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14. ABSTRACT In today's high-intensity Air Force operations, Airmen are often required to perform demanding cognitive and physical tasks simultaneously, or in close concert (e.g., Air Force Explosive Ordinance Disposal) [1]. However, most Air Force training programs [e.g., squadron physical training (PT)] do not account for these operational requirements, and thus may not optimally instill the combined skills that are required of Airmen to perform their jobs efficiently and effectively. To address this issue, we have initiated a research and development program that seeks to create and validate specific exercises, routines, and comprehensive workout programs that integrate cognitive ('brain') training with contemporary PT exercises (e.g., performing body squats while concurrently tracking incoming information to improve lower body strength and working memory capacity). This initiative is inspired by, 1) findings indicating a positive relationship between specific modes of physical exercise (e.g., agility drills and Tai Chi) and cognitive performance (e.g., attention and working memory) [2, 3], 2) growing research interest in the effects and application of "brain training" [4], and 3) the Air Force's stated goal of developing personalized health and human performance technologies [5]. To accomplish this, we are currently developing training exercises and routines based on knowledge of operator physical and cognitive requirements obtained from quantitative and qualitative reports, surveys and interviews. These requirements are then distilled and paired in creative and practical ways to generate exercises and workout routines that can be instantiated effectively and efficiently into daily PT sessions performed in garrison at base fitness centers, at home, or down-range. Here, we share some of the exercises and routines we have developed, describe the philosophy and theoretical framework of our initiative, and provide a glimpse into future research in this area.					
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Integrative physical and cognitive training development to better meet airmen mission requirements

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Abstract

In today's high-intensity Air Force operations, Airmen are often required to perform demanding cognitive and physical tasks simultaneously, or in close concert (e.g., Air Force Explosive Ordinance Disposal) [1]. However, most Air Force training programs [e.g., squadron physical training (PT)] do not account for these operational requirements, and thus may not optimally instill the combined skills that are required of Airmen to perform their jobs efficiently and effectively. To address this issue, we have initiated a research and development program that seeks to create and validate specific exercises, routines, and comprehensive workout programs that integrate cognitive ('brain') training with contemporary PT exercises (e.g., performing body squats while concurrently tracking incoming information to improve lower body strength and working memory capacity). This initiative is inspired by, 1) findings indicating a positive relationship between specific modes of physical exercise (e.g., agility drills and Tai Chi) and cognitive performance (e.g., attention and working memory) [2, 3], 2) growing research interest in the effects and application of "brain training" [4], and 3) the Air Force's stated goal of developing personalized health and human performance technologies [5]. To accomplish this, we are currently developing training exercises and routines based on knowledge of operator physical and cognitive requirements obtained from quantitative and qualitative reports, surveys and interviews. These requirements are then distilled and paired in creative and practical ways to generate exercises and workout routines that can be instantiated effectively and efficiently into daily PT sessions performed in garrison at base fitness centers, at home, or down-range. Here, we share some of the exercises and routines we have developed, describe the philosophy and theoretical framework of our initiative, and provide a glimpse into future research in this area.

Keywords: U.S. Air Force; physical training; cognition; fitness; program development; military

1. Introduction

United States Air Force (AF) operations increasingly require that specialized and technical skills be performed by operators facing high levels of both physical and mental stress. For example, AF medics, who can embed within units of any military branch, are often sent on convoys and patrols where they are faced with difficult challenges, such as performing triage, making rapid decisions about medical care in austere conditions, and evacuating the wounded. They do all this while wearing full combat gear and carrying a host of medical supplies in a rucksack (total gear weight for an AF medic can be upwards of 100 lbs.; Figure 1). For these Airmen, and many others, developing and maintaining a state of readiness poses a serious challenge to the AF.



Figure 1. United States Air Force combat medic embedded with a U.S. Army unit preparing for a patrol.

Presently, the AF provides extraordinary job-skills training for a myriad of specialized occupations through established training pipelines that often include classroom teaching, test certifications, high-fidelity simulations and live training exercises. However, training pipelines are expensive and time-consuming from fiscal and manning perspectives. Consequently, pipeline training typically takes place in concentrated bouts, whereas training meant to ensure day-to-day readiness is accomplished through regular physical training that is recommended 3 hours per week [6].

The type of PT activities performed by Airmen can vary widely due to the fact that PT development and implementation in the AF is at the discretion of local unit commanders and physical training leads (PTLs), i.e., Airmen who are given the duty of preparing PT for their units, squadrons, or flight [6]. However, recent unpublished data we obtained using semi-structured interviews ($N \sim 45$), surveys and field observations indicates that current AF PT activities tend to include mostly traditional exercises and teams sports, such as steady-state running, calisthenics, resistance training, and soccer.

Interestingly, these types of PT activities may have benefit for achieving rudimentary, but not necessarily optimal, levels of physical and cognitive readiness. With specific reference to the latter, this speculation is supported by evidence showing that physical fitness training can have positive transfer effects for cognitive functions, such as information processing speed [7,8], executive function [9], and continuous memory [3]. We posit that these effects could be enhanced if the exercises themselves better replicate AF operational demands. This speculation is based on a theoretical extension of research supporting the basic utility of 'brain' training exercises for improving some cognitive functions [e.g., executive function [4], along with research indicating that specific types of exercise, e.g., those that require heightened concentration and/or the execution of complex motor skills such as Tai Chi [2] and Speed Agility Drills [3], tend to be more effective for eliciting short- and long-term improvements in cognitive function. In particular, these latter findings hint that exercise that requires focus on mind-body interactions and/or the juggling of multiple performance goals (e.g., maintaining balance while building speed and explosive power in an agility ladder run), are more effective for driving improvements in cognition. Notably, many of the occupational tasks performed by today's AF operators require complex motor skills (e.g., a flight line operator manually inspecting a jet engine), and we suspect that performing exercises that specifically facilitate those skills in concert with operationally-relevant cognitive exercises, will tune the relationship between physical fitness and cognitive function and lead to improved job performance and overall readiness. Currently, we are developing a

series of controlled research studies to examine this theory. However, in this manuscript our goal is to layout our basic research and design (R&D) process for developing integrated physical and cognitive exercises, provide detailed description and rationales for a small set of these exercises we have created, and lend a perspective glimpse into future research in this area.

2. Overview of our R&D Process

The primary objectives for our R&D process are to create exercises that are, a) operationally relevant, b) effective for improving Airmen job performance and overall readiness, and c) are simple and safe to perform in a majority of AF PT environments (e.g., base fitness centers, outdoor sport fields, etc.). The first step to meeting these goals is to obtain information about the physical and cognitive demands of specific AF occupations, as well as the current PT activities performed by Airmen in various settings. This is accomplished using semi-structured interviews, field observations (of both job tasks and PT activities), and the careful break-down of the latest AF Occupational Analysis Reports (OAR) [10]. This three-pronged approach was chosen in order to ensure that we obtained a holistic and nuanced understanding of AF occupational demands and PT activities that might not be fully captured by using any one of these approaches alone.

Next, the information we obtain is analyzed using qualitative methods, e.g., content analysis, to provide summaries of emergent thematic outcomes [11]. These summaries are used by our research staff, which is comprised of PhDs in Exercise Physiology, Cognitive and Sport Psychology, Certified Athletic Trainers, and Active Duty Airmen, to guide the creation of PT exercises that integrate operationally-relevant physical and cognitive exercise.

Finally, these exercises are validated in two ways. First, they are subjectively evaluated by cohorts of Airmen for their perceived usability and efficacy. Second, these exercises are used in longitudinal exercise intervention experiments performed in our laboratory, where their effectiveness for producing the desired performance results are compared to other forms of exercise. At this time, it is important to report that we are still in the process of formalizing the evaluation process that will be used by our Airmen, and that initial laboratory intervention studies have begun, but have not been completed. Because of this, the exercises we describe next reflect those generated following only completion of the first two stages of our R&D process.

3. Examples of Integrated Physical and Cognitive Exercises

3.1. Tracking Squats.

Working memory, described as a temporary holding and processing system for combining new and stored information [12], is a critical cognitive function for correctly perceiving and making judgments about a current contextual state. Because of this, high levels of working memory are generally important for all AF operations, but particularly those that require complex and rapid decision-making (e.g., special operations) [13]. In addition, working memory is known to be a particularly powerful contributor to fluid intelligence [14, 15].

In controlled research studies, one of the most common ways to evaluate (and train) working memory capacity is through the digit-span test [16, 17]. In this test, participants are presented with a series of digits (e.g., '2, 5, 4, 7') that they must immediately repeat back. If they are successful, they are then given a longer list (e.g., '9, 6, 3, 2, 0') to track and recall. The length of the longest list a person can remember is that person's digit span and serves as an indicator of working memory capacity.

In Tracking Squats, we combine the basic elements of the digit span with the execution of an air squat, the latter of which is a simple, common and effective physical exercise for improving low body strength and balance (both of which are important physical attributes for a majority of our Airmen). To perform the exercise, six rows of eight number only playing cards are placed on the ground (Figure 1). Airmen must squat to pick-up the playing-cards in succession, and then immediately recall the number order of the cards following the completion of each row. Performance on the exercise can be scored according to recall accuracy, time to completion, and/or subjective evaluation of squat form.



Fig. 1. An airmen demonstrates Tracking Squats

3.2. Anagram Planks.

An anagram refers to the rearrangement of letters or words to produce a new words or phrases [18]. In previous research, anagrams have been used as indicators of both cognitive ‘flexibility’ [18, 19] and implicit memory (i.e., a cognitive function that aids performance of a task without conscious awareness of previous experience with the same, or similar, task) [20], both of which promote adaptive problem-solving, a critical skills for many Airmen operations from cyber defense to piloting aircraft.

In anagram planks, we team the use of anagrams with dynamic plank movements that requires a combination of core strength and balance. To perform this exercise, 8 to 12 notes cards with individual letters written on them are placed in a semi-circle within arms’ reach of the participant (Figure 2). An Airman is then asked to hold the plank position while reaching out with one hand to touch letters that create words from the available set of letters. The objective is to create as many unique words as possible in one minute. A potential modification of this exercise is to ask the Airman to only create words of a specific category (e.g., call signs for a pilot) that is relevant to their occupation. Performance on the exercise can be scored by the number of unique words created in the allotted time and/or subjective scoring of their form in their plank performance.

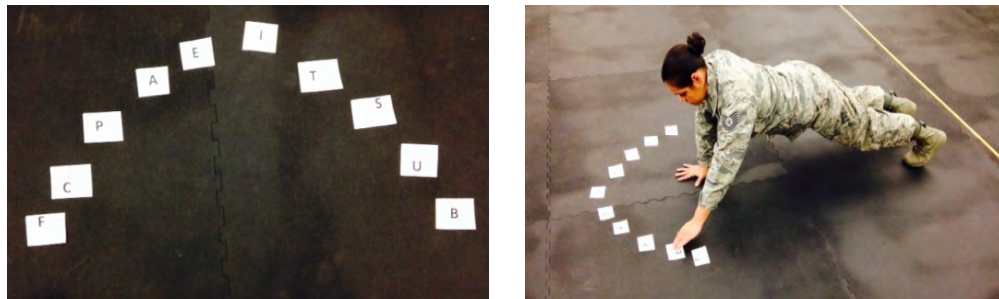


Fig. 2. (a) exercise layout; (b)an airmen demonstrates “Problem-solving planks”

3.3. Hold that Intel.

In a number of settings our air and ground-based operators, [e.g., Combat Controller, Joint Terminal Attack Controller (JTAC), and Air Battle Management (ABM) Operators] are faced with situations in which they are required to recall details from a previously reviewed operations order. These details are typically spatial, and may include features such as casualty collection sites, vantage points, suspected enemy target locations, and flight paths. With specific reference to ground-based operations, an Airman may need to quickly recall these details immediately

following, or while simultaneously engaged in, a physically stressful tasks. The purpose of “Hold that Intel” is to improve Airmen’s memory recall in such circumstance.

To perform the exercise, an Airman views and studies a geo-spatial map for a time period between 10 to 30 seconds prior to beginning an exercise circuit (Figure 3). The map is typically a low- to mid-fidelity 2D layout that contains the type information, based on their occupation, which they may encounter at their job. They then complete the exercise circuit for 5 to 60 minutes, where upon completion the Airman is asked recall the location of important map features on an unmarked grid. Performance is scored according to the accuracy of the recall (e.g., correct number of features reported and/or root mean square error distance from the actual feature location) and/or their physical performance on the exercise circuit (e.g., number of exercises completed).

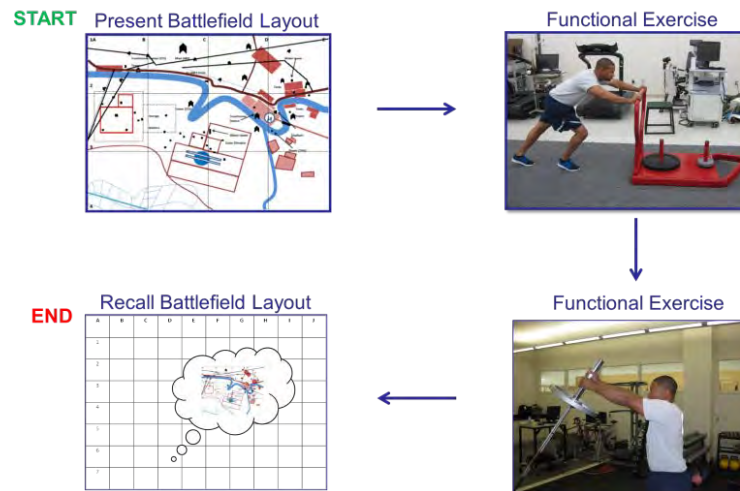


Fig. 3. (a) Initial map presented; (b & c) an airmen completed a functional circuit; (d) the airmen recalls the location of selected map structures

3.4. Safest Route Out.

Many of our Airmen are faced with circumstances in which with they must rapidly assess the state of situation, make a prediction about future events, and execute a plan. For example, a field medic may need to quickly diagnosis the injury of a fallen soldier, perform triage under hostile conditions, determine the best mode (e.g., drag or carry) and path for safe evacuation, and execute that plan while continuously monitoring for new constraints that might necessitate adaptations. Such circumstances require high levels of rapid pattern recognition, problem-solving and decision making.

In Safest Route Out, we try to promote those skills within the context of speed and agility running exercise. To perform this exercise we use the Fitlight Trainer ®, a wireless reaction system comprised of 8 LED lights controlled by a tablet. The lights are affixed at approximately hip height to sturdy surfaces in a semi-circle, though other configurations are likely suitable (Figure 4). At the onset of the exercise, an Airman stands in the center of the semi-circle while eight red, yellow, and blue lights illuminate simultaneously in a random order. The goal for the Airman is to examine the pattern, determine the most efficient route for touching and turning off all lights, and execute that plan. The only caveat is that they must turn all of the lights off in one color group before moving on to another, which makes the decision of which order to turn off the three color groups complex. For example, an Airman may decide that the most efficient plan is to turn off all the red lights first, then all the yellow lights, and finally all the blue lights. Once all lights are turned off, a new pattern is immediately illuminated. The full exercise includes three different pattern iterations-using the same color set. Performance on the exercise is evaluated by time-to-completion.

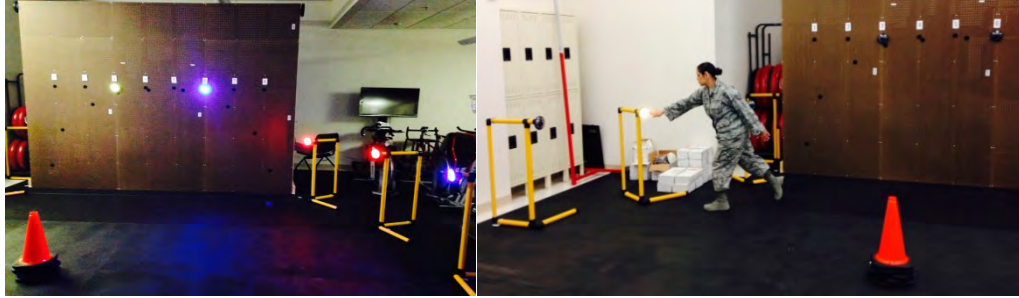


Fig. 4. (a) “route” set-up; (b) an airman completes a route iteration

3.5. The Next Steps

In this paper we provided an overview of a novel research initiative to develop exercises that better match the multi-modal demands of current AF operations through the integration of physical and cognitive exercises. In addition, we outlined of our R&D process and gave detailed descriptions of a few of the exercise we have created. Our next steps are to validate the utility and efficacy of these, and other, exercises of this type through subjective evaluation by Airmen and objective experimentation, as outlined earlier. In addition, we are also focused on developing safe and effective methods for these individual exercises to be placed into larger daily routines and comprehensive fitness programs that can be used in realistic training settings. Finally, we are considering various options for providing Airmen access to these exercises (e.g., mobile phone application), as well as the equipment (e.g., Fitlight Trainer ®) required to perform them, should they prove efficacious. Still, we believe that the developmental work shown here provides a solid foundation for meeting these goals and challenges that may lead to a new PT paradigm for the AF that will improve occupational job performance and the day-to-day readiness of our Airmen for the 21st century.

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