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Examining the Influence of Heartbeat on Expert Marksman Performance

by Tommy Goris and Keith Brawner

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14. ABSTRACT
Marksmanship training in the US Army follows a process that all marksmen must learn, understand, and experience to improve their shot. This standard can be broken down into key factors over which a marksman has control and needs to develop to improve his or her marksmanship. For that reason, in this technical note we examine the role of the heartbeat as observed from expert marksmen. The influence of the heartbeat is categorized into 3 different areas: 1) if expert marksmen time the shot on a heartbeat, 2) if they fire between heartbeats, or 3) if they simply ignore their heartbeat during marksmanship. The data support that expert marksmen ignore their heartbeat when firing. Because of this evaluation of expert behavior, we determine the heartbeat to be a nonfactor in marksmanship training.

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1. Introduction

US Army marksmanship training focuses on Basic Rifle Marksmanship (BRM), which consists of the 4 fundamentals of marksmanship: steady position, aiming, breath control, and trigger squeeze. Marksmen in the US Army first receive training in BRM fundamentals, such as communication, movement, and shooting, which are critical to the basic functions of a Soldier. Once the marksmen have mastered the fundamentals, they have a better understanding of correct and incorrect shooting behaviors. These behaviors can be analyzed and studied to provide better instructional feedback on the shot of other marksmen when compared to that of an expert marksman (Chung et al. 2009b).

The 4 fundamentals of marksmanship are the primary factors that influence how a marksman shoots, but there are also secondary factors. These factors are included as subsets of the 4 main factors, such as eye focus for aiming or trigger finger for trigger squeeze. Other factors, such as heartbeat and heart rate, may play a role on a marksman's shot as well. For instance, work has been done to determine the effect of heart rate on expert marksmanship. The results of that work show that an expert marksman's performance did not change in regard to heart rate. (Pojman et al. 2009). An expert may have control of all these factors, with each factor influencing a marksman's shot by a different margin. Observing these factors from an expert marksman can help to characterize the correct factors, which influence a marksman's shot, and the wrong factors, which do not influence performance. Once these factors are observed and characterized, they can be used to provide instruction and feedback for other marksmen to improve their technique. The instruction and feedback are in the form of basic training guidelines or multimedia-based instruction for novice marksmen, evaluated from the factors observed from expert marksman. The focus of this work is to examine expert behavior to determine which factors influence performance and should be trained and which factors have little or no influence over performance and can be safely avoided in a training regimen.

Marksmanship is not a simple skill to master; the collection of the factors outlined in the BRM and all the other factors a marksman has to control inevitably add up to portray marksmanship as a complex psychomotor skill. Even a slight movement on the gun from breathing, heartbeat, or muscle tremors can contribute to deviating the marksman's shot significantly from its target (Chung et al. 2009a). In addition to the factors a marksman has to control, shooters are under a high cognitive workload. During this period of high cognitive workload, the marksman's decision accuracy, shooting accuracy, and response time all vary greatly because of the time stress effect of shooting (Kerick and Allender 2004).

The factors observed from experts, in conjunction with novices training on these factors, constitute the first step in providing novices a way in improve performance. The ability to utilize all the behaviors an expert displays and put them it into practice is, of course, the final step to master the skill.

The first step is to determine which factors correlate positively with a marksman's shot. In this technical note, we examine the behavior of expert marksmen during shooting events, with respect to their heartbeat. The effect of the heartbeat on a marksman's shot compared to other factors, such as breath control or aiming, may seem small, but it is important to determine if the heartbeat does have some influence on how an expert shoots. We aim to ultimately review and change training guidelines as needed to either include or exclude the heartbeat as a factor for training marksmanship. In the present study, we explore data from 8 expert marksmen in the US Army to observe their behaviors and draw conclusions on whether their heartbeat has an influence on their shot. The goal is to strengthen our understanding of marksmanship and provide an overview of how the heartbeat affects an expert marksman.

2. The Heartbeat

Heartbeats are represented by a sudden rise and sudden decline on an electrocardiogram, also known as an ECG. These ECG values taken from the expert marksmen form the heartbeats during the duration of the marksmanship phase. (The ECG values are not to be confused with the heart rate, which is the frequency of the cardiac cycle.) The heartbeat on an ECG is represented by the QRS complex, which is the graphical representation of the heartbeat. The first part of the QRS complex is the Q wave, or the first negative deflection of the complex. The R wave is the first positive deflection, and the S wave is the negative deflection following an R wave. Overall, the QRS complex represents the depolarization of the right and left ventricles of the human heart, otherwise known as the start and end of a heartbeat. The QRS signal is shown graphically in Fig. 1.

Fig. 1 Sample QRS complex

3. History of Marksmanship and Data Capture

Effort has gone into researching the concepts of marksmanship. Some of this focus has been placed on the development of rifle marksmanship based on different factors (Chung et al. 2009a). This research is extremely important in improving our understanding of the basic and advanced rifle techniques in the US Army. One element of marksmanship research is to fully comprehend the differences between a novice and an expert marksman. These differences are the basic concepts of marksmanship that are known to work and can be applied. The other element of marksmanship research is the training. Even without new ways of applying marksmanship fundamentals, there are many training programs and simulations. Since the fundamentals of marksmanship are more or less set and new knowledge limited, research heavily favors the training.

3.1 Specific Data and Its Capture

Heartbeat data were collected from 8 expert marksmen from the US Army Marksmanship Unit's Service Rifle Team out of Fort Benning, Georgia. These marksmen have repeatedly been shown to possess great marksmanship skill, making them perfect for this study. The demographics for the expert marksman are 7 males and one female, with an average age of 28. The marksmen were equipped with the Zephyr Technology BioHarness BT, a compact electronics module, armed with ECG and breathing detection sensors. The BioHarness made it possible to get accurate results of the expert marksmen's heartbeats. All marksmen in this study exhibited expert-level performance during data collection. For additional information on the data, see the initial publications (Goldberg et al. 2014).

3.2 Hypothesis and Investigation of the Data Postprocessing

The main objective is to identify the influence of the heartbeat on performance. Given that all experts performed at an expert level, the question is how shot timing relates to heartbeat. There are 3 possibilities. The first of these is whether experts time their shot while their heart is undergoing a heartbeat. The second is that shots are timed so as to be between heartbeats. The third is that the experts fire randomly without regard to their heartbeat. In the first 2 cases, the expert marksman is actively reacting to how his heartbeat functions while he is shooting, rendering it likely for the heartbeat to have influence over performance. In simple terms, if experts exhibit this behavior, then it is likely that it is important for training. For the last case, if the heartbeat is effectively disregarded while shooting, it is likely that the heart has no influence on how an expert marksman shoots. Nonetheless, we hypothesize a difference when firing between heartbeats.

The data include heartbeat, or ECG values, for the 8 expert marksmen, with the time of occurrence of each heartbeat. Since we are testing whether the heartbeat plays a role in marksmanship, the times of each shot taken by the expert marksmen are also required. In all, we draw comparisons between the time a heartbeat occurs and the time a shot is taken.

3.3 Postprocessing

A heartbeat is composed of 3 different parts, as detailed by the QRS complex. To draw a fair comparison between 2 different heartbeats, we use the middle of the heartbeat, or the R wave of the QRS complex, as the point of comparison between other heartbeats. To begin, both of the ECG values, including the time for each heartbeat and the times of each marksmanship shot, are used to construct a comparison based on the time distance a marksmanship shot is taken after a heartbeat. This distance is calculated by obtaining the heartbeat just before a shot and the heartbeat just after a shot, and comparing it to the time the shot is taken between the 2 heartbeats. The time distance of a shot between heartbeats is the end result of this calculation. This time distance is represented as the percentage of the way a marksmanship shot is fired between heartbeats. Since we are using the R wave as our point of comparison, the low and high percentage values of the time distance represent times where the expert marksman shot during a heartbeat, and the middle percentage values represent times where the expert marksman shot between heartbeats. These measurements are taken until we have obtained all the time–distance percentages for each shot. The end goal is to characterize each percentage on whether it lies during a heartbeat or between heartbeats.

All the percentages are divided into 5 parts, from a scale of 0 to 100. In this case, the frequency of each shot between 0 and 20, 20 and 40, 40 and 60, 60 and 80, and 80 and 100 is calculated. The frequency of the percentages in the 0–20 and 80–100 sections will be the only sections to contain percentages located on a heartbeat while the other sections contain only percentages of shots fired between heartbeats. Classifying and analyzing these sections based on their count and comparing them to other models is the final step in determining the heartbeat as a factor in expert marksmanship.

4. Results and Discussion

The time distance a shot is fired between heartbeats in percentages is shown in Fig. 2. We tested the observed data against a randomly generated sample, also shown in Fig. 2. The random model and model of observed frequencies of shots bare close resemblance to one another observationally. This finding is supported through the performance of a t-test on the frequency model of shots compared to the random model assuming unequal variances. This test is shown in Fig. 3. The random model and the frequency model in the t-test have statistically similar mean and variance values, indicating that the null hypothesis of unequal variances should be rejected and the alternative hypothesis of equal variances is accepted. This implies that expert marksmen disregard heartbeats while shooting.

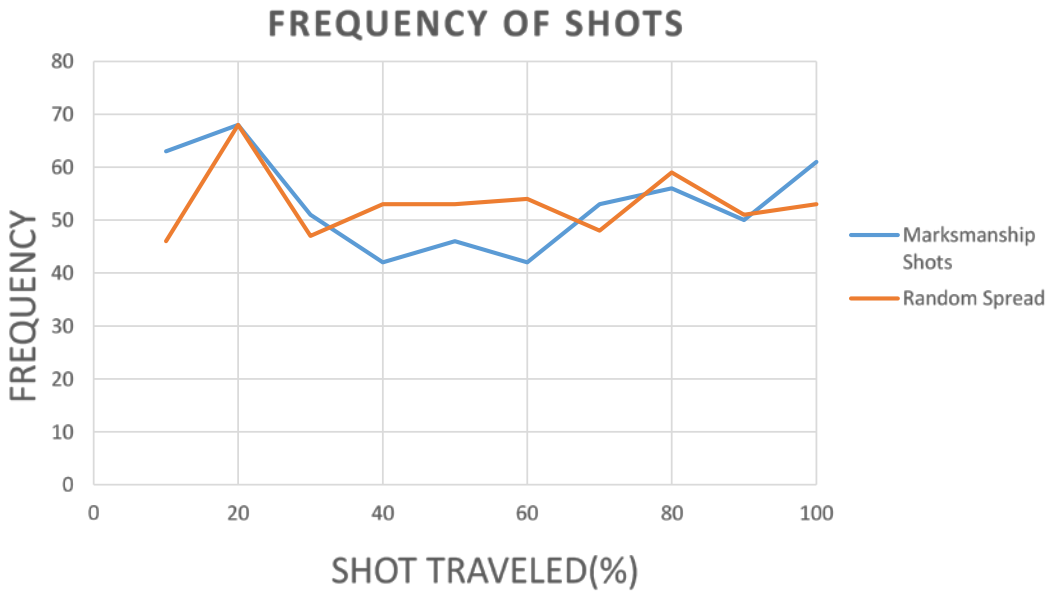

Fig. 2 A t-test assuming unequal variances compared to a random model is used to determine whether heartbeats are a random factor in marksmanship

t-Test: Two-Sample Assuming Unequal Variances		
	Marksmanship shot	
Mean	49.13994678	
Variance	922.5826096	
Observations	532	
df	1058	
t Stat	-0.482937288	
P(T<=t) one-tail	0.314620089	
t Critical one-tail	1.646295132	
P(T<=t) two-tail	0.629240178	
t Critical two-tail	1.962208731	

Fig. 3 A t-test assuming unequal variances compared to a random model is used to determine whether heartbeats are a random factor

It may be a bit surprising to see that the heartbeat, in regard to an expert marksman's shot, is completely ignored and follows a random pattern. We expected to see expert marksmen put some effort into timing their shot with their heartbeat to avoid unnecessary movement caused by the heartbeat. It is possible expert marksmen rely more on other factors they have more control over and follow this premise, ignoring smaller factors such as the heartbeat.

Another view on why the heartbeats of expert marksmen might follow a random pattern could be due to the accumulated experience these expert marksmen have. An expert marksman is less likely to succumb to pressure during a shooting event, allowing him or her to stay relaxed during the event. In this relaxed state, improved over the years, the heartbeat is unimportant, while the expert marksman prepares for the shot. Based on all factors contributing to the shot during this phase, the heartbeat might contribute to some change in accuracy, but the change is very small compared to other factors the expert marksman has more control over. It is also entirely possible that the 8 expert marksmen found no need to time their shot to their heartbeat, as the influence would have been nonexistent.

Comparing this behavior of ignoring the heartbeat to the behaviors observed in other marksmen is a key element in marksman training. If it is possible to achieve mastery in marksmanship without training the marksman to monitor the heartbeat, then there is no need to train the factor. In a sense, the contribution the heart plays in marksmanship is abysmal compared to what other factors contribute. Training a novice marksman to better control breathing instead of training the heartbeat would save the marksman time and effort on a skill contributing to the mastery of his marksmanship, where training the heartbeat would be insignificant.

The result of the heartbeat being random completely negated our hypothesis when testing to see if the heartbeat would improve a shot based on whether it was fired during a heartbeat or between heartbeats. The heartbeat plays no significant role in how an expert marksman shoots, and so the shot is neither improved nor hindered.

5. Conclusions

For the present study, work has been done in determining the influence the heartbeat has, as a factor, on the marksmanship of an expert marksman. Comparisons are drawn based on the times of the marksmanship shots and heartbeats, creating the calculation needed to justify whether the heartbeat plays a role in expert marksmanship. The timing of heartbeats and firings of expert marksmen were binned into specific segments to determine whether experts are consistently firing while taking heartbeat information into consideration. Nevertheless, expert marksmen do not appear to be actively controlling the timing of their heartbeats with respects to their shots, at least with any statistical significance. We believe that this applies to all marksmen.

The purpose of determining the role of heartbeat during a shot is to be able to compare the behaviors of expert and novice marksmen. This comparison allows us to characterize and evaluate factors based on their importance in regards to how the factor affects marksmanship. Identifying the factors that improve marksmanship allows us to share ideas and knowledge with other shooters and train skills vital for marksmanship, and ignore skills unnecessary for marksmanship. This is a way for marksmen, preferably new or novice marksmen, to be able to learn from the behaviors of expert marksman.

For future research, the behaviors of novice marksmen will be examined and compared to the behaviors of expert marksmen. Currently, our data conclude that expert marksmen fire without regard to timing in heartbeats; as such, it is not recommended to train this behavior in novices.

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