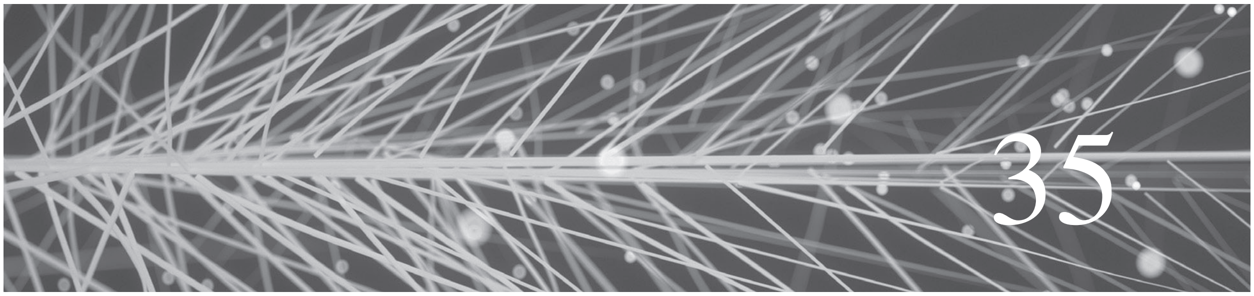

Neurobiological Foundations of Cognitive Fitness in High-Performance Applications

Gerard J. Fogarty, John E. Crampton,
Jeffrey W. Bond, Leonard D. Zaichkowsky,
Paul D. Taylor, and Eugene V. Aidman

INTRODUCTION

It is widely accepted that our ability to navigate life is driven by our knowledge, skills, and attitudes, but this common wisdom is incomplete; it overlooks fitness and its offshoot, readiness. Are you fit for a marathon race? Are you ready for that job interview? For a gruelling training regime? Deployment? Are you fit to drive home after a night shift at work? How can you improve these aspects of your fitness? Solutions for physical fitness are reasonably well known but mental and psychological fitness remain more of an art, especially when it comes to high performance, as distinct from clinical, applications. Science, though, is rapidly catching up, with applied research disciplines such as performance psychology, human factors, and neuroscience focusing on transdisciplinary discoveries and translating them into practical methods to enhance cognitive performance, to sustain psychological fitness, and to prevent mental health risks such as post-traumatic stress.

The growing interest in performance psychology is driven by a community-wide interest in healthy lifestyle and a desire in some sections of the population to acquire the psychological skills to excel in their chosen fields, often under challenging and stressful conditions. The factors contributing to such performance go beyond mere "wellness" (i.e., the absence of pathology) and include – apart from knowledge and skills – a range of 'capacity' factors, such as strength, endurance, and flexibility, that are best summarised by the concept of 'fitness' (Aidman, 2020).

This chapter explores the effects of physical exercise on brain functioning before considering the adequacy of the concepts of mental fitness and cognitive readiness as the cognitive equivalents of physical fitness. It then introduces Aidman's (2020) cognitive fitness model (CF2), along with the Research Domain Criteria framework (RDoC; Morris and Cuthbert, 2012), which serves as the platform for CF2 and provides the neurobiological foundations for the CF2 constructs. In this chapter, we detail the neural circuitry underpinning a selection of these constructs before closing with a brief description of three interventions based on the CF2 model illustrating how a combination of cognitive and physical exercises based on the model can improve brain functioning and overall well-being.

PHYSICAL EXERCISE AND PHYSICAL FITNESS

Today, we are familiar with the notion that being physically fit has positive effects on health and well-being. We have a branch of science, *Ergophysiology*, that deals with what our body does in response to muscular effort and how exercise contributes to the optimisation of human performance. The brain responds to exercise, too. Stepping back in time, the physician Hippocrates (460–370 BC) was among the first to point out that exercise has a good effect on both the body and the mind (Berryman, 2012). To the ancient Greeks, physical fitness and mental clarity were two sides of the same coin. Galen, an equally famous Greek physician, reinforced that message. In fact, he went further, distinguishing between mere physical movement and movement that required exertion (Berryman, 2012).

We make the same distinction today between physical activity and physical exercise, the former being "any bodily movement produced by skeletal muscles that requires energy expenditure" (WHO, 2010). Physical exercise, on the other hand, is a subclassification of physical activity that is planned, structured, repetitive, and has as a final or an intermediate objective the improvement or maintenance of one or more components of physical fitness" (WHO, 2010). The notion of controlled effort and planning is central to the work we present in this chapter, although in our case it refers to the exercise of cognitive abilities.

A large body of empirical work now supports the connection between physical exercise and brain functioning. Contracting muscle stimulates the release of a large range of myokines – cytokines and other peptides – which are now known to have autocrine, paracrine and endocrine effects, leading researchers to view muscle as a secretory organ (Severinsen and Pedersen, 2020). Recent findings suggest that a muscle-brain endocrine loop exists, and that myokines and exercise metabolites, such as lactate, irisin and cathepsin B, cross the blood–brain barrier to produce chemical changes within the brain (Nay et al., 2021; Severinsen and Pedersen, 2022). In relation to chemical changes, recent reviews have identified exercise-induced increases in the synthesis and release of neurotransmitters and neurotrophins, from serotonin and norepinephrine to dopamine and growth factors (such as VEGF, BDNF, GDNF and IGF-1), which positively impact neurogenesis, angiogenesis, and neuroplasticity (Arida and Teixeira-Machado, 2021; Di Liegro et al., 2019; Matta Mello Portugal et al., 2013). When coupled with the production of endocannabinoids and endorphins, these changes serve to enhance mood and cognitive function (Di Liegro et al., 2019; Matta Mello Portugal et al., 2013).

In addition to these chemical changes, experimental and clinical studies have shown that physical exercise leads to important structural and functional changes in the brain. In their review article, Mandolesi et al. (2018) claimed that some of the most important benefits of physical exercise are linked to neuroplasticity and they cite research showing that physical exercise increases grey matter in frontal and hippocampal regions. In earlier work Mandolesi et al. (2017) reported that physical exercise increases blood flow, improves cerebrovascular health, and affects glucose and lipid metabolism carrying food to the brain. Exercise may also positively impact the brain through indirect pathways, as it has recently been suggested that exercise has a modulating effect on both the liver–brain axis and the microbiome-gut-brain axis (Nay et al, 2021).

Physical exercise is also reported to act as a protective mechanism for disorders that threaten brain functioning (Firth et al., 2020; Vella et al., 2023). Recent meta-analytical evidence suggests robust positive effects of physical activity interventions reducing symptoms of depression (Schuch et al., 2018), bipolar disorder (Thompson et al, 2015), stress (Abdin et al., 2018), anxiety (McDowell et al., 2019), schizophrenia (Wang et al., 2018) and autism spectrum disorders (Ferreria et al., 2019). Physical exercise helps to reduce cognitive deficits by inducing better neuroplasticity (Arida and Teixeira-Machado, 2021). In particular, it serves to down-regulate cellular pathways involved in oxidative stress, excitotoxicity, and neuroinflammation, along with a modulating effect on HPA axis and SNS activity (Arida and Teixeira-Machado, 2021). Reviews of this topic leave little doubt that properly regulated physical exercise has beneficial effects on brain function and structure, and that it can act as a protective mechanism (Arida and Teixeira-Machado, 2021; Mandolesi et al., 2018).

If the benefits of physical exercise are well-established, so are the methods for achieving physical fitness, and that has been the case for a very long time. Greeks living in the 8th and 7th centuries BC considered it their duty to remain physically fit, and regularly attended gymnasiums for this purpose (Tipton, 2014). Hippocrates and Galen wrote prescriptions for achieving just the right amount of physical fitness (Berryman, 2012). Today, with robust measurement protocols for muscular strength, aerobic/anaerobic endurance, range of motion/joint flexibility (Jeffreys and Moody, 2021) and with validated training interventions such as strength and conditioning, cardiovascular fitness, or high-intensity interval training, we can feel reasonably comfortable about our knowledge of the physical fitness domain.

MENTAL FITNESS

The concept of mental fitness (MF) has emerged in the positive psychology literature (Seligman, 2008) to promote a positive and proactive notion of mental health. The MF literature is focused on protective factors, such as cognitive flexibility, implicated both in the prevention of mental dysfunction and in the promotion of flourishing (Keyes, 2007). However, Robinson et al. (2015) noted that the MF term lacks consistent theoretical and empirical foundations, and that there is no consensus regarding a definition or its measurement. They observed that the MF term is being used in the psychological and popular literature in much the same way as "physical fitness". In their words: "The term mental fitness employs metaphor, transposing components from one context to another". Transference from a physical to a mental context is aided by the tendency to find mental analogues of physical attributes such as strength, flexibility, and endurance. The Robinson et al. (2015) definition of MF emphasised flexibility and adaptability serving the interests of well-being: "the modifiable capacity to utilise resources and skills to flexibly adapt to challenges or advantages, enabling thriving". Four underpinning principles were: a) fitness is a positive term without connotations implied by mental health; b) mental fitness can be understood in a similar way to physical fitness; c) mental fitness is measurable; d) mental fitness can be improved in a way similar to physical fitness (Robinson et al., 2015).

The criticisms that Robinson et al. (2015) directed toward the construct of mental fitness remain relevant. The term "MF" still lacks consistent theoretical and empirical foundations. There has been no attempt to define its dimensions and, consequently, measures remain unspecified. From a neuroscientific perspective, Robinson et al. (2015) cited evidence in the positive psychology and neural plasticity literatures confirming that the human brain has the ability to change as the individual learns new behaviours. They also cited Davidson's (2005) functional magnetic resonance imaging (fMRI) study showing that individuals could learn to regulate their emotions. While this initial neuroscientific evidence was encouraging, it remained too general to provide sufficient empirical support for MF, which is clearly a wide-ranging construct.

COGNITIVE READINESS

The term "cognitive readiness" (CR) was first used by US military researchers in 2002 (Morrison and Fletcher, 2002, as cited in Grier, 2012). In the decade that followed, the term acquired two meanings. The first concerned the extent to which soldiers have learned the lessons of their training and are ready for deployment. This type of readiness may improve with further training or deteriorate through lack of opportunity. The second meaning concerned the type of cognitive readiness soldiers display in operational settings. It is a type of readiness that is affected by things like stress, fatigue, and motivation.

A decade later, Grier (2012) went one step further by proposing three types of cognitive readiness that can be distinguished by their differing locations on the timeline from selection to engagement: a) strategic cognitive readiness reflects the benefits of training and preparation; b) operational cognitive readiness refers to the typical level of mental preparation a deployed soldier brings to a mission; and c) tactical cognitive readiness refers to the state of an individual at the time of engagements where mental acuity is expected and where the emphasis is on taking remedial action should cognitive performance begin to decline.

Despite a promising start, research on cognitive readiness appears to have stalled for want of details about the mechanisms that influence it and ways to measure its different stages (cf. Crameri et al., 2021). What was needed to stimulate further research on cognitive drivers of readiness was a model that maps the phases of a military operation and provides a detailed breakdown of the cognitive skills required at each phase. After the criticisms directed at Grier's notion of cognitive readiness, it follows that any new scheme must also include measures for the cognitive skills identified. The cognitive fitness framework (CF2: Aidman, 2020) provides such a blueprint.

COGNITIVE FITNESS

The concept of cognitive fitness or CF (Aidman, 2017, 2020) has been introduced to bridge the gap between the CR and MF literatures in an attempt to develop a broader, systemic approach to this type of fitness. It is defined as a "multi-faceted and differentially malleable capacity to deploy neurocognitive resources, knowledge and skills to meet the demands of operational task performance, and to sustain this performance throughout career- and life-long application" (Aidman, 2020). This definition makes an important distinction between knowledge and skills, on one hand, and the cognitive capacity factors, on the other. Having defined the construct, Aidman (2020) hypothesised its constituent elements in a Cognitive Fitness Framework (CF2) that drew upon broad, biologically traceable domains of cognitive functioning developed in clinical neuroscience, and canvassed the research agenda to develop an evidence base for their assessment, training, and augmentation. CF2 mapped out the research agenda to identify and measure key attributes of cognitive fitness, underpinning both real-time cognitive performance under challenging conditions, and the resilience that enables career longevity and lifelong thriving. Here, we present the most recent version of the CF2 model followed by a description of its various components.

The model is based on a *Cognitive Gym* concept, that name conveying a sense that cognitive skills can be developed in the same way as physical skills, by repeatedly executing drills that are designed to improve performance on specific cognitive abilities. This comparison with the physical exercise domain has been a recurring theme in this chapter, running through the mental fitness (MF), cognitive readiness (CR), and now the cognitive fitness (CF) models. The comparison is deliberate because we know so much about the methods used to achieve physical fitness and we know the physiological and psychological benefits of physical exercise.

A notable feature of the CF2 model is that it describes an operational cycle where the notion of readiness can be applied to the different stages of the cycle. To be ready for one stage does not mean that we are ready for another. This feature aligns with the physical fitness field where athletes preparing for some sort of high-level competition will exercise differently, depending on the stage of the competition cycle. In the first part of the CF2 cycle, cognitive primaries such as attention, impulse control, and co-action are seen as underpinning most cognitive skills. These skills can be acquired through what the CF2 model refers to as Foundational Training in a cognitive gymnasium using the gold standard isolate–overload–recover regimes.

Moving in a clockwise direction around the CF2 model, the targets for Advanced Training include stress management, arousal regulation, adaptability, teamwork, situation awareness, and decision making. Cognitive readiness has been achieved when individuals feel comfortable across all these areas. How do we train these more advanced cognitive skills? Some of the elements of foundational training come into play here, but new drills and exercises are also needed. The closer these exercises mimic real-life situations, the faster the learning. Much can be accomplished by individuals working on their own provided that the exercises they are completing develop the cognitive traits that drive performance in real world settings. The blueprint laid down by the CF2 model is again helpful in that it identifies the cognitive primaries relevant to each operational phase. To give another example, stress management can be assisted through breathing exercises and relaxation drills that are learned and practised by individuals. The training program is particularly effective if such drills are interleaved with other drills targeting foundational and advanced cognitive skills.

The Performance-Ready training phase describes an advanced state of readiness. It considers what psychological readiness might mean in an operational (or competition) context. In addition to all the foundational and advanced cognitive skills, there is now a demand for tolerances and resistances. The tolerances are for pain, sleep loss, monotony, frustration, and uncertainty. The resistances are for distraction, deception, and manipulation. Some of these tolerances and resistances spill over into the physical domain where they draw upon strengths developed through exercise and lifestyle habits. The Performance Augmentation phase refers to operational aids, many of them technical, that help to boost performance. Examples include tools like decision aids and fatigue countermeasures.

The Cognitive Recovery phase completes the cycle with its role widely recognised by expert consensus (Reardon et al., 2019), employing both reflexive (e.g., mindfulness) and restorative practices (e.g., healthy eating, hydration, and sleep hygiene) and relying on social support.This phase is focused on the development of habits and practices that promote cognitive fitness and, as such, they are applicable to all other phases of the CF2 cycle. Cognitive capacities must also be restored. The individual factors that help to rebuild cognitive fitness, in addition to those already mentioned, will involve a period of relaxation before re-engaging the foundational skills leading back to a state of readiness for renewed engagement.

The full CF2 cycle, as it is shown in Figure 35.1, helps to identify what cognitive readiness means at different stages of the prepare–ready–reset cycle. Adaptability is a key feature of all stages – that is, the ability to regulate thoughts, emotions, and behaviours in response to environmental demands (Heatherton, 2011; Kashden and Rottenberg, 2010). Three distinct neuropsychological processes are involved in the self-regulation process: attentional control to overcome distractions, inhibitory control to master disruptive or maladaptive behaviours, and behavioural flexibility to maintain adaptive patterns of behaviour in the face of changing environmental circumstances (Polusny et al., 2021). The list of the constructs currently included in the CF2 model is shown in Table 35.1.

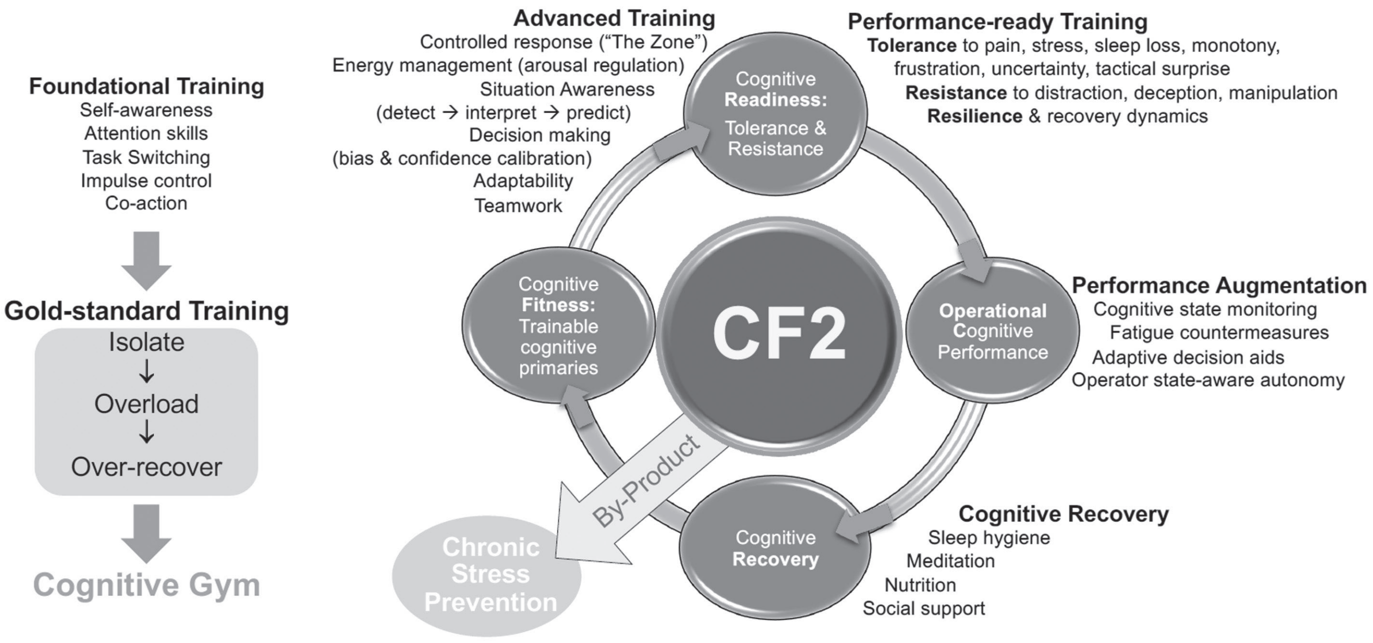

Figure 35.1 Cognitive Fitness Cycle (adapted from Aidman et al., 2022).

Table 35.1 Training targets in the Cog Gym 1.0 App (adapted from Aidman et al., 2022)

Phase	*Domain of cognitive functioning*	*Target constructs*	*Examples of training/ development objectives*
Foundational training	Cognitive fitness	Self-awareness	Stress symptoms detection
(Cognitive gym)	Trainable cognitive primaries	Attention	Focus endurance Focus control – breadth and direction
		Task switching	Dual-tasking
Advanced cognitive training	Cognitive skills	Controlled response	Effortless concentration
		Energy management	Arousal regulation
			Resonant frequency breathing
		Situation awareness	Sense-making (interpretation)
			Anticipatory skills (prediction)
		Decision making	Pattern recognition
			Confidence calibration
		Adaptability	Cognitive flexibility
Performance-ready training	Tolerance and resistance	Tolerances	Generalised discomfort tolerance
			Mental effort tolerance
			Frustration tolerance
		Resistances	Distractor resistance
			Susceptibility to deception
		Task resilience	Error detection
			Performance recovery
Performance augmentation	Operational task performance	Cognitive state	Alertness monitoring
		Cognitive Workload	Fatigue countermeasures
Cognitive Recovery	Cognitive recovery	Reflective practices	Mindfulness and meditation

THE RESEARCH DOMAIN CRITERIA (RDoC) AND DOMAINS OF COGNITIVE FUNCTIONING

We criticised both the MF and CR constructs for their lack of theoretical boundaries and associated measurement operations. Put differently, we don't know their constituent elements, how they are related, their biological foundations, or how they combine to affect performance. The CF2 model addresses these criticisms by specifying the cognitive skills that are required at different stages of the cycle (Table 35.1) and by ensuring that these skills form part of an already established taxonomy of cognitive abilities with neurological foundations and specified measurement operations. The taxonomy chosen was the Research Domain Criteria (RDoC), developed by the US National Institute of Mental Health (NIMH; Morris and Cuthbert, 2012) to encourage researchers to take a dimensional approach to the study of the genetic, neural, and behavioural features of mental disorders (Morris and Cuthbert, 2012).

RDoC identifies broad higher-level domains of functioning that comprise multiple subdimensional constructs, reflecting state-of-the-art knowledge about major systems of cognition, motivation, and social behaviour. Table 35.2 shows the domains, the constructs, and the subconstructs that have been identified to date.

As shown in Table 35.2, this simplified view of the RDoC matrix comprises six domains, 25 constructs, and 32 subconstructs. An expanded view of the matrix is a live online document that shows the domains, constructs, and subconstructs listed

Table 35.2 Simplified representation of the RDoC Matrix (adapted from RDoC, 2022)

Domains	*Constructs*	*Subconstructs*
Negative valence	• *Acute threat*	
	• *Potential threat*	
	• *Sustained threat*	
	• *Loss*	
	• *Frustrative non-reward*	
Positive valence	• Reward responsiveness	• *Reward anticipation* • *Initial response to reward* • *Reward satiation*
	• Reward earning	• *Probabilistic and reinforcement learning* • *Reward prediction error* • *Habit*
	• Reward valuation	• *Reward probability* • *Delay* • *Effort*
Cogntive systems	• *Attention*	
	• Perception	• *Visual perception* • *Auditory perception* • *Olfactory/somatosensory/multimodal perception*
	• *Declarative memory*	
	• Cognitive control	• *Goal selection, updating, representation, and maintenance* • *Response selection, inhibition/suppression* • *Performance monitoring*
	• Working memory	• *Active maintenance* • *Flexible updating* • *Limited capacity* • *Interference control*
Systems for social processes	• *Affiliation and attachment*	
	• Social communication	• *Reception of Facial Communication* • *Production of Facial Communication* • *Reception of Non-Facial Communication* • *Production of Non-Facial Communication*
	• Perception and understanding of self	• *Agency* • *Self-knowledge*
	• Perception and understanding of others	• *Animacy perception* • *Action perception* • *Understanding mental states*
Arousal/regulatory systems	• *Arousal*	
	• *Circadian rhythms*	
	• *Sleep and wakefulness*	
Sensorimotor systems	• Motor actions	• *Action planning and selection*
	• Agency and ownership	• *Sensorimotor dynamics*
	• Habit	• *Initiation*
	• Innate motor patterns	• *Execution*

Note: *Italics* indicate the lowest level in the RDoC hierarchy; these elements became subject to the Delphi expert consensus process (Albertella et al., 2023).

as rows alongside eight columns labelled “units of analysis” (RDoC, 2022). The columns represent seven levels of measurement granularity for each subconstruct, from Genes, Molecules, Cells and Circuits, to Physiology, Behaviour, and Self-Report, with a collection of known methods of capturing the RDoC constructs at different levels of granularity listed under the Paradigms column.

One gains an appreciation of the complexity and thoroughness of RDoC by selecting a subconstruct and following the entries for that row across the eight columns. Take Visual Perception, for example. It belongs to the Cognitive System group under the Perception construct (Table 35.2). In the full matrix, it has a full row dedicated to it, allowing the various units of analysis to be represented across the columns at their respective levels of measurement. Moving across the row, there are no entries in the Genes column, although these are expected as more information becomes available. There are seven entries in the Molecules column (e.g., peptides, ACH) and four entries in the Cells column (e.g., parvo, pyramidal cells). The Circuits column, the one of most relevance to neuroscience, contains four subheadings (subcortical, cortical, non-retinogeniculate, and local), each with nominated circuits (e.g., superior colliculus in the non-retinogeniculate). The Physiology column has four entries (e.g., ERP components), Behaviour has six (e.g., stimulus detection) and Self-Report has five (e.g., perceptual anomalies of schizophrenia). Paradigms, the final column, has subheadings for the various research paradigms dedicated to the study (and measurement) of visual perception. There are currently 25 entries in this column (e.g., action-perception loops).

The RDoC constructs are being continuously revised and refined. Researchers can expand the rows and the columns of the matrix, as well as fill the cells with new measures. In this way, RDoC has informed the development of reliable and valid measures across a range of units of analysis for each construct (Passell et al., 2019). These measures have enabled and inspired studies to determine the full range of variation along these measurement constructs, from deficit to norm, characterising both clinical and non-clinical populations.

The RDoC framework was an appropriate platform for the CF2 model because of its emphasis on the broad dimensions of cognitive functioning (Appelbaum, 2017; Clark et al., 2017). It is not driven by a classification system where labels are attached according to matches with diagnostic criteria. Rather, the behaviour of people suffering from mental disorders is driven by the same cognitive mechanisms as the behaviour of normal people. This philosophy sits well with the CF2 approach that considers both mental health and high-performance as “natural consequences of the varying levels of psychological functioning (including cognitive, affective and motivational) ranging from deficit to norm, and further to high or gifted performance” (Aidman, 2020).

The constructs and subconstructs shown in Table 35.1 were based on the RDoC model developed primarily on clinical populations. CF2, however, is aimed at the levels of cognitive fitness required for high performance. The one element missing in this connection was the fact that RDoC had not yet been validated against this section of the population. Extending the range to the well-adjusted functioning and high-performance domains was an important next step, given that non-clinical populations have been under-represented in the current RDoC-driven research.

Our research team was interested in testing the applicability of the model to the high-performance domain using the same methodology that was employed in the development of RDoC (Aidman et al., 2022). We employed a three-stage process to achieve this aim. The first stage involved establishing whether RDoC constructs covered the whole of the performance continuum – that is, whether its constructs were adequate to describe high performance or whether new constructs were needed. The second stage involved the identification of measures for constructs involved in high performance. The third stage involved the identification of tasks to train. All three stages were important for the ongoing development of the CF2 model. Work on the second and third stage continues, but the first stage is completed and the approach we used is described briefly in the next section.

VALIDATING THE CF2 CONSTRUCTS AGAINST THE RDoC FRAMEWORK

A strong feature of RDoC is use of expert panels to revise and expand the set of constructs and subconstructs. Expert consensus frameworks have become a best-practice standard; they are known to stimulate research discoveries and accelerate translational pathways by estimating the relevance of primary RDoC constructs (and their subdimensions) to specific application domains such as substance and behavioural addictions (Yücel et al., 2019). Accordingly, an expert consensus was sought on the relative importance of primary RDoC constructs and their subconstructs to various high-performance applications. This consensus built on the RDoC foundational evidence in defining major domains for the study of cognitive fitness (Albertella et al., 2023) and developing guidelines for assessing them using an optimal mix of biomarker, physiological, behavioural, and self-report measures (Aidman, 2017, 2020). It was expected that the project would inform the development of measurement and assessment protocols for these dimensional constructs and lead to tailored training programs aimed at maximising performance and longevity within demanding occupations.

The study (Albertella et al., 2023) included two main components, an expert advisory group phase, which developed guidance on the content and direction of the Delphi study, and the Delphi study itself. The six members of the Expert Group were selected on the basis of their established expertise in the fields of cognitive neuroscience, high performance, sports, and/or military psychology. The purpose of the study was described as establishing a cross-disciplinary expert consensus on the constituent elements (dimensions) of cognitive fitness, identifying best-practice methods for measuring them, and informing the development of tailored training programs aimed at maximising performance and longevity within these domains. The aim for the Expert Group was described as extending the RDoC focus on psychopathology to the common factors underpinning psychological functioning across the full range of behaviour, from deficit and dysfunction to the norm and peak performance.

The focus of this project was the subconstruct level of RDoC, where trainable tasks are more likely to be found. The members of the Expert Group were asked to name three to five constructs that were most involved in complex, dynamic, high-stakes environments (e.g., sport). They were also asked to specify the stage(s) of performance when the construct was most critical (e.g., preparation). The aim of this exercise was to ascertain whether all the constructs nominated by Expert Group members were already captured by RDoC. Any new constructs – that is, those not already in the RDoC framework – had to be justified by demonstrating that they were needed for optimal performance and that they could be applied across disciplines. They also had to have a neurological basis or other strong validating evidence.

At the conclusion of the Expert Group phase, preparations were made for the Delphi study itself, where international experts were recruited into four subpanels representing three application domains (Defence, Civilian High-stakes Applications and Competitive Sport) and one research specialty (Applied Neuroscience). Their task was to evaluate constructs from the neuroscience-driven Research Domain Criteria (RDoC) framework, in addition to several constructs suggested by the Expert Group. Consensus was sought within each performance panel using a multi-panel Delphi design. The study produced a transdisciplinary consensus on 10 cognitive factors, including: (1) Attention; (2) Cognitive Control—Performance Monitoring; (3) Arousal; (4) Cognitive Control—Goal Selection, Updating, Representation and Maintenance; (5) Cognitive Control—Response Selection and Inhibition/Suppression; (6) Working memory—Flexible Updating; (7) Working memory—Active Maintenance; (8) Perception and Understanding of Self—Self-knowledge; (9) Working memory—Interference Control; and (10) Shifting. Seven of the 10 constructs that reached consensus across all four Delphi panels came from RDoC's Cognitive Systems domain. The remaining three constructs came from Social Processes, Arousal, and Regulatory Systems, or were added to the RDoC construct set by the experts.

The results (Albertella et al., 2023) confirmed CF2 as a set of transdisciplinary neuroscience-informed constructs, validated through Delphi consensus. This expert consensus is seen as instrumental to standardising cognitive assessment and informing mechanism-targeted interventions in the broader field of human performance optimisation. Before describing a selection of these interventions, however, we return to a point made earlier about the need for establishing the neurobiological foundations of CF2. A brief review of this topic follows.

NEUROBIOLOGICAL FOUNDATIONS OF CF2

Given that the CF2 model is based on the RDoC platform, the detailed description of the neurological underpinnings of RDoC constructs applies to the relevant CF2 constructs. Where a sufficient body of research evidence exists, that information is available for RDoC constructs and subconstructs in the Units of Analysis section (RDoC, 2022) which provides detailed information on genetic, molecular, cellular, circuits, and physiology-level metrics. An example has already been given for the Visual Perception construct. However, not all the constructs in the CF2 model are covered to this level of detail in RDoC. For example, Attention is an important component of CF2 Foundational Training but, as Albertella et al. (2023) pointed out, the RDoC framework does not contain detailed information on vigilance, selective attention, and divided attention –that is, they are not yet recognised as subconstructs in the RDoC framework and will not gain this status until research has accumulated mapping these attentional processes onto distinct neural circuits.

As noted above, because neurobiological information is available through the RDoC framework for most of the CF2 target constructs (Table 35.1), we do not need to repeat that information here. Instead, we will comment briefly on the Training/Development objectives of CF2 and how the selected drills are likely to affect *brain states*, defined as "the reliable pattern of brain activity that involves the activation and/or connectivity of multiple large-scale brain networks" (Tang and Posner, 2014). The brain networks that support CF2 target constructs and associated exercises are not always specific. Training these abilities can therefore influence other tasks that use all or parts of the network. Tang and Posner (2014) refer to this activity as "state training", which uses practice to develop a brain state that can influence other networks. Thus, training of a certain neural circuit leads to transfer to other tasks that engage this circuit (Buschkuehl et al., 2012).

Meditation training, for example, which features in the Cognitive Recovery cycle of CF2 as an exercise to support the Reflective Practices construct, can establish a brain state that improves cognition, attention, and mood – with consequent positive effects on recovery and, ultimately, performance (Walsh et al., 2019). Tang and Posner (2014) explained that meditation reduces stress, and improves attention and mood through changes along the frontal midline brain in the anterior cingulate cortex (ACC) and its connections to the striatum and parasympathetic nervous system.

Meditation is an example of an exercise that is linked with a specific stage of the CF2 model, but that is likely to have an influence on cognition generally. There are other examples. Self-awareness and self-regulation (in the form of impulse control) appear at different points in the CF2 model (Figure 35.1). Self-regulation plays a fundamental part in competitive and professional sport. The neurotransmitter dopamine is involved in self-regulation, as is the pre-frontal cortex (Beckman and Elbe, 2015). Self-awareness appears in RDoC as the construct Perception and Understanding of Self and the neural circuitry of its subconstructs is well-mapped.

The examples above suffice to illustrate the neurological underpinnings of the constructs and exercises embedded in CF2. There are also techniques, such as neurofeedback, that can be used at any stage to accelerate and enhance training effects. Neurofeedback (NFB) is a form of operant learning, modelled on the established principles of biofeedback but implemented through neural signals to improve health and performance (Enriquez-Geppert et al., 2017; Gruzelier, 2014). NFB works as a feedback loop, with an individual's brain signal – e.g., electroencephalogram (EEG; Omejc et al., 2019), real-time functional magnetic resonance imaging (rt-fMRI; Sulzer et al., 2013; Thibault et al., 2018) or a combination of both (Zotev et al., 2014) – monitored and fed back in real time (via auditory, tactile, visual or audio-visual channels) with a task to control the chosen parameter(s) of the signal (Sitaram et al., 2017). Several types of EEG-NFB have been developed, including slow cortical potentials (SCPs) training, coherence training, aimed at modifying the connectivity patterns across cortical areas, and frequency training, targeting the power ratio of the EEG frequency – e.g., delta (< 4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (14–30 Hz), and gamma (> 40 Hz). The latter is motivated by the hypothesised association between the amplitudes of specific EEG frequencies and corresponding cognitive functions – the so-called frequency-to-function mapping (Groppe et al., 2013).

Sensori-Motor Rhythm (SMR) NFB involves up-regulating the motor frequency band (12-15Hz), usually tailored by individual alpha frequency. SMR NFB has been shown to enhance sleep quality and attention (Arns et al., 2014), improve performance on cognitive tasks (Kober et al., 2015), and enhance golf-putting performance (Cheng et al., 2015). Combining SMR-theta and AT NFB training with ophthalmic surgeons showed that both training options reduced surgery completion time, with SMR-theta training additionally improving surgical performance such as quality of sutures (Ros et al., 2009).

The overarching objective of performance NFB applications is to enhance the efficiency and effectiveness of neural networks engaged in peak performance. For example, occipital alpha activity in elite athletes (from golfers to gymnasts and pistol shooters) has been shown to differ significantly from the patterns shown by amateur and non-athletes and to differentiate between their own best and worst performances (Bablioni and Del Percio, 2008; Babiloni et al., 2009; Baumeister et al., 2008; Del Percio et al., 2007). Their findings support the view that alpha activity is related to optimal performance. Based on this evidence, NFB training has been developed to assist healthy individuals in learning to deliberately modulate their own cortical neural activity within specific regions at particular frequency bands to achieve the desired behavioural and cognitive outcomes (Vernon et al., 2003). Sport psychology applications of NFB have capitalised on its relative success in enhancing cognitive functioning and creativity, aiming at assisting elite athletes in optimising their peak performance (Rostami et al., 2012). Overall, the efficacy of NFB training is driven by its neuromodulation effects on core skills, including procedural learning, attentional control, emotional regulation, and higher-order sensory integration processes. These processes are central to the CF2 model.

Several issues limit the application potential of NFB. Insufficient protocol standardisation and the resulting heterogeneity of published studies have so far rendered meta-analytical aggregations inconclusive (Begemann et al., 2016).

The biggest issue is with the transfer of training: exactly how EEG modulation causes behavioural changes remains unclear, with the inconsistency of empirical findings adding to the confusion. A recent review found that 17 out of 28 studies reported EEG modulation but no changes in actual behaviours, while 10 out of 20 studies demonstrated behaviour changes but no EEG modulation, and no correlation between successful EEG modulation and behaviour outcomes (Rogala et al., 2016).

Despite these caveats, the weight of empirical evidence suggests that NFB is likely to add value to psychological training when used as a training aid. It does so by (a) enhancing the flexibility of an individual's neural circuitry, (b) enabling deeper learning, including non-conscious motor learning, and (c) better integrating the various skills learnt. Future improvements can be expected from mixed methodologies combining different signals that enable simultaneous exposure to, and an opportunity to self-regulate both haemodynamic (fMRI) and electrophysiological (EEG) brain activity (Zotev et al., 2014).

So far, the focus of the chapter has been on (a) the constructs that comprise the CF2 model, (b) the description of the RDoC framework that is the platform for CF2, (c) the Delphi study that investigated the applicability of the RDoC framework to the high-performance domain, and (d) the description of the neurological foundations of a sample of CF2 constructs and training techniques. What is missing is an account of intervention studies that have employed the CF2 model. The chapter closes with a brief account of three CF2 interventions and their outcomes.

Intervention 1: Cognitive Fitness Training in the Workplace

Occupational stress is known for its negative neurobiological impact, including reduced cortical activity (Chou et al., 2016) and loss of brain tissue in regions such as the right prefrontal cortex, anterior cingulate, left superior temporal gyrus and caudate, along with a concomitant increase in the size of the amygdala (Blix et al., 2013; Savic et al., 2018). These brain changes coincide with stress-induced increases in anxiety and depression which lead to serious social-economic impacts through decreased productivity, absenteeism, resignations, and premature retirement (Schaufeli et al., 2017).

Sleep is also reported to impact upon cognitive function and is an important element of the CF2 model. Chronic sleep restriction impairs the blood-brain barrier function (He et al., 2014), increases neuroinflammation that impairs overall cognitive function (Pak et al., 2020) negatively impacts mental health (Alvaro et al., 2013; Swinkels et al., 2013), health risk behaviours (Swinkels et al., 2013) and physical performance (Cullen et al., 2019). Conversely, it has been suggested that improving sleep can help sustain psychological resilience in challenging times (Cloonan et al., 2021).

Nutrition research contributes another platform to this CF2 application, again with accompanying neuroscience support. A subclass of beneficial plant-based nutrients, referred to as hormetic phytochemicals, appear to confer benefits to the brain by activating adaptive cellular response pathways (Son et al., 2008). These phytochemicals have noxious properties that dissuade insects and other pests from eating the plants, but when these phytochemicals are consumed by humans in relatively small doses, they induce mild cellular stress responses and trigger a "hormetic" or "stress preconditioning" response (Son et al., 2008). This hormetic response appears to apply to other lifestyle interventions. Regular cold showers, for example, have been reported to reduce absenteeism and sickness, and have been suggested as a novel treatment for treating and preventing depression (Buijze et al., 2016) and there is the possibility that the positive impacts of exposure to such stressors confer a benefit on the host by cross-adaptation and cross-tolerance, whereby adaptation to one stressor provides cross tolerance to resist the adverse effects of another type of stressor (Lee et al., 2019).

This combination of CF2-informed interventions was incorporated in a recent study (Taylor, 2021) which utilised the Resilient Mind Program (RMP), aimed at developing cognitive fitness through a blended methodology, with three hours of face-to-face delivery augmented with a four-week program via a mobile application. RMP draws on Acceptance Commitment Therapy, mindfulness, and cognitive reframing techniques, as well as physical "rituals", including breathing, exercise, and cold showers. It aims to help participants form healthy habits through personal effort and social interaction, and includes a range of resources and tools such as workouts, guided breathing, educational videos, and a "Ritual Board" to track progress. It also includes a social feed and a gamified leader board to facilitate behaviour change. Taylor (2021) reported that the RMP produced improvements in mental well-being and resilience, and a reduction in burnout for 800 workers in a range of businesses within the Australian corporate sector.

Intervention 2: Cognitive Fitness Training in the Military

Taylor et al. (2021) extended the RMP evaluation in a block-randomised study with Navy aviators. Seventy-eight members of a Royal Australian Navy Air Squadron completed the four-week RMP, with half the participants combining it with self-paced Functional Imagery (FI) practice. The RMP intervention was found to be effective in reducing burnout symptoms, while improving their self-reported mental well-being and resilience. Importantly, participant engagement, measured as time spent interacting with the mobile application, was found to be an important moderator, varying from a few minutes a week for those just checking off rituals, to an hour or more per week for those highly engaged with the program.

Intervention 3: Cognitive Fitness Training in Competitive Sport

The Australian Psychological Society (APS) College of Sport and Exercise Psychologists is one stakeholder group that has adopted CF2 as a new paradigm in the management of the Mental Health/Performer Wellbeing/Performance Support operating environment, having identified the need to support athletes and their support teams during the COVID-19 disruption to the sports industry. A prototype cognitive fitness program for competitive athletes has been developed, focused on fundamental mental capacities and subtending skills for resetting and adjusting training rhythms and improving mental readiness for competition (Aidman et al., 2022). In its original form, the program revealed good user acceptance, generating desirable training gains, both in measurable cognitive skills and coaches' value ratings.

The current prototype (Aidman et al., 2022) comprises a standard daily practice routine containing 10 drills representing phases of the CF2 cycle complemented by Performance Mindset instruction added by the practitioners. In a further enhancement, the revised CF2 program incorporates a new technology that significantly improves the selection of interventions for cognitive fitness training. It employs a series of filters to select the 10 drills from the very wide range of drills that are purported to enhance performance and presents them to users in a contemporary training system, the app-based *Cognitive Gym 1.0* (Aidman et al., 2022). Each drill involves systematic and disciplined execution of underpinning cognitive skills, such as concentration endurance and attentional flexibility, that combine the CF2 Delphi expert consensus on attention as a key fitness factor with practitioner wisdom of how to best deliver attentional training.

The content combines evidence-based training protocols with instructional support by practitioners experienced in the delivery of such programs in high-performance environments. The core instruction is delivered via the app and backed by a companion website providing extensive background information and additional practice options. The core recommended three-week sequence of daily interaction with the app includes practice drills, instructional material, assessments, and interactive communication systems to facilitate engagement. The effectiveness of *Cognitive Gym 1.0* will be evaluated using pre- and post-intervention assessments that will include self-report measures of well-being, resilience, and attentional style. CogMission (Kucina et al., 2023; Wells et al., 2021) will be used to assess gains in cognitive functioning.

SUMMARY AND CONCLUSIONS

The ability to perform successfully under pressure is critical across many occupations, from firefighters and first responders to sport, the performing arts and the military. A range of cognitive factors underpinning this ability have been broadly recognised (Aidman, 2020; Crameri et al., 2021; Grier, 2012), but the emerging field of high-performance cognition (HPC) is lacking a unified framework that would integrate knowledge across multiple application domains and would enable "grounds for empirical predictions and a direction for future work for many years" (Cowley et al., 2020). Despite some variability across application domains in the Delphi study, a unifying framework of high-performance cognition is emerging, with attention and cognitive control constructs at its core. This framework is likely to facilitate agreement on and to further stimulate the development of mechanism-sensitive cognitive assessment tools and neuro-cognitive mechanism-targeting interventions to optimise performance under pressure. Thus, the CF2 is maturing from a working hypothesis to an expert consensus-driven framework that maps out the research agenda to specify key attributes of cognitive fitness, the neurobiological mechanisms underpinning both real-time cognitive performance under challenging conditions, and the resilience that enables career longevity and life-long thriving.

Development of CF2 is taking place against a background where new techniques for cognitive training are being proposed. Reviews are not always complimentary (Appelbaum and Erickson, 2018; Harris et al., 2018, 2020), the main criticism being that training on specific cognitive tasks does not transfer to the actual performance environment (Vater et al., 2021). Thus, while the intention in using a perceptual-cognitive training tool may be to improve "far transfer", an improvement only on the training task itself, termed "near transfer" may be observed (Harris et al., 2020). In some CF2 competitive sport applications, this criticism is challenged by the use of outcome measures, such as reports of well-being. In the case of drills, the planned use of the cognitive test battery (CogMission) allows testing for near transfer, seeking evidence that performance has improved not just on the drills themselves, but across a broader range of cognitive abilities. Coach assessments can be used to check for evidence of far transfer. Given the close interconnection between RDoC and CF2, evidence of change also can be sought at the neurobiological level. The template for such an approach has been outlined and applied to RDoC data by Beam et al. (2021).

The Delphi study (Albertella et al., 2023) described briefly in this chapter aimed to integrate existing knowledge in the performance field through transdisciplinary expert consensus on the cognitive mechanisms that underlie optimal performance under pressure. The findings of this Delphi study are relevant to a broader understanding of human behaviour. First, an ability to perform under pressure is of benefit to all, from an Olympic athlete or a paramedic in an emergency ward to a parent dealing with their child's asthma attack or a student taking exams. The identification of the generic "cognitive fitness" constructs that transcend disciplinary bounds will inform systematic approaches to measuring and improving individuals' capacities to adapt to a wide range of life's challenges. The same cognitive fitness constructs have been implicated as protective factors in mental health. Similar to aerobic fitness mitigating cardiovascular risk, attentional control capacity can reduce the risk of anxiety disorders (Segal et al., 2020), with a growing number of similar connections emerging. This framework thus offers an important (and often missing) connection between our understanding of psychological dysfunction and peak performance with a realistic perspective of developing synergies between clinical and performance applications, both focused on optimising human behaviour across a full spectrum of functional capacity. The next challenge is extending the range of measurement of the assessment tools measuring CF constructs to cover both cognitive deficit and gifted performance and to employ best-practice measurement protocols to improve the reliability, validity, and utility of these assessment tools. These improvements in the measurement of CF constructs are critical to stimulating the design and development of the environments and protocols to improve CF, and to developing fieldable technologies to protect and enhance cognitive performance.

In this chapter, we have discussed the notion of cognitive fitness and the CF2 model. The CF2 model, so far, has mostly been concerned with peak performance in military and elite athlete populations where physical fitness is assumed. Once the challenge of its measurement has been addressed, there will be opportunities to combine physical exercise training with CF2 training in what is known as multidomain training (Rieker et al., 2022). There are stages of the CF2 model where the known beneficial impact of physical exercise on cognition suggests that it would add to the effects of CF2 training. Clearly, Performance-Ready Training, Performance Augmentation, and Cognitive Recovery stages are candidates for a multidomain approach.

REFERENCES

Abdin, S., Welch, R. K., Byron-Daniel, J., & Meyrick, J. (2018). The effectiveness of physical activity interventions in improving well-being across office-based workplace settings: A systematic review. *Public Health*, *160*, 70–76.

Aidman, E. (2020). Cognitive fitness framework: Towards assessing, training and augmenting individual-difference factors underpinning high-performance cognition. *Frontiers in Human Neuroscience*, *13*. doi: 10.3389/fnhum.2019.00466

Aidman, E. (2017). The cognitive fitness framework: A roadmap for systematic, evidence-based mental skills training and performance enhancement. *Journal of Science and Medicine in Sport*, *20,* S50–S52.

Aidman, E., Fogarty G.J., Crampton. J, Bond, J., Taylor, P., Heathcote, A., & Zaichkowsky. L. (2022) An app-enhanced cognitive fitness training program for athletes: The rationale and validation protocol. *Frontiers in Psychology*, *13*. doi: 10.3389/fpsyg.2022.957551

Albertella, L., Kirkham, R., Adler, A. B., Crampton, J., Drummond, S. P. A., Fogarty, G. J., et al. (2023). Building a transdisciplinary expert consensus on the cognitive drivers of performance under pressure: An international multi-panel Delphi study.

Frontiers in Psychology: Performance Science, *13*, 1017675. doi: 10.3389/fpsyg.2022.1017675

Alvaro, P. K., Roberts, R. M., & Harris, J. K. (2013). A systematic review assessing bidirectionality between sleep disturbances, anxiety, and depression. *Sleep*, *36*, 1059–1068.

Appelbaum, P. S. (2017). Moving toward the future in the diagnosis of mental disorders. *Psychological Science in the Public Interest*, *18*(2), 67–71.

Appelbaum, L. G., & Erickson, G. B. (2018). Sports vision training: A review of the state-of-the-art in digital training techniques. *International Review of Sport and Exercise Psychology*, *11*, 160–189.

Arida, R.M., & Teixeira-Machado, L. (2021). The contribution of physical exercise to brain resilience. *Frontiers in Behavioral Neuroscience*, *14*. doi: 10.3389/fnbeh.2020.626769

Arns, M., Feddema, I., & Kenemans, J. L. (2014). Differential effects of theta/beta and SMR neurofeedback in ADHD on sleep onset latency. *Frontiers in Human Neuroscience*, *8*. doi: 10.3389/fnhum.2014.01019

Babiloni, C., & Del Percio, C. (2008). Golf putt outcomes are predicted by sensorimotor cerebral EEG rhythms. *Journal of Physiology*, *586*, 131–139.

Babiloni, C., Del Percio, C., Rossini, P. M., Marzano, N., Iacoboni, M., Infarinato, F., … Berlutti, G. (2009). Judgment of actions in experts: A high-resolution EEG study in elite athletes. *NeuroImage*, *45*, 512–521.

Baumeister, J., Reinecke, K., Liesen, H., & Weiss, M. (2008). Cortical activity of skilled performance in a complex sports related motor task. *European Journal of Applied Physiology*, *104*, 625–631.

Beam, E., Potts, C., Poldrack, R. A., & Etkin, A. (2021). A data-driven framework for mapping domains of human neurobiology. *Nature Neuroscience*, *24*, 1733–1744.

Beckman, J., & Elbe, A. M. (2015). *Sport psychological interventions in competitive sports*. Cambridge, UK: Cambridge University Press.

Begemann, M. J., Florisse, E. J., Van Lutterveld, R., Kooyman, M., & Sommer, I. E. (2016). Efficacy of EEG neurofeedback in psychiatry: A comprehensive overview and meta-analysis. *Translational Brain Rhythmicity*, *1*, 19–29.

Berryman, J. W. (2012). Motion and rest: Galen on exercise and health. *Lancet*, *380*, 210–211.

Blix, E., Perski, A., Berglund, H., Savic, I. (2013). Long-term occupational stress is associated with regional reductions in brain tissue volumes. *PLoS One 8(6)*. doi: 10.1371/journal.pone.0064065.

Buijze, G. A., Sierevelt, I. N., van der Heijden, B. C., Dijkgraaf, M. G., & Frings-Dresen, M. H. (2016). The effect of cold showering on health and work: A randomized controlled trial. *PloS One*, *11*(9). doi: 10.1371/journal.pone.0161749

Buschkuehl, M., Jaeggi, S. M., & Jonides, J. (2012). Neuronal effects following working memory training. *Developmental Cognitive Neuroscience*, *2*, S167–S179.

Cheng, M. Y., Huang, C. J., Chang, Y. K., Koester, D., Schack, T., & Hung, T. M. (2015). Sensorimotor rhythm neurofeedback enhances golf putting performance. *Journal of Sport & Exercise Psychology*, *37*(6), 626–636.

Chou, P. H., Lin, W. H., Hung, C. A., Li, W. R., Lan, T. H., & Huang, M. W. (2016). Perceived occupational stress is associated with decreased cortical activity of the prefrontal cortex: A multichannel near-infrared spectroscopy study. *Scientific Reports, 6*(1). doi: 10.1038/srep39089.

Clark, L. A., Cuthbert, B., Lewis-Fernández, R., Narrow, W., & Reed, G. (2017). Three approaches to understanding and classifying mental disorder: ICD-11, DSM-5 and the National Institute of Mental Health's research domain criteria (RDoC). *Psychological Science in the Public Interest*, *18*, 72–145.

Cloonan, S. A., Taylor, E. C., Persich, M. R., Dailey, N. S., & Killgore, W. D. S. (2021). Sleep and resilience during the COVID-19 pandemic. *IntechOpen*. doi: 10.5772/intechopen.98298

Cowley, B. U., Dehais F, Fairclough, S., Karran, A. J., Palomäki, J. & Lappi, O. (2020). High performance cognition: Information-processing in complex skills, expert performance, and flow. *Frontiers in Psychology*, *11*. doi: 10.3389/fpsyg.2020.579950

Crameri, L., Hettiarachchi, I., & Hanoun, S. (2021). A review of individual operational cognitive readiness: Theory development and future directions. *Human Factors*, *63*(1), 66–87.

Cullen, T., Thomas, G., Wadley, A. J., Myers, T. (2019). The effects of a single night of complete and partial sleep deprivation on physical and cognitive performance: A Bayesian analysis. *Journal of Sports Sciences*, *37*, 2726–2734.

Davidson, R. J. (2005). Emotion regulation, happiness, and the neuroplasticity of the brain. *Advances in Mind–Body Medicine*, *21*, 25–58.

Del Percio, C., Marzano, N., Tilgher, S., Fiore, A., Di Ciolo, E., Aschieri, P., … Eusebi, F. (2007). Pre-stimulus alpha rhythms are correlated with post-stimulus sensorimotor performance in athletes and non-athletes: A high-resolution EEG study. *Clinical Neurophysiology*, *118*, 1711–1720.

Di Liegro, C. M., Schiera, G., Proia, P., & Di Liegro, I. (2019). Physical activity and brain health. *Genes 10*(9). doi: 10.3390/genes10090720.

Enriquez-Geppert, S., Huster, R. J., & Herrmann, C. S. (2017). EEG-neurofeedback as a tool to modulate cognition and behavior: A review tutorial. *Frontiers in Human Neuroscience*, *11*. doi: 10.3389/fnhum.2017.00051

Ferreira, J. P., Ghiarone, T., Cabral Júnior, C. R., Furtado, G. E., Moreira Carvalho, H., Machado-Rodrigues, A. M., & Andrade Toscano, C.V. (2019). Effects of physical exercise on the stereotyped behavior of children with autism spectrum disorders. *Medicina*, *55*. doi: 10.3390/medicina55100685

Firth, J., Solmi, M., Wootton, R. E., Vancampfort, D., Schuch, F. B., Hoare, E., … Stubbs, B. (2020). A meta-review of "lifestyle psychiatry": The role of exercise, smoking, diet and sleep in the prevention and treatment of mental disorders. *World Psychiatry*, *19*(3), 360–380.

Grier, R. A. (2012). Military cognitive readiness at the operational and strategic levels: A theoretical model for measurement development. *Journal of Cognitive Engineering and Decision Making*, *6*, 358–392.

Groppe, D. M., Bickel, S., Keller, C. J., Jain, S. K., Hwang, S. T., Harden, C., & Mehta, A. D. (2013). Dominant frequencies of resting human brain activity as measured by the electrocorticogram. *NeuroImage*, *79*, 223–233.

Gruzelier, J. H. (2014). EEG-neurofeedback for optimising performance. I: A review of cognitive and affective outcome in healthy participants. *Neuroscience & Biobehavioral Reviews*, 44, 124–182.

Harris, D. J., Wilson, M. R., & Vine, S. J. (2018). A systematic review of commercial cognitive training devices: Implications for use in Sport. *Frontiers in Psychology*, *9*. doi: 10.3389/fpsyg.2018.00709

Harris, D. J., Wilson, M. R., Smith, S. J. R., Meder, N., & Vine, S. J. (2020). Testing the effects of 3DMultiple Object Tracking training on near, mid and far transfer. *Frontiers in Psychology*, *11*. doi: 10.3389/fpsyg.2020.00196

He, J., Hsuchou, H., He, Y., Kastin, A. J., Wang, Y., & Pan, W. (2014). Sleep restriction impairs blood–brain barrier function. *Journal of Neuroscience*, *34*, 14697–14706.

Heatherton, T. F. (2011). Neuroscience of self and self-regulation. *Annual Review of Psychology*, *62,* 363–390.

Jeffreys, I., & Moody, J. (2021). (Eds.), *Strength and conditioning for sports performance* (2nd ed.). London: Routledge.

Kashdan, T. B., & Rottenberg, J. (2010). Psychological flexibility as a fundamental aspect of health. *Clinical Psychology Review*, *30*, 865–878.

Keyes, L. M. (2007). Promoting and protecting mental health as flourishing: A complementary strategy for improving national mental health. *American Psychologist*, *62*, 95–108.

Kober, S. E., Witte, M., Stangl, M., Väljamäe, A., Neuper, C., & Wood, G. (2015). Shutting down sensorimotor interference unblocks the networks for stimulus processing: An SMR neurofeedback training study. *Clinical Neurophysiology*, *126* (1), 82–95.

Lee, B. J., Gibson, O. R., Thake, C. D., Tipton, M., Hawley, J. A., & Cotter, J. D. (2019). Cross adaptation and cross tolerance in human health and disease. *Frontiers in Physiology*, *9*. doi: 10.3389/fphys.2018.01827

Mandolesi, L., Polverino, A., Montuori, S., Foti, F., Ferraioli, G., Sorrentino, P., & Sorrentino, G. (2018). Effects of physical exercise on cognitive functioning and wellbeing: biological and psychological benefits. *Frontiers in Psychology*, *9*. doi: 10.3389/fpsyg.2018.00509

Mandolesi, L., Gelfo, F., Serra, L., Montuori, S., Polverino, A., Curcio, G., & Sorrentino, G. (2017). Environmental factors promoting neural plasticity: Insights from animal and human studies. *Neural Plasticity*. doi: 10.1155/2017/7219461

Matta Mello Portugal, E., Cevada, T., Sobral Monteiro-Junior, R., Teixeira Guimarães, T., da Cruz Rubini, E., Lattari, E., Blois, C., & Camaz Deslandes, A. (2013). Neuroscience of exercise: From neurobiology mechanisms to mental health. *Neuropsychobiology, 68*. doi: 10.1159/000350946

McDowell, C. P., Dishman, R. K., Gordon, B. R., & Herring, M. P. (2019). Physical activity and anxiety: A systematic review and meta-analysis of prospective cohort studies. *American Journal of Preventive Medicine*, *57*(4), 545–556.

Morris, S. E., & Cuthbert, B. N. (2012). Research Domain Criteria: Cognitive systems, neural circuits, and dimensions of behavior. *Dialogues in Clinical Neuroscience*, *14*(1), 29–37.

Morrison, J. E., & Fletcher, J. D. (2002). *Cognitive readiness*. Alexandria, VA: Institute for Defense Analyses.

Nay, K., Smiles, W. J., Kaiser, J., McAloon, L. M., Loh, K., Galic, S., Oakhill, J. S., Gundlach, A. L., & Scott, J. W. (2021). Molecular mechanisms underlying the beneficial effects of exercise on brain function and neurological disorders. *International Journal of Molecular Sciences*, *22*(8). doi: 10.3390/ijms22084052

Omejc, N., Rojc, B., Battaglini, P. P., & Marusic, U. (2019). Review of the therapeutic neurofeedback method using electroencephalography: EEG Neuro feedback. *Bosnian Journal of Basic Medical Sciences*, *19*(3), 213–220.

Pak, V. M., Onen, S. H., Bliwise, D. L., Kutner, N. G., Russell, K. L., & Onen, F. (2020). Sleep disturbances in MCI and AD: Neuroinflammation as a possible mediating pathway. *Frontiers in Aging Neuroscience*, *12*. doi: 10.3389/fnagi.2020.00069.

Passell, E., Dillon, D. G., Baker, J. T., Vogel, S. C., Scheuer, L. S., Mirin, N. L., … Germine, L. (2019). *Digital cognitive assessment: Results from the TestMyBrain NIMH Research Domain Criteria*

(RDoC) field test battery report. Bethesda, MD: National Institute of Mental Health.

Polusny, M. A., Marquardt, C. A., Hagel-Campbell, E., Filetti, C. R., Noël, V. V., Disner, S. G., … Erbes, C. R. (2021). Advancing research on mechanisms of resilience (ARMOR) longitudinal cohort study of new military recruits: Results from a feasibility pilot study. *Research in Human Development*, *18*(3), 212–229.

RDoC (2022). *Research Domain Criteria Initiative*. Besthesda, MD. https://www.nimh.nih.gov/research/research-funded-by-nimh/rdoc

Reardon, C. L., Hainline, B., Aron, C. M., Baron, D., Baum, A. L., Bindra, A., … Engebretsen, L. (2019). Mental health in elite athletes: International Olympic Committee consensus statement (2019). *British Journal of Sports Medicine*, *53*, 667–699.

Rieker, J. A., Reales, J. M., Muiños, M., & Ballesteros, S. (2022). The effects of combined cognitive-physical interventions on cognitive functioning in healthy older adults: A systematic review and multilevel meta-analysis. *Frontiers in Human Neuroscience*, *112*. doi: 10.3389/fnhum.2022.838968

Robinson, P., Oades, L. G., & Caputi, P. (2015). Conceptualising and measuring mental fitness: A Delphi study. *International Journal of Wellbeing*, *5*, 53–73.

Rogala, J., Jurewicz, K., Paluch, K., Kublik, E., Cetnarski, R., & Wróbel, A. (2016). The do's and don'ts of neurofeedback training: A review of the controlled studies using healthy adults. *Frontiers in Human Neuroscience, 10*. doi: 10.3389/fnhum.2016.00301

Ros, T., Munneke, M. A. M., Parkinson, L. A., & Gruzelier, J. H. (2014). Neurofeedback facilitation of implicit motor learning. *Biological Psychology*, *95*, 54–58.

Rostami, R., Sadeghi, H., Karami, K. A., Abadi, M. N., & Salamati, P. (2012). The effects of neurofeedback on the improvement of rifle shooters' performance. *Journal of Neurotherapy*, *16*(4), 264–269.

Savic, I., Perski, A., & Osika, W. (2018). MRI shows that exhaustion syndrome due to chronic occupational stress is associated with partially reversible cerebral changes. *Cerebral Cortex*, *28*, 894–906.

Schaufeli, W. B., Maslach, C., & Marek, T. (2017). *Professional burnout: Recent developments in theory and research*. London: Routledge.

Schuch, F. B., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P. B., Silva, E. S., … Stubbs, B. (2018). Physical activity and incident depression: A meta-analysis of prospective cohort studies. *American Journal of Psychiatry*, *175*(7), 631–648.

Seligman, M. E. (2008). Positive health. *Applied Psychology*, *57*, 3–18.

Segal, A., Wald, I., Pine, D. S., Halpern, P., & Bar-Haim, Y. (2020). Attention control therapy for acute stress disorder: A randomized controlled trial. *Depression and Anxiety*, *37*, 1017–1025.

Severinsen, M. C. K., Pedersen, B. M. (2020). Muscle-organ crosstalk: The emerging roles of myokines. *Endocrine Reviews*, *41*(4), 594–609.

Sitaram, R., Ros, T., Stoeckel, L., Haller, S., Scharnowski, F., Lewis-Peacock, J., … Sulzer, J. (2017). Closed-loop brain training: The science of neurofeedback. *Nature Reviews: Neuroscience*, *18*(2), 86–100.

Son, T. G., Camandola, S., & Mattson, M. P. (2008). Hormetic dietary phytochemicals. *Neuromolecular Medicine*, *10*, 236–246.

Sulzer, J., Haller, S., Scharnowski, F., Weiskopf, N., Birbaumer, N., Blefari, M. L., … Sitaram, R. (2013). Real-time fMRI neurofeedback: Progress and challenges. *NeuroImage*, *76*, 386–399.

Swinkels, C. M., Ulmer, C. S., Beckham, J. C., Buse, N., VA Mid-Atlantic MIRECC Registry Workgroup, & Calhoun, P. S. (2013). The association of sleep duration, mental health, and health risk behaviors among US Afghanistan/Iraq era veterans. *Sleep*, *36*, 1019–1025.

Tang, Y. Y., & Posner, M. I. (2014). Training brain networks and states. *Trends in Cognitive Sciences*, *18*(7), 345–350.

Taylor, P. (2021). Physical and cognitive fitness training in the workplace: Validating a multimodal intervention in Australian corporate settings. *International Journal of Sport and Exercise Psychology*, *19*(S14–S15).

Taylor, P., Walker, F. R., Heathcote, A., & Aidman, E. (2023). Effects of Multimodal Physical and Cognitive Fitness Training on Sustaining Mental Health and Job Readiness in a Military Cohort. *Sustainability*, *15*(11), 9016. doi:10.3390/su15119016

Thibault, R. T., MacPherson, A., Lifshitz, M., Roth, R. R., & Raz, A. (2018). Neurofeedback with fMRI: A critical systematic review. *NeuroImage*, *172*, 786–807.

Thomson, D., Turner, A., Lauder, S., Gigler, M.E., Berk, L.; Singh, A.B., Pasco, J.A.; Berk, M., Sylvia, L. (2015). A brief review of exercise, bipolar disorder, and mechanistic pathways. *Frontiers in Psychology, 6*. doi: 10.3389/fpsyg.2015.00147

Tipton, C. M. (2014). The history of "Exercise Is Medicine" in ancient civilizations. *Advances in Physiology Education*, *38*(2), 109–117.

Vater, C., Gray, R., & Holcombe, A. O. (2021). A critical systematic review of the Neurotracker perceptual-cognitive training tool. *Psychonomic Bulletin & Review*, *28*, 1458–1483.

Vella, S. A., Aidman, E., Teychenne, M., Smith, J. J., Swann, C., Rosenbaum, S., ... & Lubans, D. R. (2023). Optimising the effects of physical activity on mental health and wellbeing: A joint consensus statement from Sports Medicine Australia and the Australian Psychological Society. *Journal of Science and Medicine in Sport, 26*(2), 132–139.

Vernon, D., Egner, T., Cooper, N., Compton, T., Neilands, C., Sheri, A., & Gruzelier, J. (2003). The effect of training distinct neurofeedback protocols on aspects of cognitive performance. *International Journal of Psychophysiology*, *47*(1), 75–85.

Walsh, K. M., Saab, B. J., & Farb, N. A. (2019). Effects of a mindfulness meditation app on subjective well-being: Active randomized controlled trial and experience sampling study. *JMIR Mental Health*, *6*(1). doi: 10.2196/10844

Wang, P. W., Lin, H. C., Su, C. Y., Chen, M. D., Lin, K. C., Ko, C. H., & Yen, C. F. (2018). Effect of aerobic exercise on improving symptoms of individuals with schizophrenia: A single blinded randomized control study. *Frontiers in Psychiatry*, *9*. doi: 10.3389/fpsyt.2018.00167

Wells, L., Kucina, T., Kohl, A., Lewis, I., de Salas, K., Aidman, E., & Heathcote, A. (2021). A flexible gaming environment for reliably measuring cognitive control. *Proceedings of the 2021 Human factors and medicine research symposium: Applying neuroscience to performance: From rehabilitation to human cognitive augmentation* (pp. 14.1–14.14). Rome: North Atlantic Treaty Organization.

WHO (2010). *Global recommendations on physical activity for health*. Geneva: World Health Organization.

Yücel, M., Oldenhof, E., Ahmed, S. H., Belin, D., Billieux, J., Bowden-Jones, H., … Verdejo-Garcia, A. (2019). A transdiagnostic dimensional approach towards a neuropsychological assessment for addiction: An international Delphi consensus study. *Addiction*, *114*, 1095–1109.

Zotev, V., Phillips, R., Yuan, H., Misaki, M., & Bodurka, J. (2014). Self-regulation of human brain activity using simultaneous real-time fMRI and EEG neurofeedback. *NeuroImage*, *85*, 985–995.