (Note D-M = Decision-making)**

|  |  |
| --- | --- |
| Ref | Description |
| 1.2 | Manipulate the Sceptre map view |
| 1.2.1 | Describe the Sceptre application |
| 1.2.2 | Manage the plan perspective |
| 1.2.3 | Use the ruler tool |
| 1.2.4 | Explain the BNG reference system |
| 1.2.5 | Identify features on the 1:50:000 map |
| 1.2.6 | Identify the BNG grid reference and height of a point on the Sceptre display |

|  |
| --- |
| Psychological Domain |
| **Procedural** |
| Explicit Knowledge |
| Simple D-M |
| Procedural |
| Explicit Knowledge |
| Explicit Knowledge |
| Procedural |

Where task elements/KLPs match a combination of two or more different psychological skill domains (note that this does not include the Knowledge domains) that are performed *concurrently* (i.e., integrated), the Integrative domain is matched to the subtask/EO as illustrated in Table 61. Here, the Integrative domain is responsible for managing attention to effectively coordinate the other psychological skill domains that underpin performance of this subtask/EO. As can be seen in the example at Table 6, this includes the Procedural skills, Simple Decision- making and Complex Decision-making domains. For this subtask/EO, procedural skills are essential and fully

1 Not all psychological skill domains have to be concurrent. A minimum of two concurrent psychological skill domains are required for the integrative domain to be involved.

integrated (i.e. performed concurrently) with simple and complex decision-making to form a functioning and unified whole, hence they are integrated.

**Table 6 – Example of matching a subtask/EOto the Integrative domain where a combination of coordinated psychological skill domains are matched to task elements/KLPs that are performed *concurrently*. (Note D-M = Decision-making)**

|  |  |  |  |
| --- | --- | --- | --- |
| Ref | Description |  | Psychological Domain |
| 1.3 | Develop the mission plan | **Integrative** |
| 1.3.1 | Describe UAS performance details | Explicit Knowledge |
| 1.3.2 | Describe UAS Standard Operating Procedures | Explicit Knowledge |
| 1.3.3 | Describe the Tactical situation considerations | Explicit Knowledge |
| 1.3.4 | Select optimum AV height and stand-off range | Simple D-M |
| 1.3.5 | Describe airspace deconfliction methods | Explicit Knowledge |
| 1.3.6 | Calculate safety altitude | Procedural |
| 1.3.7 | Evaluate the airspace constraints | Complex D-M |
| 1.3.8 | Evaluate the intelligence picture | Complex D-M |
| 1.3.9 | Analyse UAS constraints |  | Complex D-M |
| 1.3.10 | Prioritise mission tasks |  | Complex D-M |
| 1.3.11 | Develop the optimum mission plan |  | Complex D-M |

Table 7 illustrates the full DSAT-compliant Learning Scalar for the pseudo military UAS Mission Planning task, with subtasks/EOs and task elements/KLPs matched to the psychological domains. This will be used as the exemplar in Step 3 of the CRA-T process onwards.

**Table 7 – Complete Learning Scalar with subtasks/EOs and task elements/KLPs matched to the psychological domains. (Note D-M = Decision-making)**

|  |  |
| --- | --- |
| Ref | Description |
| 1 | Plan UAS mission |
| 1.1 | Set up the mission planner |
| 1.1.1 | Power up |
| 1.1.2 | Create a new mission |
| 1.1.3 | Open a previously saved database |
| 1.1.4 | Create a mission for a previously saved database |
| 1.1.5 | Update mission security classifications |
| 1.2 | Manipulate the Sceptre map view |
| 1.2.1 | Describe the Sceptre application |
| 1.2.2 | Manage the plan perspective |
| 1.2.3 | Use the ruler tool |
| 1.2.4 | Explain the BNG reference system |

|  |
| --- |
| Psychological Domain |
|  |
| **Procedural** |
| Procedural |
| Procedural |
| Procedural |
| Procedural |
| Procedural |
| **Procedural** |
| Explicit  Knowledge |
| Simple D-M |
| Procedural |
| Explicit Knowledge |

|  |  |  |  |
| --- | --- | --- | --- |
| Ref | Description |  | Psychological Domain |
| 1.2.5 | Identify features on the 1:50:000 map | Explicit Knowledge |
| 1.2.6 | Identify the BNG grid reference and height of a point on the Sceptre display | Procedural |
| 1.3 | Develop the mission plan | **Integrative** |
| 1.3.1 | Describe UAS performance details | Explicit Knowledge |
| 1.3.2 | Describe UAS Standard Operating Procedures | Explicit Knowledge |
| 1.3.3 | Describe the Tactical situation considerations | Explicit Knowledge |
| 1.3.4 | Select optimum AV height and stand-off range | Simple D-M |
| 1.3.5 | Describe airspace deconfliction methods | Explicit Knowledge |
| 1.3.6 | Calculate safety altitude | Procedural |
| 1.3.7 | Evaluate the airspace constraints | Complex D-M |
| 1.3.8 | Evaluate the intelligence picture | Complex D-M |
| 1.3.9 | Analyse UAS constraints |  | Complex D-M |
| 1.3.10 | Prioritise mission tasks |  | Complex D-M |
| 1.3.11 | Develop the optimum mission plan |  | Complex D-M |
| 1.4 | Enter a flight plan into Sceptre |  | **Procedural** |
| 1.4.1 | Plot RFI locations |  | Procedural |
| 1.4.2 | Create a new mission task using a pre-prepared template |  | Procedural |
| 1.4.3 | Enter the mission waypoints |  | Procedural |
| 1.4.4 | Plan the inbound and outbound route |  | Procedural |
| 1.4.5 | Review the plan using the Nav Card view |  | Simple D-M |
| 1.5 | Manage the mission database | **Procedural** |
| 1.5.1 | Archive mission date at the end of the mission | Procedural |
| 1.5.2 | Manage archived imagery data | Simple D-M |
| 1.5.3 | Back up archived mission data to external media | Procedural |

In Table 7, only one of the subtasks/EOs (1.3) is mapped to the Integrative domain, where the management of attention is required to effectively integrate and coordinate Procedural skills with Simple and Complex Decision- making. The remaining subtasks/EOs are mapped to the Procedural domain.

In Table 7, the psychological domains are mapped to the task elements/KLPs and then to the subtasks/EOs but not to the task level. Where all subtasks are not mapped to the same psychological domain, the Task/TO cannot be mapped to a psychological domain because a combination of psychological domains is involved in performance of the Task/TO. In such cases only the task elements/KLPs and then the subtasks/EOs can be mapped to a psychological domain. In cases where all subtasks/EOs are mapped to the same psychological domain, thenthe Task/TO (i.e., the brown text level) should also be mapped to that domain. This single domain, as opposed to a combination, determines retention at the task level.

For example, in cases where all subtasks/EOs are mapped to the Integrative domain, then the Task/TO (i.e., the brown text level) should also be mapped to the Integrative domain. Where this is the case, the Integrative domain acts as a psychological ‘meta-skill’ and is responsible for managing attention to effectively integrate and

coordinate the other psychological skill domains that underpin performance of each subtask/EO, along with any underlying explicit knowledge.

## Step 3 – Assign Retention Level to Subtasks/EOs



The output of Step 3 can inform decisions on refresher training interval specification or priorities. This output can also support training designers in the refinement of DIF analysis training categories.

### Step 3 Guidance – How Does Frequency of Application of Subtasks/EOs Affect Retention? What Are Retention Levels?

The purpose of Step 3 is to consider the impact of how often subtasks/EOs are performed on the retention of knowledge and skills. This is because the frequency with which knowledge and skills are practised can moderate the rate at which they fade over time.

As an example, a subtask/EO mapped to the Procedural skills domain would be expected to have a low level of retention in comparison to other psychological domains (refer to Figure 3). However, Table 8 demonstrates how frequency of application moderates the alignment of psychological domains to a particular retention level. It uses the same traffic light system as Figure 3: GREEN meaning high retention (greater than 50% of workforce competent after 12 months non-practice); AMBER meaning moderate retention (50% of workforce competent after 5 months non-practice); and RED meaning low retention (50% of the workforce competent after 2 months non-practice). Therefore, if the same subtask/EO mapped to the Procedural skills domain was performed very frequently, the expected retention level would be moderate, rather than low.

Information on the frequency with which subtasks/EOs are performed can be obtained from the DIF analysis, which is gathered during the TNA. If a TNA/DIF analysis is not available, then SME judgement should be used.

**Table 8 – Mapping generic psychological knowledge and skill domains to indicated retention levels after considering frequency of application**

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain | Description | Frequency | CRA Retention Level |
| Explicit | Explicit knowledge required to | **\*Very Frequent** | Greater than 50% of workforce competent after 12 months non- practice |
| Knowledge | conduct a task such as facts, concepts,  theories, quality and engineering hygiene measures, safety regulations,  knowledge of how to use hand tools |  |
| **\*Moderately Frequent** |
| Continuous |  |
| and testing equipment. | **\*Infrequent** |
| Psychomotor skills | A combination of higher motor and  lower cognitive demands. The ability to perform well-trained and practised |  |
|  | motor actions that do not have |  |
|  | distinct beginnings or endings. |  |
| Discrete | A combination of higher motor and | **Very Frequent** | Greater than |
| psychomotor skills | moderate cognitive demands (i.e., procedural skill). The ability to |  | 50% of workforce |
|  | perform well-trained sequences of |  | competent after |
| Simple Decision- | actions with a distinct beginning and |  | 12 months non- |
| making skills | end. |  | practice |
|  | Processes with moderate cognitive |  |  |
|  | demand and no motor demands. Executing a series of processes |  |  |
|  | involving analysis and evaluation with |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain | Description | Frequency | CRA Retention Level |
|  | discrete outputs that have a definite beginning and end and result in a decision. The options available during a simple decision-making process are | **Moderately Frequent** | 50% of workforce competent after  5 months non- |
| **Infrequent** |
| usually binary (e.g., 'Yes'/'No, 'A' or |  | practice |
| 'B'). The processes involved are |  |  |
| declarative (can be articulated). |  |  |
| Procedural skills | A combination of moderate cognitive | **Very Frequent** | 50% of |
|  | demands and minimal motor |  | workforce |
|  | demands. The ability to remember a |  | competent after |
|  | sequence of steps and their order to execute a task. It relies on the working |  | 5 months non-  practice |
|  | memory capacity of an individual, and | **Moderately** | 50% of |
|  | hence the procedural aspect of the  execution of the task is inherently cognitive in nature. | **Frequent** | workforce competent after 2 months non- |
| **Infrequent** |
|  |  |  | practice |
| Implicit | Non-declarative knowledge of actions | **Very Frequent** | \*Not Known |
| Knowledge | required to complete a task. Tacit, |  |  |
|  | unconscious knowledge about 'doing' |  |  |
|  | that cannot be articulated. |  |  |
| Adaptive Cognition | Processes with high cognitive demand and either high, moderate, or no |  |  |
|  | motor demands. The ability to adapt |  |  |
|  | existing knowledge and skills to meet |  |  |
|  | the demands of a new situation where |  |  |
| Integrative | the context changes.  A mental ‘meta-skill’ representing the ability of an individual to manage their attention in order to integrate and coordinate two or more concurrent  psychological skill domains. It is |  |  |
| **Moderately**  **Frequent** |
| **Infrequent** |
|  | required for integrated tasks, where two or more coordinated components |  |  |
|  | of a task must be performed |  |  |
|  | concurrently. As a psychological skill, it |  |  |
|  | is trainable. |  |  |

\*Very Frequent: More frequent than once every 2 months .

\*Moderately Frequent: Between once every 2 months and once every 5 months .

\*Infrequent: Once in a period greater than 5 months .

\*Not Known: Available evidence is insufficient but suggests 6 months .

Given the current level of validation for the CRA-T, the retention levels in Table 8 are fixed at the 50% point and cannot be adjusted. Therefore, the low (RED), moderate (AMBER) and high (GREEN) retention levels and their respective definitions should be considered as indicative of when refresher training is required and not conclusive. For example, the final column of Table 8 indicates that procedural skills that are practised infrequently need to be refreshed after 2 months of no practice. For more information see Appendix B, Section B.3.

Note that the GREY retention level is used for implicit knowledge and the three complex cognitive skills (i.e., the Complex Decision-making, Adaptive Cognition, and the Integrative Domains). A retention level cannot yet be assigned to these complex skill domains due to insufficient scientific evidence. Although insufficient, the available evidence suggests implicit knowledge and complex cognitive skills are retained for 6 months.

Proceed to perform Step 3.

### Perform Step 3 – Consider Frequency of Application and Assign Retention Level

The output of Step 3 of the CRA-T should be recorded using the template in Appendix A.

In order to address frequency as a moderator of retention, it is necessary to know the frequency at which each subtask/EO will be performed (see column 3 of Table 8). Note that task elements/KLPs are integral components of subtasks/EOs and therefore these should be at the same frequency as the subtasks/EOs. Consequently, frequency is considered at the subtask/EO level rather than the task element/KLP level.

Having allocated a frequency to each subtask/EO, an indicative retention level for each subtask/EO can be identified by using the information in Column 4 (the CRA Retention Level) of Table 8.

The outputs of the analysis conducted in Step 3 so far will look like Table 9.

**Table 9 – Learning Scalar example withsubtasks/EOs matchedto psychological domains and frequency, with indicated retention levels**

|  |  |  |  |
| --- | --- | --- | --- |
| Ref | Description |  | Psychological Domain |
| 1 | Plan UAS mission |  |
| 1.1 | Set up the mission planner | **Procedural** |
| 1.2 | Manipulate the Sceptre map view | **Procedural** |
| 1.3 | Develop the mission plan | **Integrative** |
| 1.4 | Enter a flight plan into Sceptre | **Procedural** |
| 1.5 | Manage the mission database |  | **Procedural** |

|  |  |
| --- | --- |
| Frequency | CRA  Retention Level |
|  |  |
| Very  frequent | 5 months |
| Very frequent | 5 months |
| Very frequent | Not Known |
| Very  frequent | 5 months |
| Infrequent | 2 months |

## Step 4 – Consider Subtask/EO Criticality



The output of Step 4, criticality analysis, is an SME judgement about subtask/EO criticality. Criticality in this context refers to the impact of an inadequately performed subtask/EO on operational capability and safety. Subtask/EO criticality does not affect retention levels; however, subtask/EO criticality analysis should be completed to identify the risks carried with regards to the susceptibility of the subtasks/EOs to knowledge and skills fade. This can support training designers by informing the refinement of the initial training categorisation and the allocation of limited training resources.

### Step 4 Guidance – What is Subtask/EO Criticality and How Should I Consider the Knowledge and Skills Fade Risk Held?

Criticality analysis is informed by the importance of the subtasks/EOs as identified by the DIF analysis. This analysis enables the consideration of the relative criticality of each subtask/EO to performance of the overall

task/job. Although a subtask/EO may be matched to a low retention level, if it is deemed not critical then the risk to overall job performance is reduced.

Table 10 presents the three criticality levels and their associated impact.

**Table 10 – Three levels of criticality**

|  |  |
| --- | --- |
| Criticality Level | Description |
| Very Critical | Failure is likely to have a severe impact upon operational capability or the wellbeing of personnel or equipment. |
| Moderately Critical | Failure is likely to have a moderate impact upon operational capability or the wellbeing of personnel or equipment. |
| Not Critical | Failure is unlikely to have an impact upon operational capability or the  wellbeing of personnel or equipment. |

### Perform Step 4 – Match Subtasks/EOs to a Criticality Level

The output of Step 4 should be recorded using the template in Appendix A.

Assign a criticality level to each subtask/EO. Considering the criticality of successful performance of subtasks/EOs enables the prioritisation of subtasks/EOs when making decisions regarding the allocation of resources to refresher training and/or the design and delivery of training.

The output of the analysis conducted up to Step 4 so far will look like Table 11. Within this example, four out of the five subtasks/EOs are very critical in terms of their successful performance. Although the subtask/EO 1.5 is underpinned by the Procedural domain and has a low retention level, it is deemed not critical. Therefore, the risk of skill fade to overall job performance is reduced. This subtask/EO would be of a lower priority in terms of training design and the allocation of resources/ frequency of refresher training required to maintain subtask/EO proficiency.

To perform a final check of the indicative retention intervals, proceed to Step 5 to consider other factors, in addition to frequency, which may affect knowledge and skills retention. Step 5 should only be performed on the subtasks/EOs identified as very critical and/or moderately critical.

**Table 11 – Learning Scalar example with output from Step 1 to Step 4**

|  |  |  |  |
| --- | --- | --- | --- |
| Ref | Description |  | Psychological Domain |
| 1 | Plan UAS mission |  |
| 1.1 | Set up the mission planner | **Procedural** |
| 1.2 | Manipulate the Sceptre map view | **Procedural** |
| 1.3 | Develop the mission plan | **Integrative** |
| 1.4 | Enter a flight plan into Sceptre | **Procedural** |
| 1.5 | Manage the mission database |  | **Procedural** |

|  |  |
| --- | --- |
| Frequency | CRA  Retention Level |
|  |  |
| Very frequent | 5 months |
| Very frequent | 5 months |
| Very  frequent | Not  Known |
| Very  frequent | 5 months |
| Infrequent | 2 Months |

|  |
| --- |
| Criticality |
|  |
| Very Critical |
| Very Critical |
| Very  Critical |
| Very  Critical |
| Not Critical |

## Step 5 – Use of Competence Retention Analysis Technique Output in Training Design and Delivery



Step 5 is about considering other factors, in addition to task frequency, which may influence the retention of the knowledge and skills that underpin the very critical and/or moderately critical subtasks/EOs identified in Step 4. Considering how these influencing factors can be addressed within training design and/or delivery supports the management and retention of knowledge and skills.

### Step 5 Guidance – What Additional Influencing Factors Should I Consider and How Do They Affect Retention?

It is necessary to have an understanding of the context in which a task is conducted in order to effectively consider the additional influencing factors. The Conditions and Standards associated with the list of Performance Objectives should be articulated within the RPS. This information can be used as a supporting input to Step 5.

### General Factors Influencing Knowledge and Skills Retention.

Table 12 presents general factors that can influence the retention of knowledge and skills in all psychological domains.

**Table 12 – General factors influencing retention of knowledge and skills in all psychological domains**

|  |  |  |
| --- | --- | --- |
| Factor | Description | Effect on Retention |
| Assessment - enhanced learning | Formative assessment combined with the provision of feedback during initial training practice sessions. Provide detailed feedback stemming from a learner’s performance during training practice sessions, combined with a chance to improve performance. | Increases retention by aiding the encoding of knowledge and skills into memory. Feedback early in training improves retention. Whilst feedback still has a positive effect on retention later in training, reducing its frequency during later training sessions promotes long term retention and skill transfer. |
| Communicating the utility of training | Training is perceived as having high utility when a link is perceived between required performance and outcomes valued by trainees. | Increases retention by aiding the encoding of knowledge and skills into memory and facilitating more effective recall. Those who perceive training as valuable are more likely to apply newly acquired knowledge, skills, and behaviours to the job than trainees who do not. |
| Initial Training Conditions | The training context and situational cues are similar to those which are experienced in the operational environment. Individuals should be exposed to as many different situations and content-based scenarios as possible to promote knowledge and skill transfer. For example, novel scenarios can be used when training Precision Gunners in simple decision-making skills. Practising the application of simple decision-making during the engagement cycle  will aid the transfer of Precision Gunnery knowledge and skills. | Increases retention through the provision of retrieval cues and promotes knowledge and skills transfer to the workplace. |

|  |  |  |
| --- | --- | --- |
| Factor | Description | Effect on Retention |
| Standardised and recorded assessment | Recording every aspect of student performance helps trainersin making objective assessments of students’ skill acquisition and in targeting the provision of feedback. This helps in monitoring overall training and would enable the development of a longitudinal database of performance. | Increases retention through targeted provision of feedback during knowledge and skill acquisition. |
| Information load | Overall amount of information to be processed during learning events. | A high level of information load reduces retention by impacting the extent to which knowledge and skills are encoded into  memory. |
| Individual differences | Aptitude and cognitive ability; self-efficacy. | Higher aptitude and cognitive ability in individuals increases knowledge and skills retention because more knowledge and skills are acquired in the same amount of time. This may be due to individuals with higher ability being more effective at acquiring knowledge and skills.  Higher self-efficacy results in a greater degree of knowledge and skills transfer to the workplace. |
| Importance of skills | Commander or Organisational emphasis on the importance of learning this skill. | Communicating the importance of learning the knowledge and/or skill to trainees increases retention. Those who perceive the importance of learning skills are more likely to encode them into memory at a deeper level than trainees who do not. |
| Technology changes | How frequently any technology involved in task performance has changed. | Frequent changes in technology reduces retention of the knowledge and skills required to use technology involved in task performance. Changes in technology may require adaptation of learnt knowledge and skills. |
| Technology reliability | The reliability of the technology involved in task performance. | Unreliable technology reduces retention. Lack of confidence in the technology that has to be used during task performance impedes efficient encoding, consolidation and retrieval of the knowledge and skills underpinning proficiency. |
| Information  displays | User-friendly displays. | Increase retention by minimising memory  for the location of interface items. |

In addition to general influencing factors listed above, there are specific influencing factors, included below, relevant to explicit knowledge, physical and simple cognitive skills and those which are applicable only to implicit knowledge and complex cognitive skills.

If the very critical and/or moderately critical subtasks/EOs are limited to explicit knowledge, physical skills and/or simple cognitive skills, go to Section 2.5.3. This section covers additional influencing factors matched to the relevant psychological domain(s).

If the very critical and/or moderately critical subtasks/EOs retention only involve implicit knowledge and complex cognitive skills, go to Section 2.5.4.

Go to both Section 2.5.3 and Section 2.5.4 if the very critical and/or moderately critical subtasks/EOs involve a mix of physical and/or simple and complex cognitive skills.

### Additional Factors Influencing Physical and Simple Cognitive Skills Retention

Table 13 presents additional factors known to influence the retention of explicit knowledge, physical and simple cognitive skills, with each factor matched to the relevant psychological domain(s). The effect on retention is also presented. The retention of these knowledge and skills relies heavily on job holders being able to hold a lot of information, procedures and/or stepped decisional processes in working memory.

The effect of the factors on retention, matched to the psychological domain underpinning the very critical or moderately critical subtask/EO, should be considered. It is necessary to have an understanding of the context in which a subtask/EO is conducted in order to effectively consider where these influencing factors could be designed into training to maximise retention.

For example, where a well-designed and mandated job aid exists for a subtask/EO that was originally matched to the Procedural or Simple Decision-making domain in Step 2, then the subtask/EO may now be remapped to another domain as appropriate. This is because memory for the procedures, or stepped decisional processes, which are now represented by the job aid is no longer required. For example, the subtask/EO mapped to the Procedural domain in Table 5 would now be remapped to the Explicit Knowledge domain. Subtasks/EOs matched to the Explicit Knowledge psychological domain have a high (GREEN) level of retention regardless of frequency (see Table 8).

**Table 13 – Additional factors influencing physical and simple cognitive skills retention**

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain(s) | Factor | Description | Effect on Retention |
| Explicit Knowledge | Mandatory use | Well-designed job aids provide clear, complete, useful, and practical guidance for the whole task. Their mandated use during training and in the workplace eliminates memory demands.  The following are examples of different types of job aids:   * Technical manuals, pamphlets, or task handbooks (when followed to perform the job). * Manuals published by manufacturers to be used while performing maintenance tasks on equipment. * Instructions printed out or attached to equipment or containers. * Checklists, flowcharts, worksheets, decision tables, and system-fault tables. * Standard Operating Procedures. | Increases retention |
|  | of well- | through minimising |
| Discrete | designed job | memory load on the job |
| Psychomotor | aids. | holder who no longer |
|  |  | needs to remember |
| Procedural |  | sequences of task steps  and terms, facts, or |
| Simple Decision- making |  | principles in order to  perform the task. |
| Explicit Knowledge | Well-designed (Human | Well-designed HMIs support task performance. | Increases retention through performance |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain(s) | Factor | Description | Effect on Retention |
| Discrete  Psychomotor  Procedural  Simple Decision- making | Machine  Interface) HMI. | The following are examples of different types of  performance support:   * Well-designed HMI with built- in-feedback (e.g., prompts) and/or constraints that do not allow steps to be performed out of sequence. * Computer-based procedures implemented within an interface that guide job holders step-by-step through a procedure, for example, flow charts and graphics. * Recognition cues to support the retrieval of procedurals. Recognition cues can be used to ‘prompt’ a user as to what the next step should be in a task performed on a digital BIMS. * Adaptive HMIs guide an operator's attention to significant areas on the screen (e.g., a developing conflict or critical event) enabling them to locate relevant information efficiently). * Onboard diagnostic systems. | support. Well-designed  HMIs minimise memory load on the job holder who no longer needs to remember sequences of task steps and the correct performance of steps. |
| Explicit Knowledge  Continuous Psychomotor | Time limits. | It is important to build realistic time limits for the completion of tasks into training. If a task must be performed under severe time pressure on operations, a scaffolded2 approach to building time pressure into training should be used. Here, the task is initially trained under less severe time pressure, which allows trainees to learn and develop the required knowledge and skills. The time pressure should then be increased to a realistic level. This provides trainees with the opportunity to practise application of the taught knowledge and skills under realistic conditions representative of  operational performance. | Increases retention and promotes knowledge and skills transfer to the workplace. |
| Discrete Psychomotor |  |  |
| Procedural |  |  |
| Simple Decision- making |  |  |

2 Scaffolding is an instructional approach, where learners complete manageable tasks which progress in difficulty. Trainers demonstrate the task at each stage and explain the steps. Learners are provided with the opportunity to practise at eachstage.

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain(s) | Factor | Description | Effect on Retention |
| Explicit knowledge  Continuous | Over-training (Over- | The continuation of practising a task after error- free performance has been achieved. The | Increases retention through skill |
| Psychomotor | learning). | benefits of over-training are stronger for tasks | automation. The |
| Discrete |  | with a cognitive element (e.g., memory for | greater the |
| Psychomotor |  | procedures), for example, safety critical drills. | overlearning, the  greater the retention of |
|  |  |  | material. |
| Explicit knowledge | Combined | Augmented (i.e., external) feedback relates an | Increases retention by |
| Continuous | expert and | individual’s performance to a performance | reducing learners’ |
| Psychomotor | display-based | standard. There is a superior effect of | cognitive load during |
|  | augmented  feedback. | combining augmented feedback from an expert  with that which is delivered via a display | practice. This supports  the assimilation of |
|  |  | compared to expert augmented feedback alone. | explicit knowledge with |
|  |  | Displays can provide enhanced feedback | the psychomotor skills |
|  |  | regarding a learner’s physical movements (e.g., continuous psychomotor skills domain). Experts | domain and therefore, the automation of |
|  |  | should guide learners by helping them to use | motor actions. |
|  |  | and interpret the feedback delivered via a |  |
|  |  | display, e.g., a help screen, without the |  |
|  |  | cognitive load associated with using a help |  |
|  |  | screen by itself. |  |
| Discrete | Part-task | Involves personnel learning and practising | Increases retention by |
| Psychomotor | training. | subtasks in isolation. Once mastered, the whole | reducing cognitive load |
| Procedural |  | task should be practised. Part-task training | during training. As a |
|  |  | allows trainees to practise the subtasks/EOs to  predefined standards without being distracted | result, more cognitive  resource can be |
|  |  | by other aspects of the whole task. | devoted to learning. |
| Continuous | Appropriate | Psychological fidelity (also known as functional | Increases retention by |
| Psychomotor | simulation | fidelity) concerns the extent to which simulated | supporting skill |
| Discrete | fidelity. | tasks reproduce behaviours that are required for the actual, real-world target application. | consolidation during acquisition. |
| Psychomotor |  | Physical fidelity is concerned with how well the | Psychological fidelity |
|  |  | virtual environment mimics the appearance of | supports the acquisition |
| Procedural  Simple Decision- making |  | the real-world counterpart. | and retention of  procedures and stepped decisional processes. Where such simple cognitive skills |
|  |  |  | are combined with the |
|  |  |  | continuous or discrete psychomotor skill |
|  |  |  | domains, high |
|  |  |  | psychological along |
|  |  |  | with physical fidelity simulation helps the |
|  |  |  | consolidation of skills, |
|  |  |  | e.g., engagement |
|  |  |  | decisions made by a |
|  |  |  | Precision Gunner. |
|  |  |  | Psychological fidelity is  associated more closely |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain(s) | Factor | Description | Effect on Retention |
|  |  |  | with transfer of trained  knowledge and skills  than physical fidelity. |
| Discrete | Refresher | Targeted refresher assessment reduces the | Increases retention of |
| Psychomotor | assessment  (post training). | burden on refresher training. Training is only required where performance is below the | memory for procedures or stepped decisional |
| Procedural |  | required level of proficiency. This can exploit | processes through |
|  |  | advances in new training technologies for the | provision of the |
| Simple Decision- making |  | assessment of core knowledge and skills at any point in time. Simple decision-making skills can be assessed using novel scenarios. | opportunity to recall  the skill. |
| Explicit Knowledge | Interleaved | Use of varied practice of knowledge and skills so | Increases long-term |
|  | practice. | that practice of task elements is intermixed | retention because |
| Continuous |  | across the training programme rather than | memory is more |
| Psychomotor |  | taught in concentrated blocks. | organised through  generalisation and |
| Discrete Psychomotor  Procedural |  |  | discrimination. General  similarity of approach can be inferred by comparing problems and specific features for |
| Simple Decision- making |  |  | each problem can be  distinguished. |
| Explicit Knowledge | Spaced practice. | Use of space between practice sessions rather than massed practice, where there is no space | Increases retention. Consolidating |
| Continuous |  | between practice sessions. | knowledge and skills in |
| Psychomotor |  |  | memory takes time; |
|  |  |  | later (i.e., spaced) |
| Discrete Psychomotor |  |  | repetitions will support consolidation.  Repetition enables |
| Procedural |  |  | retrieval practice which  creates more |
| Simple Decision- making |  |  | interconnections. Practice should be spaced rather than |
|  |  |  | massed. Space between |
|  |  |  | practice should be 10- 20% of the time that |
|  |  |  | individuals need to |
|  |  |  | retain the material (i.e., |
|  |  |  | the retention interval). |
| Discrete | Error | Provision of error management training. Where relevant, trainees are given the opportunity to make errors and learn from them. Trainers should do the following:  1. Present trainees with a series of practice examples illustrating the range of different conditions that they  may subsequently encounter | Increases retention |
| psychomotor | management  training. | through provision of a  training environment |
| Procedural |  | that allows trainees to: |
|  |  | i) learn to organise new |
| Simple Decision- making |  | information into  existing mental  frameworks holding |
|  |  | prior knowledge in |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain(s) | Factor | Description | Effect on Retention |
|  |  | in the field including any unusual situations.  2. Encourage trainees to think about these situations, make errors and learn from them.  Trainees should experience the same set of errors and not feel responsible for them. | order to generate new |
| knowledge about the |
| context; and ii) practise |
| the application of newly  acquired knowledge |
| and skills. |
| Explicit Knowledge | Task-oriented | Training is designed around the context of the | Increases the level of |
| Simple Decision- | training. | task instead of teaching material at an abstract level, without reference to how it will be | proficiency achieved at the end of initial |
| making |  | applied on the job. | training and therefore |
|  |  |  | retention. |
| Explicit Knowledge | Scenario-based | Development and use of standard scenarios | Increases retention |
|  | training. | that are progressive in difficulty would allow | through knowledge and |
| Continuous Psychomotor |  | students to build on knowledge and skills already gained. Standardisation of scenarios | skills consolidation. |
|  |  | also enables comparisons to be made between |  |
| Discrete |  | students and training facilities. |  |
| Psychomotor |  |  |  |
| Procedural |  |  |  |
| Simple Decision- |  |  |  |
| making |  |  |  |

### Factors Influencing Implicit Knowledge and Complex Cognitive Skills Retention

Advances in science have identified factors that can influence the retention of implicit knowledge and complex cognitive skills (e.g., the Complex Decision-making, Adaptive Cognition, and Integrative domains). These are presented in Table 14, including their effect on retention. It is necessary to have an understanding of the context in which a subtask/EO is conducted. Therefore, a panel of SMEs should consider how these factors can be integrated into training design and delivery. The Conditions and Standards associated with the list of Performance Objectives should be articulated within the RPS and this information can be used as a supporting input to Step 5. Implementation of these influencing factors will support the management of implicit knowledge and complex cognitive skills retention.

**Table 14 – Factors which influence implicit knowledge and complex cognitive skills retention**

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological  Domain | Factor | Description | Effect on Retention |
| Implicit Knowledge | Understanding | Relevant where there are conceptual relationships between subtasks/EOs\*. Tasks are considered complex where increases across the three dimensions of task complexity combine to place higher demand on cognitive (i.e., mental) resources.   * Component complexity. The number of   subtasks/EOs and | Task complexity acts to |
|  | task | increase retention of the |
| Complex Decision- making | complexity. | knowledge and skills  underpinning more complex |
|  |  | tasks when conceptual |
| Adaptive Cognition |  | relationships between  subtasks/EOs are acquired. |
| Integrative |  | Unlike when performing simple  tasks, individuals engage in |
|  |  | deeper and more elaborative |
|  |  | processing for complex tasks |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain | Factor | Description | Effect on Retention |
|  |  | the underpinning  task elements/KLPs, along with the underlying type of skill (i.e., simple cognitive or complex cognitive).   * Coordinative complexity. The nature of the conceptual relationships between subtask/EOs. * Dynamic complexity. Expected input (i.e., information or environmental cues) and output (i.e., the required physical or cognitive response) changes to one or more subtasks/EOs that may impact whole task performance.   \**See Section 2.5.4.1 to understand the importance of capturing task complexity, including the importance*  *of conceptual relationships.* | and consequently should  achieve higher retention. |
| Implicit Knowledge | Developing mental models. | An individual’s mental representation of a task’s complexity and how it places demand on cognitive (i.e., mental) resources. A mental model organises the conceptual relationships (i.e., interconnections) between subtasks/EOs.  Cognitive Task Analysis (CTA) supplements traditional task analysis techniques to enable training designers to identify the conceptual relationships that underpin complex task performance so that these can be designed into training as additional KLPs\*. CTA involves the use of knowledge elicitation techniques, for example, the  application of verbal protocols with | Understanding the conceptual relationships (i.e., interconnections) between subtasks/EOs promotes task meaningfulness by providing the conceptual ‘glue’ which helps bind subtask/EO components (i.e., task elements/KLPs) in long-term memory. Meaningful processing induces more elaborative processing, which supports the acquisition and increases the long-term retention of complex tasks. |
| Complex Decision- making |  |
| Adaptive Cognition |  |
| Integrative |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain | Factor | Description | Effect on Retention |
|  |  | experts thinking aloud while  performing a task.  \**See Section 2.5.4.1 for guidance on how to illustrate task complexity and conceptual relationships within a graphical representation of a mental*  *model.* |  |
| Implicit Knowledge | Use of multiple | Use of multiple variants of a task that | Increases retention by |
|  | variants of a | are related and use the same | supporting the development of |
| Complex Decision- | task. | scenario (i.e., cover story). A set of | a deeper conceptual |
| making |  | multiple variants of the task should  be developed to cover the training | understanding of the task that  enables more efficient retrieval |
|  |  | phase and assessment phase (i.e., | of information from memory. |
| Integrative |  | skill acquisition and retention tests).  These should appear to be very different but require the participant |  |
|  |  | to access the same knowledge and |  |
|  |  | skills learned during training. |  |
|  |  | Examples of variations within a task |  |
|  |  | using the same scenario include timings (e.g., border crossing or route |  |
|  |  | clearance) or locations (e.g., map |  |
|  |  | symbols and/or defence assets). The |  |
|  |  | provision of multiple variants of tasks combined with reflection provides |  |
|  |  | trainees with the opportunity to |  |
|  |  | analyse the variations and draw out |  |
|  |  | any similarities and patterns across |  |
|  |  | task variants. |  |
| Adaptive Cognition | Use of different scenarios. | Use of multiple training exercises that present different scenarios. This provides trainees with meaningful variation and supports the formation  of generalisations across experiences. | Increases retention by supporting the development of a deeper conceptual understanding of response  requirements and actions. |
| Integrative | Introducing whole-task practice. | Complex tasks can be partially or fully integrated. If a complex task is fully integrated, where all subtasks are matched to the Integrative domain, then it should be practised and assessed at the whole task level.  Here, all subtasks/EOs are brought together and practised as a whole task. This ensures the integrative ‘glue’, essential for the effective integration and coordination of the other psychological skills underpinning task elements/KLPs, is fully integrated into the training programme. If a complex task is only partially integrated, where some but not all subtasks/EOs are matched to  the integrative domain, then it may | Supports the acquisition and increases the retention by providing the integrative ‘glue’, which helps bind subtask/EO components (i.e., task elements/KLPs) in long-term memory. |

|  |  |  |  |
| --- | --- | --- | --- |
| Psychological Domain | Factor | Description | Effect on Retention |
|  |  | be possible for some subtasks/EOs to  be practised and assessed at the part  task level. |  |
| Integrative | Guided practice in the workplace with immediate feedback. | Expert guidance during deliberate practice in the workplace allows trainees to apply, develop, and master the skills introduced during formal training of complex cognitive tasks. Feedback improves performance if it is immediate and detailed. In addition to emphasising successful performance, feedback highlights errors in performance that  need correcting. | Increases retention by enabling trainees to practise attention- sharing demands essential for the effective integration of coordinated psychological skill domains underpinning task elements/KLPs. |

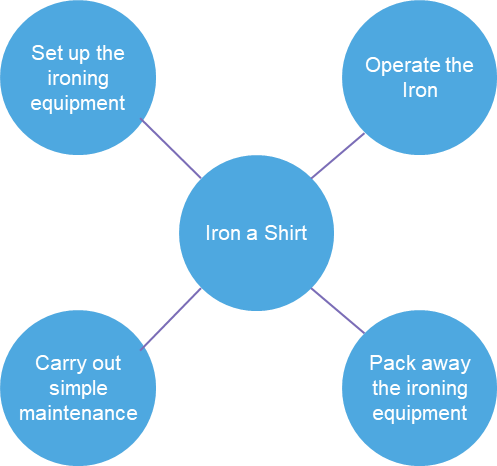
#### Developing Graphical Representations of Task Mental Models

The acquisition and retention of implicit knowledge and complex cognitive skills that underpin complex tasks is enhanced by the development of a strong mental model. A mental model is a mental representation of a task, which captures how it is understood or conceptualised and performed. It includes an understanding of the task components and the purpose(s) of the whole task and its subtasks/EOs, the conceptual relationships between subtasks/EOs, and how they work together during performance of the whole task. Developing a strong mental model is a key factor influencing the acquisition and retention of implicit knowledge and complex cognitive skills. This is because a strong mental model provides the conceptual ‘glue’ required to bind subtask/EO components (i.e., task elements/KLPs) in long-term memory. It also aids the encoding of task complexity. The positive effect on retention of the other influencing factors summarised in Table 14, is dependent on the acquisition of a strong mental model.

Mental models enable trainees to mentally acquire, organise and retain a wide range of task types from the simple to the complex. The more complex the task, the more important it is for the mind to be able to develop, retain and update the mental model for the task. In general, individuals are not conscious of their task mental models and do not explicitly articulate them. However, mental models for any task can be explicitly articulated through analysis to identify what has to be learned. By analysing the mental model, the conceptual relationships between the subtasks/EOs can be identified. These can then be specified as additional KLPs and incorporated into the training design and delivery. It is important to note that these KLPs would not have been identified using traditional KSA analysis techniques.

The external representation of a task’s mental model can be captured graphically to enable visualisation of complexity. The external representation enables visualisation of the conceptual relationships between the subtasks/EOs listed and detailed in the Task/Learning Scalar. These relationships represent the task concept and where, when, and how subtasks/EOs work together during whole task performance. The greater the number of relationships, the more complex the task. Having identified the complexity of the task, training can be designed to support acquisition and retention of complex tasks. If this is done successfully, the jobholder will have acquired the strong, subconscious, mental representation of the task required for proficient performance; however, job holders should not be expected to describe their mental model.

Simple tasks are underpinned by physical and/or simple cognitive skills and involve discrete subtasks/EOs that are performed separately. Such discrete subtasks/EOs can be performed in isolation from each other and there are no conceptual relationships between them. For example, Figure 4 shows the simple task of ‘Ironing a shirt’. Here, there is a single relationship (i.e., link) radiating out from the whole task to each subtask/EO. To illustrate, setting up the ironing equipment can be conducted independently of thinking about the other subtasks/EOs. Mental models for simple tasks do not need to be made explicit during training. This is because the retention of simple tasks is determined by working memory capacity i.e., memory for procedurals and/or stepped decisional processes.



**Figure 4 – Example of a simple task –‘Ironing a shirt’**

In contrast with simple tasks, complex tasks involve complex cognitive skills. They may also involve physical and/or simple cognitive skills. The subtasks/EOs of complex tasks can be performed separately or concurrently, but conceptual relationships will exist between two or more of the subtasks/EOs. Complex tasks require the acquisition of a strong and flexible (i.e., adaptable) mental model. To support acquisition and retention of a complex task, it is important for training designers to explicitly specify this task mental model. This can be done by developing an external representation, which illustrates the conceptual understanding that has to be developed in the learner through practice. This then allows the training designer to identify the conceptual learning points which will support subconscious acquisition of the task mental model.

There are three dimensions to understanding task complexity; component, coordinative, and dynamic complexity:

* Component complexity of a task is determined by the number of subtasks/EOs and their underpinning task elements/KLPs;
* Coordinative complexity is determined by the nature of the conceptual relationships between subtasks/EOs. There are two types of conceptual relationship. The first type is coordinated but not integrated (i.e., not performed concurrently). The second type is integrated (i.e., performed concurrently);
* Dynamic complexity refers to expected input/output changes to one or more subtasks/EOs that may impact whole task performance.

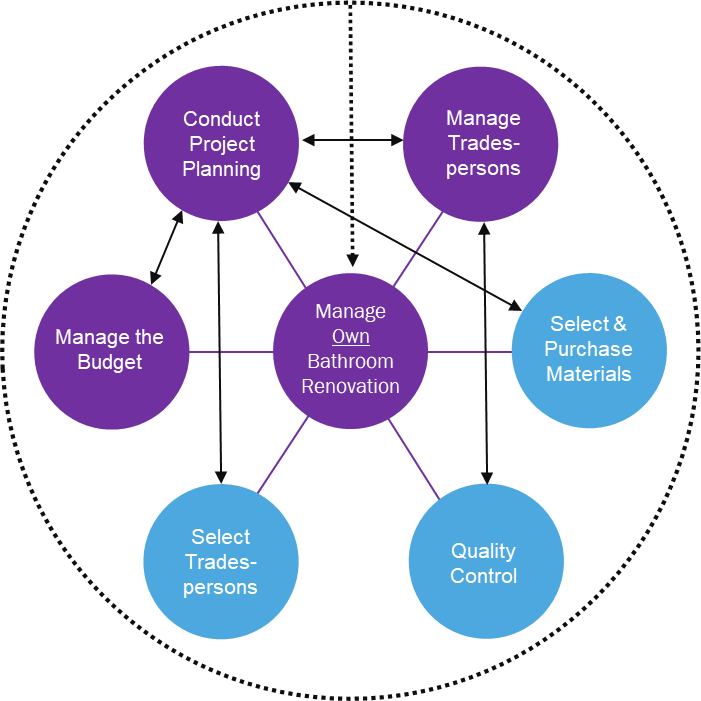
The set of symbols in Table 15 can be used to represent component, coordinative and dynamic complexity within a graphical mental model. Training should be designed so that it helps trainees to learn and understand the conceptual relationships between task components (i.e., subtasks/EOs). Doing so will bind the subtasks/EOs in memory, developing the conceptual glue that holds the complex task together.

**Table 15 – Key with symbols for dimensions of complexity**

|  |  |  |
| --- | --- | --- |
| Symbol | Dimension of Complexity | Description |
|  | Component Complexity: The number of subtasks/EOs and their underpinning task elements/KLPs, along with the type of underlying skill (i.e., simple or complex cognitive) reflect the component complexity of a task. Blue and purple distinguish between subtasks/EOs underpinned by simple (blue) or complex (purple) cognitive skills. | Simple task or subtask/EO (blue) that is underpinned by physical and/or simple cognitive skills. |
|  | Complex task or subtask/EO (purple) that is underpinned by complex cognitive skills. |
|  | Coordinative Complexity: The arrow styles indicate the type of coordinative complexity depending on the nature of the conceptual relationship between subtasks/EOs. | Coordinated but not integrated (i.e., not performed concurrently). Requires the job holder to apply their conceptual understanding of the relationship between subtasks/EOs in terms of their sequencing, timing, frequency, dependency, and location. |
|  | Integrated i.e., performed concurrently and  therefore underpinned by the Integrative Domain. |
|  | Dynamic Complexity: The line style of the circle and number of arrows represent dynamic complexity. They indicate the level of dynamic complexity resulting from increases in expected input/output changes to one or more subtasks/EOs that may impact whole task performance. | Low dynamic complexity. Few expected input/output changes to one or more subtasks/EOs. |
|  | High dynamic complexity. Multiple expected input/output changes to one or more subtasks/EOs. |

Consider analysing the (non-military) example complex task, ‘Manage own bathroom renovation’. In Figure 5, the central circle represents the whole task, supported by complex cognitive and simple cognitive skills. The central circle is purple as opposed to blue because of the presence of complex cognitive skills, in this case required for three of the surrounding subtasks/EOs (also purple). The blue circles indicate subtasks/EOs that are only supported by simple cognitive skills. Together, the purple and blue circles represent the component complexity of the task.

The subtasks/EOs are performed separately. Five coordinated but not integrated (i.e., not performed concurrently) conceptual relationships have been identified between some of the subtasks/EOs, as indicated by the five double-ended single arrows.



**Figure 5 – Mental model for the complex task, ‘Manage own bathroom renovation’**

These coordinated relationships relate to aspects of sequencing, timing, frequency, dependency, or location between pairs of subtasks/EOs. For example, the subtask/EO of Conduct Project Planning is an essential part of a bathroom renovation and begins with the setting the budget (i.e., sequencing) and its ongoing management as the project evolves. Ongoing management requires coordination in terms of timing (budget usually comes first). Managing the Budget is dependent on ongoing adjustments to the project plan, resulting from changes in other subtasks/EO. For example, it may be necessary to cancel the purchase of previously selected materials due to unforeseen delays in the supply chain. Updating the budget as a result of changes to the plan is likely to be frequent, given the component complexity.

The timing of the selection and purchase of materials is coordinated with the project plan. If selected materials become unavailable, project planning, and by extension the budget, will have to be updated accordingly.

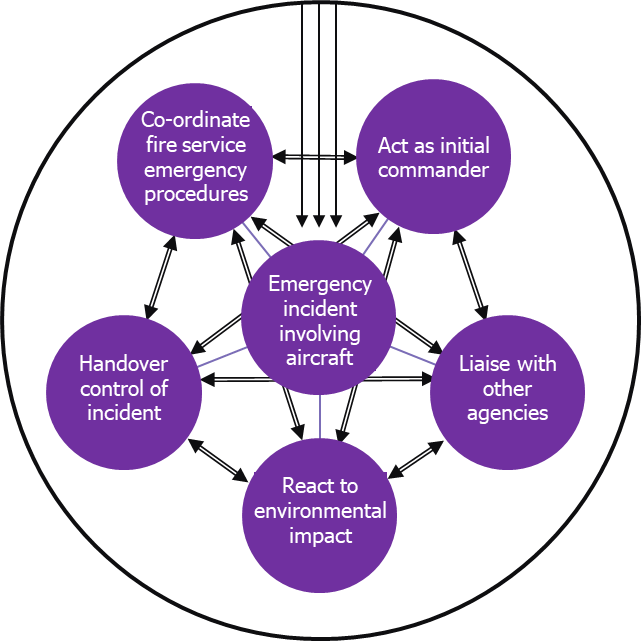
The selection of skilled tradespersons (e.g., plasterer, plumber, electrician, and tiler) relates to the project plan and the budget. This initially involves establishing communication and gathering quotations and estimates. The success of the project plan is dependent on the selection of tradespersons early in the project. Other coordinated subtasks/EOs, i.e., Quality Control and Manage Tradespersons, may highlight the need within the project plan to replace one or more of the initially selected tradespersons, thus reactivating the relationship with the Select Tradespersons subtask/EO. As consequence, the budget may need to be updated.

Having selected the tradespersons, their individual tasks will have to be coordinated and managed within the project plan, in terms of sequencing, timing, frequency, dependencies and location. For example, some jobs will have to be done before others: The plumber will need to decommission the old bathroom and cap- off the water pipes before other work can commence and the plasterer will have to complete their work before tiling can begin. Even if there are no dependencies between some activities, the size of the workspace (i.e., location) may determine how many tradespersons can be working at any one time.

In order to ensure that the renovation work is being carried out to the standards agreed at the time of selection, the ongoing subtask/EO of Quality Control is coordinated with the Management of Tradespersons.

In Figure 5, the outer circle surrounding the task and subtasks/EOs comprises a dotted line with a single dotted line arrow pointing towards the task. With reference to the key to symbols for dimensions of complexity in Table 15, this type of circle and arrow indicates that dynamic complexity is low for this task. There are few expected input/output changes to one or more subtasks/EOs. Thus, the impact on whole task performance resulting from an increase in cognitive demand is correspondingly low. An example of an input change to the ‘Select Tradespersons’ subtask/EO would be where a tradesperson is no longer available. This would result in an adjustment (i.e., output change) to the ‘Conduct Project Planning’ subtask/EO. However, if more dynamic input/output changes to one or more subtasks/EOs were to be expected, the task mental model could be adjusted by using the symbol for high dynamic complexity (see Table 15).

Figure 6 illustrates the mental model for the complex task, ‘Carry out actions on arriving at an emergency incident involving aircraft’. It is very different from managing the renovation of a bathroom. Here, the incident commander will be carrying out all of the subtasks/EOs concurrently. The central purple circle represents the whole task, underpinned by complex cognitive skills. The outer purple circles represent subtasks/EOs involving complex cognitive skill domains. In addition to lines radiating from the whole task to each subtask/EO, there are double ended arrows with two lines between all the subtasks/EOs. This illustrates that the subtasks/EOs are integrated (i.e., performed concurrently), thus representing a fully integrated complex cognitive task. [Note that five of the double ended arrows are partially obscured by the central circles representing the whole task].



**Figure 6 – Mental model for the task, ‘Carry out actions on arriving at an emergency incident involving Aircraft’ as an example of a fully integratedcomplex cognitive task**

At the whole task level, the Integrative domain enables the integration of the subtasks/EOs and the coordinated psychological skill domains that underpin them. At the subtask/EO level, the Integrative domain

enables the integration of the psychological skill domains that underpin the task elements/KLPs. As all the subtasks/EOs are integrated (i.e., performed concurrently), the task should be practised and assessed at the whole task level. That is, all subtasks/EOs should be brought together and practised as a whole task. This ensures the integrative conceptual ‘glue’, essential for the effective integration of the other psychological skills underpinning task elements/KLPs, is addressed in the design of the training.

The mental model in Figure 6 illustrates how multiple, interdependent subtasks/EOs have to be integrated (i.e., performed concurrently) for successful performance of the whole task. The conceptual relationships between subtasks/EOs will become more or less activated during task performance, dependent upon task goals. Any new task inputs to the incident commander will require dynamic changes to the plan.

In Figure 6, the outer circle surrounding the task and subtasks/EOs comprises a solid line with three arrows pointing towards the task. As can be seen from the key in Table 15, the dynamic complexity for this task is high. It is highly likely that there will be multiple input/output changes to one or more subtasks/EOs. An example of an input change to the ‘React to environmental impact’ subtask/EO would be where an unpredicted impact on the environment is identified by the incident commander (e.g., hazardous cargo exploding). This would result in an adjustment (i.e., output change) to the ‘Liaise with other agencies’ subtask/EO. Thus, the impact on whole task performance resulting from an increase in cognitive demand is correspondingly high.

To enable acquisition of complex tasks, the level of dynamic complexity should be designed into task exercises. Where a task mental model indicates high dynamic complexity, training designers and deliverers should ensure that learners practise responding to multiple dynamic (i.e., unpredictable) input/output changes to one or more subtasks/EOs. Conversely, where low dynamic complexity is indicated, training designers and deliverers should build in some dynamic input/output changes to one or more subtasks/EOs. This will exercise the conceptual relationships between the subtasks/EOs. By building in authentic, meaningful, varied, and unpredictable task inputs/outputs, training designers and deliverers will ensure the conceptual relationships between the subtasks/EOs are strongly bound in memory. How well complex cognitive tasks are acquired and retained is inferred from whole task performance and not the ability of trainees to describe or repeat the structure of the task mental model.

Acquisition of strong mental models will enable job holders to respond effectively to dynamic complexity (i.e., new task inputs). If job holders understand the conceptual relationships between subtasks/EOs, they can consider how dynamic input changes to one or more subtasks/EOs may impact whole task performance.

In summary, the complete Task/Learning Scalar with subtasks/EOs and task elements/KLPs matched to the psychological domains (i.e., Step 2 output) should be considered by a panel of SMEs to inform the development of the graphical mental model for the complex task. CTA as a supplement to traditional task analysis can support the identification and specification of the conceptual relationships between subtasks/EOs. The conceptual relationships drawn between the subtasks/EOs can then be specified as additional KLPs. These KLPs will make explicit how subtasks/EOs are conceptually related and can be incorporated into initial training. This will promote task meaningfulness, thus inducing more elaborative processing which supports the acquisition and long-term retention of a strong mental model for complex tasks.

Proceed to perform Step 5.

### Perform Step 5 – Identify Relevant Influencing Factors

The output of Step 5 should be recorded using the template in Appendix A.

Identify additional influencing factors aligned to the psychological domains matched to the very critical and/or moderately critical subtasks/EOs. The factors identified should be practical options for implementation in training design and delivery.

The output of the analysis conducted up to Step 5 will look like Table 16.

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**Table 16 – Example of a complete Learning Scalar with output from Step1 to Step 5**

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|  |  |
| --- | --- |
| Ref | Description |
| 1 | Plan UA) mission |
| 1.1 | Set up the mission planner |
| 1.2 | Manipulate the Sceptre map view |
| 1.3 | Develop the mission plan |
| 1.4 | Enter a flight plan into Sceptre |
| 1.5 | Manage the mission database |

|  |
| --- |
| Psychological Domain |
|  |
| **Procedural** |
| **Procedural** |
| **Integrative** |
| **Procedural** |
| **Procedural** |

|  |  |
| --- | --- |
| Frequency | CRA  Retention  Level |
|  |  |
| Very frequent | 5 months |
| Very frequent | 5 months |
| Very frequent | Not Known |
| Very frequent | 5 months |
| Infrequent | 2 months |

|  |  |
| --- | --- |
| Criticality | Additional Influencing Factors  (see Table 12, Table 13 and/or Table 14) |
|  |  |
| Very Critical | Develop a well-designed HMI with appropriate simulation fidelity and introduce variable practice. |
| Very Critical | Develop a well-designed HMI with appropriate simulation fidelity and  introduce variable practice. |
| Very Critical | Develop the subtask mental model and introduce practice and assessment for this subtask/EO at the whole task level. |
| Very Critical | Develop a well-designed HMI with appropriate simulation fidelity and  introduce variable practice. |
| Not Critical | Develop a well-designed HMI with  appropriate simulation fidelity and introduce variable practice. |

Where subtasks/EOs involving complex cognitive skills have been identified, develop a graphical representation of the task mental model. This will provide a visual interpretation of the task’s complexity in terms of its components (i.e., subtasks/EOs) and the conceptual relationships that exist between them. Development of the graphical representation of the task mental model should be undertaken by a panel of SMEs, using: i) the complete Task/Learning Scalar with the subtasks/EOs and task elements/KLPs matched to psychological domains (i.e., Step 2 output); and ii) the symbols for dimensions of complexity (see Table 15). To further support the identification and specification of the conceptual relationships between subtasks/EOs, a CTA can be performed.

The first step in developing a graphical representation of a task’s mental model is to draw the central circle representing the whole task, and then the outer circles representing the subtasks/EOs. These circles will illustrate the component complexity of the task. Next, links should be drawn between the subtasks/EOs to explicitly represent the task’s coordinative complexity and define the conceptual relationships, i.e., what conceptually ‘glues’ the sub-tasks/EOs together. The conceptual relationships will either be coordinated (but not integrated) or integrated (i.e., performed concurrently). An outer circle should then be drawn, with the line of the circle and arrows representative of the task’s dynamic complexity and thus the likely occurrence of dynamic input/output changes to one or more subtasks/EOs that may impact whole task performance. The greater the number of task components and conceptual relationships, and the higher the dynamic complexity, the more complex the task.

Once the graphical representation of the mental model has been developed, the other factors known to improve retention of implicit knowledge and complex cognitive skills can be designed into training. For example, where integrated conceptual relationships have been identified between all subtasks/EOs because these are matched to the Integrative domain, then the complex task is fully integrated. Consequently, all subtasks/EOs should be brought together and practised and assessed as a whole task. This ensures the conceptual integrative ‘glue’, essential for the effective integration and coordination of the other psychological skills underpinning task elements/KLPs, is fully integrated into the training programme. However, if a complex task is only partially integrated, where some but not all subtasks/EOs are matched to the integrative domain, then it may be possible for some subtasks/EOs to be practised and assessed at the part task level.

Having performed Step 5, the revised CRA-T process is now complete.

## Summary

As Defence tasks become more cognitively complex, now and in the future, the CRA process provides a simple mechanism for identifying the psychological domains that underpin task and subtask performance. This is important for training designers and deliverers as it helps to identify when different learning approaches must be adopted to ensure both the acquisition and retention of knowledge and skills.

Further detail on competence retention key concepts, including new insights into competence retention is provided in Section 1.

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# Appendix A Template For Recording CRA-T Output

The table below shows the format for a template suitable for recording CRA-T output**,** which may then be used to inform training design and delivery.

**Table 17 – Template for recording CRA-T Output**

|  |  |
| --- | --- |
| Ref | Description |
| 1 | Plan UAS mission |
| 1.1 | Set up the mission planner |
| 1.1.1 | Power up |
| 1.1.2 | Create a new mission |
| 1.1.3 | Open a previously saved database |
| 1.1.4 | Create a mission for a previously saved  database |
| 1.1.5 | Update mission security classifications |

|  |
| --- |
| Psychological Domain |
|  |
| **Procedural** |
| **Procedural** |
| **Procedural** |
| **Procedural** |
| **Procedural** |
| **Procedural** |

|  |  |
| --- | --- |
| Frequency | CRA  Retention Level |
|  |  |
| Very frequent | 5 months |
| Very frequent | 5 months |
| Very frequent | 5 months |
| Very frequent | 5 months |
| Very  frequent | 5 months |
| Very frequent | 5 months |

|  |  |
| --- | --- |
| Criticality | Additional Influencing Factors  (see Table 12, Table 13 and/or Table 14) |
|  |  |
| Very Critical | Develop a well-designed HMI with appropriate simulation fidelity and introduce variable practice. |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

**Appendix B Competence Retention Key Concepts and New**

**Insights**

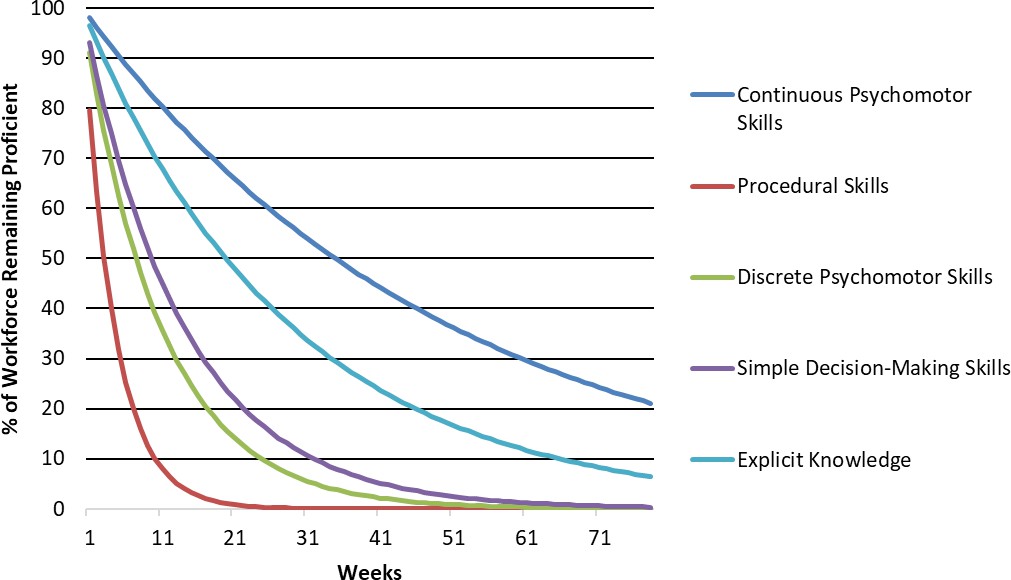
This Appendix describes the science behind the development of the CRA-T’s ‘RED’, ‘AMBER’ and ‘GREEN’ retention levels for explicit knowledge, physical and simple cognitive skills. These retention levels are included in the original User Guide and this handbook. The key concepts on which CRA is based are also outlined.

## Predicting Competence Retention

Two predictive models of individual skill retention that consider multiple factors known to affect the retention of knowledge and skills have been identified. The US Army Research Institute’s (ARI) UDA model (Rose, Radtke et al., 1985) predicts knowledge and skills retention by rating task-based characteristics of individual tasks, whereas its revised version, the Trainers’ Decision Aid (TDA) includes training-related factors in addition to those which are tasked-based (Cianciolo et al., 2010).

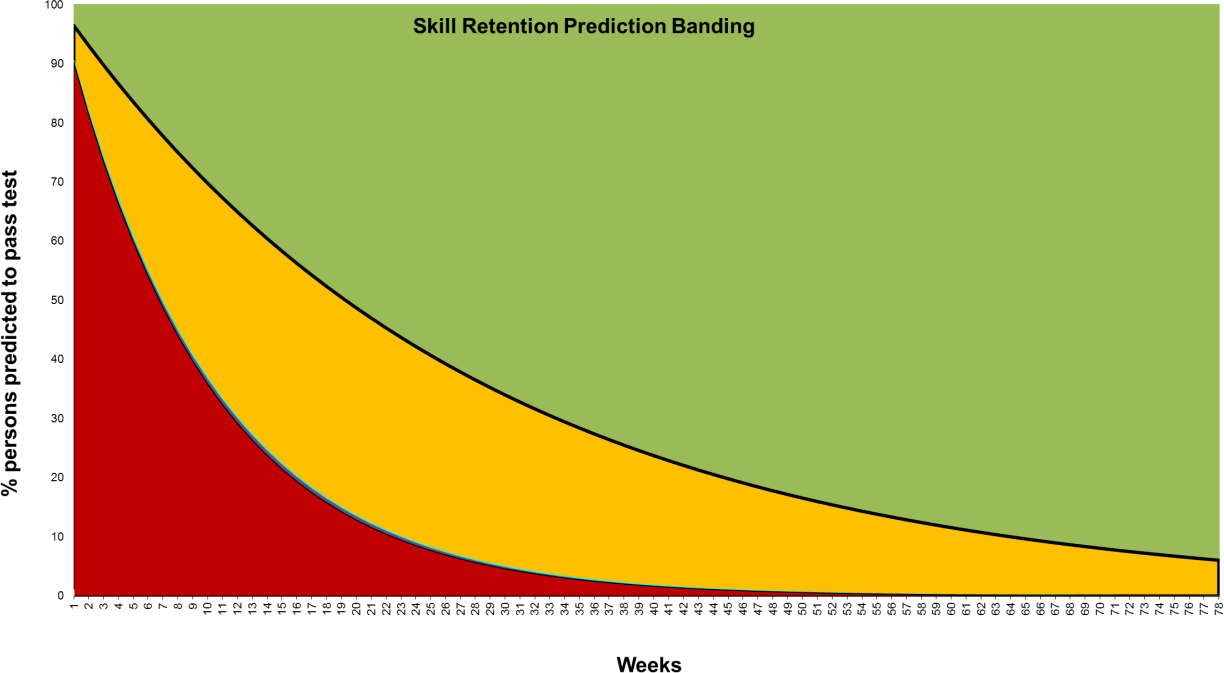
The UDA was identified as the only fully developed predictive model that considers multiple factors known to be strong predictors of knowledge and skills retention. In developing the original CRA-T for the User Guide, the UDA was applied by SMEs to tasks representative of the following domains: Explicit Knowledge, Continuous Psychomotor, Discrete Psychomotor, Simple Decision-making, and Procedural skills (Cahillane et al., 2013). The set of tasks cases were defined in consultation with Defence stakeholders, with each representing the application of one of the psychological domains.

Application of the UDA resulted in a series of indicative retention curves for the generic psychological knowledge and skill domains (see Figure 7). The UDA model assumes no practice has taken place in the generation of predicted retention curves.



**Figure 7 – UDA retention curves for different psychological domains**

The retention curves in Figure 7 were categorised into a practical traffic light system of three retention levels: High retention (GREEN), moderate retention (AMBER), and low retention (RED), based on the UDA score range. Using the UDA scores, the retention categories were translated into indicative retention bandings, as shown in Figure 8 on to which the indicative retention curves can be overlaid.



**Figure 8 – Indicative retention bandings**

The indicative retention bandings for the low, moderate and high retention levels displayed in Figure 8 define the CRA-T competence retention levels in Table 18. The retention level definitions are distinguished by the point at which 50% of a workforce would remain competent in applying the knowledge and/or skills after a specified period of time has elapsed since they were last applied.

The indicative green retention banding, which denotes the high retention level indicates that greater than 50% of a workforce will be competent after 12 months (i.e., 52 weeks) has elapsed since the knowledge or skill was applied.

**Table 18 – Definition of retention levels**

|  |  |
| --- | --- |
| Retention Level | Definition |
| High | A high level of retention is predicted after periods of no practice.  (Greater than 50% competent after 12 months non-practice) |
| Moderate | A moderate level of retention is predicted after periods of no practice.  (50% competent after 5 months non-practice) |
| Low | A low level of retention is predicted after periods of no practice.  (50% competent after 2 months non-practice) |
| Not Known | The retention level cannot be defined. Available evidence is  insufficient but suggests 6 months. |

The retention level definitions are fixed at the 50% point and cannot be adjusted, given the current level of validation for the CRA-T. The low (RED), moderate (AMBER) and high (GREEN) retention levels should be considered as indicative of when refresher training is required and not conclusive. This is because the CRA-T is based on the UDA predictive skills retention model, which was originally developed for tasks requiring the recall of procedures and stepped processes. In addition, although this predictive skills retention model has received some validation, it has not been widely validated and is known to be pessimistic. In general, the UDA predicts on average a smaller percentage of a workforce will be competent than the actual performance data would suggest. For some tasks, this difference has been as large as 30% (Rose, Czarnolewski et al., 1985).

Although the retention levels in Table 18 are based on retention curves that may be pessimistic, they can be considered as representative of the worst-case scenario. This is in terms of the percentage of a workforce indicated to be competent after a period of non-practice or application.

To date, the CRA-T is the only scientific methodology developed as a practical approach to predicting knowledge and skills retention at the workforce level. Further research and/or the collection of performance data is required to validate the indicative retention level definitions more widely. It is also required to

develop definitions for the GREY (Not Known) retention levels for implicit knowledge and the complex cognitive skill domains.

The CRA-T was designed to provide a framework to consider competence retention through training, in particular beyond the acquisition of the required knowledge and skills during initial training. The output from the CRA-T process provides information on competence retention because it is based on the psychological domains that underpin tasks.

## Prediction Limitations and Assumptions

Those applying the CRA-T should be aware that its existing retention levels (red, amber, and green) are based on decay curves generated by the application of the UDA model. Although the UDA is based on task-related factors that are known to influence the retention of explicit knowledge, physical and simple cognitive skills, the algorithm applied in the generation of its decay curves is based on the aggregation of individual performance data. Therefore, the decay curves represent the percentage of a workforce predicted to remain proficient after a period of time has elapsed since the knowledge or skill was last applied. Given the CRA-T extant retention levels are based on UDA-generated retention curves, they do not indicate knowledge and skill fade at the level of the individual. It follows that the CRA-T retention levels cannot be used to identify the point at which an individual’s performance would fall below criterion.

The CRA-T retention bandings assume 100% of personnel within a workforce or unit are competent at the end of their last training session. They also assume that the workforce has received the same training, to the same standard, and that personnel meet the same level of proficiency at the time of skill acquisition. To address these limitations, new decay explanations of knowledge and skills retention must be based on individual retention of acquired knowledge and skills over an extended period of non-use. Key to the generation of individual skills retention curves is the requirement for a standardised approach where the same individuals: i) are at or above a criterion performance level; ii) have had equivalent training experience during acquisition; and iii) have been assessed at the point of acquisition and after a specified retent ion interval(s). Guidance for the collection of longitudinal empirical evidence is covered in a Top Tips document for the Planning, Conduct and Analysis of Future skill Fade research (Cahillane & Anderson, 2021).

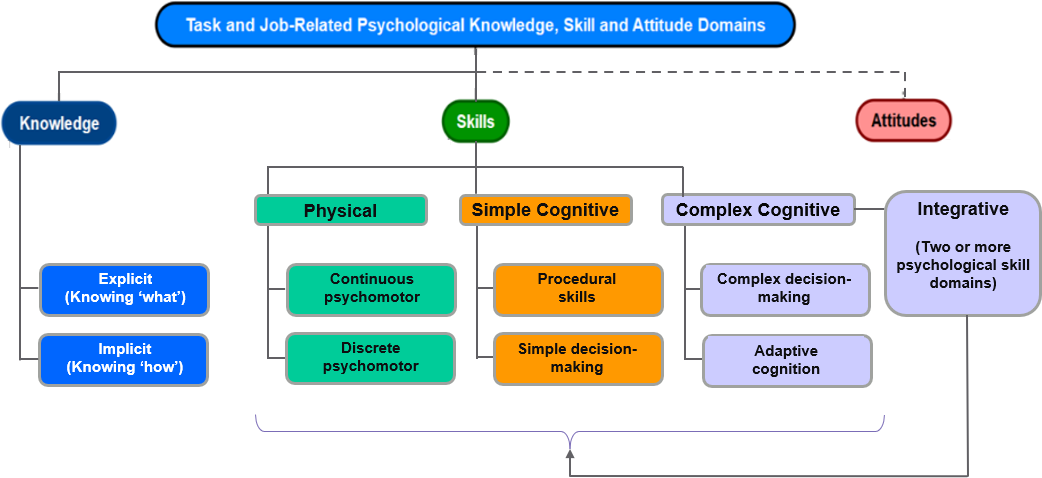
The UDA model decay curves predict retention out to 12 months. As the CRA-T extant retention levels are based on the UDA model, the CRA-T does not predict retention beyond 12 months. However, the CRA-T still has utility if the intent is to understand which task elements/KLPs and subtasks/EOs would be most and least prone to fade. If the ambition is to extend a refresher training interval to beyond 12 months, then performance data would need to be collected and analysed.

## New Insights

New insights into different types of current and future knowledge and skills were established during a programme of research commissioned by Dstl through the HSSRC framework (Cahillane et al., 2020). These are summarised in the following sections.

### A Revised Taxonomy of Psychological Knowledge and Skill Domains

The current scientific literature, alongside defence case studies (Cahillane et al., 2020), provided the basis for the revised taxonomy of psychological knowledge and skill domains in Figure 9. It was developed due to concerns that the original may not reflect the knowledge and skills considered important by Defence today and in the future, given emerging roles (MacLean et al., 2015; Richards & Deighton, 2019). The re- classification of KSA in terms of the psychological knowledge and skill domains outlines knowledge, skills and attitudes in a manner that is consistent with advances in the psychological literature on human cognition (Green & Bavelier, 2015; Sanli & Carnaham, 2018; Stasielowicz, 2019). There are no attitudinal domains because attitudes do not decay over time. Nevertheless, there is a relationship between attitudes and skills retention, hence the taxonomy’s acknowledgement of Attitudes.



**Figure 9 – Revised Taxonomy of Psychological Knowledge and Skills Domains**

Understanding the retention of knowledge and skills is important to Defence because it is known that knowledge and skills are retained at different rates over time. Understanding the rate at which different types of knowledge and skills fade can inform training design and delivery decisions.

Knowledge is organised into that which is explicit (knowing ‘what) and implicit (knowing ‘how’). Explicit knowledge refers to basic facts and principles, for example, safety regulations, including any procedures to be followed. Implicit knowledge refers to tacit (non-declarative), unconscious knowledge about ‘doing’. For example, when faced with complex situations, firefighters and incident commanders do not consciously articulate the knowledge they are using because it is implicit. Based on their experience, they automatically recognise salient situational cues which match a course of action. However, research shows that when prompted after an incident, firefighters and incident commanders can describe what they were thinking.

The psychological skills domains are organised into Physical, Simple Cognitive, and Complex Cognitive categories. In terms of the Physical category, the Continuous Psychomotor skills domain refers to the ability to perform motor actions that do not have distinct beginnings or ends (for example driving or flying and manoeuvring an aircraft. Performing well trained sequences of motor actions with discrete beginnings and endings reflects discrete psychomotor skills, such as performing weapon handling drills.

The Cognitive categories refer to mental skills and distinguish between simple and complex cognitive skills**.** Simple cognitive skills include the Procedural skills domain, which represents the ability to remember a sequence of steps and their order to execute a task. There are minimal physical demands. For example, when using a BIMS to create map overlays, the physical component only constitutes using a mouse and the procedural aspect dominates. This distinguishes procedural skills from discrete psychomotor skills such as weapon handling, which have greater physical demands and require the recall of a sequence of actions. Simple Decision-making involves a series of processes involving analysis and evaluation with discrete outputs that have a definite beginning and end and result in a decision. The options available during a simple decision- making process are usually binary, such as 'Yes' and ‘No’ when a decision tree is followed, for example, combat casualty drills.

Complex cognitive skills include the Complex Decision-making, Adaptive Cognition and the Integrative domains. Complex decision-making involves an iteration of situational assessment, analysis and evaluation cycles that continue until an optimal decision is reached. Examples include carrying out an intelligence estimate or threat analysis and assessment.

Adaptive Cognition reflects the ability to constantly monitor the discrepancies between the current and desired state and adapt behaviour to meet the demands of a new situation where the context changes. Problem-solving tasks represent an example where the ability to identify desired goal states (i.e., the need for a solution) and to apply and/or adapt existing strategies (derived from knowledge and experience) are

required to arrive at a solution. The example of the US Airways Flight 1549 Hudson River plane crash provides an illustration of the use of adaptive cognition. The pilot, ‘Sully’ had to consider all of the conceptual components of the landing task and their relationships within a new context and adapt his existing learnt strategies to successfully land the plane in the Hudson River.

The Integrative domain is a complex cognitive (i.e., mental) ‘meta-skill’. It sits above the other skill domains and represents the ability of an individual to manage their attention in order to perform within two or more different psychological skill domains concurrently. The Integrative domain is required for subtasks where the task elements match a combination of two or more different psychological skill domains that are performed concurrently (i.e., integrated). An example is a firefighter responsible for responding to an incident (simple decision-making) and deciding what and how information should be communicated to multiple agencies (complex decision-making), whilst managing events immediate to the scene of a fire (procedural skills). Note that the procedural skills and discrete psychomotor skills cannot be integrated (i.e., performed concurrently). This because discrete psychomotor skills involve the recall of a sequence of motor actions. Hence, higher motor demands are combined with moderate cognitive demands (i.e., procedural skill). An example of two simple cognitive skills that might be performed concurrently (i.e., integrated) are continuous psychomotor and adaptive cognition, for example, a UAS pilot having to adapt their thinking in order to drive behavioural, i.e., continuous psychomotor output. The UAS pilot has to adapt to constant changes in the information being fed back to them by the sensors, which they are simultaneously controlling.

Although a high-level distinction between mental and physical skills is provided in JSP 822 Part 2 (2021), it does not define different types of mental skills that are consistent with advances in the psychological literature (e.g., simple and complex cognitive skills). The accurate consideration of competence acquisition and retention is constrained as a result. However, JSP 822 acknowledges the CRA-T as a process specifically designed to facilitate the retention of knowledge and skills. Based on the original CRA-T, Annex B to JSP 822 Part 2 provides definitions of the psychological knowledge and skill domains and illustrates the effect of task frequency on their retention. A summary of practical training ‘strategies’ are also presented.

### Simple vs. Complex Cognitive Skills

The rate at which a skill decays is moderated by the type of skill involved (e.g., Cahillane et al., 2013; Cahillane et al., 2020; Richards & Deighton, 2019). Simple cognitive skills (procedural and simple decision-making) are known decay rapidly (e.g., Cahillane, MacLean & Smy, 2018; Cahillane & Morin, 2012). The rapid rate of decay observed for simple cognitive skills is explained by the fact that they have a combination of low physical demands and moderate cognitive (i.e., mental) demands. The moderate cognitive demand relates to the need to recall cognitive processes or explicit information.

Retention is improved where the physical demand is higher. Skills are retained better when they require a combination of moderate to high physical demands and moderate cognitive demands, for example, discrete psychomotor skills such as weapon handling drills. These types of skills require rote memory for cognitive stepped processes and procedures, and their rehearsal to aid their acquisition and retention.

Complex cognitive skills (complex decision-making and adaptive cognition) are also better retained than simple cognitive skills (Villado et al., 2013). Complex cognitive skills place much higher demands on cognition, irrespective of physical demand. The higher cognitive demands account for the reduced skill fade found to date for complex cognitive skills. To date, only one study (Sanli & Carnahan, 2018) has considered the retention rate of complex cognitive skills and reported retention up to 6 months after initial training. Hence, there is currently insufficient evidence to define retention levels for complex cognitive skills.

### Defence and Security Task Cases

The revised taxonomy of psychological knowledge and skill domains (Figure 9) was incorporated into a systematic analysis of the following five Defence and Security task cases with SMEs (Cahillane et al., 2020):

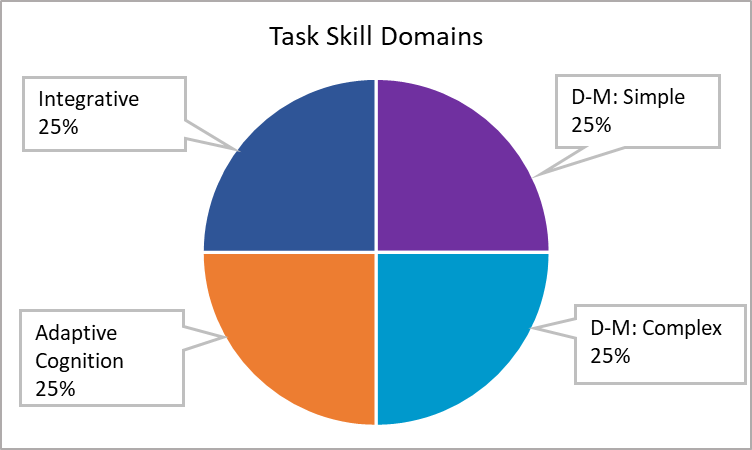
* + - * Larkhill - UAS Pilot role
        + Task Case 1: Carry out decision-making in an emergency;
        + Task Case 2: Control the Payload (Payload handling).
      * RAF High Wycombe - Firefighter role
        + Task Case 3: Operate as a Breathing Apparatus wearer;
        + Task Case 4: Incident Commander - Respond to an incident.
      * RAF Brize Norton - Multi-Engine pilot role
        + Task Case 5: Conduct Natural Surface Operations with Night Vision Goggles.

These task cases were down-selected in consultation with the Dstl as being representative of current and future Defence and Security skills. For each task, the revised taxonomy was applied at the subtask level of analysis to capture the psychological domains underpinning the subtask elements. Frequency counts for each psychological domain demonstrated the proportion of the domains involved in each task.

For each task, the UDA model was applied at the whole task level. The weighted values associated with the selected responses to the ten questions from the UDA were summed producing a total UDA score. This was then fed into the UDA formula to generate a predictive retention curve out to 52 weeks (i.e., 12 months). Questions addressing additional moderators of skills retention (e.g., training and context-related) were also applied. However, responses to these only suggested how the retention rate predicted by the UDA may be improved given a lack of longitudinal empirical data and weighted values for the combined effects of these additional factors.

There was evidence of complex cognitive skills underpinning all the Defence and Security tasks examined. Furthermore, multiple psychological domains were found to underpin current and future tasks and this reflected either a combination of skills or an integration of interdependent skills. Where the Integrative domain was identified, this reflected that two or more coordinated skill domains were integrated (i.e., performed concurrently). These findings highlighted gaps in the UDA and CRA-T models. A full description of the findings for all five task cases is provided in the HS1.004 Skill Fade Phase 1 Technical Report (Cahillane et al., 2020).

Application of the UDA to the Royal Air Force (RAF) Firefighter task, ‘Incident Commander – Respond to an Incident’ resulted in no decay curve (UDA Total score 66.) Understanding the psychological domains that underpin this task provides an explanation for the lack of a curve. The pie chart in Figure 10 displays the proportion of the underlying psychological skill domains involved in performance of this task as a whole. 75% of the task involves complex cognitive skills. The remaining 25% draws on the Simple Decision-making domain, a simple cognitive skill relying on memory for discrete stepped processes.



**Figure 10 – Psychological domains underpinning RAF Firefighter role: ‘Incident Commander – Respond to an incident’. (Note: D-M = Decision-Making)**

SMEs perceived that the subtasks were underpinned by both explicit and implicit knowledge, with the latter being more complex. A probable explanation for this is that Incident Commanders make rapid intuitive decisions when faced with complex situations based upon patterns in associative memory (Klein, 1999). At the time, they do not consciously articulate the knowledge they are using and therefore it is implicit. However, research shows that when prompted after the incident, incident commanders can articulate their implicit knowledge.

Rather than being determined by working memory capacity, the science indicates that the retention of complex cognitive skills and implicit knowledge is enhanced by the development of a mental model; in this

case, patterns of incidents and cognitive (i.e., mental) responses stored in associative memory. The UDA, which underpins CRA’s retention levels (i.e., green, amber, and red) and corresponding retention level definitions, only considers working memory capacity for discrete stepped processes and procedures. Therefore, the UDA is only valid for physical skills (i.e., the Continuous Psychomotor and Discrete Psychomotor domains), simple cognitive skills (i.e., the Simple Decision-making and Procedural domains) and the Explicit Knowledge domain.

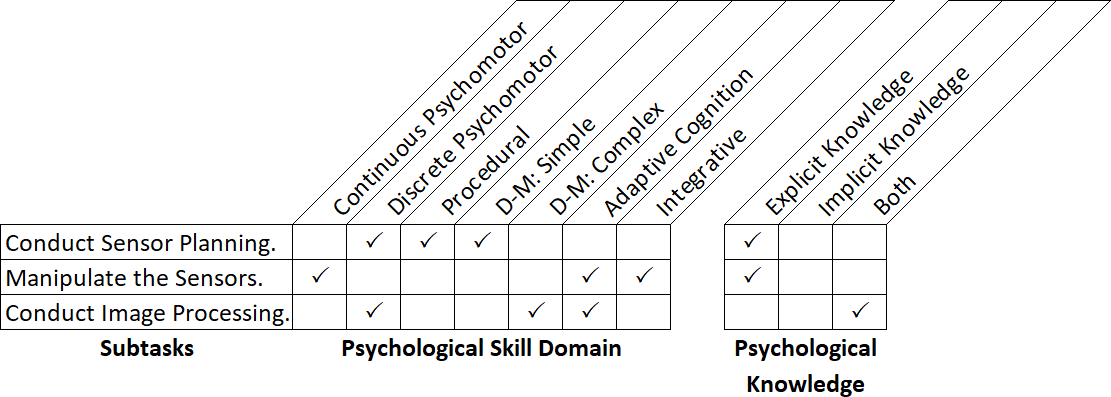
### Simple vs. Complex Tasks

‘Simple’ tasks are underpinned by physical and/or simple cognitive skills and involve discrete subtasks/EOs that are performed separately. Such discrete subtasks/EOs can be performed in isolation from each other and there are no conceptual relationships between them. For example, weapon handling involves the Discrete Psychomotor domain. This underpins the ability to perform well trained sequences of motor actions with discrete beginnings and endings. These motor actions refer to the weapon handling drills. Explicit knowledge also underpins this task, as it does all tasks.

As tasks become more complex, the psychological domains involved become more complex and they involve either combinations and/or an integration of psychological domains. Furthermore, resea rch indicates that task complexity and the combination of cognitive and physical demands are associated with the rate of skill decay (Wang et al., 2013). Therefore, to understand and manage the retention of complex tasks, tasks should not be thought of in a single psychological domain. Instead, they should be considered as involving a combination and/or integration of domains.

Integration is understood by looking at the whole task. Some complex tasks can be partially integrated whereas other can be fully integrated. This is important to understand because the Integrative domain is used to control and coordinate the other psychological skill domains at the task element/KLP level. This provides the ‘glue’ that holds these elements together (Cahillane et al., 2020). If a task is fully integrated (all subtasks are underpinned by the integrative domain), then it should be practised and assessed at the whole task level. This ensures the integrative ‘glue’, essential for effective task completion, is addressed in the design of the training. If, however, a task is only partially integrated (some but not all of the subtasks are underpinned by the integrative domain), then it may be possible for some subtasks to be practised and assessed at the part task level.

An example of a complex task that is partially integrated is the UAS Pilot task, ‘Control the payload’. This involves handling payloads which consist of Synthetic Aperture Radar, Ground Moving Target Indicator radar, and an Electrical Optical and Infrared camera. The matrix in Figure 11 shows the three subtasks on the left and the combinations of psychological domains that underpin these along the top (Cahillane et al., 2020).

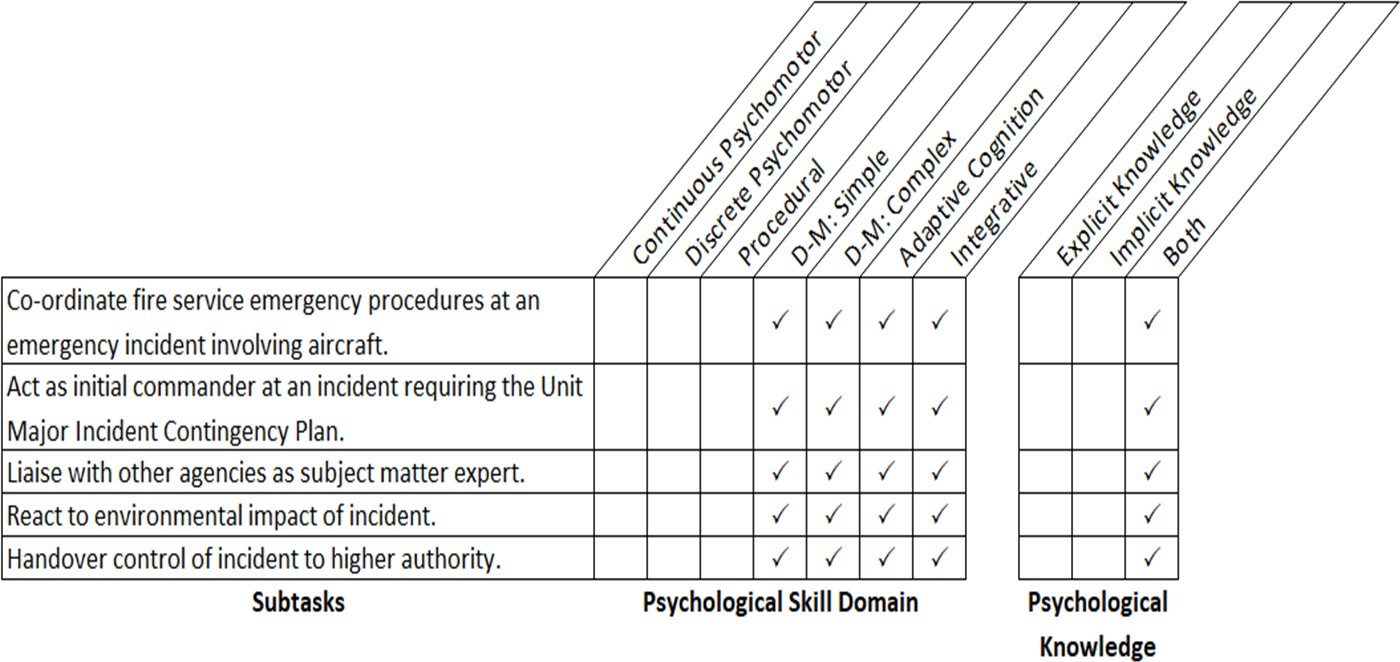


**Figure 11 – UAS Pilot Task: ‘Control the payload’. (Note: D-M = Decision-Making)**

This task provides an example of how tasks are becoming more complex because they involve the use of more than one psychological domain within the subtasks. ‘Conduct Sensor Planning’ and ‘Conduct Image Processing’ are complex subtasks which use the combination of psychological domains separately. ‘Manipulate the Sensors’, however, uses the combination of the Continuous Psychomotor and Adaptive Cognition domains concurrently (i.e., they are integrated - as indicated by the selection of the Integrative

domain in the matrix). Hence, the Integrative domain is used to manage attention to integrate and coordinate the other two psychological skill domains that underpin performance of this subtask. Therefore, this task represents a partially integrated complex task.

An example of a fully integrated complex task is the RAF Firefighter task, ‘Incident Commander – Respond to an incident’. As illustrated by Figure 12, all subtasks involve the Integrative domain. Therefore, the Integrative domain sits at the whole task level and, in order to bring all components together, the task must be practised and assessed at the whole task level.



**Figure 12 – RAF Firefighter Task: ‘Incident Commander – Respond to an incident’. (Note D-M = Decision-Making)**

As Defence tasks become more cognitively complex, now and in the future, CRA provides a simple mechanism for identifying the psychological skill domains that underpin task and subtask/EO performance.

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