Introduction

The Air Combat Domain
This paper focuses on expert skilled performance of military pilots in the complex spatiotemporal domain of air combat. Fighter pilots operate fast jet aircraft capable of cruising speeds in excess of 1500 km/hr, and often fly in formations separated by less than the width of the aircraft. While operating at these very high speeds, they perform complex and coordinated aerobatic manoeuvres to achieve tactical advantage over enemy aircraft and to provide air supremacy in support of other force element groups (FEGs). It costs millions of dollars to train fighter pilots (e.g., see Doyle, 2003), and their operational aircraft cost orders of magnitude more that amount (e.g., Kopp, 2007), so there is a clear financial motivation for research interest into effective and efficient fighter pilot training.

Fighter pilots are often portrayed as the elite of pilots (for a popular culture example, consider Tom Cruise's role in the 1986 movie “Top Gun”). It is undeniable that fighter pilots need elite psychomotor and cognitive skills to succeed in their air combat training, specifically in the spatiotemporal domain of interest for this paper. It is more open to question as to whether some of the specific skills and training required for air combat are counterproductive for flying in crewed environments, on long-haul routine flights, or on lower performance aircraft (e.g., see Ganesh & Joseph, 2005, for a review of aircrew personality traits). Suffice to say that across the aviation domain, there are many flying roles all of which require a high degree of flying proficiency (in the form of expert skilled performance), and the highest degree of compression and complexity occurs within the spatiotemporal flying and decision-making domain of the air combat environment.

Military Flying Training
Each FEG in the Australian Defence Force (ADF) has a different military flying role. Within the Royal Australian Air Force (RAAF), the Air Lift Group (ALG) has a strategic and tactical role, the Surveillance and Response Group (SRG) conducts maritime patrol, air defence and air battle management, and Air Combat Group (ACG) operates strike fighters and bombing aircraft. Australian Army Aviation (AAAvn) and Navy Aviation Group (NAG) operate a range of rotary wing aircraft, with NAG helicopters operating routinely over water often with the added difficulty of landing on the deck of aircraft carriers in poor visibility. Despite some core similarities in military flying, the domain expertise required in operational flying roles in each FEG often relies on very different forms expert flying performance. The training continuum to

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1 This paper is based on work carried out in collaboration with Mr James Quealy and Dr Helen Pongracic, for a number of DSTO research projects. The ideas presented in this paper are the author’s input to the project, and the aim of the paper is to highlight the relevance of these insights to professional training environments other than military flying training.
achieve operational capability for each FEG begins at basic training and is completed in the operational conversion phase at the squadrons.2

Despite the different requirements for different military flying roles, the basic flying training is the same for all ADF military pilots (see Figure 2 for a generic overview of ADF pilot training). The current ADF pilot training continuum aims to produce pilots capable of becoming fighter pilots. It is generally agreed that military flying training focused on the needs of fighter pilots prepares students adequately for all military flying streams, and it has even been argued that for some streams, students are “overprepared”3. However, if basic flying training were to be restructured based on cost and numbers to focus on the specific needs of transport or rotary wing pilots (the final destination of the majority of ADF military pilots), it may not be adequate preparation for the fast jet flying stream.

![Training Continuum Diagram](image-url)

**Figure 2 Schematic view of possible phases and streams of ADF flying training**

From a training perspective, it is important to understand that the basic training phase is where the initial mental models of the future domain of expertise are first laid down. Although there might be efficiencies in terms of cost of training and availability of instructors in contracting out early training to non-military flying instructors and using expert instructors only for later stages of training, there may be hidden training deficiencies because the basic

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2 This description is based on ADF training, but a similar framework applies to most military flying training, with slight differences in the streaming process and allocation of responsibilities.

3 The concept of “overprepared” comes from a Competency Based Training and Assessment (CBTA) perspective that maps each trained competency to a job requirement. In such a framework, competencies achieved during training that are not part of a final job requirement would be considered “over-training”. For example, aerobatic manoeuvres are not performed in Navy helicopters (or in commercial aviation), and would therefore be seen as “over-training”, despite the fact that aerobatic manoeuvring provides a deeper understanding of the flying environment and a greater capability to avoid or recover from dangerous situations.
Flying instructors have never themselves experienced the final stage of expertise. Without domain expertise, these instructors may not fully appreciate the finer nuances of meaning they need to highlight in early training, yet the habits developed in early training will form the basic conceptual layer upon which later skills will be layered. Also, the act of instructing, as will be discussed later in this paper, is itself a major contributor to the development of expertise, through forcing expert skilled performers to reflect on their own performance and analyse the performance of others, and to do so while engaged in the primary task of captaining an aircraft.

**Competence versus Expertise**

Aviation is arguably the most proceduralised domain of professional practice (e.g., see Diskmukes, Berman & Loukopoulos, 2007) with flight operation manuals (FOMs) covering all aspects of normal and non-normal (e.g., emergency) operations. Written scripts in the form of checklists cover each operation, providing clear instructions for what to do in any given situation, including any foreseeable technical error or extreme environmental condition. In commercial aviation, it is paramount for pilots of passenger aircraft to remain within “normal routine” and to provide certainty for their passengers in terms of timetabling and passenger comfort while travelling on specified air routes between pre-determined, known locations. Commercial airlines pilots require a very high level of competence and professionalism to carry out a set of specified duties to a consistent high standard of performance.

In contrast, although military aviation also makes extensive use of FOMs and checklists and military pilots file flight plans prior to each sortie, most operational military flying involves intentionally pushing boundaries while trying to minimise the risk of losing aircraft or lives. Military pilots require a high level of expertise in their domain, to allow them to carry out specified roles using the expert performance skills acquired during training. They need to be flexible and adaptable, and most operational missions they perform will be similar to, but not the same as, training scenarios or previous operational experience. Competency Based Training and Assessment (CBTA) provides a framework for detailed analysis of job skills, training requirements and skills assessment which works best for domains in which the professional (operational) practice is the same as the training environment (at least in the later stages of training). Training for expertise, on the other hand, teaches a range of skills and emphasises characteristics of the environment that indicate or contra-indicate employment of that skill. A focus on correct skilled technique, skill selection and situation assessment from the earliest stages of training allow skills to be used flexibly and pilots to adapt to novel situations as their range of skills and experience level increase. Although the distinction is subtle, there is nevertheless an important change of emphasis when the focus is switched to the role rather than the task.

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4 CBTA focuses on tasks not roles, and breaks down each task into its component subtasks which are then allocated to people occupying particular roles. Skill development is evidenced by an increasing number of tasks a trainee is able to complete competently, which will then determine the roles for which they are eligible. Military pilots will be “tasked” with various missions, but specifics of future tasks are unknown at the time of training.
CBTA is well-suited to routine tasks in specified environments where all the skills and knowledge required has already been documented, whereas training for expertise requires the ability to handle uncertain environments by adapting available skills and knowledge to the new situation. The important point is that CBTA cannot be properly implemented when competencies cannot be specified to an appropriate level of detail\(^5\). CBTA is not well-suited to the task of specifying flying training in the military aviation domain despite its widespread use in the routine environment of commercial aviation.

**High-level Cognitive Skills**

As the cockpits of modern day aircraft become more technologically advanced concerns have been expressed that current pilot training systems focused on fundamental flying skills will not adequately prepare students for the complex information management tasks of new age aircraft (e.g., see the AOPA Air Safety Foundation’s report on technologically advanced aircraft in general aviation). The challenges of integrating information deriving from a range of new sensors and displays are seen to require higher order cognitive skills rather than the traditionally- emphasised psychomotor skills associated with flying proficiency. There is growing pressure to move to more technologically advanced training systems (including ground-based and in-aircraft simulation) to match the technologically advanced aircraft, and to ensure a new focus on cognitive skills training and information management (e.g., Ebbage & Spencer, 2004, Kern, 1997).

Simultaneous with the focus on cognitive skills training is a focus on CBTA approaches to military training of vocational skills, including flying training. The CBTA approach adopted by the ADF, among other things, aims to make it easier to transfer vocational skills learned in military settings to civilian settings and vice versa by aligning military training to competencies defined by the National Training Framework (see http://www.training.com.au/).

CBTA approaches to pilot training have difficulty accommodating the types of cognitive skills required in military aviation because they operate across all flying tasks and are not easily assigned to self-contained units of training or assessment. The commonly agreed-on high level cognitive skills identified as essential for military aircrew include:

- spatiotemporal awareness;
- situational assessment;
- prioritisation;
- decision-making;
- communication; and

\(^5\) Note that the repetition of this point highlights the lack of understanding among many educational designers of the inherent problem with CBTA for uncertain environments (such as military aviation or medical surgery). It is not through recalcitrance of subject matter experts, lack of will or lack of energy, but through the inherent nature of the operational environments that the details of competencies cannot be specified.
This paper focuses on spatiotemporal awareness, which is the primary cognitive skill required for expert skilled performance in the air combat environment, and arguably, the defining feature of successful practitioners in that environment. It is important to note that the other cognitive skills listed apply equally well to a range of professional environments, with airmanship / captaincy loosely aligned with notions of professionalism (see November 2007 issue of Academic Medicine on professionalism in medicine) and leadership6 (e.g., Hollander, 1992; Kelley, 1992).

Method
This paper focuses an analysis of 4D spatiotemporal awareness in the context of a broader study of cognitive skills training in the air combat domain. The broader study used a range of research methods including structured interviews, informal discussion and observation of subject matter experts in flying training and in the air combat domain, along with analysis of training documents and relevant literature in the cognitive science and training area. Similar methods have been described by Crandall et al. (2006) in Appendix A of their book on Cognitive Task Analysis. Such methods are used to generate an overview of the work environment (in this case, in particular, spatiotemporal aspects of the air combat domain, and more generally, the overall military flying training system), to capture individual viewpoints and perspectives, and to understand the complexity of interacting forces shaping workplace processes. The approach is similar to ethnography (Forsythe, 1999) and cognitive ethology (Kingstone et al, 2008). Methodological issues in this type of research are addressed in more detail in Hoffman and Milatello (2009).

This paper, while informed by the methods described above, does not report any data directly. Instead, it provides an analysis of the development of spatiotemporal awareness within the air combat domain with the dual aim of understanding training for expertise within complex and uncertain environments, and understanding the nature of spatiotemporal parameters in the context of cognitive skills and information management.

Analysis and Findings

Analysis of Spatio-temporal Awareness
The notion of 2D, 3D and 4D spatio-temporal skills embodies a number of layers of meaning in the aviation domain. In its simplest form, 2D space represents flying as a planar view of space within an altitude buffer, which is referenced to the ground and to the horizon. Alternatively, 2D space can refer to instrument displays, which generally map two main dynamic features (e.g., on the x and y axes of a Cartesian plot, or the r and θ axes of a polar plot), along with other static indicators of status (see Figure 3). Such displays, while

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6 It would be more appropriate, but possibly less accessible to most readers, to align airmanship with “followership” rather than leadership (see Kelley, 1988; Kern, 1997).
obviously 2D in the trivial “rendered on a flat surface” sense, are also two dimensional in terms of a parameter space. In flying training, the parameter space is inherently spatial, however, through discussion with aviation subject matter experts (SMEs), the 2D concept appears to refer primarily to the dimensionality of the parameter space rather than to planar space.

3D space, in a strictly spatial sense, includes altitude as a dynamic dimension. Altitude in a 2D framework is static while cruising and can be viewed as a static gradient while taking off and landing. However altitude must be conceptualised as a truly dynamic variable to generate mental models of aerobatic manoeuvres. Although 3D space as a spatial coordinate system is clearly a necessary framework for aerobatics, the conceptual dimensionality in terms of flying skill is not strictly spatial. Rather, altitude represents the availability of ground clearance and potential energy both in the strict physical sense and in the aerobatic manoeuvring sense. The subtle distinction between understanding the physics of the flying environment and operationalising the dynamic physical factors in terms of their flying affordances is a critical step in understanding the crucial role of emerging 3D spatial awareness in situational assessment, prioritisation, decision-making, and airmanship.

Figure 3 Examples of 2D instrument displays that, in combination, can provide a vast array of multidimensional information. A. A generic instrument panel in a cockpit showing the many 2D

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7 The concept of “affordances” offered by the environment is attributed to Gibson (1979). There is a subtle but critical difference between interpreting the environment in a strictly physical sense, and interpreting the affordances of the environment in terms of the goals of the sensing agent (e.g., the pilot).
displays from which information must be derived. B: A modern version of a display incorporating a Head-Up Display (HUD) which is also 2D in terms of parameter space. C: The 6 main instruments in the cockpit display which are incorporated into a selective scan sequence which is dependent on the flying task at hand. These instruments are each 2D, but the scanning sequence allows for much more complex information integration. D: A generic Horizontal Situation Indicator (HSI) that combines a number of 2D instruments into the one display to reduce the pilot’s instrument scan.

The notion of 4D space takes aerobatic manoeuvring to the next step which includes a temporal constraint, as would be required for the interception other dynamic entities operating according to their own agenda. The boundary between 3D and 4D space is fuzzy. There is undoubtedly a temporal coordination factor required when flying in formation, but each member of the formation is actively trying to coordinate with each other, and the “conductor” is the flight lead. The act of intercepting an enemy aircraft (bandit) takes on a different degree of temporal constraint. It requires the ability to predict the trajectory of the bandit and often requires an understanding both of affordances, intent, and interaction of these, for multiple entities, some of which are not aiming to coordinate with each other. An understanding of the dynamics of affordances and intent inherent within the dynamic spatiotemporal characteristics of the air combat domain requires a 4D spatial awareness that embodies much more than a strictly physical interpretation of environment. This form of dynamic 4D spatial awareness is a fundamental component of situational assessment in the air combat environment, and, as such, is the cornerstone of complex decision-making.

Development of Spatiotemporal Awareness in Fighter Pilot Training
Trainee fighter pilots progress through an increasingly complex spatio-temporal domain during training, as they sequentially acquire the skills for solo flying in a fast jet, flying in close and tactical formations, basic fighter manoeuvres (BFM), air combat manoeuvres (ACM), culminating in ACM within a mission context (see Figure 4).

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8 The twin notions of complexity and uncertainty are gaining prominence in a number of fields (see Gigerenzer, 2007; Hirstein, 2006; Kluger, 2007).
Early phases of pilot training aim to build appropriate mental models to underpin spatiotemporal awareness. As has been argued earlier in this paper, spatiotemporal awareness provides the basic foundation for higher-order cognitive skills culminating in complex decision-making. Although it has been proposed that increasing technological complexity of modern aircraft requires a shift in training away from fundamental flying skills towards information management, this paper argues that the training of fundamental flying skills (aimed at fighter pilots) build an understanding of the spatiotemporal domain of flying for all pilots, and is the foundation for the higher-order cognitive skills of flying including information management.

Three key concepts emerge when talking to military flying instructors: spare cognitive capacity, maintaining an appropriate “rate-of-learning”, and a need for pilots to “keep to the timeline”. Spare cognitive capacity is required for managing and monitoring information relating to the sortie mission. Spare cognitive capacity is also required to allow learning of
new skills. When rate-of-learning is too slow or pilots are unable to keep to the timeline while flying particular sorties, it is most often reflected in a breakdown in airmanship.\(^9\)

The training paradigm used in flying training (Demo – Direct – Monitor) can be described as an apprenticeship model based on observational learning (e.g., see Cosman et al., 2007; Lave & Wenger, 1991; Lintern, 1995). Due to the nature of the flying environment, flying instructors must initially instruct in the aircraft with their student, with the major goal being readiness for solo flying. Instructors demonstrate each flying task (Demo), then guide their student through execution of the task (Direct), and finally observe the student executing the task independently (Monitor). The instruction is performed in the live environment, and the instructor must have sufficient skill in simultaneous flying and instructing to perform manoeuvres within appropriate parameters during the demonstration phase, and to be able to recover the aircraft if students fail to perform manoeuvres successfully during the direct and monitor phases.

The additional cognitive load inherent in each new training phase (as can be seen from Figure 4) can lead to a breakdown in airmanship (i.e., performing previously learned procedures out of sequence, committing unsafe acts, suffering information overload, and failing to prioritise appropriately) (e.g., see Dismukes, et al., 2007; Kern, 1997). To ensure the appropriate layering of automated skills during training, there is a need for supplementary cognitive load that can be applied at each training level before the next set of skills are learned. Appropriately applied and contextually relevant cognitive load during training facilitates the development of spare cognitive capacity that can be used to learn new skills, or to process mission-relevant information and perform situational assessment in the operational environment.

The BASE Model of Learning\(^{10}\) for expert skilled performance shown in Figure 5 was developed by Wise and Quealy (2007) in the context of a study on use of simulation in pilot training. This BASE Model of Learning has been crossed-referenced to Salthouse’s description of the cognitive capabilities of experts (Salthouse, 1991). This model provides a way of understanding the factors that contribute to the development of expertise, irrespective of whether the curriculum and training practice were designed with the achievement of expert skilled performance as the primary goal. The Integration Preparation and Integrated Rehearsal phases, where trainees develop an understanding of the interrelations among variables and the ability to combine information from multiple sources are the key phases in

\(^{9}\) The fact that breakdown of airmanship is the primary indicator used by experienced flying instructors to denote the difficulty a student is having with the new task being trained (which may itself be being successfully demonstrated) provides strong evidence that airmanship is not a competency as such. It, like leadership, is extremely context-dependent and is more of a performance indicator or a state of mind, than a specific competency that can be ticked off as “achieved”.

\(^{10}\) The BASE Model of Learning was first articulated in a 2007 DSTO Client Report on the Balance in the mix of Aircraft and Synthetic Environments for early pilot training, which was conducted for the ADF AIR 5428 Task by Wise and Quealy.
development of automaticity (see Clark & Elens, 2006). If automaticity is based on incorrect components or an incorrect understanding of variables, bad habits become entrenched at this level of skilled performance. The fundamental flying skills for military pilots become automatic during the basic training phase, and thus provide a critical foundation for later expertise in whatever operational flying stream the students end up in.

It has been proposed that costs of flying training could be substantially reduced by more extensive use of simulation particularly in early phases of training (e.g., see the AOPA Air Safety report on training for technologically advanced aircraft). Evidence-based practice from commercial aviation and general aviation has been cited to suggest that simulators can provide very efficient and effective training. The BASE Model of Learning highlights the importance of fundamental flying skills in determining what information is relevant and understanding the complex relationships amongst variables. Whereas the initial proficiency (competence) of pilots may depend on using a simple set of cues for each task, the future expertise of pilots depends on understanding the complex interrelationships amongst variables the spatiotemporal environment (see Clark & Elens, 2006). If tasks are represented with only the minimal preferred cues available within a synthetic training environment or ground-based simulator, the layering of later skills will be on a potentially impoverished foundation. While simulators can be very beneficial in the Task Orientation phase and initial phase of component rehearsal (see Figure 5), to help understand what to expect, what to do and when to do it, the real environment is the best place for integration preparation, integrated rehearsal and consolidation of new skills (see van Gog et al., 2005). Only in the real environment are students exposed to the spatiotemporal rhythm of normal operations that must be somehow factored into a realistic understanding of interrelationships between variables and a possibility of identifying non-normal patterns of information.

Use of Cognitive Workload to Enhance Training Efficiency

In order to facilitate automaticity and the ability to manage information, and to ensure the “rate of learning” is maintained for all students within a cohort, integrated rehearsal can be undertaken using additional cognitive load generated by contextually-relevant additional tasks. The use of in-aircraft simulated systems such as advanced sensor systems and simulated weapons systems can create contextually relevant tasks to be performed while flying the aircraft (i.e., while maintaining the real risks and real timeline of the actual flying environment). By judicious use of simulated systems, cognitive load can be adjusted to suit the requirements of individual students, for example, to develop information integration skills, or to underscore the need to fly within given parameters or to understand the future operational context including the complexity of the communications space.

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11 An attempt to address the notion of spatiotemporal rhythm and its role in conveying base rates of risk is beyond the scope of this paper, but it is important to note that extensive use of simulation disrupts exposure to true base rates of events in the real world.
Figure 5 Sequential learning in expert skilled performance, adapted from BASE Model of Learning (Wise & Quealy, 2007) and aligned with Salthouse’s model of the cognitive capacity of experts. The first stage of learning involves Task Orientation, during which the student learns what to expect, what to do and when to do it. As students practise each component of a skill (Component Rehearsal), they become familiar with what information is relevant and when it is relevant. During Integration Preparation, students become familiar with interrelations among variables. They test their understanding during Integrated Rehearsal as they develop the ability to combine task relevant information. During the Consolidation phase, students show finer sensitivity to sensory and perceptual task dimensions, and the skilled performance is at the stage where it can become automated. Skill maintenance entails ongoing demonstration of production proficiency. Note that each component of a task can be considered a task in its own right, and what constitutes a task or a sub-task depends entirely on the perspective or level of analysis being undertaken.

The rate of learning required for the development of expertise can be calibrated with respect to the notion of a “comfort zone”, within which students are comfortable with their level of performance. While it is imperative that military operational pilots aim to operate within their comfort zone, thereby maintaining spare cognitive capacity for the high risk portion of their missions and to deal with unexpected events, it is important for trainee pilots to be forced to maintain a high cognitive workload while training.

On the premise that challenging tasks will consume as many cognitive resources as are made available to them, extra cognitive workload is imposed during training to ensure that each newly-learned challenging task can eventually operate with as small a “cognitive footprint” as is feasible. As training progresses, tasks that initially imposed a high (perceived) cognitive workload will move within the comfort zone (acceptable performance without undue
cognitive effort) as aspects of skilled performance becomes automated. If students are allowed to become too comfortable at a given skill level without additional workload, skills are rehearsed using all the cognitive resources available to them without any pressure to become more cognitively efficient. If these skills become automated, they leave a bigger cognitive footprint because they have not been forced to become lean, efficient and modular (see the notion of tasks comprising modular sub-tasks implicit in Figure 5). Under pressure, rather than being able to load-shed or prioritise amongst multiple optimised automated subtasks (modular building blocks) for optimal performance, tasks are either attended to completely (tunnel vision) or not at all.

The skill of the instructor is in maintaining an appropriate balance between the time spent in the comfort zone to consolidate skills and the time spent in the high cognitive workload zone to encourage automaticity. Too little time in consolidation will lead to automation of poorly learned, or incorrect, techniques that are later hard to remediate. Too much time in the comfort zone may interfere with the degree of adaptability and flexibility incorporated into automated skills that have been allowed to use more cognitive resources than optimally required. Ideally, high cognitive workload will comprise a series of lean, modular automated tasks and sub-tasks that can be rapidly reprioritised if load-shedding is required. Otherwise, when aircrew become overloaded, haphazard load-shedding due to poor prioritisation and incorrect techniques, will compromise the safety of the aircraft and the success of the mission.

The aim of using the high-cognitive-workload training zone to develop “cognitive resilience” and to enforce automaticity and appropriate layering of skills is represented in the diagram in Figure 6. Correct foundations for expertise must be laid in early training so that expert skilled performance is layered on automated (habitual) modes of behaving based on patterns laid down early by repetition (memory reflex). The skill of the instructor is in identifying the transition from high cognitive workload to overload (evidenced by a breakdown in airmanship), and the transition from high cognitive workload back to comfort zone, at which time there is a need to inject contextually relevant extra workload to maintain peak performance capability. It should be noted that the act of instructing in a live environment is itself an expert skill and requires a higher level of expert performance because of the need to monitor the student and to ensure the safety of the aircrew and aircraft.
Spatial awareness involves spatial parameters based on the purely physical notion of space. The flying skills of fighter pilots are elite in terms of spatial awareness and decision-making on a compressed timeline, and training designed to enhance those skills is beneficial (although not necessarily cost-efficient) to skill development of all military pilots.

Spatial awareness involves spatial parameters based on the purely physical notion of space and the biological notion of sensori-motor integration. It is argued in this paper that spatial awareness could more usefully be conceptualised as a more metaphysical notion of
parameters within an information space\textsuperscript{12} (which is inherently spatial for the air combat domain). The development of the elite level of spatial awareness necessary for the air combat domain requires a successive layering of skills and habits upon a foundation of fundamental flying skills. These skills are acquired during flying training in which additional cognitive workload is judiciously imposed by instructors to ensure that trainees remain in the high cognitive workload training zone to enforce automaticity of skills, and to develop spare cognitive capacity for learning new skills, or for undertaking operational missions.

**Conclusions**

Spatiotemporal awareness, particularly 4D awareness, is critical for situational assessment, prioritisation, decision-making, communication and airmanship. That is to say, spatiotemporal awareness is the cornerstone of "situation awareness" in the air combat domain and embodies more than a purely physical interpretation of space. The dimensionality of the parameter space (i.e., how many dynamic parameters can be considered simultaneously) and the ability to prioritise dynamic information is critical to situation awareness.

Development of expertise requires optimal cognitive workload during training to enforce automaticity of appropriately layered skills. High rate-of-learning and spare cognitive capacity are important indicators of adaptable, flexible expert skilled performance in dynamic and uncertain environments. Expert skilled performance requires appropriate mental models for expertise and appropriate layering and automaticity of component skills supporting skilled performance.

Professionalism (airmanship) and complex decision-making require an ability to operate within a multi-dimensional parameter space which is representational rather than purely physical, but which captures the nuances of affordances and intent which underscore the ability to predict future event trajectories.

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\textsuperscript{12} The non-spatial version of spatial awareness is reminiscent of Pylyshyn’s description of visual imagery and fact that it stops being sensory immediately it begins to be processed (e.g., Pylyshyn, 2003) – spatial reasoning is in fact symbolic reasoning, with conceptualisation of the dimensionality of parameter space based on the processing capacity of higher-order “sensory processing”.

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References


