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Timing of the trigger pull and the cardiac cycle among novice shooters

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Abstract

The present study examined the timing of the triggering in the cardiac cycle. The participants in the study were 20 (male) inexperienced novice shooters. ECG and HR were used as the physiological measures. All the participants used a standard airrifle on a 10meter indoor track and each of them performed 100 shots. Cardiac cycle was divided into five equally long (20% each) periods, to find out, in which period of the cycle the shooter performed his shot. The study also included a control condition in which the participant was not aware when the experiment leader triggered the measurement system. The relationship between the shooting and control situation was first examined. The results showed that there was a significant difference in the timing of the triggering in the cardiac cycle in the shooting condition compared to the control condition. Second the performance outcome and the timing of the triggering were not significantly associated. Third, the timing of the triggering and its relation to the outcome was not related to the HR level. The present data suggest that the novice shooters pull the trigger accidently more frequently during the late systolic and in the beginning of the diastolic phase of the cardiac cycle, due to the mechanical movement caused by the heart.

1. Introduction

The purpose of the present study was to investigate the psychological determinants of skilled sharpshooting. These aspects have been studied using the traditional psychological methods, such as self-reports, observation, interviews and psychometric inventories. These methods have benefits in certain situations, but in sports like sharpshooting the duration of the period, during which the critical adjustments are made, is considerably short. That is why the psychophysiological approach is the most suitable and accurate method for the examination of sharpshooting performance. The aim of the present study was to offer a more comprehensive insight into the underlying mechanisms of sharpshooting performance focusing on the timing of the triggering in the cardiac cycle. This was done applying physiological moment-by-moment recordings.

Psychophysiology is a field of science that shares both the psychological and physiological concepts and methods. Two basic premises of psychophysiology are that (a) cognitions, emotions and action are embodied phenomena, and (b) the responses of this corpereal body can provide insights into the mechanisms underlying human behaviour (Cacioppo & Tassinary, 1990). Basic psychophysiological methods for studying human behaviour include for instance the measurement of heart rate (HR), blood pressure (BP), electroencephalography (EEG) and electrocardiography (ECG). During the past decade psychophysiological approach has been used to enhance the understanding of the covert aspects of sport performance. The most widely investigated sports in the sport psychophysiology have been sharpshooting, archery and golf (Collins, 1995).

The present study applied thus a psychophysiological approach to the investigation of skilled shooting performance. Sharpshooting is a sport that can easily be moved into a controlled laboratory setting. The athlete is expected to perform similarly in the laboratory as in an actual situation. Sharpshooting also allows the experiment to be carried out without muscular artifacts, that result from gross bodily movements.

Psychophysiological approach is specifically useful in the sports, where the athlete is very much aware of his or her bodily functions (see Collins, 1995).
Experienced elite shooters can, for instance, sense their heart beats and control their breathing, but they cannot always tell what is wrong with their performance. Psychophysiological approach can help the shooters, coaches and researchers to examine the optimal level of performance and to help to perform better in a competitive situation.

According to coaches and elite shooters there is an optimal moment for the pulling of the trigger in the human cardiac cycle. This moment seems to be located in the diastolic ventricular, during which the human heart is in its resting phase. In this particular phase the mechanical movement of the heart that affects on the body is also in its minimum. The coaches have not taken into account, that when the mechanical movement produced by the heart muscle is in its maximum, it may cause an interference to the trigger pull. In other words the mechanical movement affects on the triggering finger and the shooter performs the shot by accident. The present study aims to examine if there is an optimal place for the trigger pulling, and whether it is located in diastolic ventricular (see Helin, Hänninen, & Sihvonen, 1987).

The aim of the introduction section is to provide some basic physiological issues on cardiac functioning that are needed to take in account in the examination of the shooter`s performance from the psychophysiological point of view. Following this the relation of cardiac functioning to the concomitant bodily movements are examined. Thirdly, the relevant earlier empirical findings are reviewed. Finally, the hypotheses of the present study are represented.

1. 1. Physiological basis of the heart

Heart is a muscle, which begins its work from early embryonic life and proceeds it until death. In a lifetime heart beats 3×10^9 to 4×10^9 times. It is about a size of a fist and contracts about 72 times a minute at rest (Andreassi, 1992). The main functions of the heart and cardiovascular system is to maintain adequate perfusion by delivering oxygen and nutrients and removing waste products from tissue. They also regulate body temperature and transport hormones and other chemicals.

As the heart beats it pumps blood to the lungs, the heart and the rest of the body. The heart consists of two pumps, left and right. The right pump moves the blood to the pulmonary system, and the left pump supplies the oxygenated blood to the rest of the body. The blood that is low in oxygen returns to the heart and enters the right atrium. When the right atrium contracts it forces blood into the right ventricle. Then the right ventricle contracts, forcing blood into the lungs through the pulmonary artery. From the left atrium the blood is pumped into the left ventricle. Following this, the contradiction, or systolic action of the heart, forces the blood into the aorta for distribution throughout the body.

Distribution of blood consists system of arteries, small vessels referred to as arterioles and capillaries. The majority of the blood is in veins, which act as reservoirs. Through the veins blood returns to the heart. Sympathetic nervous system (SNS) stimulates and brings a redistribution of blood into the heart and other organs. The amount of blood the heart pumps is referred as cardiac output. At rest, this is about 5 liters per minute, but during a heavy exercise it can increase 400 to 600 percent. During exercise muscles receive most of the blood, which can be up to 75 percent.

1.2 Electrical activity of the heart

The electrical activity of the heart muscle that is recorded at the surface of the skin is known as electrocardiography. When this record is printed it is called the electrocardiogram (ECG). The ECG is divided into two phases, systolic and diastolic and it consists of five different waves P, Q, R, S, and T. (See figure 1.) These waves are the events in the cardiac cycle. The most prominent component in the cardiac cycle is the R -wave.

All the changes in the cardiac cycle are produced by depolarization and repolarization of ventricles. These changes occur in a similar way as the repolarization and depolarization in neurons; depolarization occurs when the ionic activity inside of the fiber becomes positive with respect to outside, and repolarization is a return to internal negativity and external positivity.

The measurement of ECG is carried out using electrodes and an amplifier that amplifies the electrical current. The placement of the electrodes is very crucial when measuring the activity of the heart. In most cases four elecrodes are placed on the surface of the skin. For active subjects sternal or axillary electrode placements (leads) are used. Sternal leads are placed over bone (sternum), and are therefore relatively immune to movements (Heikkilä, 1982).

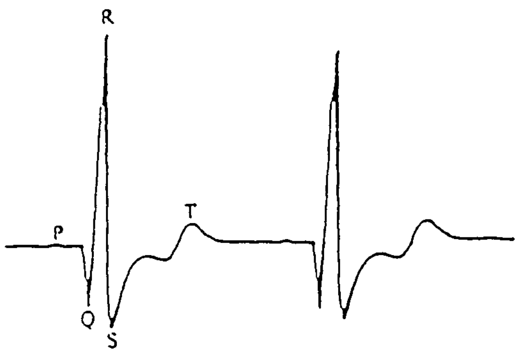

Figure 1. The ECG -waveform.

1.2.1. Duration of the cardiac cycle

Systolic phase of the cardiac cycle begins at peak of the R wave and ends in the end of T wave. (Åstrand & Rodahl 1977, Guyton 1996) Among normal persons systolic phase ratio is 0.35 with a standard deviation of 0.04. If this ratio increases to 0.44 or greater, the performance of left ventricular performance is diminished. Changes in the systolic-time intervals can indicate for instance chronic left ventricular disease, such as coronary-artery and primary myocardial disease (Weissler, 1977). Diastole phase of the cardiac cycle begins at the end of the T -wave and ends in the R- wave peak. When heart rate increases the diastolic phase diminishes to a greater extent relative to the systolic phase.

As given before the average resting rate of the heart is about 72 beats per minute. (Andreassi, 1992). At this heart rate (bpm) the duration of the cardiac cycle is about 830 ms, of which the ventricular systolic phase lasts for 300 ms and diastolic for about 500 ms. The time interval between the P -wave and the Q -wave is about 160 ms and the time from the beginning of the Q -wave to the end of the T -wave is about 300 ms. This duration of cardiac cycle can also be called heart period (HP) or heart rate (HR) The HP measures the time between two consecutive R-wave peaks. HP can also be referred as the interbeat interval (IBI), and is expressed in milliseconds as durations of waves in the cardiac cycle. The HR is based on the number of R waves or beats per a certain unit of time, for example, in beats per minute. In the present study the HR will be used as the index of the duration of the cardiac cycle.

1.3. Ballistocardiography

The mechanical activation of the heart produces small movements, that can be recorded with the ballistocardiography (BCG). BCG is one of the oldest noninvasive methods that is used in this kind of evaluation of the cardiac activity. The BCG has been known since the 1800`s. The first recording was made by Gordon in 1877 (see Smith, 1974).

These early recording devices were poor and unreliable, and the first one to really put some interest in the technique was Starr in 1936 (Smith, 1974). He developed a recording device that made the recording of the BCG possible, Starr was also the man who gave the name "ballistocardiography" from Greek *ballein* -to throw, *kardia* -heart, *graphein* -to write. Starr`s high-frequency BCG was still a robust technique, that lasted about fifteen years (Smith, 1974). Following this the ultra low frequency BCG was developed, which was based on the low natural frequency, 0.3 Hz or less. The modern age BCG is recorded with the static charge-sensitive bed (SCSB), where the subject lays on a mattress in a common bed (Alihanka, 1981).

1.3.1 The BCG wave-form

BCG is divided into eight different waves (H-O), that are based in the heart`s mechanical activity (see figure 2). H-wave, the first wave of the BCG, starts in the beginning of the QRS complex. It should be noted that a wave or a tip of the wave is not directly attributed by a single physiological event, even though one event may be a major contributor to the wave -form. This is in contrast with the ECG measurement (Smith, 1974). Smith (1974) divides the BCG waves into three groups: pre-ejection (FGH), ejection (IJK) and diastolic (LMN).

According to Smith (1974) the pre-ejection waves are caused either by venous return to the heart, plus atrial filling or by atrial contraction. The I -wave coincides with maximal acceleration of blood in the descending and abdominal aorta, and iliac and femoral arteries plus initial deceleration of blood in the ascending aorta when body moves headward. The KL -waves reflect the deceleration and cassation of flow and closing the aortic valve. The MN -waves correspond to blood flow on peripheral arteries as well as to ventricular relaxation and initial passive ventricular filling (Smith, 1974).

The wave -form in the ULF -and SCSB -recordings is slightly different, but the physiological basis in both cases is the same. In the BCG recording the most important thing is the acceleration of blood from the left ventricle, acceleration being the most useful motion derivative. According to Smith (1974) the BCG wave -form can differ a little in a standing position as referred to the normal lying position.

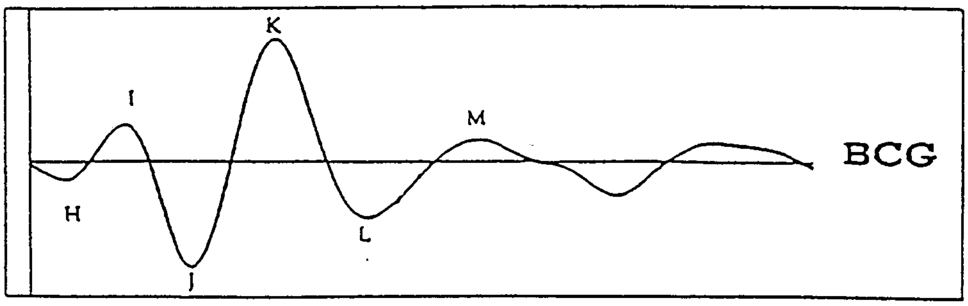

Figure 2. BCG wave-form.

1.3.2. Breathing and BCG

Breathing is one of the most important factors contributing to the shooting performance. According to Konttinen & Lyytinen (1992), the mean course of breathing pattern is continuous slow expiration followed by breath holding just before the trigger pull. Holding of the breath makes it important to examine how the breathing pattern affects to the BCG.

In normal breathing pattern there is a slight respiratory oscillation in the systolic wave amplitude that is called ballistocardiographic respiratory variation.

There seems to be at least two factors, that are responsible of ballistocardiographic variation. First, breathing changes the position of the heart: when a person inhales the heart becomes more vertical and produces more pronounced footward component of cardiac recoil. (Brown,de Lalla, Epstein & Hoffman, 1952) Second, it produces changes in blood flow to and from the right and left heart- inspiration increases venous return to the right heart by diminishing intrapleural pressure at the same time that it decreases venous return to the left heart, and the reverse occurs with expiration.

Respiration changes the actual BCG-waveform amplitude in a slight way. The waves that make the biggest alterations in the BCG are H -, I -, J - and K -waves. The study that examined 40 normal adults Brown and de Lalla (1950b) found alterations in the BCG-waves. In expiration the H-wave increased in 55 percent of these subjects. I-wave that is probably produced by the cardiac recoil, and one would expect to find normal individuals whose I valley is deeper in inspiration than in expiration.
The I -wave showed inspiratory increase in 85 percent among the 40 subjects.
The J -wave -peak, was greater in inspiration than in expiration in 39 out of 40 cases. When the IJ amplitude in expiration is about one half than that in expiration, it can be stated that the respiratory variation is abnormal. The variation of the K-wave with respiration seems to be a paradox; JK would be expected to be less in inspiration. However, the BCG measurement showed, that in 32 out of 40 subjects the JK stroke increased in lenght in inspiration. As a conclusion, inspiration and expiration have a different effect on the BCG-waveform.

1. 4. Earlier findings

Previous studies on sharpshooting and its psychophysiological concomitants have focused mainly on the motor preparation and, on the moments before the trigger pull (see Konttinen, Lyytinen, & Viitasalo, 1998; Boutcher & Crews, 1987, Hatfield, Landers, & Ray, 1987). Why are the cardiac cycle and the timing of triggering so important in the sharpshooting? The most important matter seems to be a small mechanical movement caused by the heart muscle, that jerks the whole human body. During the systolic phase of the cardiac cycle this movement reaches its peak, and it is measured by ballistocardiography (BCG). This mechanical movement affects on the shooting performance by moving the rifle`s barrel.

Helin et al. (1987) studied the timing of the triggering with elite and beginner shooters with smallbore rifle. Helin et al. (1987) divided the cardiac into two sections ventricular systole and diastole. In their opinion the best time to pull the trigger is in the diastolic phase of the cardiac cycle. According to Helin et al. (1987) the elite shooters fired almost constantly during the ventricular diastolic phase and the beginners (fired) either during systolic or during diastolic phase. In Helin et al. the elite level shooters obtained better scores, and the beginner shooters also achieved better scores when they triggered during the diastolic phase of the cardiac cycle relative to the scores that were triggered during systolic phase of the cardiac cycle.

Daniels, Landers, & Hatfield (1980) examined the cardiac cycle and HR to determine patterns of autonomic self-regulation in timing of the trigger pull in elite and subelite rifle shooters (n = 62). Daniels et al. (1980) found that several shooters performed better when they performed the shot later in the cardiac cycle (diastolic phase). They also found that the air rifle shooters rarely shot on the r-wave peak in the cardiac cycle, and their performance was poorer when the shot was performed then. On the other hand several smallbore shooters performed best when they performed the shot on the r-peak. Daniels et al. (1980) suggested that different techniques involved in air and smallbore shooting may explain these differences. Also differences in rifles, targets and shooting distances can explain some of these differences.

Paananen (1993) studied the timing of the triggering in the cardiac cycle in his master`s thesis. All the subjects used smallbore rifle in the experiment. The subjects were nine elite sharpshooters from, eight subelite and eight novice riflemen. Paananen examined the timing of the triggering (R-R -interval) and HR at the time of the trigger pull. In the elite and subelite groups there were nine subjects who did not trigger the gun equally in the cardiac cycle, whereas in the novice group only one subject did not pull the trigger equally in the cardiac cycle. Most of the shots were triggered during the first 100 ms period from the R-peak, and 31.4-61.1 % (depending on the subject) of the shots were triggered during the systolic phase of the cardiac cycle.

In addition to the measures that were directly related to shooting performance Paananen went further than the previous studies, and measured ballistocardiography (BCG) of the eight voluntary participants. He used the Static charge-sensitive bed

(SCSB), that records hearts contraction and the blood circulation that produce a mechanical movement in the human body.

The experiment consisted of three different tasks: (1) baseline condition i.e. resting, (2) physical stress (subjects did situps so as to elevate the HR), (3) physical stress (the participants were asked to hold their breath). Paananen examined the waves that make the greatest amplitude in the BCG, J-, K- and L -waves. During the physical stress task (3) the J-and L-wave latencies were 212 ms and 429 ms among the participants, measured from the preceding R-wave peak. In the baseline condition, measured from the preceding R-wave peak the latencies were 230ms and 492ms.

In addition to the sharpshooting studies, there are some relevant studies that have examined the heart beat detection. These studies are of particular interest from the practical point of view, because they can offer sharpshooters and coaches some new insights into the timing aspect. It has been shown that the elite shooters can sense their heart beats during the sharpshooting task, although it is not easy. Several studies have examined the heart beat detection on the (Brener & Jones, 1974.; Whitehead, Drescher, & Heiman.1977.; Yates, Jones, Marie, & Hogeben, 1985., Ring, Liu, & Brener, 1994) subjects, that were not shooters. Many of these studies have found, that it is possible to learn to detect your heartbeat, even with a training that does not take too much time.

1.5 Hypotheses

The following three hypotheses were formulated. First, it was hypothesized that in the shooting task there would be different amount of shots fired either during the systolic or in the diastolic phase, when referred to the control condition where the experiment leader triggered and the subject was not aware when the triggering occurred (Hypothesis 1). Second, the shooting scores were expected to be better when fired during the resting phase of the cardiac cycle i.e. the diastolic phase. (Hypothesis 2). Third, when the HR is elevated or higher than the median HR, the participants should shoot more frequently during the ventricular systolic, because of the diminuation of the ventricular diastole phase as the HR increases. (Hypothesis 3).

2. Method

2.1.Participants

The participants in this experiment were 20 inexperienced right-handed male novice shooters. None of them were competitive shooters or ranked internationally or nationally. They ranged in age from 23 to 36 years (mean = 26.3). Their heights ranged from 176 to 192 cm (mean = 181.9) and their weights ranged from 67 to 88 kg (mean = 77.4). All of the participants were healthy and exercised at least once a week. Participants received one basic lecture in rifleshooting consisting vital elements of shooting i.e posture, breathing, trigger pull and hold. Before the experiment, the study procedures were explained to the participants and they were asked to provide informed consent.

2.2.Task

The experiment consisted two conditions. In the control condition the participants were told to relax and to avoid eye blinks and unnecessary bodily movements. This period lasted about 6-7 seconds. During this period the experimenter triggered the measurement system without the participant knowing it. Following this, the experimenter instructed the participant to perform the shot. The rifle was placed on the rest so that all the unnecessary movements would be minimized. Prior to the trigger pull the participant was told to hold the rifle about 6-7 seconds. The participant performed the shot and put the rifle on the rest. All the participants performed the 100 shooting trials and 100 control (standing) trials.

2.3.Instrumentation

ECG was recorded with a Beckman-type cardiotachometric intstrumentation (Type 9857B cardiotachometer coupler). The data was collected using disposable Skintact AgCl FS 50 electrodes (Meditec s.a.r.l., Italy). The upper active electrocardiogram electrode was placed on the participant`s sternum. The lower one was located on the right side, just below V5, and the electrical ground electrode in the same area, but on the side of heart. The sampling rate for the cardiotachometric ECG was 100 Hz and for HR 10 Hz. The trials were buffered prior the triggering and stored for the off-line analysis with a special software (DSAMP) run on PC based microcomputer.

A commercial optoelectronic Noptel ST-2000 training and analysis system (Noptel Co.,Finland) was used to provide information about the degree of rifle stability and shooting scores. The system consisted four parts: an optical transmitter/receiver mounted on the rifle, a control unit, a microcomputer and a target. In addition to the hit point, it measured and stored the on-target trajectory of the alignment of the rifle at a sampling rate of 100 times per second to an accuracy of 0.2 mm, providing a reliable measure for the investigation of the rifle`s barrel movement.

2.4. Statistical methods: Cross-tabulation

Crosstabulation is a method that includes variables in columns, cells and rows in the crosstabulation table. The number of cases for each combination of the variables is displayed in a cell in the table, with various percentages. The cells provide information about relationships between the variables. With three categories of the column variable and two of the row, there are six cells in the table. In the table the first entry is the number of cases, *frequency*, in that cell. It is labeled as count in the upper-left corner of the table.

It is always possible to interchange the rows and columns of any table, and general rules about when to use row and column percentages cannot be given. Even though the percentages are usually depended on the nature of the variables. If one of the variables is under experimental control, it is termed *independent variable*. This independent variable is hypothesized to affect to the *dependent variable*. Examination of the various row and column in a crosstabulation percentages are useful studying the relationship between two variables, but they do not allow for quantification or testing of that relationship. For these purposes, it is useful to consider indexes that measure the extent of association as well as statistical tests of the hypothesis that there is no association. Researchers are often interested in whether the two variables of a crosstabulation are *independent* of each other.
Two variables are independent if the probability that a case falls into given cell is simply the product of the marginal probabilities of the two categories defining the cell. A statistic that is often used to test the hypothesis that the row and column variables are independent is the *Pearson chi-square*. It is calculated by summing over

all cells the squared residuals divided by the expected values. In the present study *Pearson chi-square* was used to test the independence between the variables.

2.5. Data reduction

The cardiac cycle of each trial was divided into five equally long R-R - intervals (I, II, III, IV, V.) The first phase (0-20%) began from the R-wave peak and the last phase (80-100%) ended to the next R-wave peak. This procedure allowed to determine relatively exact time interval within the cardiac cycle during which the timing of the triggering occurred. Crosstabulation procedure 2 (shooting, control) × 5 (I -V) was used examine the relationship between the variables.

The shooting scores were divided into two categories, median being 7.1, low score (shots worse than 7.1) and high score (shots better than 7.1). The present study used the median of the shots as a dividing point because the studied shooters were inexperienced novices. The relationship between the performance outcome and the timing of the triggering was examined by using 2 (low, high) × 5 (I-V) crosstabulation.

The HR was divided on a median basis (median=77.92 bpm) into two classes, the low HR (below 77.92) and high HR (above 77.92). This was related to the score that the participant achieved during the task. The 2 (low, high) × (I-V) crosstabulation was used to examine the relationship between these two variables.

3. Results

3.1. Timing of the triggering

The cardiac cycle was divided into five sections, as given before (see 2.5.). The Chi-Square test revealed a significant difference between the timing of the triggering in the shooting situation when referred to the control situation. The present data showed, that the shooters pulled the trigger more frequently during the II and III phases in the cardiac cycle, i.e. during the late systolic and in the beginning of the diastolic phase. In the control situation the trigger timings were more equally divided in the cardiac cycle. See table 1.

Table 1.

Timing of the triggering related to the cardiac cycle

Count
Exp.Value
Adj. Residuals

% in cardiac cycle	0-20	20-40	40-60	60-80	80-100	Row
Shooting	358	473	425	341	368	Total
	370	432	399	375	387	1965
	-1.0	3.1	2.0	-2.8	-1.6	49.8%
Standing	386	396	377	413	411	1983
	373	436	402	378	391	50.2%
	1.0	-3.1	-2.0	2.8	1.6	

Chi-Square = 19.94, DF= 4, $p < .001$

3.2. Timing of the triggering and the performance outcome

The relationship between the timing of the triggering and the performance outcome was examined by using the same crosstabulation as given earlier (see. 2.5.) Chi-Square test revealed a nonsignificant effect between the variables. The results indicate that the present study did not find a phase in the cardiac cycle, where the shooter can gain better performance outcome. See table 2.

Table 2.

Timing of the triggering and the performance outcome

Count
Exp.Value
Adj. Residuals

% in cardiac cycle		0-20	20-40	40-60	60-80	80-100	Row Total
HIT							
	Low	164	233	216	181	175	969
		175	234	209	168	182	49.6%
		-1.3	-.1	.7	1.5	-.8	
	High	189	239	206	159	192	985
		178	238	212	171	185	50.4%
		1.3	.1	-.7	-1.5	.8	

Chi-square= 4.17, DF= 4, n.s.

3.3. Timing of the triggering and the HR level

The relationship between the timing of the triggering and the HR level was examined using the same crosstabulation, as given before (see 2.5.). Chi-Square test showed a nonsignificant relationship between the timing of the triggering and the HR level. The results showed that the HR level did not influence the phase where the shooter performed the shot. See table 3.

Table 3.

Timing of the triggering and the HR level

Count
Exp.Value
Adj. Residuals

% in cardiac cycle	HIT	0-20	20-40	40-60	60-80	80-100	Row Total
Low HR	Low	91	132	95	99	95	512
		97	132	98	91	93	52.2%
		-1.0	.0	-.5	1.3	.3	
	High	95	121	93	76	84	469
		88	121	89	83	85	47.8%
		1.0	.0	.5	-1.3	-.3	

ChiSquare = 2.41, DF = 4, n.s.

	HIT	0-20	20-40	40-60	60-80	80-100	Row Total
High HR	Low	73	101	121	82	80	457
		78	102	109	77	88	47.0%
		-.9	-.3	1.7	.8	1.4	
	High	94	118	113	83	108	
		88	116	124	87	99	
		.9	.3	-1.7	-.8	1.4	

Chi-Square = 4.85, DF= 4, n.s.

4. Discussion

The present study attempted to examine (a) whether a novice shooter fires his rifle equally in the cardiac cycle, and (b) if there is an optimal phase for the trigger pull. These questions were investigated by contrasting the timing of the triggering executed by a shooter to the triggering performed by the experimenter. In addition, it was investigated whether there was a significant interaction between the moment for the trigger pull and the performance outcome (i.e. result).

The results showed that there was a statistically significant difference between the timing of the triggering, when the participant triggered the rifle, or the experimenter triggered the measurement system. The novice shooters seemed to trigger during the time period of 20-60% of the R-R -interval of cardiac cycle, that is in the late systolic and in the beginning of the diastolic phase. In the control condition the shots were fired more equally in the cardiac cycle related to the shooting condition. As expected (Hypothesis 1) the amount of the shots were differently distributed in the shooting and the control conditions. Coaches have not thought that the heart could produce an interference to the shooting performance during the systolic phase when the mechanical movement of the heart is in its maximum. The novice pulled the trigger in this phase, which may be due the mechanical movement that jerks their body and their finger.

The relationship between the cardiac cycle and the performance outcome was not significant; the hypothesis 2 was not confirmed. When the timing of the triggering in the cardiac cycle was referred to the HR level the results were nonsignificant, so the third hypothesis was also not confirmed. It should be noted, that although the results concerning the hypotheses 2 and 3 are nonsignificant, the novice shooters seemed to trigger during the systolic phase, right after the R-wave peak, or during the diastolic phase, right before the next R -wave peak. The reason for the nonsignificant results may be that the present study investigated the novice shooters, who do not apply a consistent performance pattern like the experienced athletes do. The mechanical movement does not reach the rifle`s barrel during the triggering phase, when the novice shooters perform shot. This might also be an explanation to the nonsignificant results in the hypothesis 2.

The results of the present study are not in accordance with Helin et. al (1987). According to Helin et al. (1987) the best time to trigger is during the diastolic phase of the cardiac cycle. In their study the elite shooters fired almost constantly during this period and also achieved better scores when they triggered during the systolic phase. The novice shooters triggered either in the systolic or diastolic phase, but achieved better scores when they triggered during the diastolic phase. It should be noted that Helin et al. (1987) did not consider the mechanical movement that affects on the body.

In the study by Daniels et al. (1980) results showed that several shooters achieved better scores when they triggered during the diastolic phase of the cardiac cycle. These findings by Daniels et al. (1980) are not in contrast to the present study where there were no significant differences between the cardiac cycle and the performance outcome. In the present study there were no significant differences in the trigger timings that occurred during the R- wave-peak.

In Paananen (1993), the novice shooters triggered equally in the cardiac cycle. Elite, subelite and novice shooters altogether triggered most frequently during the first ten percent period after the R -wave peak. 13 of the 17 elite or subelite shooters achieved better scores during the systole phase. Most of the shots were triggered during the systole phase. Paananen (1993) found that only the subelite group performed worse when the triggering happened 201-500ms after the R -wave peak. The present study is in concert with Paananen`s findings in that the novice shooters did not achieve better scores when the triggering occured either during the systolic or the diastolic phase of the cardiac cycle. In the present study the novice shooters did not trigger equally in the cardiac cycle, so this was contrast to the Paananen.

Most of the previous studies have almost exclusively examined elite or subelite shooters. The present study concentrated solely on the novice riflemen. In the previous studies (Helin et al.1987, Paananen, 1993) the mechanical movement of the heart that affects on the human body was considered as the critical point why the timing of the triggering in the certain phase of the cardiac cycle affects to the quality of the shot. These studies, however, have forgotten one crucial point; how the mechanical movement of the heart affects to the shooting performance.

In the ballistocardiographic- studies the largest mechanical movement appears to end in the systole phase (See Smith, 1977). Paananen examined BCG-wave, but he did not consider how the mechanical movement affects on the shooting performance, especially among the novice shooters.

The present study proposes, that the reason why the novice shooters triggered more frequently in the late systolic phase and in the beginning of the diastolic phase is that the mechanical movement caused by the heart muscle produces an interference to their performance. This interference affects to the finger, that executes the trigger pull. It is argued, that because the mechanical movement affects to the triggering finger, but not to the rifle`s barrel, the performance outcome is not affected.

For future research what has to be solved is how the novice shooter can learn the optimal timing for the pulling of the trigger. And learn to avoid the trigger pull during the phase, that causes an interference to the trigger pull. There are many studies that have examined how humans can learn to detect their heart beats. Brener and Jones (1974) found that R -wave peak is the moment when the detection of heartbeat occurs. Whitehead et al. (1977) presented that mechanical contraction of the heart requires about 150ms before the blood pulse wave reaches the neck or wrist. In the training the subjects learned to discriminate was the presented stimulus at 128ms or at 384ms after the r-peak. In the study by Yates et al. (1985) the subjects chose stimuli that were presented 200-400ms after the r-peak to present their detected heartbeats. Yates et al. (1985) also stated that there are individual differences in the heartbeat detection. Jones et al. (1987) required their subjects to perform a heartbeat detection task while sitting and standing. The subjects in their study made fewer correct responses in the standing position (67%) than when sitting (83%). Brener and Kluvitse (1988) found that the subjects detected their heartbeats 200ms and 300ms after the r-peak. Ring et al. (1994) examined heartbeat detection and the effects in the passive body tilt positions. Results showed that the passive body tilt did not influence heartbeat detection. The stroke volume increases in the supine position, while the heart rate decreases. In the upright position the effect is contrary. The subjects in Ring et al. (1994) study detected their heartbeats best at 200ms and 300ms after the R-wave peak.

The next step is to use a training program with novice athletes and to examine how the learning affects to the timing of the triggering. The training program could provide us with some knowledge on, how long it takes to learn to avoid the interference phase in the cardiac cycle. If the optimal phase were found, the use of biofeedback procedure could be useful. Previously biofeedback has been used used almost exclusively as a means of learning to relax. That being the case, to teach a shooter to detect his or her heart beat, and to take advantage of this skill in shooting training would be a totally new approach to the applied sport psychology. Elite shooter`s peak rifle hold lasts about 300ms (Ratinen, 1992), so teaching the optimal phase for triggering could be possible. If a novice shooter obtained better results applying this procedure it might be possible that also the subelite and elite shooters, who already are aware of their bodily functions and can sense their heartbeats better than the novice shooters, could gain better results within a few months of training. This study concentrated only on novice shooters and further research is needed to achieve a better understanding of the topic by studying the elite shooters.

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