Runnin' On Emptu?

"Go Pills," Fatigue and Aviator Safety

USAF Photos by SSgt Greg Suhay and Keith Pederson
Photo Illustration by Dan Harman

JOHN A. CALDWELL, PH.D.
U.S. Air Force Research Laboratory
COL LEX BROWN, M.D.
U.S. Air Force School of Aerospace Medicine

In late '96, we prepared to launch F-117s to an undisclosed location 16 or more hours across the ocean. About 48 hours from launch time, the Wing CC asked whether we thought such a deployment was "do-able" or not, and we said yes, although we were concerned about pilot fatigue. The boss told me to talk to the flight surgeon about the possible use of Go Pills and to interview each pilot to ensure they knew the duration of the mission and the potential hazards.

When we briefed the mission, everyone said they were ready to go, and when I talked to the flight doc, he said he would make the Go Pills available, so I focused on planning and making sure the jets were ready to go.

At our departure time of 1600 Central, the weather wasn't great, but the mission was too important to cancel. We took off into low clouds and joined up approximately 50 miles east of Holloman to continue toward the tanker rejoin point. Weather delayed our first refuel, which put us an hour behind schedule and caused a faster fatigue onset. Later off the coast of Boston, more poor weather slowed the tanker swap to the KC-10s that would take us the rest of the way to our destination, and overcast conditions throughout the night portion crossing the Atlantic further complicated things by obscuring our visual cues. Things got better as we approached the Rock of Gibraltar, and after receiving our destination via secure radio link and digging through three feet of pubs to find the approach plate for Al Jaber, we crossed the Mediterranean Sea in beautiful skies, flew through intermediate ceilings across Egypt, and finally approached Kuwait in a "red out" caused by 35-knot winds whipping the desert sands into a frenzy.

As we approached Kuwait under instrument conditions, we were low on gas and fighting weather that was below minimums and a fierce crosswind. To make matters worse, fatigue was becoming a real problem because we were approaching 18 hours of airborne time, and I could feel the last Go Pill wearing off. It took every ounce of concentration to come up with a plan, but I knew we had to get our planes on the ground. I announced that we were going to split for individual ILS approaches, use the IRADS (Infra-Red Acquisition and Detection System…a bombing sensor, not an instrument approach aid) to find the runway, make the landing, deploy the drag chute, and hit the brakes. I'm sure I sounded more confident in this plan than I actually felt, but it was the only chance we had to get our jets on the ground before either running out of gas or suffering the debilitating effects of fatigue. So in we pressed. As soon as I landed, I exited the runway and pivoted my jet to be able to see the final approach course. I waited breathlessly as each stealthy aircraft appeared out of the dust and made its landing. Thankfully, all eight jets made it to the ground safely.

—Col Gary Woltering

Col Woltering's account of this first-ever 18-hour F-117 sortie is a great example of the modern mission requirements that are increasingly a part of Air Force operations. Long flights, unpredictable destinations or target locations, poor weather, and unforeseen events are "facts of life" throughout the aviation environment, but especially in combat and contingency operations. Besides the routine stress of facing the unknown under less-than-optimal conditions for an unspecified period of time, the situation is often further complicated by potentially dangerous levels of fatigue from disruptions to the body's clock and sleep deprivation. Most of us try to get the sleep we need, but job demands, anxiety, uncomfortable sleep environments and other problems often get in the way. Anyone who has ever flown long-range sorties or been deployed in some far-away place knows about the "real world" causes of fatigue and the problems associated with being overly tired. Why is fatigue a particular concern for the military, and what can we do about it? The Air Force has decided that Go Pills are at least part of the solution, and despite recent media hype to the contrary, many scientists, physicians, decision makers and operators feel that stimulants have a rightful place in our armament of fatigue countermeasures. Is this the case, or should we just rely only on other strategies?

This article will briefly review the problem of fatigue during intense military operations and discuss a countermeasure (i.e., Go Pills) that is being used in some sustained aviation missions. The overall objective is to inform aircrew members about the research that has been performed on Go Pills so they can make educated decisions about the use of this fatigue countermeasure in demanding flight operations.

Although different people have different opinions about the wisdom of using Go Pills to maintain alertness and performance, the fact is that at some point in your career you may well have to decide whether you will use these medicines which are currently approved for some types of air operations. (The Air Force does not *require* the use of Go Pills under any circumstance.) At various times in our military history, the U.S. has relied on Go Pills to maximize aviator safety and effectiveness while accomplishing difficult missions (Cornum, Caldwell, and Cornum, 1997). Nothing much has changed about the intensity and unpredictability of combat throughout our history except that technology has placed even higher demands on aircrews, so Go Pills likely will continue to be used to counter high levels of operational fatigue in the future. Assuming that Air Force policy and your chain of command have decided that these medications will be an authorized alternative for your unit, you might want to consider the information presented here before you decide what you will do when the "crunch" comes.

Military Sustained Operations are a Tactical Necessity Despite Some of the Problems They May Cause

U.S. superiority on the battlefield in part stems from our ability to maintain pressure on the enemy by making them fight around the clock. By keeping up a 24-hour-a-day operational tempo, we can virtually guarantee that enemy forces will suffer from the severe sleepiness that leads to procedural errors, sloppy judgment, poor planning and a general inability to react properly to rapidly changing situations. This gives us the tactical advantage, but only if we guard against severe fatigue ourselves. Unfortunately, this is difficult because fully staffing three eight-hour work shifts with well-rested personnel around the clock for seven days a week in combat and contingency operations is a daunting task. Prolonged work bouts are common, shorter-than-normal sleep periods are unavoidable, and fatigue from both of these factors threatens to impact operational readiness (Department of the Army, 1991; Krueger, 1989). It is well established that sustained wakefulness and the resulting sleep debt increase the likelihood that personnel will briefly (and uncontrollably) nod off on the job, even during flights (Dinges, 1995). The longer someone remains awake, the more likely he/she is to experience these uncontrollable periods of drowsiness. In addition, sleepiness takes a heavy toll on reaction time, motivation, attention, memory, endurance and judgment (Naitoh and Kelly, 1993). Even in peacetime, overly-tired pilots are thought to be responsible for four to seven percent of civilian U.S. aviation incidents or accidents every year (Kirsh, 1996), and a recent report identi-

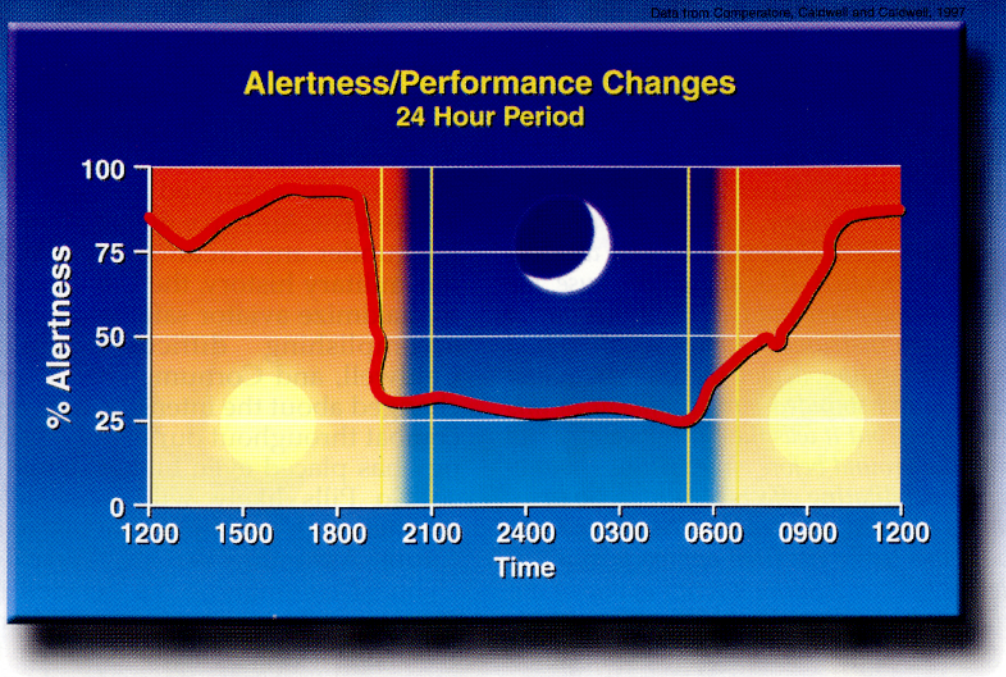

Figure 1

fied fatigue as a contributing factor in four percent of Army aviation mishaps from 1990-1999 (personal communication, U.S. Army Safety Center help desk; helpdesk@safetycenter.army.mil) while fatigue was cited as contributing to 7.78 percent of Air Force Class A reportable aircraft mishaps from 1972-2000 (personal communication, Lt Col Thomas Luna, U.S. Air Force Safety Center).

Severe Sleep Loss Creates Serious Problems

Although predictions about the exact effects of fatigue are difficult to make, most researchers agree that fatigue-related performance and alertness decrements follow a fairly reliable time course. Canadian researchers have reported that certain mental abilities decline about 30 percent after one night without sleep and 60 percent after two nights without sleep (Angus and Heslegrave, 1985). Scientists at the Walter Reed Army Institute of Research predict soldiers lose about 25 percent of their ability to perform useful mental work for every 24 hours without sleep (Belenky et al., 1994). A Norwegian field study found the fighting capability of soldiers dropped a full 80 percent after four consecutive days of sleep loss (Roussel, 1995). Thus, it seems clear that one to two days of sleep deprivation will seriously degrade aircrew performance while three to four days of sleeplessness will produce virtual incapacitation in the operational environment.

The Body's Circadian Clock Is Important

Anyone who has worked reverse cycle knows that sleepiness and fatigue are worse in the early morning hours (from about 0200-0500) than at other times (Akerstedt, 1995). This is because the body's internal rhythms are programmed to "wind down" at night (since this is when we are usually asleep) and "rev up" during the day (when we're usually awake). As any shift worker will testify, it takes several days to adjust to a new working and resting schedule, and many people never fully adjust no matter how long they stay on the night shift in particular. People who aren't adjusted to their working and resting schedules suffer in terms of their feelings (tired, upset stomach, poor mood, etc.), their alertness (slow and drowsy), and their performance (reduced accuracy, poor vigilance and slow reactions). People who transition from one time zone to another experience similar problems.

Disruptions to the body's clock compound the fatigue associated with long hours of wakefulness so that someone who is trying to work early in the morning (after being awake since the previous day) is suddenly vulnerable to involuntary "sleep attacks" even though they were fine just a few hours before. These same people might deceive themselves into thinking they've overcome fatigue after the sun comes up even though they haven't slept a wink during the night. Unfortunately, this sets them up for even greater problems later in the day, and since they don't expect the next drop in performance, their safety is more at risk than it was in the first place.

An Example of the Effects of Fatigue

An example of the performance decline associated with sleep loss and the circadian cycle is shown in Figure 2. This graph was produced by the Air Force Fatigue Avoidance Scheduling Tool™ which predicts performance efficiency based on the amount of sleep obtained and the circadian phase (time of day). The schedule used in this example is based on a schedule from a recent field exercise.

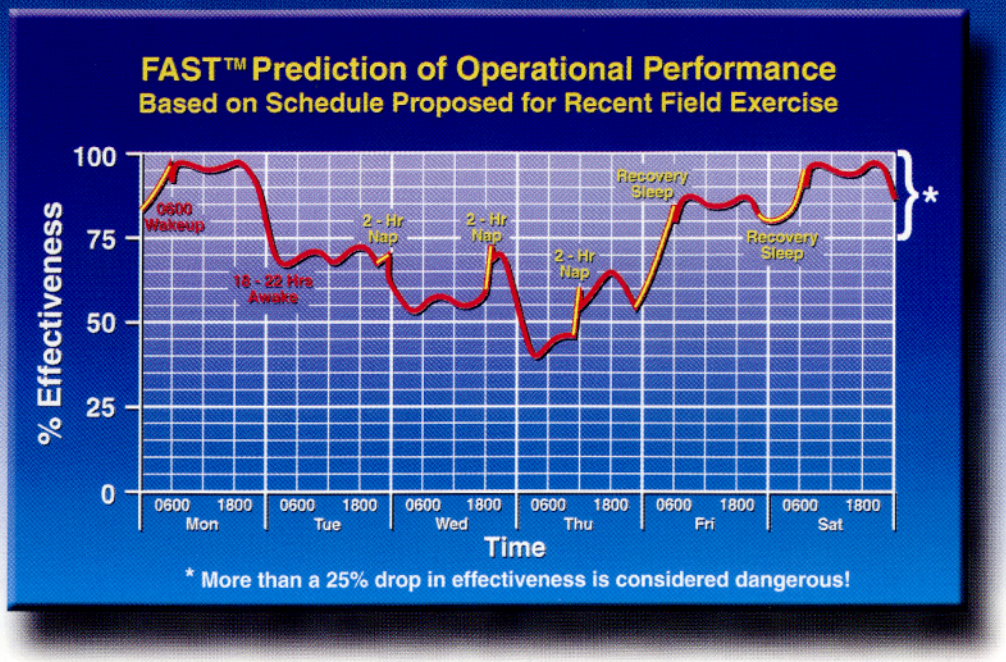

Figure 2

Serious deficits in operational effectiveness were predicted by 0300 on the morning of the second day. At this point, effectiveness was expected to fall below 75 percent of normal. Also, due to the subsequent lack of sleep (with only a two-hour nap on days two and three), performance likely would have declined until it degraded to less than 50 percent of optimal levels. Decrements of this magnitude could create serious problems in the operational environment unless a proven fatigue countermeasure is implemented. Note that the greatest decrement on Tuesday was predicted to occur after 18-22 hours of continuous wakefulness, a time associated with fatigue-induced performance losses similar to those produced by blood alcohol concentrations (BACs) of .05 to .10—the legal level for "driving while intoxicated"!

Clearly, fatigue is an important issue, especially during actual real-world missions. It is for this reason that feasible countermeasures must be developed and implemented.

What are the Strategies for Dealing with Operational Fatigue?

Nonpharmacological (or "Natural") Strategies

A number of fatigue remedies have been proposed, but few are easy to correctly use, especially in intense military operations. Emphasizing proper sleep management and controlling the duration of duty periods constitute the first line of defense against fatigue, and the Air Force rightfully places a great deal of emphasis on this approach. However, when the intensity of operations reaches a certain point, or long-range flights are required, it can be very difficult to properly control sleep periods, and this can lead to a huge problem with fatigue in the cockpit. Evidence of this has been found in almost every military conflict. Fatigue was definitely a problem in Desert Shield and Desert Storm, and subsequent operations have led to similar reports. Even during peacetime, a recent survey of Army pilots revealed that 26 percent complained of poor sleep while in the field or while traveling compared to only five percent complaining of poor sleep at home (Caldwell and Gilreath, 2002).

In addition to sleep difficulties, it is often impossible to avoid working at times when circadian factors increase the prevalence of attentional lapses and involuntary sleep episodes. Attempts to remedy fatigue have included several novel approaches such as a reliance on exercise (LeDuc, et al., 1998), work breaks (Angus, Pigeau, and Heslegrave, 1992), or high levels of physical fitness, as well as the use of strategic naps (Angus, Pigeau, and Heslegrave, 1992). Unfortunately, exercise appears to offer only temporary relief from fatigue, and work breaks offer short-lived relief as well. Ensuring a high degree of physical fitness, while excellent for sustaining physical work capacity, has almost no impact on the ability to maintain the mental performance of sleep-deprived people. Naps, while excellent for improving alertness, often are not feasible in high-ops-tempo settings. These are just some of the reasons why the military has explored the feasibility of using pharmacological (or "drug-based") fatigue countermeasures.

Go Pill (Pharmacological or Drug) Strategies

Although the rule of thumb is that "drugs and flying don't mix," Go Pills may be the only reliable method for temporarily maintaining the performance of aviators during those lengthy sustained

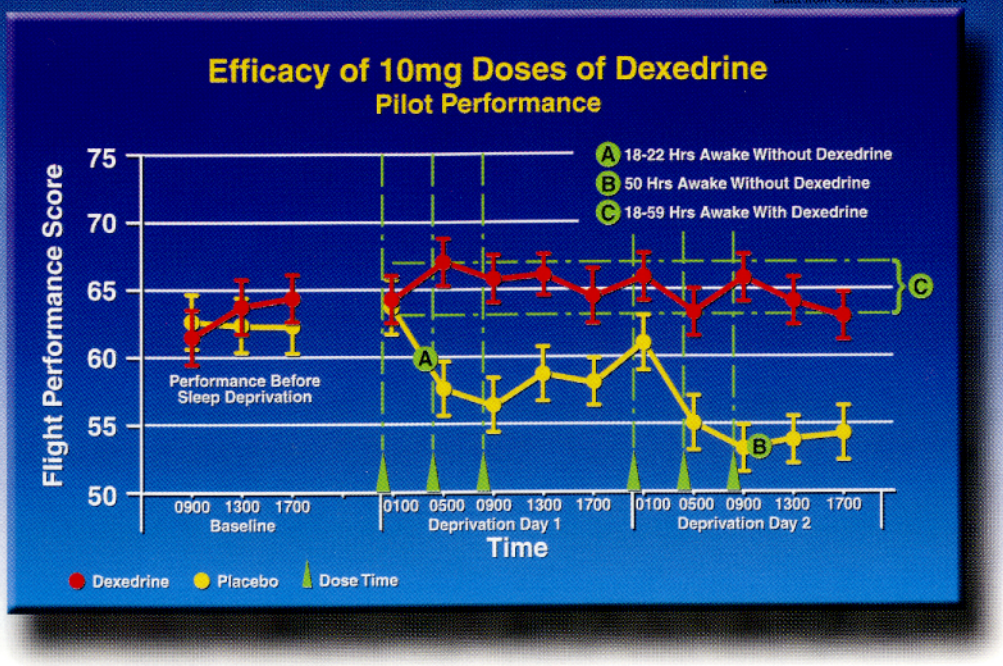

Figure 3

operations when, despite everyone's best efforts, adequate sleep is simply not an option. In these situations, after every other countermeasure has been tried, Go Pills should be considered for a variety of reasons. They are effective and easy to use. Their feasibility is not dependent upon environmental manipulations such as creating comfortable daytime and nighttime sleep quarters in the middle of the desert (or next to an active runway, or in the back of an aircraft). Their effectiveness does not depend on making complex modifications to work schedules in order to ensure that everyone works only eight to 12 hours a day, while simultaneously making sure each individual has enough time off-duty to get at least eight hours of sleep. Also, Go Pills have been proven effective for temporarily overcoming sleep deprivation in laboratory studies and in field environments. This explains why medicines such as amphetamines have been used extensively in several military conflicts. Despite debate on this topic, dextroamphetamine (Dexedrine®) remains one of the best Go Pill choices because its actions are well understood and its effectiveness in sleep-deprived personnel is well known. However, there are other possible alternatives that deserve mention.

- **Amphetamines**. Amphetamine psychostimulants have been available in the U.S. since 1937, and these drugs have been widely used to treat the symptoms of medical conditions such as narcolepsy (with excessive daytime sleepiness) and hyperactivity/attention deficit disorder. In the 1940s and 1950s, studies were undertaken to explore the military significance of psychostimulants, and the general consensus was that they were effective for restoring or maintaining the performance of sleep-deprived subjects at well-rested levels. Recently, their positive reputation has been tempered by the recognition that they can have significant abuse potential if they are not used properly, and they are not completely free of side effects, but despite this fact the military has successfully used dextroamphetamine for years. There are reports that amphetamines were used in combat in World War II, and it is an established fact that the Air Force authorized the use of dextroamphetamine to sustain the performance of sleep-deprived pilots as early as 1961. Dexedrine continues to be authorized under Air Force policy for certain situations today, and its successful track record has been maintained by ensuring that it is provided in accordance with carefully planned guidance and used in a well-controlled fashion.

The effects of Dexedrine have been extensively studied in the laboratory and in the field (Weiss and Laties, 1967). In the laboratory, single doses (20 mg) of dextroamphetamine have been shown to return alertness and cognitive performance of non-aviators to near baseline levels and maintain this recovery for seven to 12 hours, even after 48 hours of total sleep deprivation (Newhouse et al., 1989). In addition, a single 20-mg dose has been found to temporarily prevent performance decrements in people kept awake for approximately 34 continuous hours, and to restore the performance of volunteers deprived of sleep for 48 continuous hours (Pigeau, et al., 1995). Studies conducted by the U.S. Army Aeromedical Research Laboratory (USAARL) determined that multiple 10-mg doses of Dexedrine, administered prior to the onset of fatigue degradations, will sustain the performance of pilots throughout 40 hours without sleep

(Caldwell, et al., 1995; Caldwell, Caldwell, and Crowley, 1996; Caldwell and Caldwell, 1997). In addition, a recent USAARL study showed that Dexedrine maintained the flight performance of pilots even after 60 hours of continuous wakefulness (Caldwell et al., 2000a).

A flight surgeon who administered 5 mg of Dexedrine to EF-111A Raven jet crews (used for electronic jamming) during an Air Force strike on Libya in April of 1986, reported crews were able to overcome the fatigue of the mission itself and the sleep deprivation which occurred during mission preparations (Senechal, 1988). There were no in-flight or landing problems, and all of these aircraft returned safely to base[1]. When Colonel Kory Cornum, an Air Force flight surgeon, provided Dexedrine to F-15C pilots flying lengthy combat air patrol sorties, it was clear that the medicine enabled flight crews to overcome the fatigue from sleep deprivation and circadian disruptions (Cornum, 1992). (In practice, the pilots self-administered 5-mg doses at a frequency of one tablet approximately every two to three hours.) The unit commander concluded Dexedrine administration contributed to the safety of air operations. There were no reported adverse effects, even in personnel who took 10 mg at a time, and no aviators reported a need to continue the drug once proper working and sleeping schedules were reinstated. This agrees with the results of a survey of Air Force pilots which indicated that Dexedrine was helpful in maintaining performance during sustained operations without unwanted side effects (Emonson and Vanderbeek, 1993).

Because of such reports, the U.S. Air Force recently approved Dexedrine for sustaining the performance of pilots in single- and dual-seat aircraft. Under this policy, doses of 10 mgs are authorized. The number of doses issued to the aircrew member by the flight surgeon is appropriate to the mission duration.

• **Caffeine.** Caffeine is another alertness-promoting compound that is suitable for fighting fatigue particularly in relatively short periods of continuous wakefulness (i.e., 37 hours). However, some scientists have found that caffeine may not be appropriate for longer sustained operations (i.e., 64 hours or more) (Lagarde and Batejat, 1995). As with everything in life, no clear-cut answer is available; there are people who believe caffeine is a better alternative than amphetamines, and others who feel caffeine is less effective and more prone to produce unwanted side effects like "the shakes," dehydration and a frequent need to urinate.

Every day, Americans consume various amounts of caffeine in all sorts of products (Griffiths and Mumford, 1995), and they may not even be aware of it. Everyone knows about the caffeine in coffee (100-175 mg per cup), but what about the caffeine in Coke (31 mg), Mountain Dew (55 mg), and tea (about 40 mg) (Lieberman, 1992)? Also, few people may realize that over-the-counter medications often contain caffeine. For instance, just one Excedrin tablet has 65 mg. Compare these amounts to the caffeine found in stimulants such as NoDoz® and Vivarin® (200 mg per pill). By the way, 200 mgs of caffeine is the minimum amount recommended to sustain alertness in sleep-deprived people. Be aware that your body may quickly adjust to the effects of daily caffeine consumption, so if you are a heavy caffeine user, you may not get the boost you really need from those two cups of coffee when you're fighting off sleep in the middle of the night. People who find they frequently need some help staying alert on night shift or when doing those extra long missions should only use caffeine during the times when they really need it. Although this is tantamount to sacrilege, such people should switch to decaffeinated products on normal work days.

The bottom line is that when operational demands make pre-mission sleep difficult or impossible to obtain, caffeine could be considered a "first-line" approach to sustaining alertness and performance in sleepy individuals. In other words, caffeinated products such as coffee, soft drinks, caffeine-containing candy and gum, or caffeine tablets often can help to manage the fatigue that stems from unavoidable sleep deprivation[2].

• **Modafinil**. Modafinil may someday be an alternative to Dexedrine and caffeine for use in situations where a prescription medication is needed to sustain performance during prolonged periods of total sleep loss. This new drug was only recently approved for use in the United States (as of December 1998), so more research is needed before the military will use it on a widespread basis. However, there is great interest in modafinil (sold under the brand name Provigil®) because it supposedly has the positive benefits of amphetamines without the drawbacks of increasing heart rate and blood pressure (and without the possibility of disturbing the quality of any sleep that is taken too close to the most recent dose). Researchers have found that Provigil maintains the alertness of people with sleep disorders and it improves the functioning of people who can't sleep because of night work or really long duty periods. It does this without increasing heart rate and blood pressure. Also, people seem to be able to use Provigil without worrying about "getting hooked."[3]

The USAARL conducted an aviator-performance study in 1999 (with three 200-mg doses of modafinil during 40 hours of sleep deprivation), and the results were promising. Provigil sustained the alertness and performance of pilots, and kept them working at well-rested levels even at 0500 in the morning after they had been awake for 22 straight hours (Caldwell, et al., 2000b). However,

there were some side effects (dizziness and vertigo) that may have been related to the high dose. It seems likely that a lower dose of modafinil may provide the same alerting benefit with fewer problems, but this has yet to be determined in an aviation context. However, both Walter Reed Army Institute of Research (Wesensten et al., 2002) and the Air Force Research Laboratory (Eddy, et al., 2001) have performed modafinil studies (with non-aviators) in which the results were positive with no side effects related to dizziness and vertigo.

After more research, modafinil may become a suitable alternative to Dexedrine. However, until these studies are performed, Dexedrine may be a better choice in terms of what is known about the drug and its proven potential for sustaining alertness for relatively long periods in sleep-deprived subjects.

What is the Bottom Line?

Fatigue will probably always be a problem in combat and contingency operations because of the intensity and unpredictability of these missions. There are solutions for operational fatigue, but the most appropriate countermeasure depends on several factors.

Obviously, the best way to prevent fatigue on the job is to ensure that everyone gets enough sleep before the mission even starts (sleep experts recommend eight hours of sleep per day to maintain top-notch performance). It is best for this sleep to occur during the normal nighttime sleep period whenever possible because this is the time the body is "programmed" to sleep. Also, there should be a comfortable place to sleep that is dark and free of noise and activity. When this is impossible, earplugs and sleep masks can help. Remember, proper sleep is the only sure way to avoid a buildup of fatigue.

If a full eight-hour sleep period is not possible, naps are a great compromise. Naps should be long enough to provide at least 45 continuous minutes of sleep, although longer naps (two hours) are better. In general, the shorter each individual nap period is, the more frequent the naps should be. Once again, to promote the most restorative sleep during these naps, the same rules about environmental comfort apply to them as they do to the longer sleep episodes.

When it is simply impossible to obtain any sleep, stimulants or Go Pills may be the only realistic alternative to falling asleep at the controls. Although stimulants cannot replace the need for sleep, they can temporarily postpone it. This is especially important in sustained aviation operations because sleepiness in the cockpit is a serious problem which cannot be overcome through motivation, training or experience. Once the body reaches a certain point, involuntary lapses into sleep will occur, and these can last anywhere from a few seconds to several minutes. Research has shown that people often aren't aware that they are lapsing into sleep until the lapses stretch into periods of a minute or longer! Go Pills can stave off these effects for a while.

If your chain of command makes a decision to provide Go Pills, the basic choices are caffeine or Dexedrine. Modafinil may be an alternative for the future. Of these choices, only caffeinated beverages can be used without explicit flight surgeon and command authorization. Caffeinated tablets can be used following flight surgeon clearance. However, the long-term efficacy of caffeine has not yet been established, especially for people who normally consume a lot of caffeinated products. Dexedrine is likely a better choice for extreme cases of fatigue, but while Dexedrine is highly effective, it also is a controlled prescription drug that can only be used under specific circumstances. Dexedrine is not a perfect, 100-percent solution, but it certainly beats falling asleep at the controls.

When you find yourself in a situation where the mission simply must be accomplished but sleep is impossible either because of the lengthy flight duration, circadian factors or environmental circumstances, your flight surgeon may offer the option of using a stimulant, and it may be Dexedrine. This will only be done on a time- and/or mission-specific basis and only with the approval of the senior flight surgeon and Wing Commander (or deployed equivalent) operating under MAJCOM guidance. If you feel that you may potentially elect to use Dexedrine you will first be educated on Dexedrine and its effects. If you elect to proceed you will be asked to sign an informed consent form and will be provided a test dose to take on the ground to familiarize you with how it will make you feel and ensure that you do not have any unexpected adverse effects. Your Dexedrine ground test as well as any operational use will be documented. The final decision about whether to take advantage of this option will be left to you. Hopefully, you can now make an informed choice about whether or not you will use it.

The views expressed in this paper are those of the author and do not necessarily reflect the official stance of the Department of Defense. Mention of specific drug products should not be construed as an official endorsement of these compounds.

[1] Although one of the strike F-111s involved in this mission was taken out by a surface-to-air missile, all of the EF-111s and the remaining F-111s returned safely.

[2] Aircrew are required to inform their flight surgeons about any nutritional or dietary supplementation (including caffeine tablets) that they are using in accordance with AFMOA Policy Letter, 28 Oct 1999, Use of Nutritional Substances.

[3] Although the absence of addiction potential associated with modafinil is a widely-touted benefit of this medicine, the reader should know that HQ Air Force Medical Operations Agency has no evidence that any U.S. Air Force aviator has ever become addicted to the Air Force's current stimulant of choice, Dexedrine.

References

Akerstedt, T. 1995. Work hours, sleepiness and the underlying mechanisms. Journal of sleep research, 4(suppl. 2):15-22.

Angus, R. G., and Heslegrave, R. J. 1985. Effects of sleep loss on sustained cognitive performance during a command and control simulation. Behavior research methods, instruments, and computers, 17(1):55-67.

Angus, R. G., Pigeau, R. A., and Heslegrave, R. J. 1992. Sustained operation studies: from the field to the laboratory, in C. Stampi (Ed.) Why we nap: Evolution, chronobiology, and functions of polyphasic and ultrashort sleep, 217-244. Boston: Birkhäuser.

Babkoff, H., and Krueger, G. P. 1992. Use of stimulants to ameliorate the effects of sleep loss during sustained performance. Military psychology, 4(4):191-205.

Baranski, J. V., and Pigeau, R. A. 1997. Self-monitoring cognitive performance during sleep deprivation: effects of modafinil, d-amphetamine and placebo. Journal of sleep research, 6:84-91.

Belenky, G., Penetar, D. M., Thorne, D., Popp, K., Leu, J., Thomas, M., Sing, H., Balkin, T., Wesensten, N., and Redmond, D. 1994. The effects of sleep deprivation on performance during continuous combat operations. In Food Components to Enhance Performance, 127-135. Washington, DC: National Academy Press.

Caldwell, J. A. and Caldwell, J. L. 1997. An in-flight investigation of the efficacy of dextroamphetamine for sustaining helicopter pilot performance. Aviation, space, and environmental medicine, 68(12):1073-1080.

Caldwell, J. A., Caldwell, J. L., and Crowley, J. S. 1996. Sustaining female helicopter pilot performance with Dexedrine during sustained operations. International journal of aviation psychology, 7(1):15-36.

Caldwell, J. A., Caldwell, J. L., Crowley, J. S., and Jones, H. D. 1995. Sustaining helicopter pilot performance with Dexedrine during periods of sleep deprivation. Aviation, space, and environmental medicine, 66(10):930-937.

Caldwell, J. A., Caldwell, J. L., Smythe, N. K., and Hall, K. K. 2000. A double-blind, placebo-controlled investigation of the efficacy of modafinil for sustaining the alertness and performance of aviators: a helicopter simulator study. Psychopharmacology, 150:272-282.

Caldwell, J. A., and Gilreath, S. R. 2002. A survey of aircrew fatigue in a sample of Army aviation personnel. Aviation, space, and environmental medicine, 73:472-480.

Caldwell, J. A., Smythe, N. K., LeDuc, P. A., and Caldwell, J. L. 2000. Efficacy of dextroamphetamine for the maintenance of aviator performance during 64 hours of sustained wakefulness. Aviation, space, and environmental medicine, 71(1):7-18.

Comperatore, C., Caldwell, J., and Caldwell, L. 1997. Leader's guide to crew endurance. Fort Rucker, AL: U.S. Army Safety Center and U.S. Army Aeromedical Research Laboratory.

Cornum, K. G. 1992. Sustained operations: An F-15 squadron in the Gulf war. Minutes of the Department of Defense Human Factors Engineering technical group 29th meeting. Huntsville, AL. November, 1992.

Department of the Army 1991. Soldier performance in continuous operations. FM 22-9. Washington DC: Department of the Army.

Dinges, D. F. 1995. An overview of sleepiness and accidents. Journal of sleep research. 4(suppl. 2): 4-14.

Eddy, D., Gibbons, J., Storm, W., Miller, J., Cardenas, R., Stevens, K., Hickey, P., Barton, E., Beckinger, R., Fischer, J., and Whitmore, J. 2001. The effect of modafinil upon cognitive and vestibular performance under a single night of sleep loss. Proceedings of the 15th International Symposium on Night and Shiftwork. 10-13 Sep, Hayama, Japan.

Emonson, D. L. and Vanderbeek, R. D. 1993. The use of dextroamphetamine in support of tactical air operations during Operation Desert Shield/Storm. Aviation, space, and environmental medicine, 64(5):421.

Griffiths, R. R., and Mumford, G. K. 1995. Caffeine—A drug of abuse? In Bloom F.E., and Kupfer, D. J. (eds.) Psychopharmacology: The fourth generation of progress, pp. 1699-1713. New York: Raven Press.

Higgins, E. A., Chiles, W. D., McKenzie, J. M., Iampietro, P. F., Vaughan, J. A., Funkhouser, G. E., Burr, M. J., Jennings, A. E., and West, G. 1975. The effects of dextroamphetamine on physiological responses and complex performance during sleep loss. Federal Aviation Administration Report No. FAA-AM-75-14. Washington: U.S. Department of Transportation.

LeDuc, P.A., Caldwell, J.A., Ruyak, P.S., Prazinko, B., Gardner, S., Colon, J., Norman, D., Cruz, V., Jones, R., and Brock, M. 1998. The effects of exercise as a countermeasure for fatigue in sleep deprived aviators. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report, No. 98-35.

Kirsch AD. (1996). Report on the statistical methods employed by the U.S. FAA in its cost benefit analysis of the proposed "Flight Crewmember Duty Period Limitations, Flight Time Limitations and Rest Requirements," Docket No. 28081. Comments of the Air Transport Association of America to FAA notice 95-18, FAA Docket No. 28081. Appendix D, pp. 1-36.

Krueger, G. P. 1989. Sustaining military performance in continuous operations: Combatant fatigue, rest and sleep needs. Handbook of military psychology, pp 255-277. New York: John Wiley and Sons.

Lagarde, D., and Batejat, D. 1995. Some measures to reduce effects of prolonged sleep deprivation. Neurophysiology clinical, 25:376-385.

Lieberman, H. R. 1992. Caffeine. In Jones, D., and Smith, A. (eds.) Factors affecting human performance, Vol. II: The physical environment, pp. 49-72. London: Academic Press.

Newhouse, P. A., Belenky, G., Thomas, M., Thorne, D., Sing, H.C., and Fertig, J. 1989. The effects of d-amphetamine on arousal, cognition, and mood after prolonged total sleep deprivation. Neuropsychopharmacology, 2(2):153-164.

Naitoh, P., and Kelly, T. L. 1993. Sleep management user's guide for special operations personnel. Naval Health Research Center. San Diego: Naval Health Research Center. Report No. 92-28.

Physician's Desk Reference Electronic Library. 2001. Montvale, NJ: Medical Economics Company, Inc.

Pigeau, R., Naitoh, P., Buguet, A., McCann, C., Baranski, J., Taylor, M., Thompson, M., and Mack, I. 1995. Modafinil, d-amphetamine, and placebo during 64 hours of sustained mental work. I. Effects on mood, fatigue, cognitive performance and body temperature. Journal of sleep research, 4:212-228.

Roussel, B. 1995. Wakefulness, performance, and sleep under operational conditions: for the attention of officers of the armed services. NATO document 3199/AA. North Atlantic Treaty Organization.

Senechal, P. K. 1988. Flight surgeon support of combat operations at RAF Upper Heyford. Aviation, space, and environmental medicine, 59:776-777.

Weiss, B., and Laties, V. G. 1967. Enhancement of human performance by caffeine and the amphetamines. Pharmacological reviews, 14:1-36.

Wesensten, N. J., Belenky, G., Kautz, M. A., Thorne, D., and Balkin, T. J. 2002. Sustaining cognitive performance during sleep deprivation—relative efficacy of modafinil (100, 200, and 400 mg) versus caffeine (600 mg). Psychopharmacology. 159: 238-247.