TARGET DETECTION, IDENTIFICATION, AND MARKSMANSHIP
UNDER VARIOUS TYPES OF PHYSIOLOGICAL STRAIN

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ABSTRACT

The advent of high resolution interactive simulation has made it possible to bring greater realism into the laboratory where experimental rigour is more easily controlled than in a field setting. Using a small arms trainer (SAT), target detection, identification, and engagement were tested under a variety of conditions including heat and cold exposure, fatiguing exercise, and sleep deprivation, with caffeine intervention applied in the latter two trials. Target presentations were random and varied from standing pop-ups to moving figures of both foe and friendly types appearing seldom or frequently. Performance was judged according to the number of targets detected, correct identifications, and marksmanship. The main findings suggest that target detection is susceptible to fatigue, which can be alleviated with caffeine. However, once a target has been detected with or without fatigue, its engagement, which requires intense but short-term focus (i.e., 6 s or less), can be competently managed under significant levels of physiological strain, as if no strain was present.

1. INTRODUCTION

Soldiers rarely operate in a stress-free environmental and must be prepared to surmount a variety of challenges beyond facing an adversary. These include external stressors such as climatic extremes and internal stressors such as fatigue from physical effort and sleep deprivation. It is self-evident that proficiency in performance must be maintained under such stressors, especially when adversarial contact is imminent. To apply the most appropriate countermeasures to stressors, it is essential to understand the soldier's tolerance to them and, equally important, to document their impact on performance. The focus in this paper is on the dismounted soldier's ability to detect, identify, and engage targets under thermal stress (hot and cold conditions) and under fatigue due to physical exertion or sleep deprivation. Psychological stressors will not be examined herein.

A limited number of studies have documented the detrimental impact on marksmanship due to the various stressors cited above. For example, Johnson and Kobrick (1997) reported a small decrement in shooting accuracy in the case of heat exposure. However, body temperatures were not measured making it impossible to ascertain a threshold effect. In the case of cold exposure,

Reading et al. (1994) reported a modest increase in shot deviation despite no decrease in core (deep body) temperature, clearly implicating the role of a cold periphery, but leaving unclear the impact of a cool core. The effect of exercise on marksmanship has been examined in conjunction with several confounding or mitigating factors. In one study, for example, Tharion et al. (1997) failed to find an ergogenic benefit from a carbohyrdrate-electrolyte beverage with respect to marksmanship. It would be of interest to extend this work to caffeine, not only for exercise fatigue, but also for sleep deprivation, which has been reported to degrade marksmanship by varying degrees (Haslam, 1982) but reversible with caffeine intervention (Lieberman et al., 2002). The series of studies described herein were conducted to add to this body of knowledge, by extending thermal stress levels along with body temperature measurements, and by further examining the efficacy of caffeine ingestion on marksmanship during exercise fatigue and sleep deprivation.

For the purposes of this presentation, physiological stress is defined as the environmental insult to the body whereas strain is the consequential change in the body. For example, exposure to heat or cold presents a thermal stress and the resultant physiological change (eg., hyperthermia or hypothermia) is the strain. However, it is very difficult to separate the contributions of stress and strain to any degradation in performance. While stress is easily quantified, strain is more challenging, relying, for example, on subjective measures for fatigue and objective measures such as body temperatures for thermal strain.

Rather than present the methods of all the trials under one section followed by the results in another, as customarily done, the methods and results will be presented for each trial under separate sub-sections. This will simplify keeping track of each trial given the number and variation of trials reported herein. Greater details of the trials can be found in the corresponding cited references. This paper summarizes the findings in a holistic approach with generalized conclusions.

2. TRIALS

2.1 General

All trials were conducted using the FATS IV Combat Firing Simulator (FATS Inc., Suwanee, GA) in

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an environmentally-controlled room. The SAT provides high resolution interactive simulation whereby targets appearing on the screen are engaged using laser-firing weapons with authentic blast audio and recoil. Subjects were relatively young rifle-trained military volunteers with prior experience with the SAT. The subjects were also medically screened and a full explanation of the procedures, discomforts, and risks were given before written informed consents were obtained prior to their participation. All studies were approved by the Human Ethics Review Committee for Defence R&D Canada.

Subjects underwent the following procedure prior to each trial including familarization: i) calibration procedure (zeroing and grouping) of the rifle (C-7A1) and optical scope (C79), ii) donning of clothing required for the study, iii) completion of applicable questionnaires (typically on perceived exertion and thermal sensation), and iv) assumption of position/posture required for the study. In addition for thermally stressful trials, subjects self-inserted a rectal probe (Yellow Springs Instruments, Dayton, OH) for core temperature measurement, had heat flow transducers (Concept Engineering, Old Saybrook, CT) applied for various skin temperature measurements, and had a heart rate monitor (Sports-Tester, Polar Electro Oy, Kempele, Finland) strapped around their chest for heart rate measurement.

All trials were counterbalanced and conducted as a repeated measures ANOVA design, and analyzed accordingly with significance reported at $p < 0.05$. The Newman-Keuls test was used for post-hoc analyses where main differences were found. Textual results will be reported as mean ± SD and figure results will be presented as mean ± SE.

2.2 Moderate Thermal Exposure

Twelve subjects were thermally strained prior to testing by passive immersion in a water bath to achieve either a starting core temperature of 38.2ºC for the HOT trial, a heat loss of 1 $W \cdot h \cdot kg^{-1}$ body mass for the COLD trial, or thermal neutrality (no change) for the CONTROL trial (Tikuisis et al., 2002). Following the ~1 h immersion, the subject entered the SAT room respectively held at 35, 5, or 22ºC, changed into combat attire, and assumed a prone position in front of the SAT screen.

Over the next ~ 1.5 h, the subject underwent 16 shooting sessions of 5 min each in mixed order, half involving 5 randomly appearing pop-up lane targets (1.14 m high x 0.45 m wide) at 125 m range (vertical angle of target was 0.5º) and the other half involving 20 randomly appearing running targets from 50 to 200 m away in an urban scene. In each case, the subject was instructed to fire at the target when they perceived to

have the best chance of a direct hit, and was discouraged from using suppression fire. Performance was based on shooting accuracy (closeness to target centre of mass) and precision (shot group tightness) during the lane engagements, and on the number of shots fired and successful hits of the running targets.

The heating and cooling protocols caused significant separations in core temperature (Fig. 1), as expected. The trend of a decreasing core temperature in all trials is a normal response when assuming a prone position and does not imply that the individual was cooling during HOT and CONTROL (Tikuisis et al., 1996). The exaggerated cooling rate of the core during COLD reflects true cooling during the 5ºC air exposure. Top of the hand temperature reached 19.4 ± 3.0ºC by the end of COLD. The subjects rated their thermal sensations as comfortable, cold and warm at the end of CONTROL, COLD, and HOT, respectively. Perceived exertions were slightly tired (CONTROL and COLD) and moderately tired (HOT).
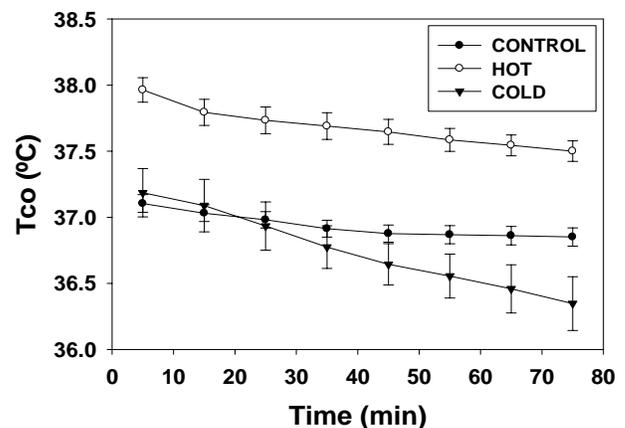

Fig.1. Mean ± SE of core temperature plotted against time.

Despite the thermal strains imposed during HOT and COLD, neither condition degraded shooting performance of the pop-up lane targets (Fig. 2) and running targets. In the former case, shooting error (SE, average shot distance from centre of mass) was fairly consistent at about 25 cm or 0.11º, but did tend to be higher during CONTROL. Shot mean radius (MR, average of the straight line distance between each shot and the center of impact) was also fairly consistent at about 14 cm or 0.06º. The overall hit percentage of running targets averaged 84.2%, which was quite consistent across all trials, and the ratio of shots fired over the number of targets hit averaged 51.3%.

The lack of any detrimental impact on performance, despite significant objective and subjective measures of thermal strain, led to the subsequent two

trials that pushed the limits of human tolerance to thermal strain.
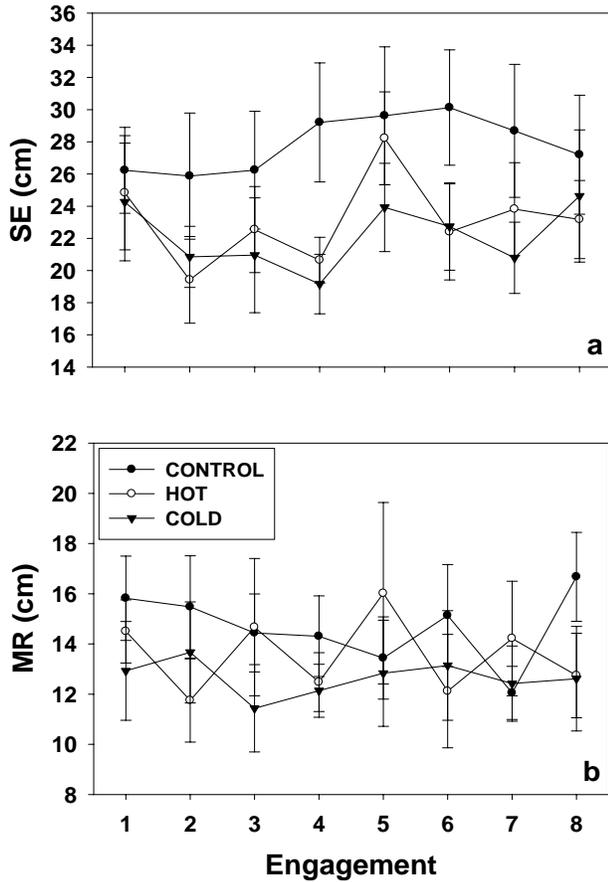
Fig. 2. Mean ± SE of a) shooting error (SE) and b) shot mean radius (MR) plotted against engagement session of pop-up lane targets.

2.3 Hot Exposure

Eleven subjects were exposed to uncompensable heat strain at 29ºC during two trials, one with hydration (HYD, where subjects were replenished with water) and the other without (DYD) (Tikuisis et al., 2005). The subjects wore a vapour-impermeable protective garment and walked on a treadmill at 3 km·h^{-1} for 25 min every half hour of the trial. In addition, water at 42ºC was circulated through a tube suit worn underneath the protective garment to control the rate of increase of core temperature. A third trial was conducted at 22ºC without any water circulation for control purposes (CONTROL). Each trial lasted 4 h unless the subject was removed due to complaint or upon reaching a core temperature of 39.5ºC.

During 15 min every half hour, the subject viewed a moving landscape in synch with their walking pace, and traversed through an open field, entered a

small rural village, and exited through open field again. During these segments of 5 min each, 8 foe and 4 friendly targets would appear randomly in time and location along an arc at 60 m range. Performance was based on target detection and engagement time, friend/foe discrimination, and shooting accuracy. Foe targets were identified by a disruptive dark green patterned uniform in a standing posture or disruptive light green patterned uniform in a kneeling posture; friendly target uniforms and postures were the opposite of the foes. These arbitrary target designations were chosen to challenge the subject with non-obvious presentations. The subjects were instructed to immediately squeeze the trigger of the rifle upon sighting a target. If friendly, they were to continue walking. If foe, they were required to quickly dismount the treadmill to secure a stable shooting position and take one well-aimed shot at the target, and resume walking immediately afterwards. Dismounting the treadmill was practiced and took an average of ~ 0.7 s.

The subjects attained high values of heat strain as attested by their significant rises in core temperature and heart rate during both HYD and DYH (Fig. 3), reaching average values of about 38.8ºC and 138 bpm by the end of the trials.
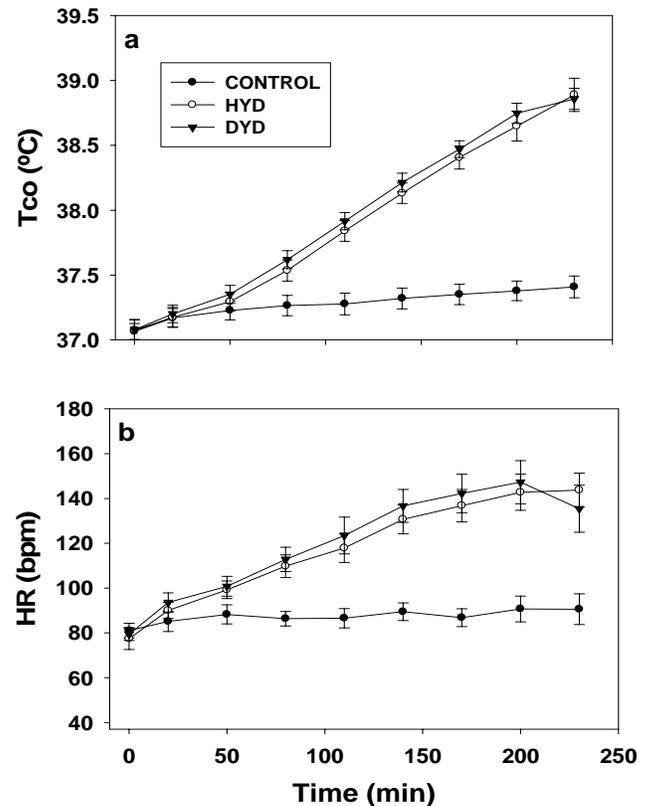

Fig. 3. Mean ± SE of a) core temperature and b) heart rate against time.

Surprisingly, however, neither trial nor time on task degraded the subjects' performance, as shown in Table 1 (not shown are the detection of friendly target results, which were similar to the foes).

Table 1. Initial and final measures of foe target detection and marksmanship where engage(ment) time includes ~0.7 s required for dismounting the treadmill before aiming and firing could take place, and %hit pertains only to the targets that were detected.

Measure	Time	CONTROL	HYD	DYD
% detected	Initial	94.7 ± 4.6	96.4 ± 3.9	96.2 ± 4.4
	Final	95.2 ± 5.7	96.1 ± 4.0	95.8 ± 3.7
% identified	Initial	94.8 ± 6.1	89.9 ± 12.3	94.8 ± 3.8
	Final	92.5 ± 5.5	96.3 ± 4.6	96.8 ± 2.8
detect time (s)	Initial	1.19 ± 0.26	1.27 ± 0.19	1.22 ± 0.23
	Final	1.28 ± 0.24	1.17 ± 0.27	1.15 ± 0.24
engage time (s)	Initial	4.65 ± 0.42	4.65 ± 0.40	4.75 ± 0.40
	Final	4.68 ± 0.31	4.64 ± 0.34	4.62 ± 0.37
% hit	Initial	75.1 ± 14.4	76.9 ± 12.8	74.5 ± 15.6
	Final	75.4 ± 17.5	71.2 ± 14.9	77.3 ± 10.3

2.4 Cold Exposure

Twelve subjects were exposed to cold (COLD) via a combination of 0ºC air environment while wearing shorts, a t-shirt, and a tube suit through which water at 5ºC was circulated (Tikuisis et al., 2006). Additional trials were conducted under thermal-neutral conditions (room at 22ºC) for control (CONTROL) and to test the efficacy of imposing a secondary (dual) task to enhance attentiveness during the sentry duty portion of the trial (DUAL). The secondary task was the FAAF (Four Alternative Auditory Feature) word recognition test (Foster and Haggard, 1987), which was administered every 15 min, took less than 1 min to complete, and was unrelated to the main task of target detection.

Subjects were challenged by two separate scenarios, one that involved engaging frequently appearing targets in an urban scene and the other involving the detection of fewer targets during sentry duty. The urban scenario, which lasted 15 min, was conducted at the beginning, mid-point, and end of the trial. The second scenario lasted 1 h and was applied twice, sandwiched between the urban segments. Sixty, mostly moving targets appeared in the urban scene anywhere from 25 to 250 m away, and of these 15 displayed hostile intent upon raising a weapon and aiming it at the subject. Further, 6 and 9 of these hostiles were civilians and soldiers, respectively. The subject was tasked with engaging all hostile targets. During sentry duty, the subject overlooked a 4 x 4 km mountainous/ desert terrain that contained 4 stationary targets that were always present and 8 moving targets that appeared randomly and briefly (10 s) during each 1 h observation period. The subject was tasked with detecting, identifying, and locating all targets, and assessing their threat (on a scale from 0 to 100), which was compared to

an expert's opinion. The threat was based on a combination of the location and lethality of the target.

The subjects were significantly cold-strained during COLD (Fig. 4). Core, finger, hand, forearm, and upper arm temperatures reached 36.3 ± 0.7, 10.8 ± 1.9, 17.5 ± 3.8, 22.4 ± 2.3, and 23.0 ± 3.1ºC, respectively, by the end of the trial, compared with overall average values of 36.7, 25.7, 29.0, 32.6, 31.5ºC for CONTROL and DUAL. Further, finger temperature was less than 15°C during COLD at all times except after the first 15 min of the exposure. Hand temperature was less than 19°C during COLD after the first sentry duty session. Heart rate was fairly consistent throughout all trials, averaging around 74 bpm. The subjects rated their thermal sensation during COLD as very cold by the end of the trial, yet their perceived exertion remained 'little' throughout all trials.
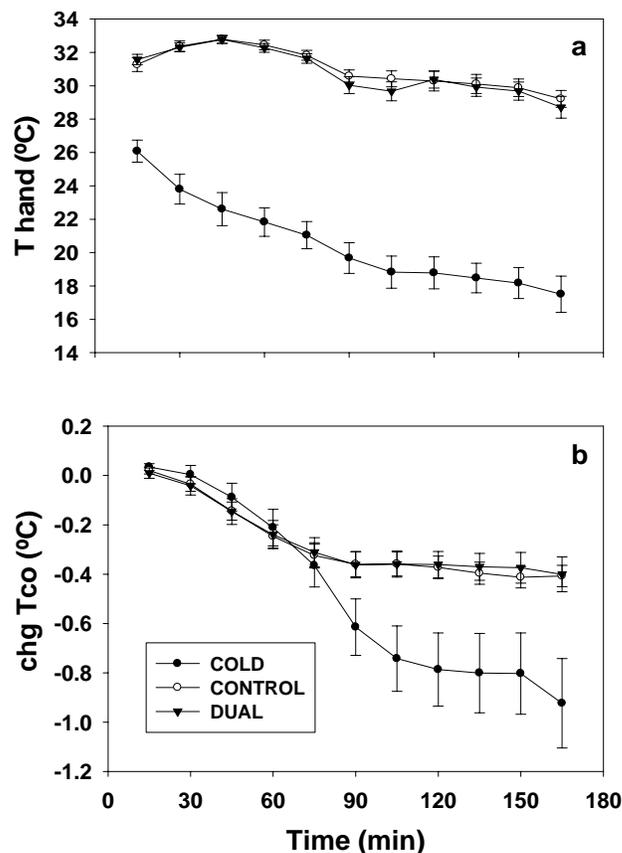

Fig. 4. Mean ± SE of a) hand temperature and b) change in core temperature against time.

The number of correct word recognitions (FAAF test) tended to decrease after the first sentry duty session during DUAL (25.0 ± 24.3 vs. 16.7 ± 22.3%), but the change was not significant. This secondary task failed, however, to enhance target detection compared to CONTROL.

4

Surprisingly, no degradation in performance occurred despite the considerable decreases in core and skin temperatures during COLD. Overall performance results are summarized in Table 2. The average percentage of hostile targets hit relative to the number engaged was 80% during the urban scenario. The percentage of targets detected during sentry duty was considerably higher for stationary vs. moving targets, yet their identifications and relative location errors were similar. The subjects' threat assessments of these respective targets were close to the expert's, differing on average by only +0.4 and -11.1 (+/-ve = over/under estimated) on a scale of 0 to 100.

Table 2. Mean results across all trials; % relative location error refers to the distance from the target to its estimated position relative to the target's distance from the subject.

Measure	Mean ± SD	Range
Urban Scenario		
% hostiles engaged	76.7 ± 8.7	62.0 – 90.0
% non-hostiles engaged	0.9 ± 0.9	0 – 2.5
% hostile targets hit	61.3 ± 14.7	22.7 – 80.7
hostile engage time (s)	4.0 ± 0.5	3.4 – 5.0
Sentry Duty		
Stationary Targets		
% targets detected	78.8 ± 11.5	60.0 – 91.8
% correctly identified	95.0 ± 6.8	83.3 - 100
detection time (min)	8.5 ± 3.7	4.3 – 16.6
% relative location error	42.4 ± 19.4	21.5 – 89.7
Moving Targets		
% targets detected	12.0 ± 8.9	0 – 25.0
% correctly identified	98.6 ± 2.4	93.8 - 100
% relative location error	39.1 ± 25.3	11.0 – 84.3

2.5 Exercise Fatigue

Twelve subjects underwent an exercise regime that began with a 2.5 h loaded (25 kg backpack) march at 6 km·h⁻¹ and ended with a 1 h period of sandbag wall construction (20 x 15 kg bags moved back and forth across a 4.5 m room) (Gillingham et al., 2004). Subjects completed 4 trials: PP, PC, CP, and CC where P and C refer to placebo and caffeine ingestion, respectively. The first and second letters designate which was given, by capsule, at the start and at the end of the exercise period (if caffeine, then at 5 and 2.5 mg·kg⁻¹ body mass, respectively). 100 mg of caffeine is approximately equivalent to the caffeine in a cup of coffee, hence, the initial and re-dose caffeine ingestions represent 4 and 2 cups of coffee, respectively, for an 80 kg individual.

Following exercise, the subject conducted a marksmanship task that began and ended with a 10 min urban scenario where 48 randomly appearing targets at 30 – 60 m range walked or ran across a street taking between 1.5 and 2.8 s. Between these sessions, the subject was presented with 30 lane pop-up targets at 200

m range appearing randomly for 4 s over two consecutive 1 h periods. The subject was tasked with engaging targets with unlimited rounds during the urban scenario and engaging targets with a single shot during the 2 h vigilance scenario. Performance was based on the number of shots fired (urban scenario), number of targets hit, and engagement time (vigilance scenario).

Pre-shooting caffeine levels in the blood were 3.5 ± 3.9, 19.8 ± 13.2, 28.8 ± 12.0, and 40.4 ± 16.5 µmol·L⁻¹ for PP, PC, CP, and CC, respectively. Despite these differences, caffeine had no effect on marksmanship for both the urban and vigilance scenarios (Fig. 5). The respective overall ratios of hits to shots fired were 41.3 and 56.0%. Caffeine did, however, lower the engagement time slightly, but significantly for CC (2.82 ± 0.27 s) compared to PP (3.00 ± 0.26 s) during the vigilance scenario (engagement times for PC and CP were not affected).
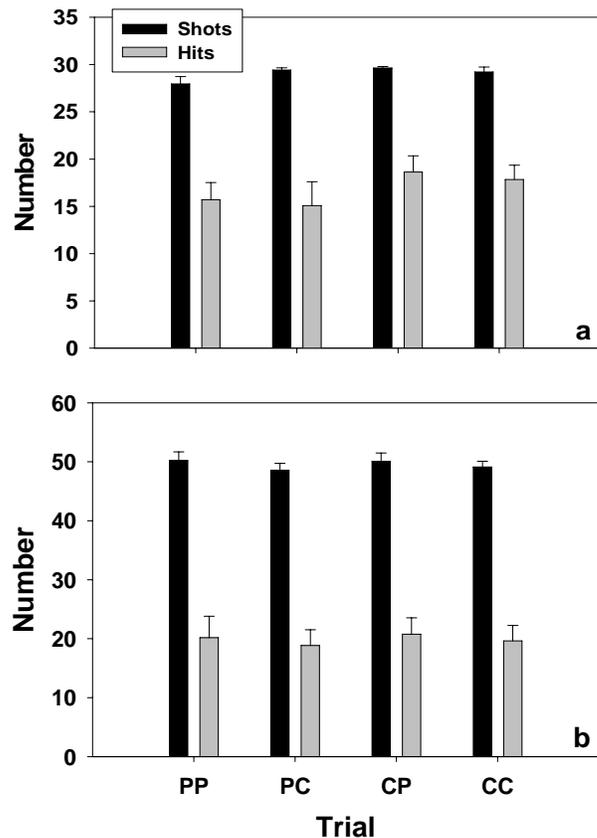
Fig. 5. Mean ± SE of the number of shots and hits during the a) vigilance (out of 30 targets per session) and b) urban (out of 48 targets per session) scenarios.

2.6 Sleep Deprivation

Twenty subjects underwent two trials of 22 h of active wakefulness before being tested on target detection and marksmanship (Tikuisis et al., 2004). Pre-

testing activities included a mixture of mental and physical tasks (McLellan et al., 2004). Subjects were also given 400, 100, and 100 mg of CAFFEINE (via chewing gum) or PLACEBO at 7.5, 3, and 0 h prior to testing.

Fifteen hostile and 5 non-hostile lane pop-up targets at 200 m range appeared for 4 s randomly in time over two consecutive 30 min periods. Performance was based on friend/foe discrimination, target engagement time, and marksmanship. Comparisons were also made with BASELINE measurements taken 18 h prior to testing (i.e., after 4 h of wakefulness).

The number of friend/foe errors was consistently low throughout the trials (0.9 ± 1.4, 0.8 ± 1.4, and 0.9 ± 1.7% for BASELINE, PLACEBO, and CAFFEINE, respectively). Target engagement time, on the other hand, was affected by sleep deprivation, increasing from a BASELINE value of 3.03 ± 0.26 s to 3.29 ± 0.17 s during PLACEBO (Fig. 6). However, it was restored (3.04 ± 0.25 s) during CAFFEINE.
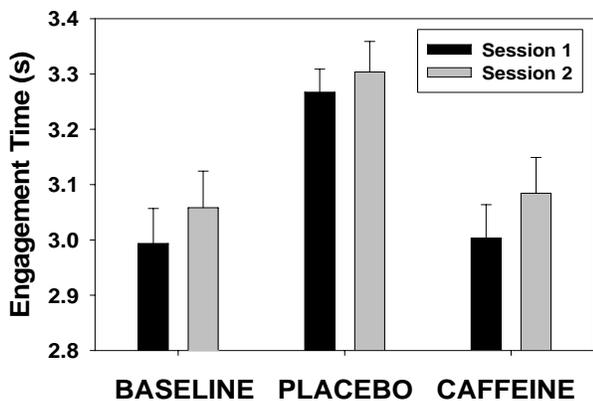
Fig. 6. Mean ± SE of target engagement times during both 30 min sessions, which was significantly higher during PLACEBO than the other two conditions.
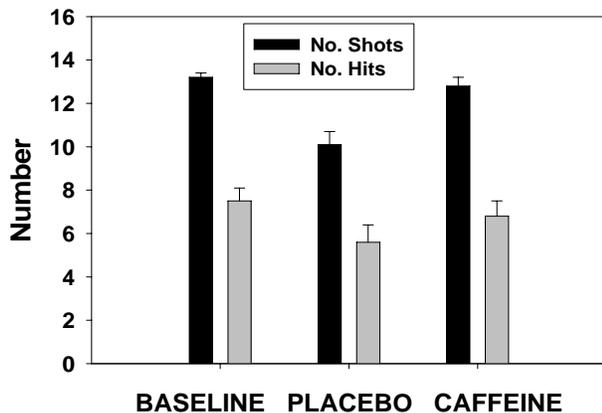
Fig. 7. Overall mean ± SE of the number of shots and hits of both 30 min sessions, which was significantly lower during PLACEBO than the other two conditions.

Caffeine also restored the number of shots fired (Fig. 7), but not accuracy (although the number of hits tended to be higher than PLACEBO). The overall ratios of hits to shots fired were 56.8, 55.4, and 53.1% for BASELINE, PLACEBO, and CAFFEINE, respectively.

Shooting error (SE) and the shot mean radius (MR) were affected by sleep deprivation and caffeine (Fig. 8). SE increased during the second session in both trials compared to BASELINE. MR was also higher for both PLACEBO (due to its value during the second session) and CAFFEINE.
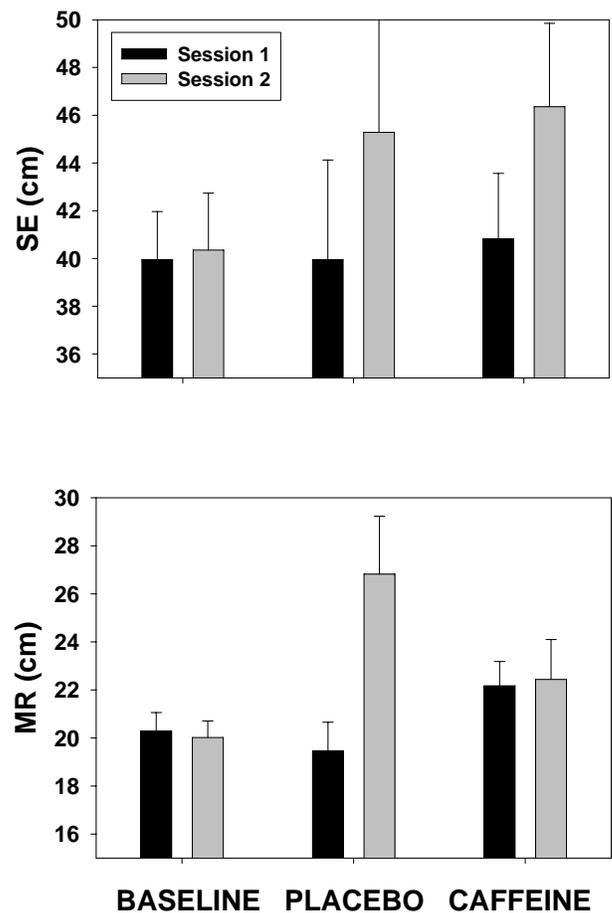
Fig. 8. Mean ± SE of shooting error (SE) and shot mean radius (MR) during both 30 min sessions.

3. DISCUSSION

The overwhelming impression that emerges from this series of studies is that humans can be highly tolerant to various stressors despite significant measures of physiological strain when tasked with target detection, identification, and marksmanship. The exceptions to this are fatigue, which impairs one's ability to detect targets and specific aspects of marksmanship seen in the sleep deprivation study. However, attention deficit due to

fatigue can largely be reversed with caffeine ingestion. On the other hand, attempts to enhance attention during sentry duty using a secondary task (FAAF in this case) did not succeed.

The first study in this series involved moderate levels of heat and cold exposure that not only failed to demonstrate performance impairment, but actually indicated that certain aspects of marksmanship improved (Tikuisis et al., 2002). This was attributed to a beneficial, albeit discomforting, arousal that promoted task-focusing (Enander and Hygge, 1990). That no degradation in performance occurred was also attributed to thermal strains that were perhaps insufficiently severe according to Ramsey (1995) with regard to the heat exposure, and to Reading et al. (1994) who suggested that suppression of shivering can mitigate poor aim during cold stress. These findings were the impetus for increasing thermal strain in search of a threshold effect.

Objective and subjective measures in the subsequent hot and cold trials confirmed that significantly higher levels of heat and cold strain were achieved than in the previous study. Indeed, only 7 out of the original 11 subjects lasted the 4 h heat exposure, reaching a mean core temperature of 38.8ºC, yet again without any decrement in performance. That the subjects were at or very close to the end of their heat tolerance suggests that any degradation in performance would not likely occur until physiological heat collapse. During the cold exposure trial, core and skin temperatures evoked a noticeable shivering response, but marksmanship was still unaffected, which can again be attributed to a conscious suppression of shivering tremor given that engagement times were brief. Indeed, the briefness of target engagement is perhaps the key to the subjects' ability to perform well under physiological strain in contrast to several other reports of degradation involving psychomotor performance of longer duration (eg., Enander, 1987; Epstein et al., 1980). In other words, the subjects were able to surmount their thermal strain and engage targets at or near baseline level performance during the 6 s or less of target detection and engagement periods.

This still leaves open the threshold for marksmanship degradation during cold exposure. Clearly, cold strain must be more severe than finger, hand, and core temperatures of 10, 17, and 36ºC, respectively, attained in the cold study. Yet, to achieve hand/arm incapacitation and/or uncontrollable shivering requires prolonged or very intense exposure to either cold air or immersion in cold water, which must be balanced against the likelihood of such cold strain occurring operationally. Sentry duty and missions that require traversing cold water are possible candidates that might warrant further investigation in this area.

The detection of targets during sentry duty in the cold study displayed an interesting dichotomy unrelated to any actual exposure to cold. Nearly 80% of stationary targets were detected (across all trials) in contrast to only 12% of moving targets. This difference can perhaps be explained by noting that stationary targets were detected relatively early (mean time of 8.5 min) whereas the moving targets required attention throughout the 1 h sentry duty. It is conceivable that the subjects lost focus/interest soon after the task began, or that the detection of moving targets was more difficult than anticipated (it turned out that the detected moving targets were half as far away as the detected stationary targets). That the stationary targets were detected quickly can also help explain why the secondary task was inconsequential during DUAL, since the first FAAF was administered 15 min after the task began, long after most targets were detected. It is also apparent that the FAAF test failed to improve the detection rate of the moving targets throughout the 1 h task.

Neither exercise fatigue nor sleep deprivation caused any serious degradation in target identification and marksmanship (notwithstanding the minor increases in shooting error and shot mean radius due to sleep deprivation). Target engagement time, on the other hand, was delayed by fatigue, which was effectively restored with caffeine ingestion. Further, there was no evidence that caffeine consumption negatively impacted on marksmanship. These findings concur with other studies that, for example, have demonstrated that 200 - 250 mg of caffeine can be used to enhance cognitive and psychomotor performance (Lieberman, 2001; Rees et al., 1999). Johnson and Merullo (2000) found that 200 mg of caffeine reduced friend-foe discrimination errors and diminished the decrement in target detection time associated with time on the task during sentry duty, while not affecting marksmanship capability. Similarly, Lieberman et al. (2002) found that the administration of 200 and 300 mg of caffeine did not negatively affect marksmanship in sleep-deprived Navy SEAL Trainees, but did improve their performance of a visual vigilance task.

4. CONCLUSIONS

These findings involving thermal exposure, physical exertion, and sleep deprivation suggest that marksmanship, which in this case required intense, but short-term focus (i.e., 6 s or less), can be competently managed under significant levels of physiological strain. Still unknown is the threshold for performance degradation due to cold, which would have to be substantially severe beyond the strain documented herein. Fatigue might delay the detection of a target, but not seriously affect its engagement, as if the individual becomes sufficiently aroused and therefore invariant to

their state of physiological strain after they have detected a target. This also suggests that it would be naïve to simply extrapolate the negative effects of stressors on psychomotor performance, as reported by others (Enander, 1987; Epstein et al., 1980), to marksmanship. In other words, the effects on performance, or lack of, due to various stressors should be considered task-specific.

In addition, it would be prudent to be aware of the absence of the psychological stress of lethal danger when conducting experimental studies as described herein. Whether the operational consequences of stressors are negligible with respect to target detection, identification, and marksmanship remains to be ascertained in the presence of lethal danger either through well-documented case histories or increasingly realistic simulations.

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Target Detection, Identification & Marksmanship Under Various Types of Physiological Strain

Peter Tikuisis, DRDC Toronto

25th Army Science Conference 2006

Defence R&D
Canada

R et D pour la défense
Canada

Canada

- **Rationale**
- **Studies**
- **Summary**

Data Challenge

high

Resolution ↑

Laboratory	**SAT offers improved realism in laboratory setting**
	Field

low ⟶ **Validity** ⟶ high
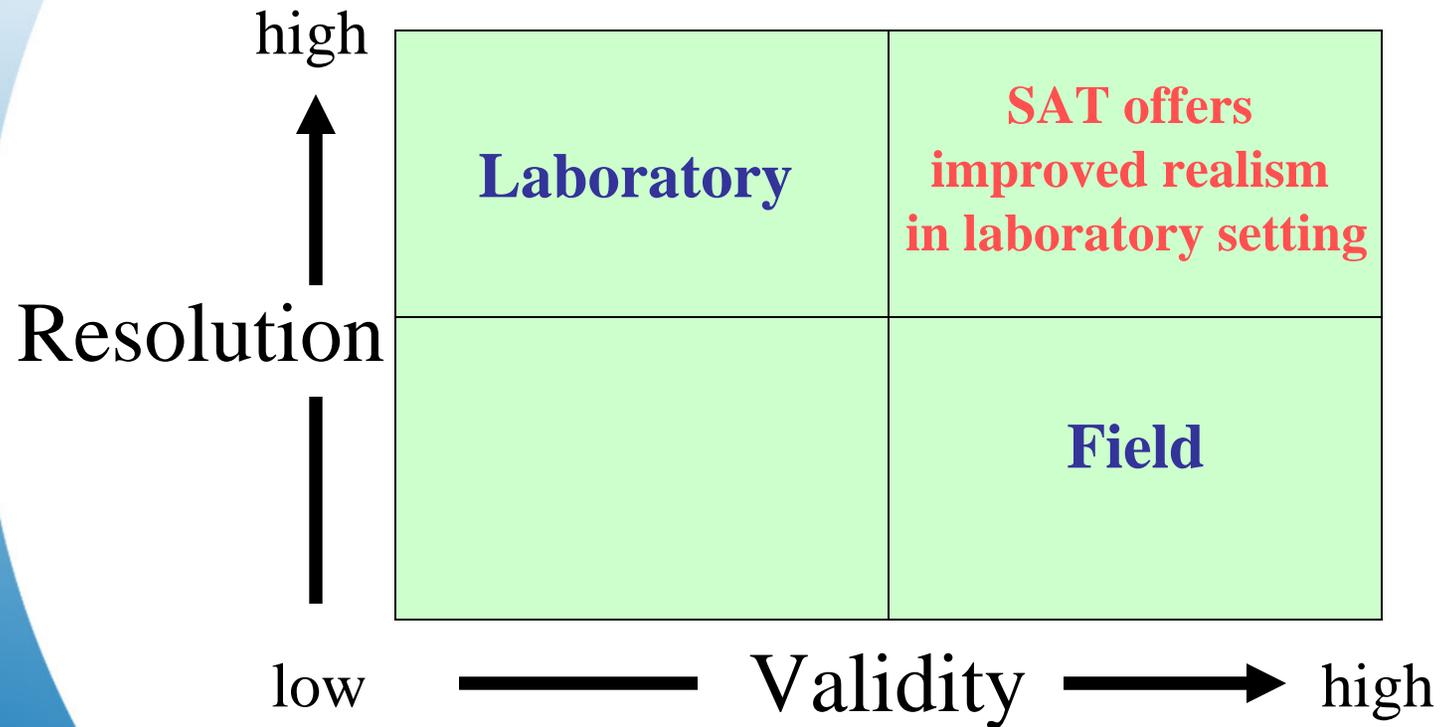
Small Arms Trainer (SAT)
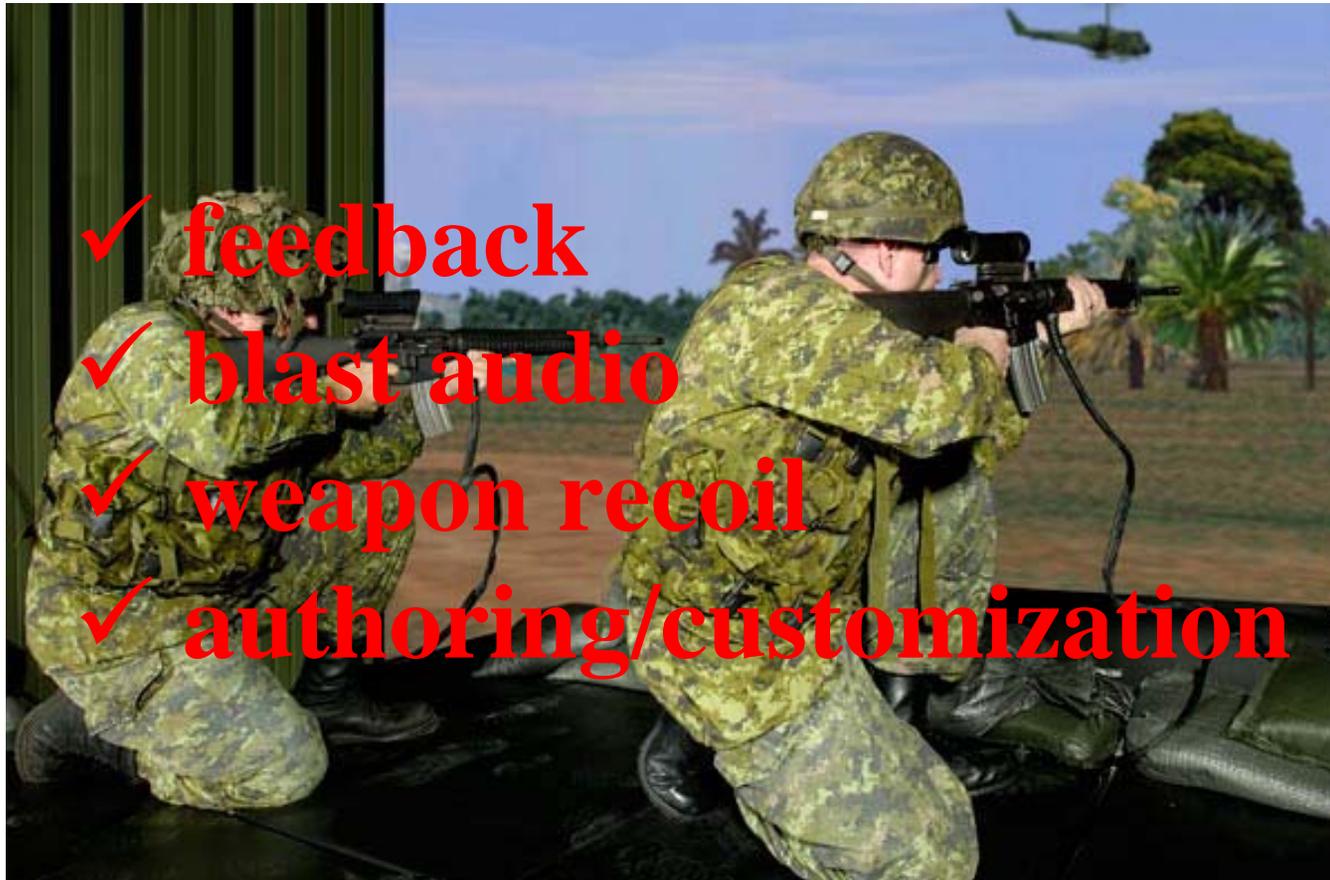
✓ **feedback**
✓ **blast audio**
✓ **weapon recoil**
✓ **authoring/customization**

Goal & Purpose

Quantify the effect of stressors on Target Detection, Identification & Engagement:

- thermal exposure (heat & cold)
- fatigue (heavy physical activity, sleep loss)

To advise/improve:

- doctrine & training (tactical/operational use of force)
- simulation of combatant behavior in training and wargamming

Defence Research and Development Canada - Toronto

Studies

1) **Moderate Thermal Exposure**
2) **Hot Exposure**
3) **Cold Exposure**
4) **Exercise Fatigue**
5) **Sleep Deprivation**

Moderate Thermal Exposure

8 lane + 8 urban 5 min engagements per trial (CONTROL, HOT, & COLD)
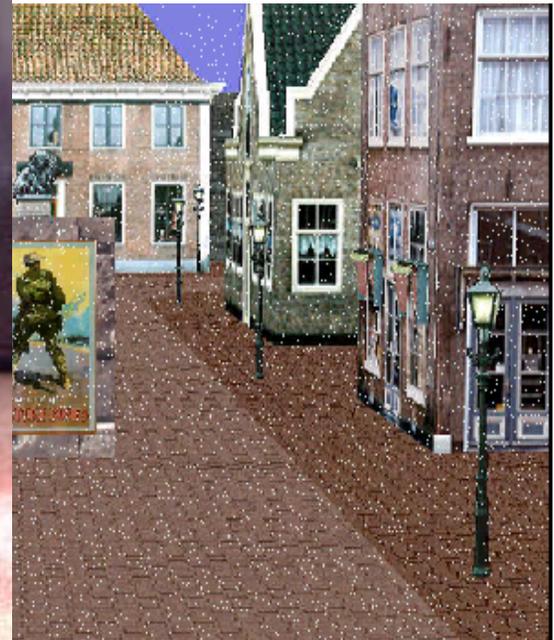
lane
- **5 targets**
- **125 m range**

urban
- **20 targets**
- **50 - 200 m range**

Moderate Thermal Exposure
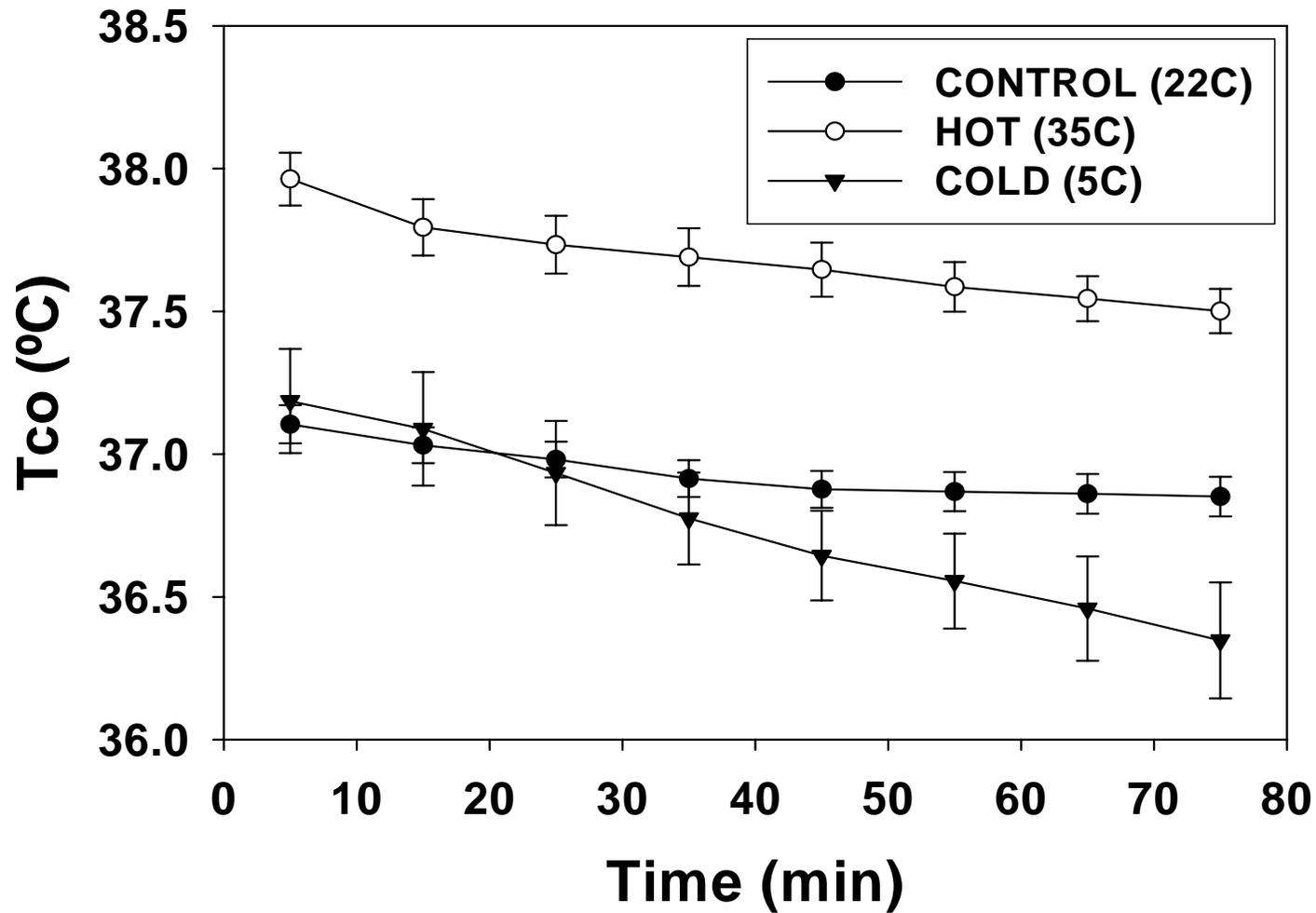
Moderate Thermal Exposure
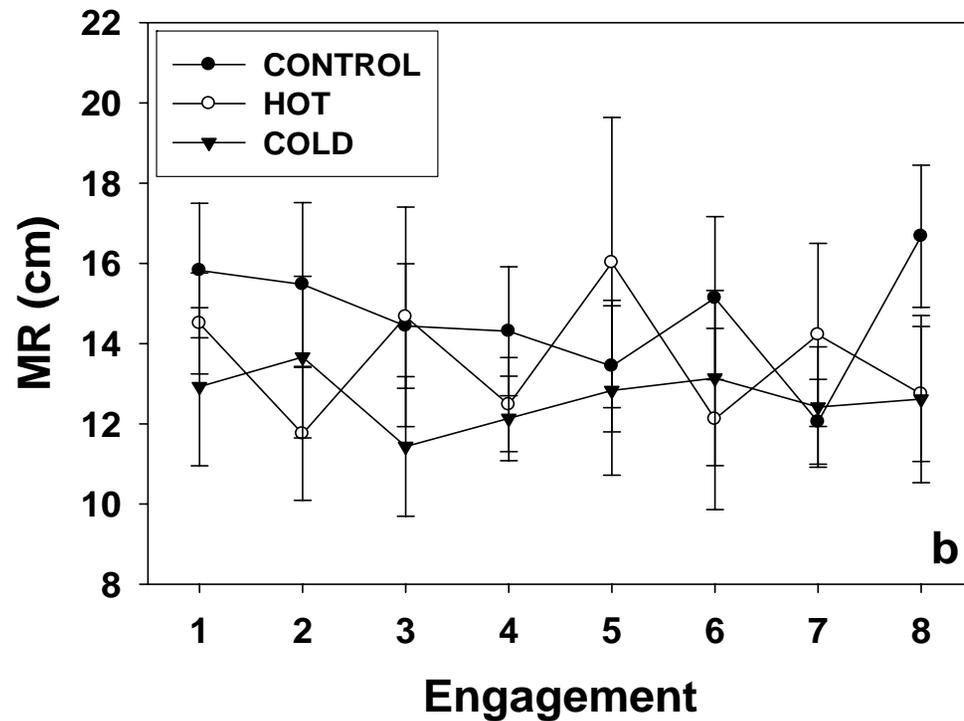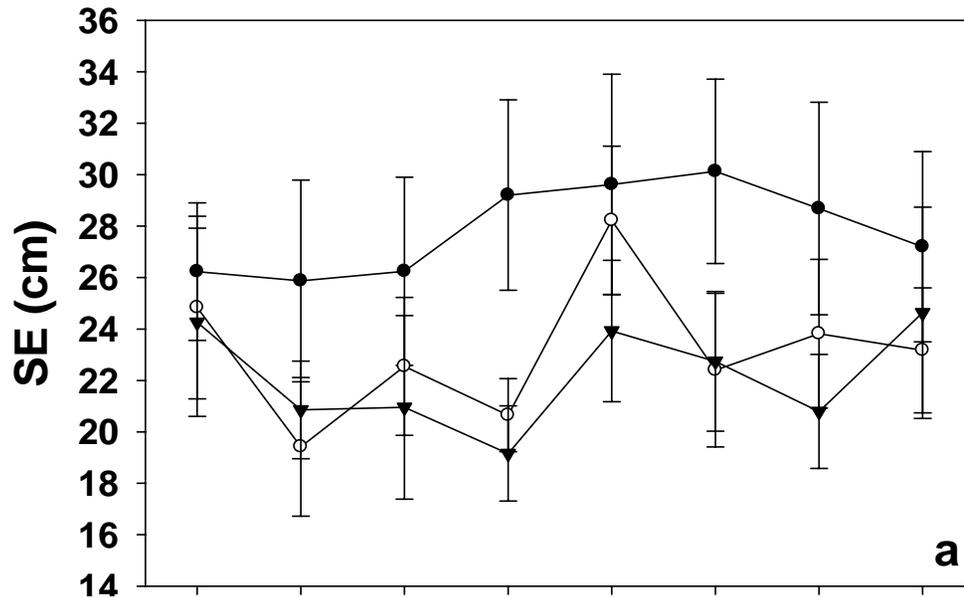
Mean ± SE of
a) Shooting Error (accuracy)
b) Shot Mean Radius (precision)

Conclusion: Moderate levels of heat and cold strain do not degrade marksmanship.

Hot Exposure

Hot Exposure
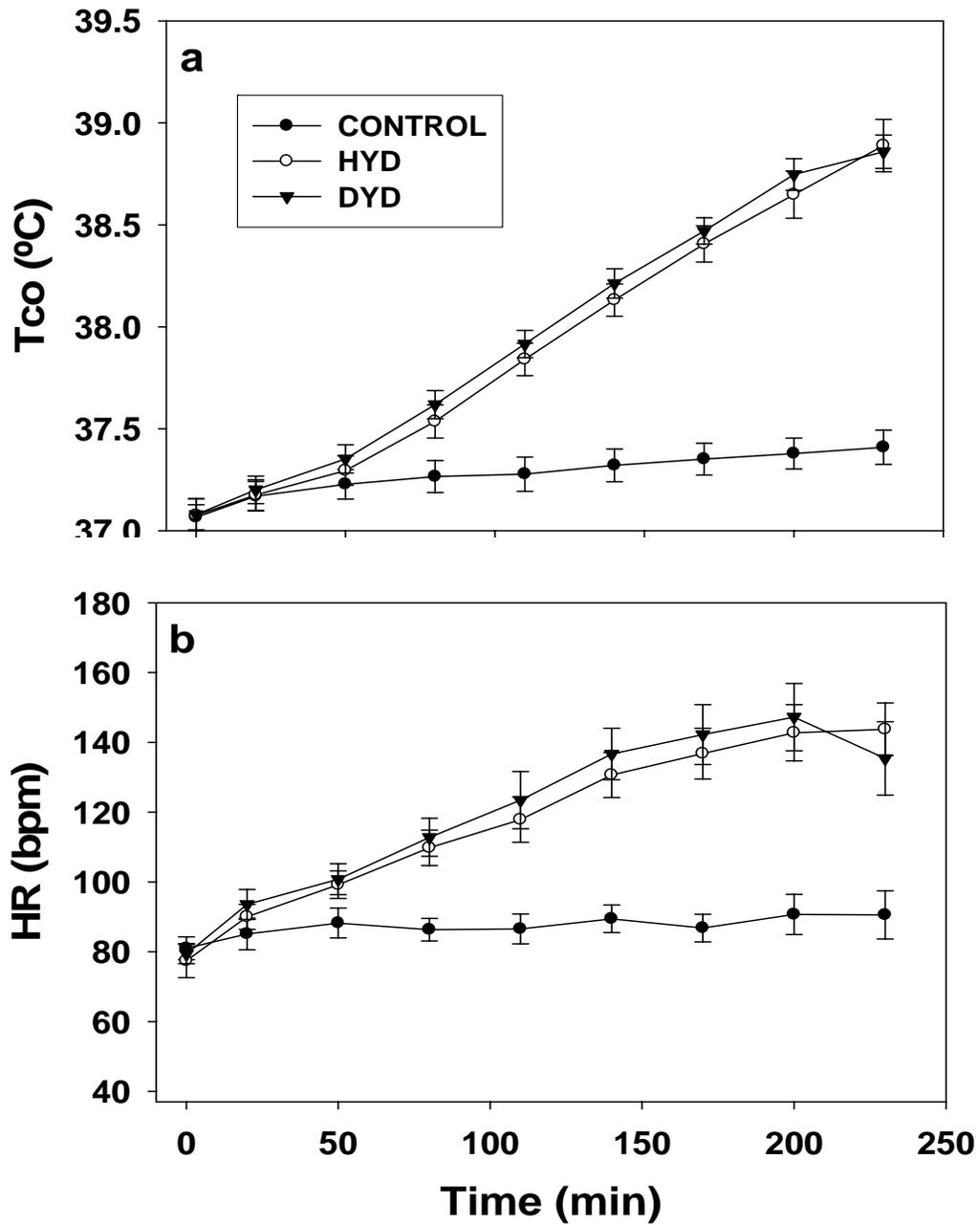
Mean ± SE of
a) core temperature and
b) heart rate against time

Hot Exposure
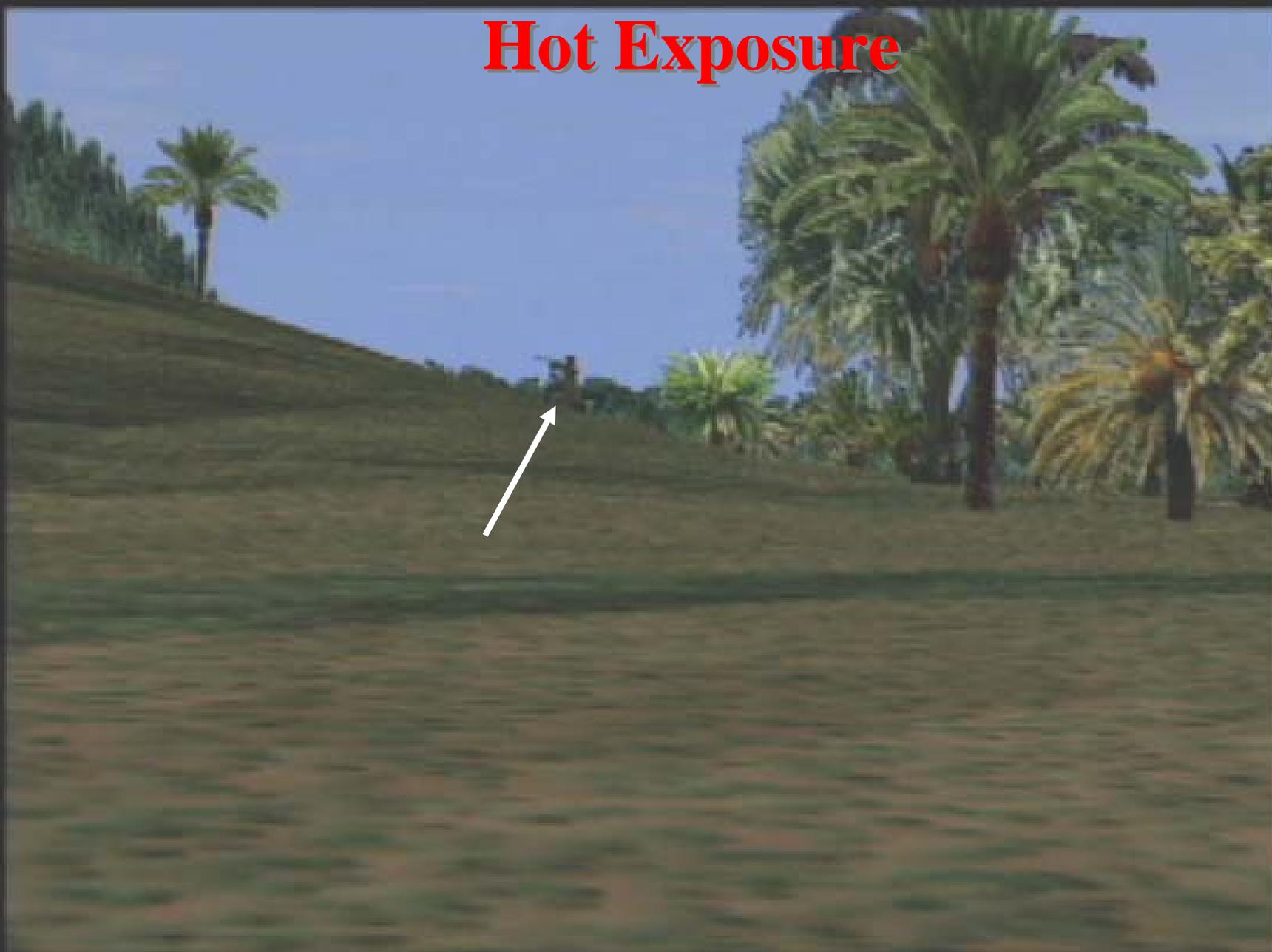
Hot Exposure
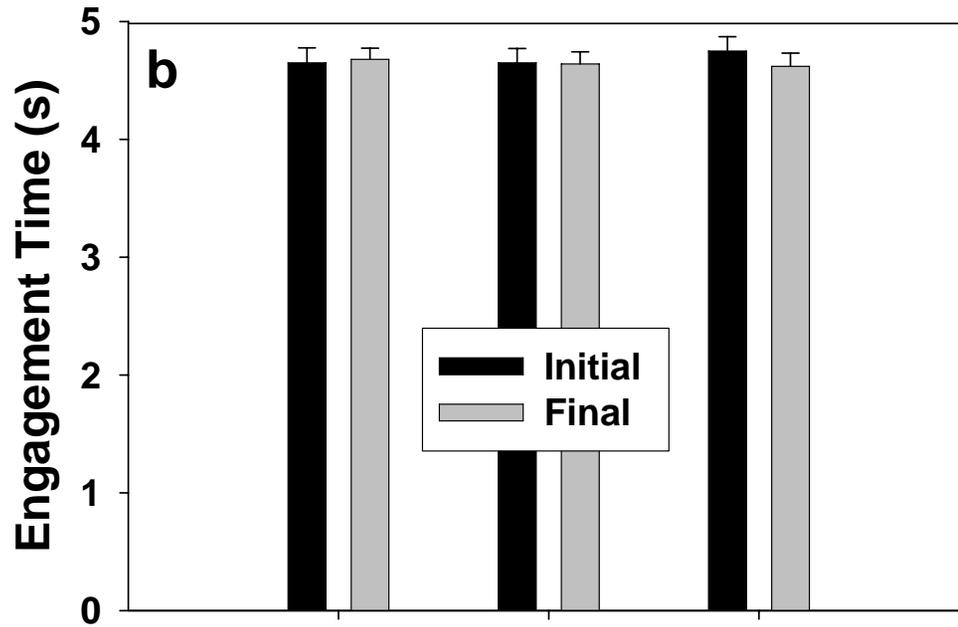
Hot Exposure

Hot Exposure

Mean ± SE of
a) % targets hit
b) engagement time
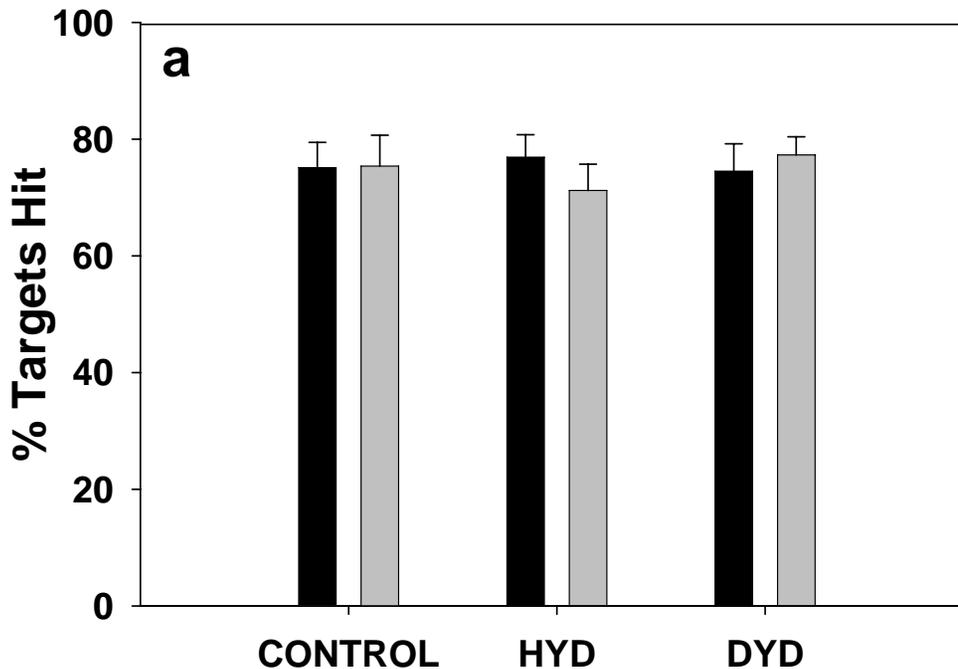
Conclusion: Despite significant heat strain, subjects were able to detect, identify, and engage targets at baseline levels.

Cold

Exposure

Cold Exposure
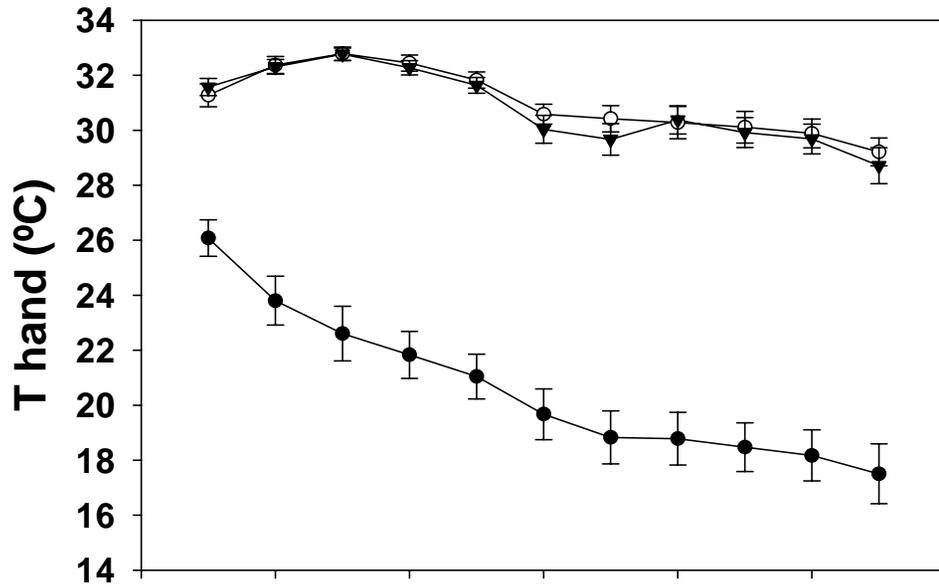
CONTROL Trial – 22°C

COLD – Chamber 0°C, vest circulated with 5°C water

DUAL – Word identification task every 15 min during TDI (Tair at 22°C)

Legend:
- COLD
- CONTROL
- DUAL

Cold Exposure

Weapon Calibration | TDI 1 | TDI 2 | TDI 3
TDE 1 | TDE 2 | TDE 3

TDE

TDI

12:01:20

6x
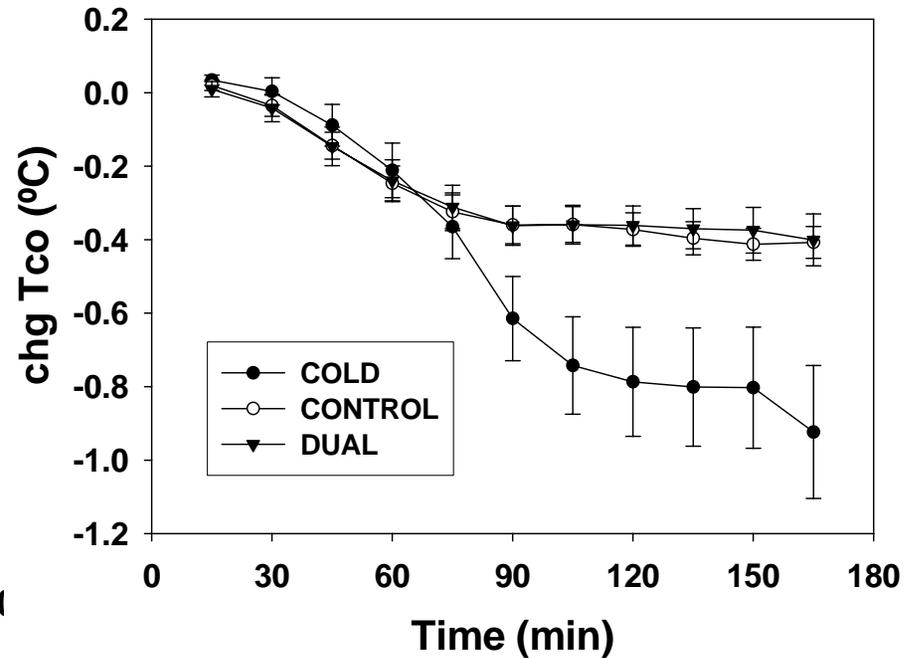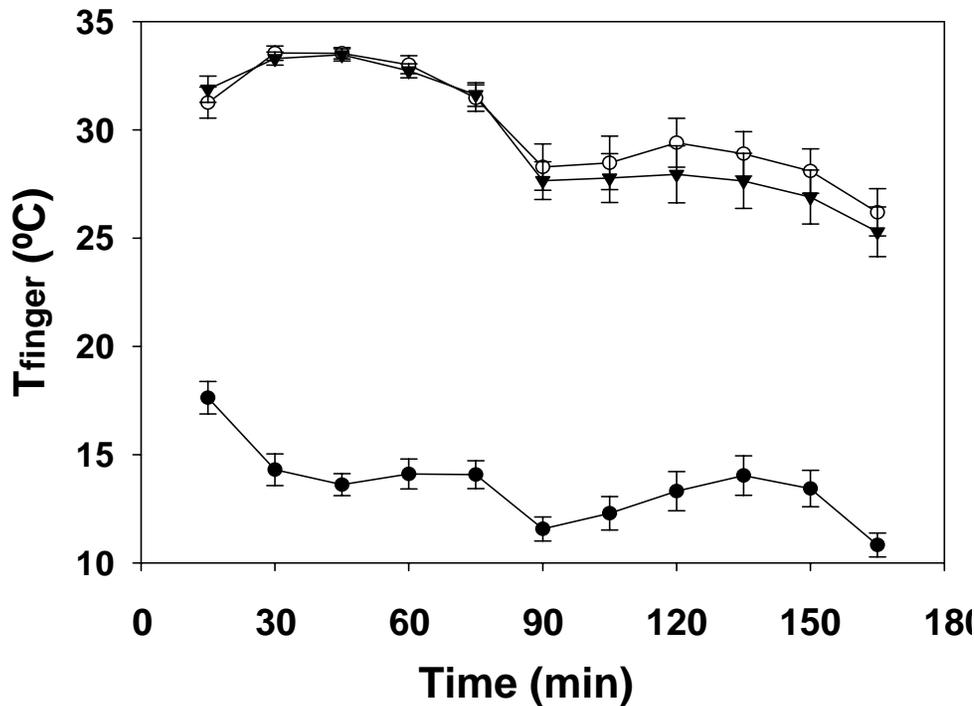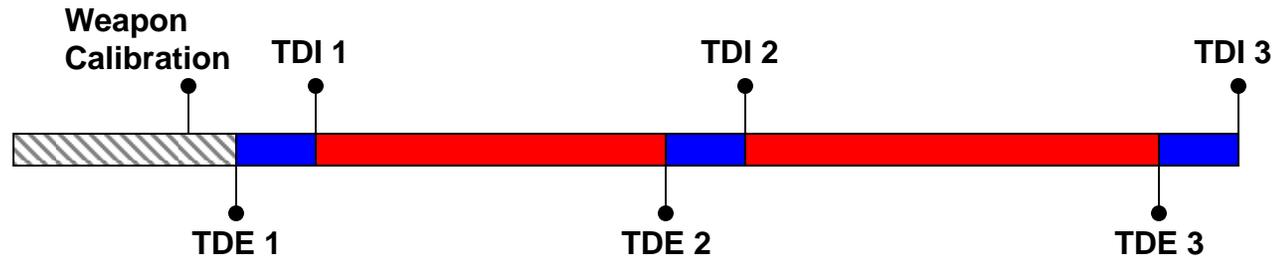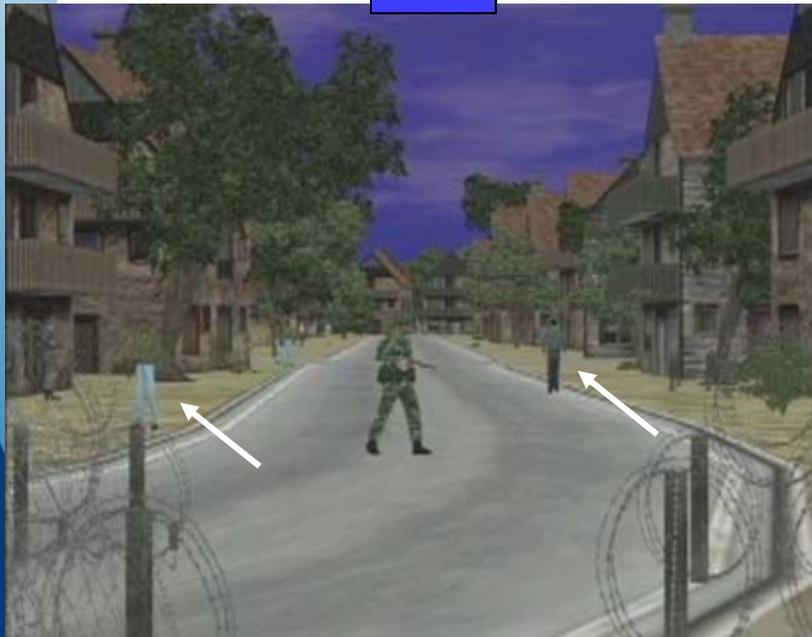
45 friendly + 15 hostile targets from 25 – 250 m
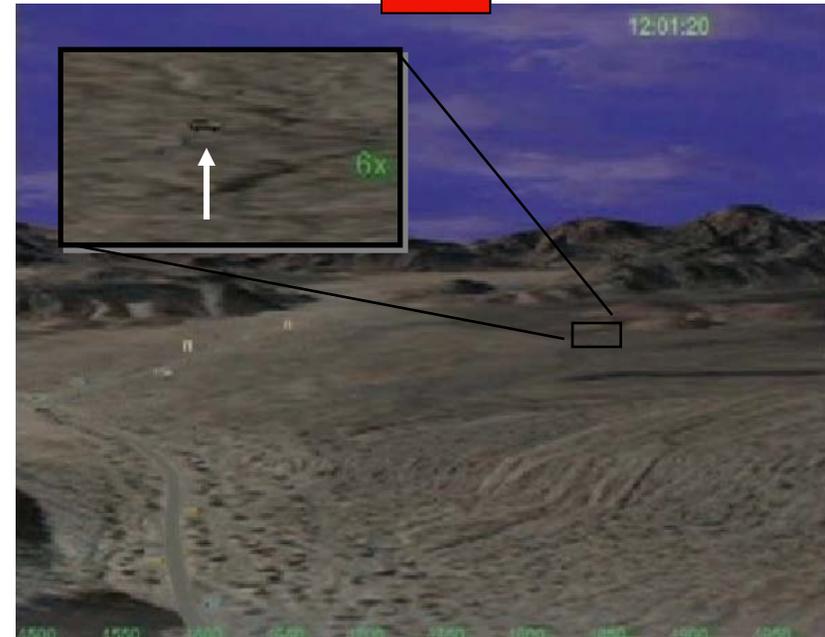
4 static + 8 moving targets up to 3000 m range

Cold Exposure
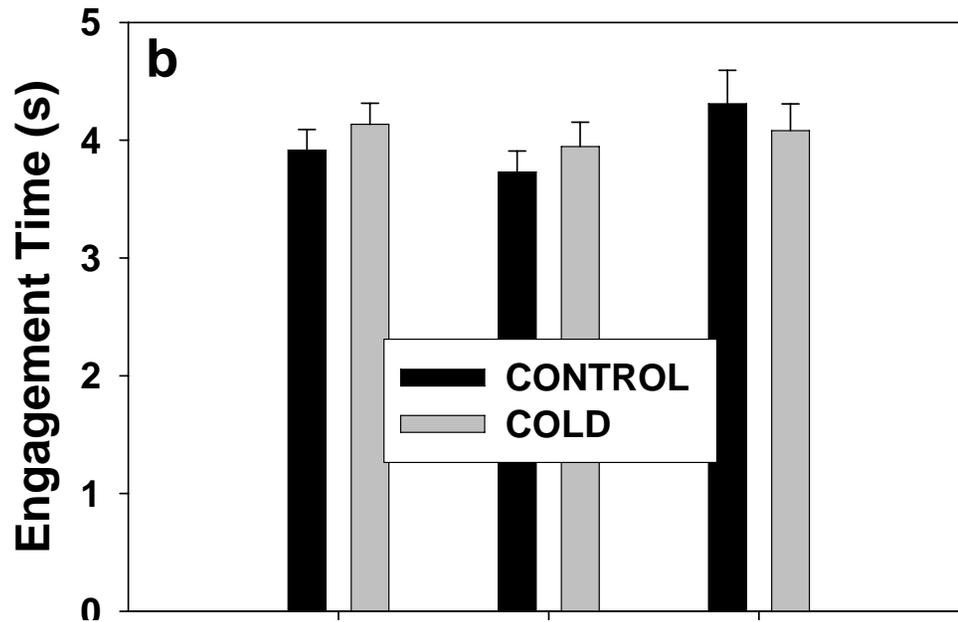
Mean ± SE of
a) % targets hit
b) engagement time
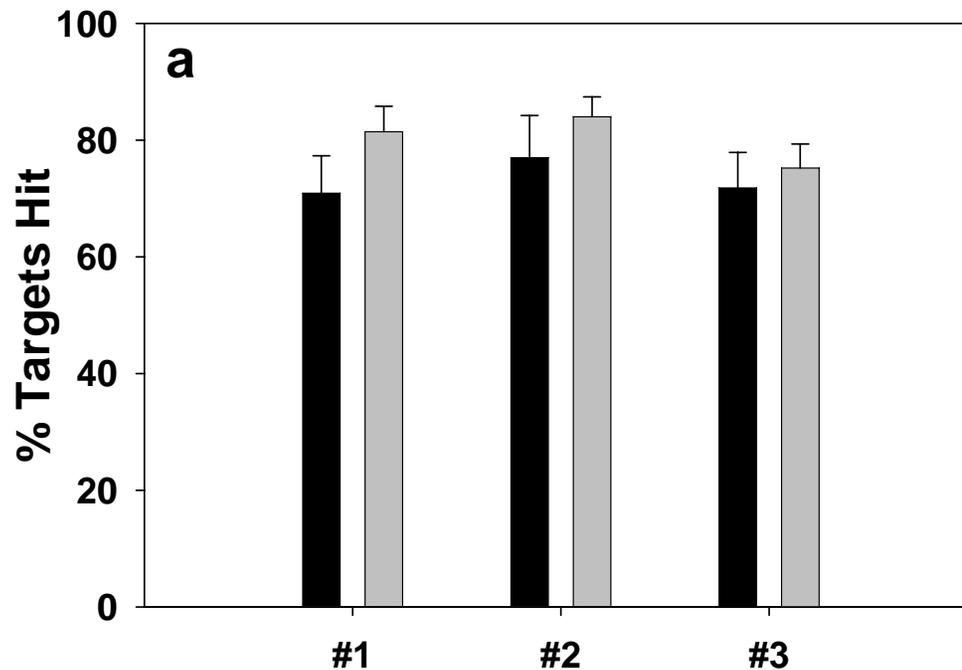
Conclusion: Despite significant cold strain, subjects were able to detect, identify, and engage targets at baseline levels.

Exercise Fatigue

Rifle zeroing	13 km loaded march	Sandbag wall construction	Pre-Shooting	Shooting session	End
Ingestion of P or C	VO$_2$	Saliva sample	Nude weight	(10 min FF +	TS
Breakfast	TS & RPE	TS & RPE	Rehydration	2 h VIG +	RPE
Nude weight			**Re-dose of P or C**	10 min FF)	TLX
Dress/Fatigues			Meal	TS & RPE	ESQ
Blood sample			Dress/Combat		
Saliva sample			Blood sample		
Exercise prep			Saliva sample		
TS & RPE			TS & RPE		
0645 h	0800	1030	1130	1300	1700

Exercise Fatigue
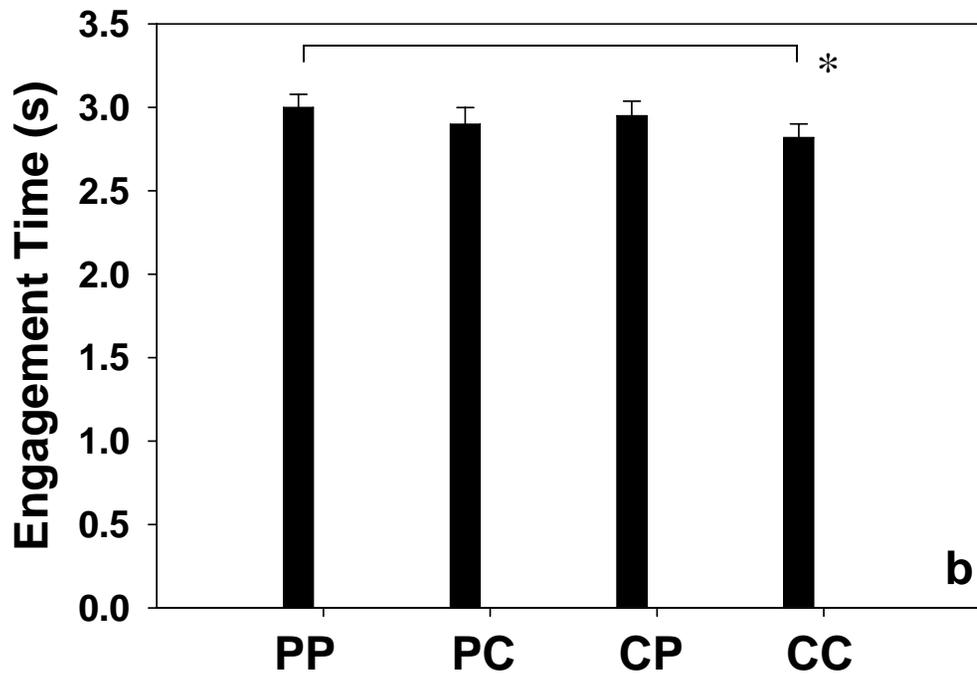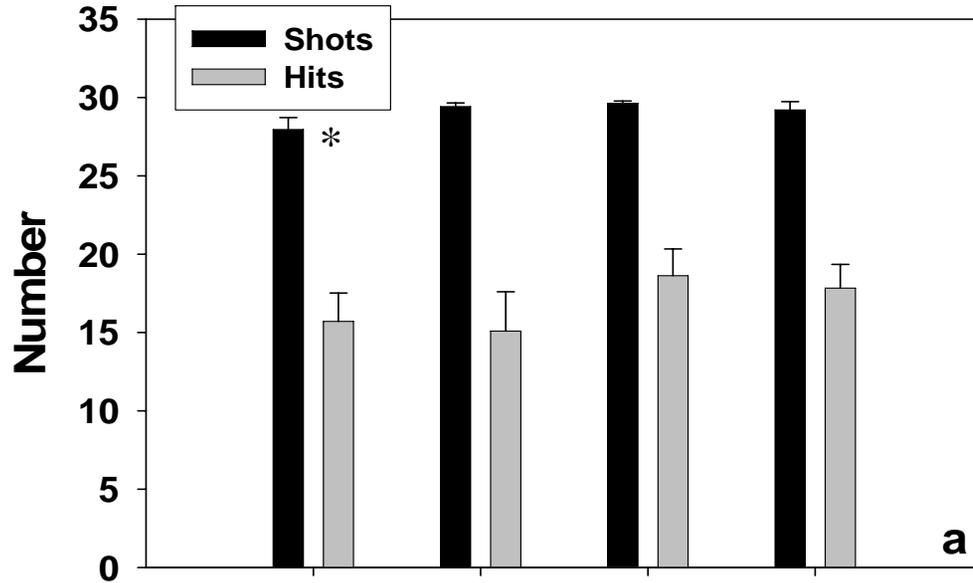
Mean ± SE during vigilance of
a) the number of shots and hits
    (out of 30 targets per hr)
b) target engagement time

Conclusion: Fatigue affected engagement time and number of shots fired during vigilance, which were improved by caffeine without an adverse affect on marksmanship.

# Sleep Deprivation
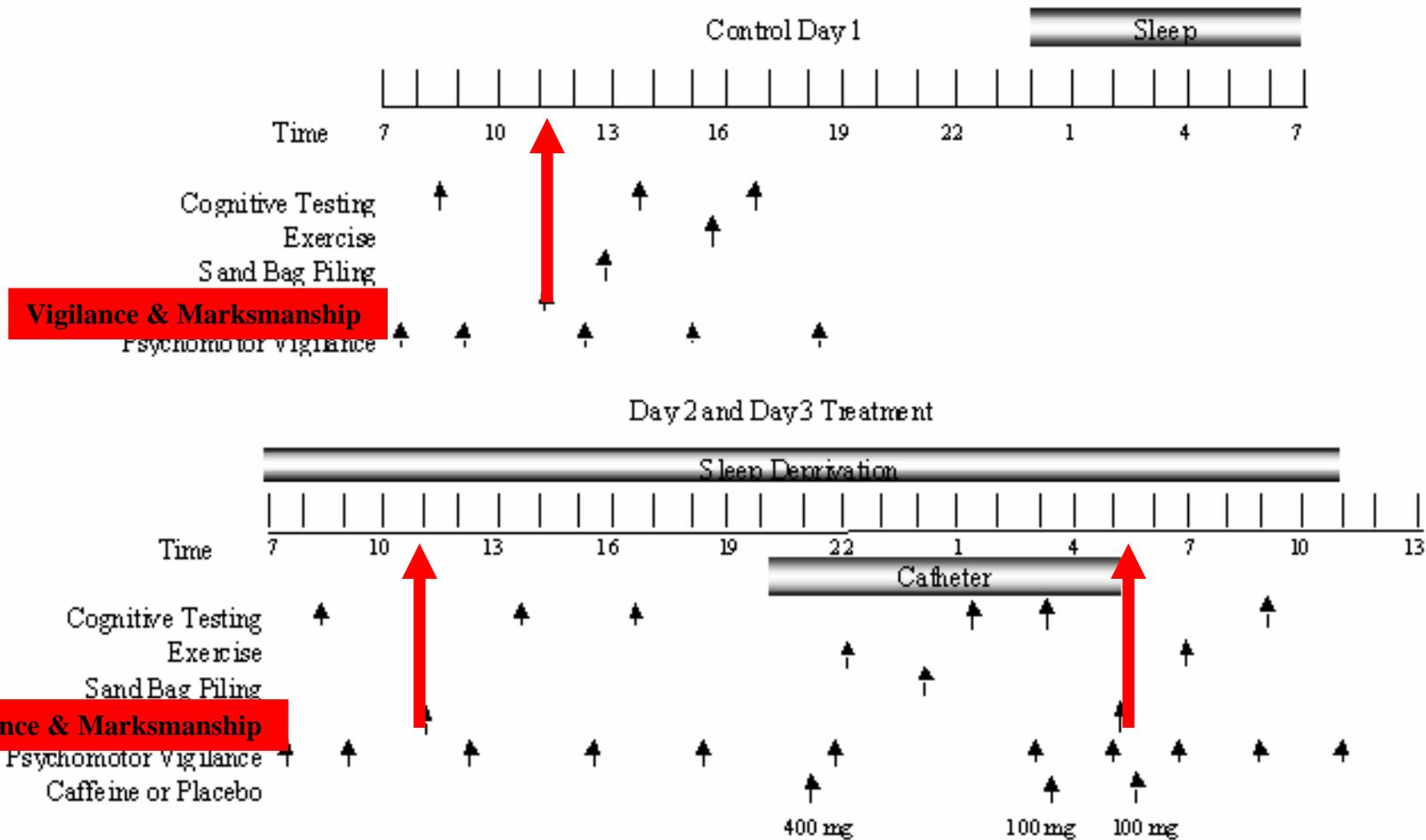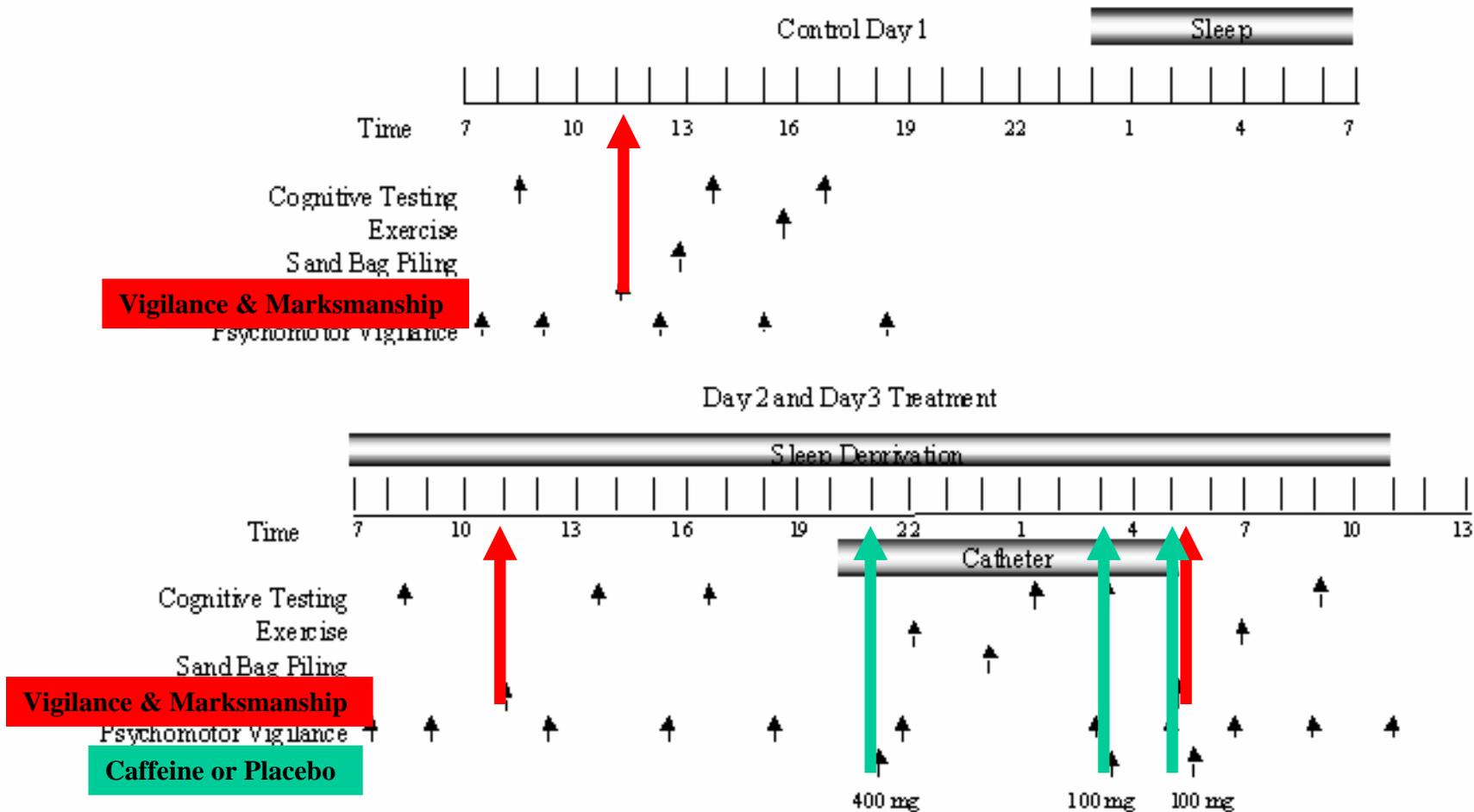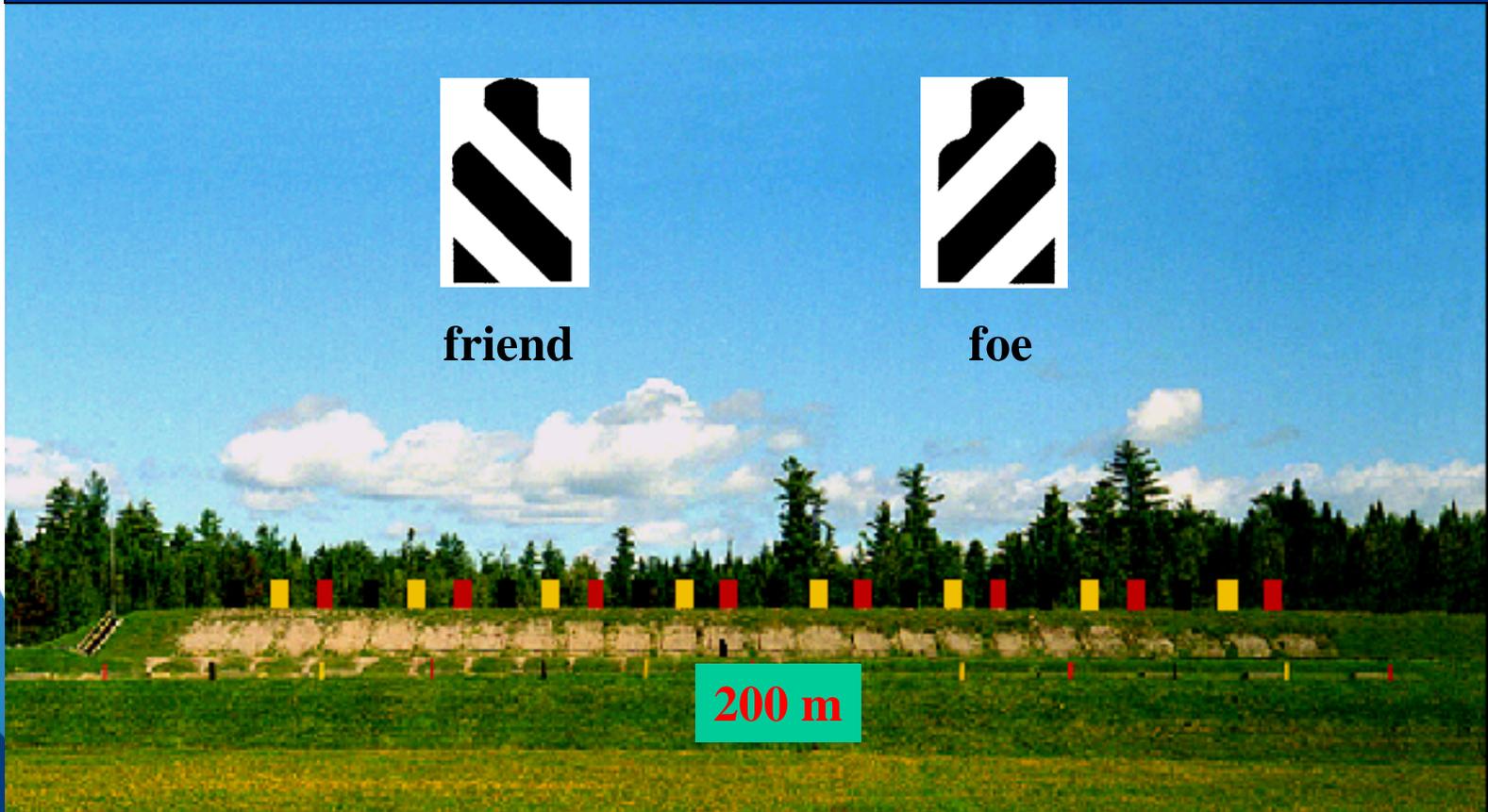
Sleep Deprivation

Sleep Deprivation
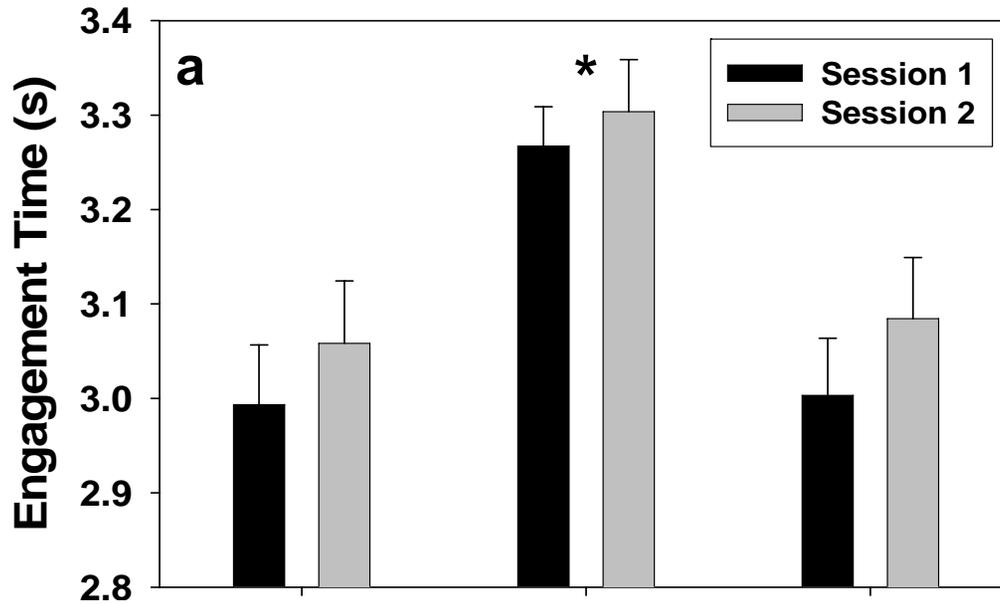
Mean ± SE of
a) target engagement time
b) no. shots fired & targets hit
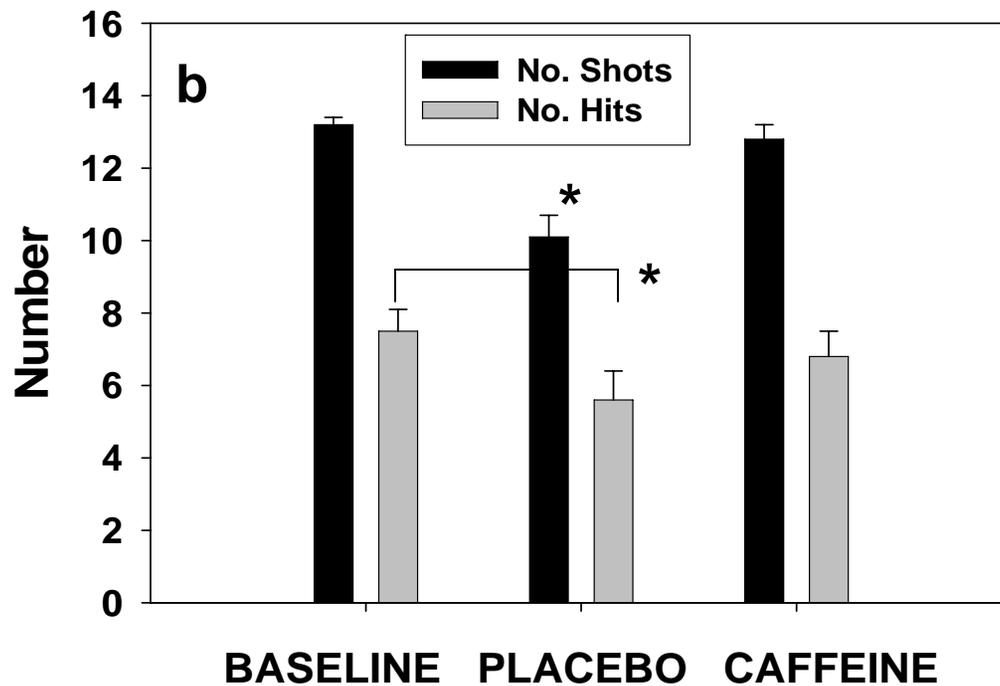
Conclusion: Caffeine restored engagement time and number of shots fired, with neither a beneficial nor adverse effect on marksmanship.

Summary

- **Fatigue is likely to inhibit or delay the detection of a target, but not seriously affect marksmanship.**

- **Marksmanship, which in this case required intense short-term focus (i.e., 6 s or less), can be competently managed under significant levels of physiological strain.**

- **Moderately high caffeine ingestion can restore target detection at baseline levels and not adversely affect marksmanship.**

Caveat

• **The absence of lethal danger in these studies ignores an important psychological stress that is impossible to replicate in the laboratory.**

• **Whether or not environmental stressors exacerbate operational performance in the presence of lethal danger remains to be determined either through well-documented case histories or increasingly realistic simulations.**
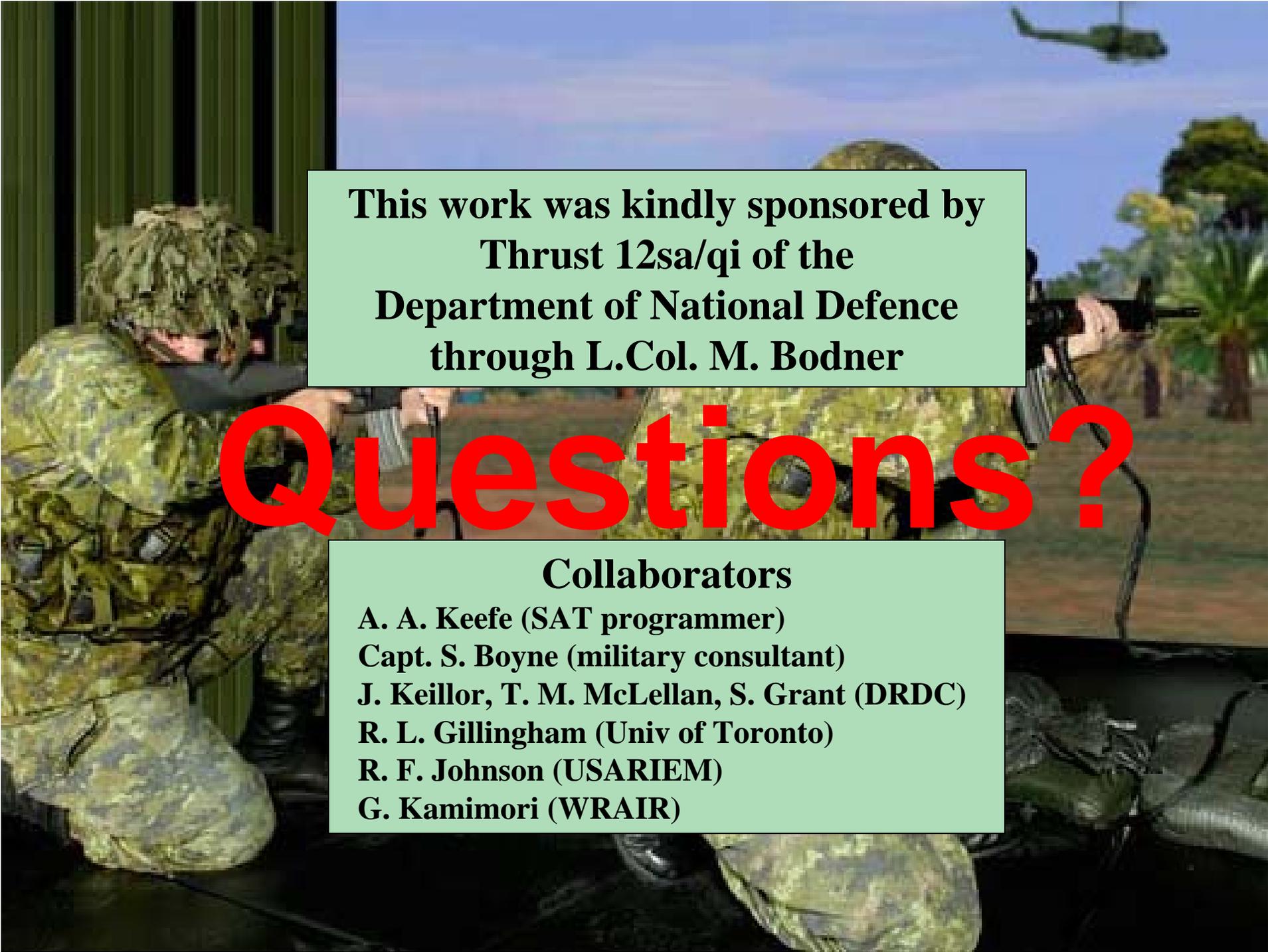
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Questions?

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