

Fight or flight

Measuring and understanding human stress response in tactical situations

By David K. Spierer, Eddie Griffiths and Tricia Sterland

Defusing a bomb is a multi-faceted and intricate task. Time constraints, hostile environments and high-level complexity add to the potential for stress-induced mistakes. Mental acuity, sharp attention and executive decision-making become paramount. The origin of the human stress response is well understood and appreciated in its utility as a protective mechanism to prepare the body for adversity. Scientists are now focused on the interpretation of the human stress response and how, if at all, it can be modified.

The purpose of this article is threefold: 1) to provide a brief scientific explanation of the human response to stress, 2) to outline methods, present data and interpret the stress response of two Navy explosive ordnance disposal (EOD) technicians examined during varied stress-inducing improvised explosive device (IED) scenarios and 3) to highlight a critical need to implement objective methods of heart rate and heart rate variability to measure stress during tactical operations.

Should I stay or should I go?

The human nervous system is a complicated messaging system that relays information to and from the body's tissues, spinal cord and

brain, working in a similar fashion to electrical wiring. In large part, the human stress response, an integration of rapidly traveling signals, resides in the autonomic (automatic) branch of the human nervous system (ANS). It is here that signals travel to and fro involuntarily and require no conscious effort to be engaged.

When confronted with a challenge, you have two choices: you can run or you can fight. In an instant, the ANS processes information and a decision is made whether running or fighting would be more valuable to your overall health. The "fight or flight" response, as it is known, is a mechanism designed to get the body "ready." It is this branch (sympathetic) of the human nervous system, which greatly influences hormone levels in the blood to increase heart rate, blood pressure and body temperature, not to mention several other bodily functions.

The other half of the ANS equation considers wiring that is engaged during rest and is often most active during sleep. It is this branch (parasympathetic) that is frequently activated in young subjects, in individuals who demonstrate high levels of fitness and often, in individuals who show composure under stress. Chronic elevations in sympathetic activity and long-term reductions in parasympathetic activation are associated with depression, anxiety¹ and cardiac disease.^{2,3} Thus, physiological alterations in a manner consistent with the influence of either branch

of the ANS can have a profound effect on behavior or performance. The activity of either branch of the ANS can be found in a measurement known as heart rate variability. Although this is not a science class, it is important to understand that the variability the heart possesses to slow down or speed up in response to physical and mental stress and even normal respiration speaks volumes about its efficiency and health. Heart rate variability can be assessed in two domains: time and frequency. The time domain refers to the rate at which the heart beats; in other words, how much time between beats. The frequency domain is reflected in the control of heart rate through changes in rhythm, reflecting the connection between the heart and the nervous system. It has been shown that when the heart rate is very high, the time is fast and the frequency is low; conversely, when the heart rate is low, the time is slow and the frequency is high.^{4,5,6} Although an in-depth discussion of cardiovascular science is beyond the scope of this article, research over the past 30 years has identified heart rate and heart rate variability as excellent indicators of the ANS's response to stress.

Stress-induced scenarios

Unlike conventional EOD operations where the utilization of remote methods is standard protocol, the mission at hand requires bomb technicians to utilize manual techniques to "hand enter" and render safe an

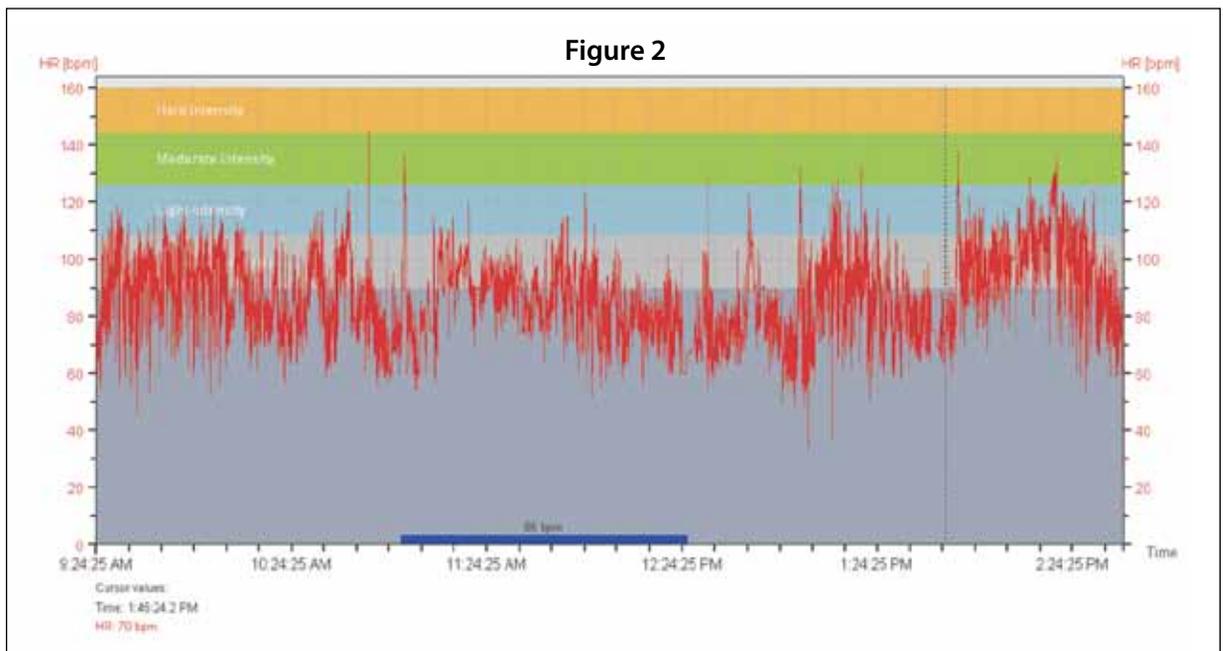
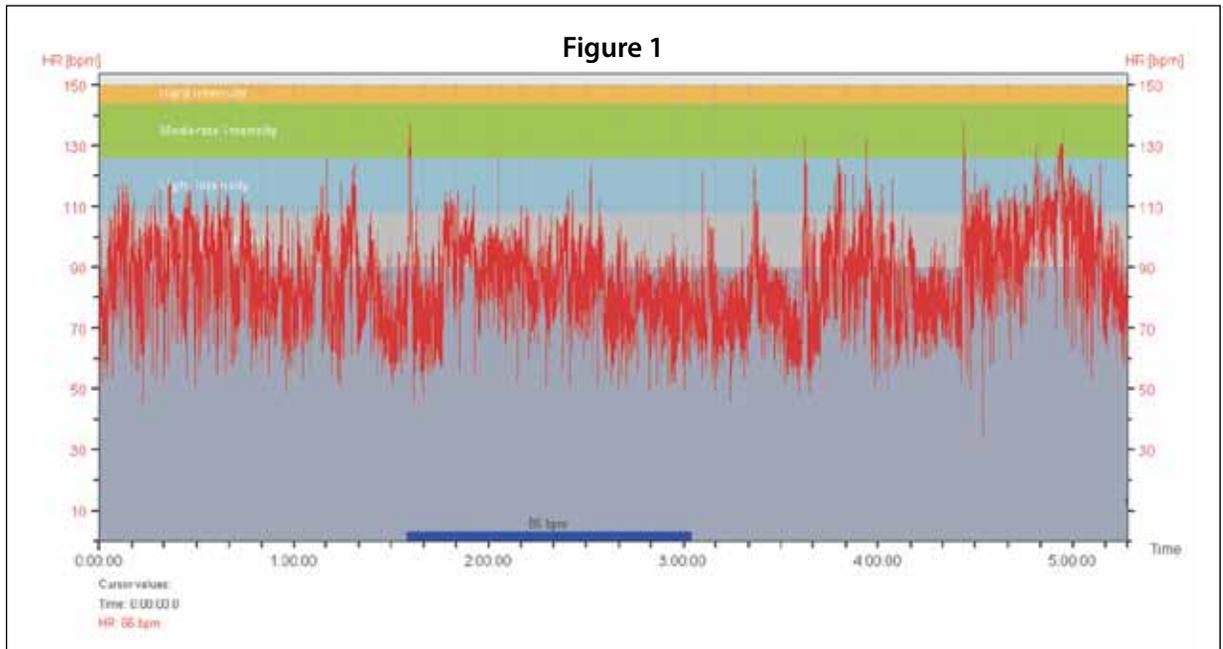
IED (Photo 1). This is a multifaceted assignment that breeds stress, requires great attention to detail and demands executive decision-making. Two Navy EOD technicians, attendees of an Advanced Manual Techniques course of instruction at Tactical Electronics, were recruited for this study. EOD Technician 1 (TAC1) was more experienced, while EOD Technician 2 (TAC2) had considerably less experience with manual techniques.

Each technician was outfitted with a Polar RS800cx heart monitor, which allowed for continuous data

collection of heart rate and heart rate variability during 20 minutes of rest (taken 24 hours before the scenarios were presented) and throughout each of the scenarios (Photo 2). In addition, a Modified State Trait Anxiety Inventory MSTAI (18 questions used to measure level of anxiety) was given to each EOD technician before and after each scenario. Data was then stored and downloaded into a proprietary computer software program for analysis. During each scenario, two analysts were present to troubleshoot the monitors or take notes on specific

emotions being expressed by each technician.

Rest: Table 1 depicts the resting heart rate tracing of each EOD technician. TAC1 in this situation demonstrates a heart rate of 56 beats per minute (bpm) where the average heart rate for humans is approximately 72 bpm. TAC1 is well-rested and presents with a very efficient heart. In addition, TAC1 also demonstrates a balance of sympathetic and parasympathetic activity, indicating that he is not under stress. TAC2 also shows an average heart rate of 56 bpm. As



shown in Table 1, both technicians are similar in that they have a balanced ANS with approximately 45% parasympathetic activation. This is what would be expected in well-trained young individuals.

Scenario #1: This scenario required the technicians to safe an IED with no time limit or hostage situation present. While both technicians during this scenario worked methodically to assess the situation and analyze their options, heart rate for TAC1 was recorded at an average of 89 bpm with a peak heart rate of 126 bpm. TAC2, the less experienced of the two technicians, put up an average heart rate of 90 bpm with a peak heart rate of 120 bpm. TAC2 also showed a predominance of sympathetic (stress activity) with only 7% of the balance being parasympathetic activation.

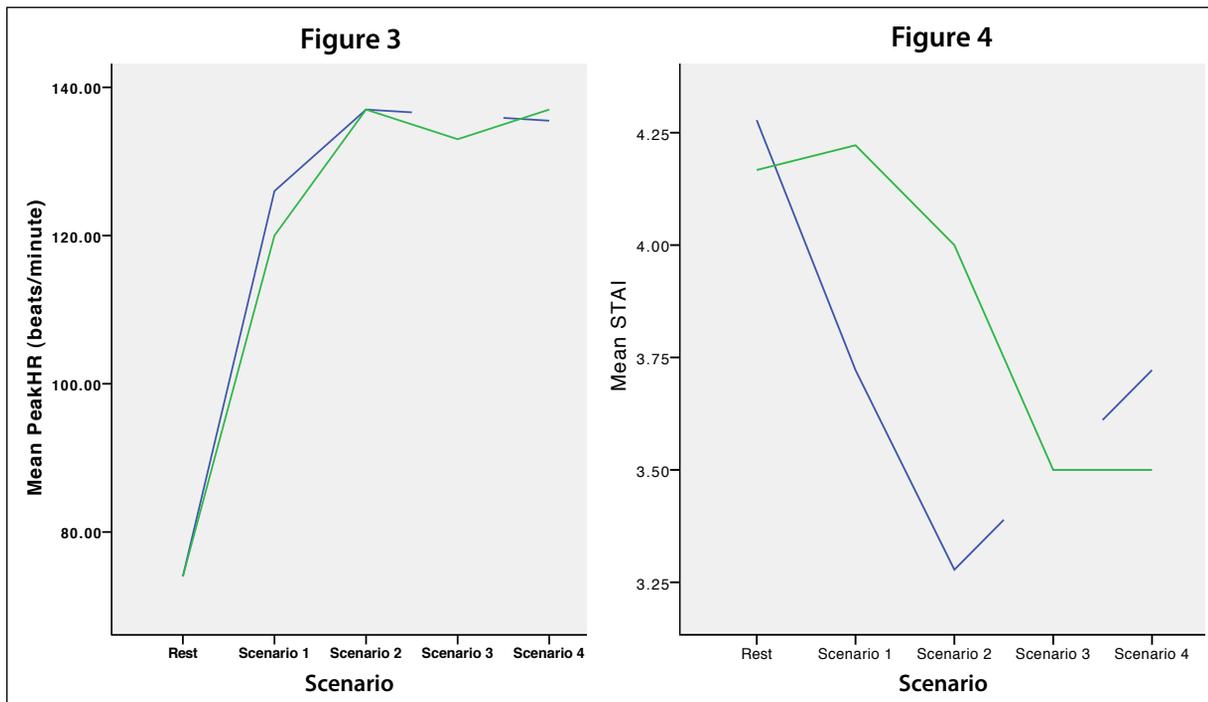
Scenario #2: This tactical operation involved a compliant hostage. Similar to Scenario #1, both technicians took some time to assess and analyze the situation. To begin this scenario, both technicians had to climb one flight of stairs to get to the designated location. Approximately 50 minutes into the scenario, the bomb was detonated. The heart rate and heart rate variability for

both technicians up until the point of detonation were normal with an average heart rate of 85 bpm. After the IED detonated the first time, the ability of the technicians to compose themselves was altered. Both technicians' heart rates then spiked to 137 bpm. Following the initial detonation, the technicians were clearly having difficulty performing critical tasks. Six minutes after the first detonation, they made another error and the IED functioned again. When they finally completed the task, their heart rates were reduced to 20 percent of what was recorded at the highest spike (Figures 1 and 2).

Scenario #3: This scenario presented the technicians with a noncompliant hostage who was unruly at times (Photo 3). The average heart rate for the technicians was 90 bpm and 91 bpm for TAC1 and TAC2, respectively. Both technicians also demonstrated a predominance of stress-induced sympathetic activity. Emotions ran high during this scenario. About 10 minutes into the operation, TAC1 become verbally forceful with the hostage. This induced a heart rate of 126 bpm in TAC1 and a parasympathetic activation of under 10 percent. TAC1 was be-

ing influenced by the fight or flight response of the ANS. During this time decision-making is not as acute. TAC2, although seemingly calm to an outside observer, demonstrated a peak heart rate of 128 bpm with a similar challenge to the ANS. The IED was successfully rendered safe in 21 minutes after the technicians became more composed, with heart rates of approximately 90 bpm.

Scenario #4: The final scenario also involved a hostage who was quite anxious. Again, the effect of the difficult hostage was evident in the elevation of heart rate and the alterations in heart rate variability of the EOD technicians. This scenario also presented the technicians with a time element, increasing the stress they experienced. During this scenario the average heart rates started above 100 bpm for both technicians, with peak heart rates recorded at approximately 137 bpm. During this scenario there was an evident change in the ANS response, where approximately 93 percent of the ANS was under sympathetic influence. The IED was rendered safe approximately 30 minutes into the operation. It is interesting to note that the average heart rates elevated as the



scenarios became more difficult. This will be discussed later.

Modified State Trait Anxiety Inventory (MSTAI): As mentioned earlier, an inventory of 18 questions related to mood and emotion were administered to the technicians before and after each scenario. The technicians were instructed to complete the inventory with the previous scenario in mind. Results from the MSTAI suggest that both EOD technicians increased their heart rate with each progressive scenario and both technicians associated their mental state with less optimism (Figures 3 and 4).

What does it all mean?

Heart rate and heart rate variability have been extensively studied.⁷ Coronary artery disease, depression and anxiety are all associated with negative outcomes related to low heart rate variability.^{1-3, 8, 9} Recent data on heart rate and heart rate variability in response to high stress suggest high heart rates may be necessary for preparation. Morgan et al. presented three experiments where military personnel were required to undergo

stressful situations (such as high intensity military training).¹⁰ His findings suggest that a higher heart rate and lower variability is associated with superior performance during these training operations. This is contradictory to what was once thought, but it may speak to a level of training beyond that which is typically experienced by most military personnel. The level of preparation may have been necessary to maintain a high level of alertness.

In the present experiment, we found just the opposite to be true. When both technicians exhibited high heart rates of over 130 bpm, their decision-making ability, executive functioning and focus were negatively affected. This change in heart rate was also reflected in their mood and mental state. It is this piece of information that we are suggesting is so imperative to tactical operations. Parasympathetic activation, on average, is usually eliminated after 110 bpm. However, in our scenarios, the technicians were not participating in any physical exertion and their heart rates averaged more than 120 bpm. Thus, it appears that what we

observed were heart rate and heart rate variability alterations induced by emotion and state of mind.

As seen in the second scenario, the detonation of the IED shortly after the operation began was enough to change the behavior of the two technicians, regardless of experience. Heart rate spiked in both technicians, and they experienced difficulty carrying out a standard operating procedure. Additionally, high emotions were enough to fluster the technicians and the resultant heart rate was elevated once again. Also, returning to a point made earlier, the average heart rates of both technicians at the beginning of each scenario was elevated. It seems odd that after 15-20 minutes of rest between each scenario the sympathetic activation would not be dampened.

Physical training has been shown to alter heart rate and heart rate variability in a positive way, at rest and during submaximal exercise.^{11, 12} By repeatedly exposing an individual to a given stress, an adaptation will occur; otherwise, there will be an organism shutdown. This is paramount with military training. As we have seen

Table 1: Baseline Chart

Data	Baseline TAC 1	Scenario 2 TAC 1	Baseline TAC 2	Scenario 2 TAC 2
Duration	18:08	1:29:12	24:45	1:28:20
Energy expenditure	30 kcal	126 kcal	35 kcal	124 kcal
Number of heart beats	1017 beats	7563 beats	1385 beats	7469 beats
Minimum R-R Interval	716 ms (84 bpm)	438 ms (137 bpm)	715 ms (84 bpm)	438 ms (137 bpm)
Average R-R Interval	1071 ms (56 bpm)	708 ms (85 bpm)	1072 ms (56 bpm)	710 ms (85 bpm)
Maximum R-R Interval	1404 ms (43 bpm)	1305 ms (46 bpm)	1499 ms (40 bpm)	1160 ms (52 bpm)
Standard deviation	91.8 ms	105.8 ms	109.5 ms	102.3 ms
Max/Min ratio	1.96	2.98	2.10	2.65
Weighted R-R average	1079 ms	724 ms	1084 ms	724 ms
SD1	70.4 ms	36.3 ms	67.7 ms	18.5 ms
SD2	113.9 ms	144.9 ms	141.9 ms	143.1 ms
RMSSD	95.6 ms	51.3 ms	93.6 ms	26.1 ms
pNN50	29.1%	8.0%	26.6%	2.9%
Total Power (0.000-0.400 Hz)	8623.54 ms ²	8723.82 ms ²	13322.10 ms ²	6763.13 ms ²
VLF (0.000-0.040 Hz)	3681.86 ms ² (42.7%)	5479.46 ms ² (62.8%)	8398.46 ms ² (63%)	5411.02 ms ² (80.0%)
LF (0.040-0.150 Hz)	1520.17 ms ² (17.6%)	2211.55 ms ² (25.4%)	1585.88 ms ² (11.9%)	1152.09 ms ² (17.0%)
HF (0.150-0.400 Hz)	3421.52 ms ² (39.7%)	1032.80 ms ² (11.8%)	3337.76 ms ² (25.1%)	200.02 ms ² (3.0%)
LF/HF ratio	44.5%	214.2%	47.6%	576.0%

in the past, soldiers and technicians in the military prepare and practice various operations ad nauseam to provide a given nervous system response. It is clear from our data that regardless of experience, the fight or flight response is always present.

This was evident in Scenario #3 when TAC1 was engaged in a verbal conflict with the hostage and his stress was apparent. This is perfectly reflected in the spike in heart rate and the change in heart rate variability. Unlike the soldiers observed by Morgan et al., the technicians in these experiments were highly influenced by emotion and situations that did not involve physical exertion. It may be that the soldiers Morgan et al. observed were trained at a higher level or put through different stressful operations (such as interrogations with verbal abuse and other procedures that honed their stress response).

Morgan et al. suggest that some soldiers he studied have a “metronomic heart,” a heart that beats

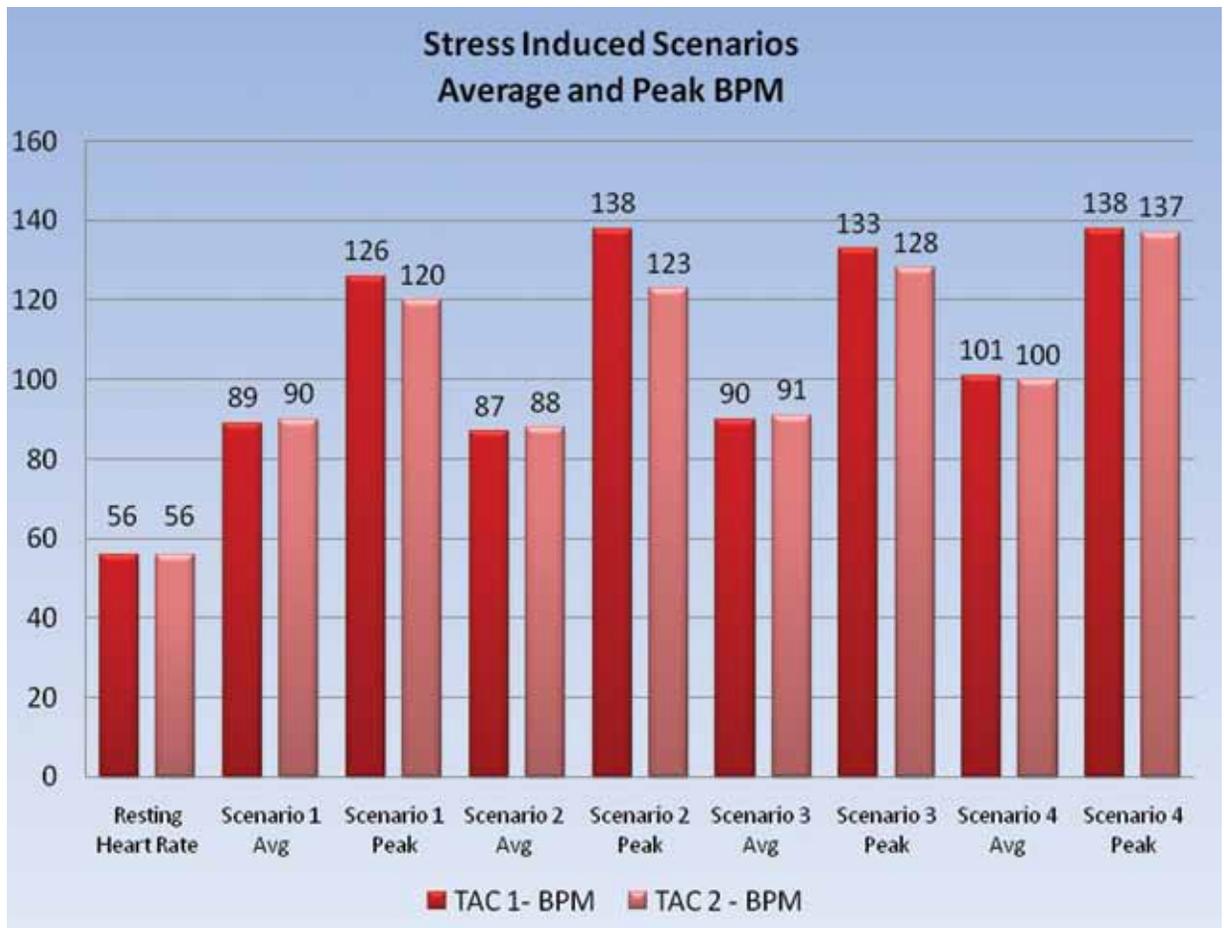
without any variability like a metronome.¹⁰ Constant challenge to the ANS in the form of mental stress may provide an abnormal preparedness for the short term, but may predict difficulty or dysfunction in the future. This is supported by what we know about heart rate variability — the less variability, the greater chance for disease and dysfunction. Although intense physiological preparation may be necessary to achieve the “metronomic heart,” too much stimulus on the heart and circulation may be a bad thing.

In any case, heart rate and heart rate variability, as evidenced in the present experiment, are associated with a stress response, and from what we observed, these changes may significantly impact how decisions are made. The heart rate and heart rate variability of both technicians rivals that found in the physical stress of moderate exercise. However, because there was no increased demand for oxygen in working muscle tissue

related to intense physical activity during the bomb defusing scenarios, the changes in ANS influence were most likely due to mental stress.

Increasing heart rates at a rapid pace reflected in the heart rate spikes in TAC1 and TAC2 is reminiscent of what has been demonstrated in law enforcement and firefighting during stressful situations.¹³ Rapid changes in heart rate due to emotion may have a very negative effect on the vascular system and the heart. It is well-established that an influx of sympathetic activity is associated with a bombardment of potent hormones on receptors in the blood vessels. Too much of the hormone can render the receptors useless and cause damage to the walls of the vessels.

Performing render safe procedures on an IED requires tremendous focus and demands that stress levels remain as low as possible. Is this possible to train for? Studies from decades ago show that the ANS responds favorably to training and the resultant



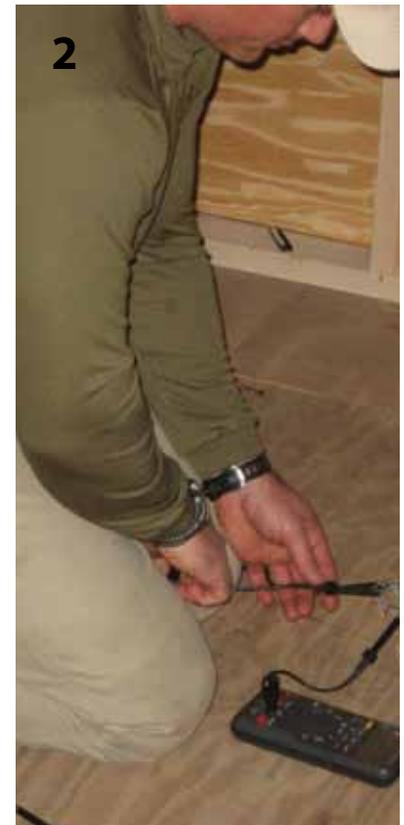


Photo 1 – During category “A” scenarios, bomb technicians are authorized to abandon conventional remote procedures and “hand enter” a suspect IED.

Photo 2 – Bomb technician training with Tactical Electronics wears heart rate monitor while working through scenario.

Photo 3 – In Scenario 3, bomb technicians must contend with an IED attached to a hostage under extreme duress.

effect is an ANS balance tipping more toward parasympathetic activation.¹²
¹⁴ Athletes who consistently train for sport are known to have extremely low heart rates and an abundance of cardio-protective parasympathetic activity.

Among bomb technicians, this training may have to take a different tact to achieve the same results that athletes have reached over the years. Thus, technician training may need to be altered to provide more of a parasympathetic stimulus (low heart rate) or a dampened sympathetic response during sensitive and stressful operations. Training that requires

the ANS to engage the fight or flight response may be what is needed. By continuously calling up the sympathetic system, an adaptation of the nervous system will occur to lessen the fight or flight response when lives are on the line and physical exertion is not required.

By just simple observation, during two of the scenarios, TAC2 appeared to be significantly less stressed than TAC1. However, with the physiologic measurement of heart rate and heart rate variability using a simple piece of equipment, the high stress level of TAC2 was evident. A lesson learned from this experiment, as reflected in

heart rate and heart rate variability, is that less experienced technicians should be additionally trained to avoid a complete sympathetic takeover.

Simple observations are not always apparent; they may not give a clear view of reality. Thus, objective data such as that collected from a heart rate monitor is an excellent tool to help decide how training techniques for stressful tasks should be implemented and who should be trained; this will insure that the technician’s response is appropriate when necessary.

With such a meticulous, life-threat-

“ . . . objective data such as that collected from a heart rate monitor is an excellent tool to help decide how training techniques for stressful tasks should be implemented and who should be trained; this will insure that the technician’s response is appropriate when necessary. ”

ening task at hand, it makes sense to always be prepared. This being said, future research should be focused on examining the proper training regimens needed to keep technicians, like the ones presented in this article, focused and mentally acute. ◀

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