NOPTEL OY
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Technical analysis of shooting performance using the Noptel ST-1000 PC and ST-2000 equipment

NOStat

Version 1.0, September 1996

1. Principles

1.2. Gun orientation path

The Noptel ST-1000 PC and ST-2000 systems can be used to measure accurately the **gun orientation path on the target surface** before the shot, to record the shot and to continue measurements over a selected period of time after the shot (Fig. 1). This path indicates **how the shot was generated**. No two absolutely identical paths exist, i.e. each shot has a unique history. The gun orientation path in fact contains almost all the information required for the technical evaluation of shooting performance. We prefer here to use the term "gun orientation path" rather than "aiming path". Basically, they refer to one and the same thing, but there is a slight but important conceptual difference in that aiming implies a conscious, deliberate action focused on the target, while orientation is a broader concept. The practical difference lies in the fact that although the shooter makes an effort to **aim** precisely at a certain point on the target, the gun tends to **be oriented** somewhere just beyond that point, because the shooter is unable to hold the gun perfectly in position.

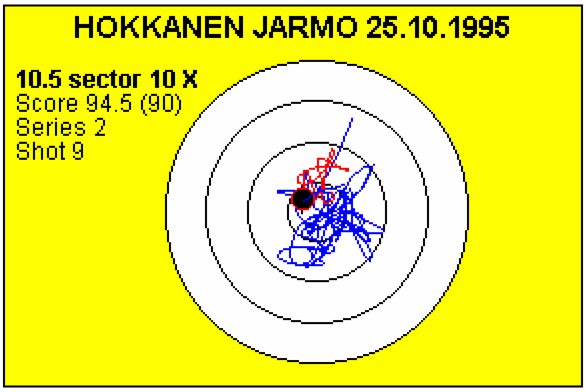


Figure 1a. X-Y display mode

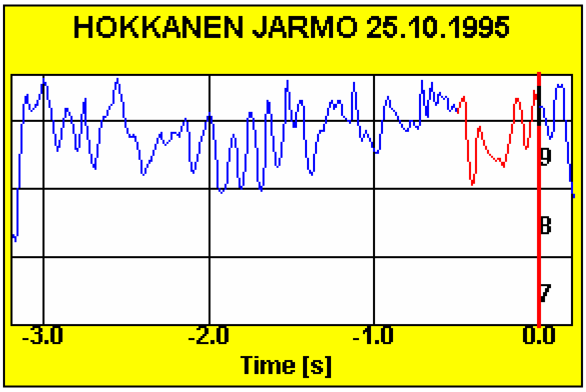


Figure 1b. R(t) display mode

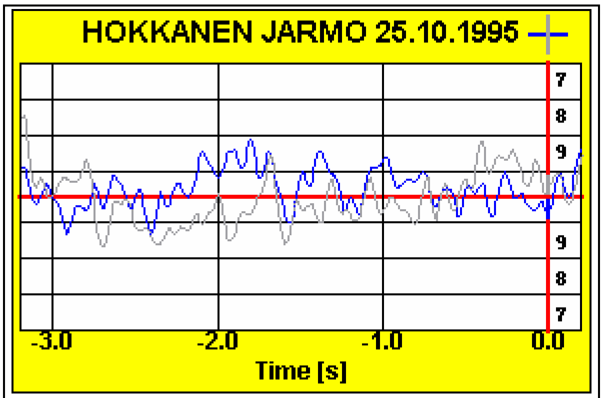


Figure 1c. XY(t) display mode

Figure 1. NOS and STX display modes

The above figures show the three main graphical display modes used in Noptel's basic software. Figure 1a shows the gun path on the surface of the target, Figure 1b shows the distance between gun orientation and the centre of the target as a function of time, and 1c shows a corresponding temporal analysis in terms of the horizontal and vertical axis. These three displays as such are practicable for evaluating shooting performance, in that they reveal the shooter's holding, aiming and triggering capabilities at one glance.

1.2. Use of path data for the evaluation of shooting performance

The gun orientation path itself describes the history of the shot and can be used as such for visual evaluation. Skilled analysts are able to evaluate the technical execution of a shot rapidly and in a fairly reliable manner on this basis alone. Even at its best, however, visual evaluation is qualitative, subjective and difficult to store, so that it lends itself best for use as immediate feedback after the shot. Tools can be obtained for reliable, objective evaluation by converting the path data into **numerical form** for use in analysing shooting performance at the level of both individual shots and series of shots, in calculating a variety of derived parameters and in comparing shooters or the performance of a single shooter at different points in time. In order to be of practical value, such numerical data should describe the shooting performance correctly and convincingly, which means that the manner of presentation should be acceptable to the shooters and their trainers.

Noptel Oy have been examining shooting performance both theoretically and by means of extensive measurements for a number of years, creating a numerical method of description which is both correct and convincing. Its reliability has been verified through practical measurements, while it is rendered convincing through the fact that the descriptions it uses are based on concepts understood by shooters themselves. Data on a total of 350 series, comprising more than 21.000 shots, were collected from more than 100 shooters ranging from internationally renowned marksmen to untrained amateurs in order to develop the model and verify its reliability.

The purpose of this article is to explain to shooters and trainers what information the graphical and statistical data produced by Noptel's training systems (the ST-1000 PC and the ST-2000 product family) provide about shooting performance. We will thus discuss both the gun orientation path and the parameters calculated from it, some of which are already available through the basic software, while some will be included in later versions. We will also present below the model for the description of shooting performance that lies behind the calculations, to be referred to here as **NOStat**, in order to facilitate understanding of the numerical analysis. The description lends itself best for use in the evaluation of complete series of shots, though it can also be applied to individual shots if interpreted correctly.

2. Technical description and modelling of shooting performance

Lets us first take a brief look at the shooting event itself. The event begins when the shooter raises his gun and begins to aim at the target. The view he has of the target through the sights of the gun changes constantly because his non-ideal holding technique means that the gun is in continuous motion. When he is satisfied with his aim and otherwise feels ready, he either pulls the trigger or lets the gun fire. Precisely how this feeling of 'satisfaction' arises and is perceived is still poorly understood and must vary from one individual to another.

2.1. Success factors

Shooting performance is technically speaking the product of three **basic success factors: hold, aim and trigger control**. A shooter's hold denotes his ability to control his muscles and prevent unwanted movement, his aim denotes the accuracy with which he is able to direct the gun at the desired point on the target, and trigger control denotes the timing of the actual triggering event relative to the hold/aim process and the cleanness with which triggering takes place.

2.2. Relations of results to success factors

In reality, there is a complex connection between the above basic factors and the result achieved, as illustrated in the following figure.

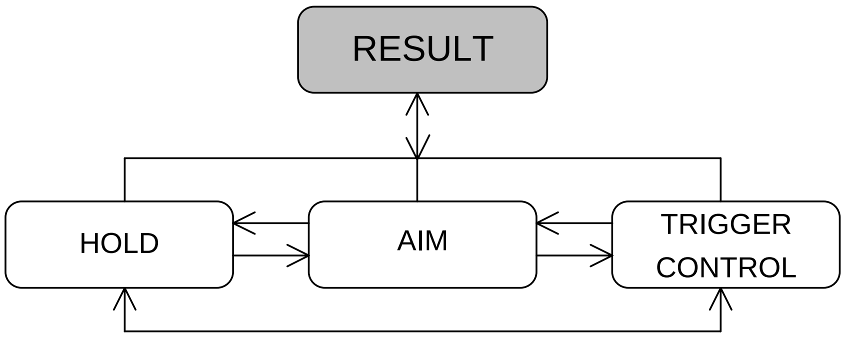


Figure 2. Relation of the result to the success factors, and relations between the success factors.

As indicated in Figure 2, the success factors interact with each other. The key position is occupied by the hold factor, which is linked to the other success factors and to the result itself, i.e. it affects the result both directly and via the aim and trigger control. In addition, the result may have a counter-effect on the hold etc. Numerous **contributory factors** affecting hold, aim and trigger control can be listed, but it is not necessary to discuss them in any more detail here. The essential point is that they are reflected in the result through the above success factors.

2.3. Effect of success factors on the result

The effect of the success factors on the result can be illustrated as follows:

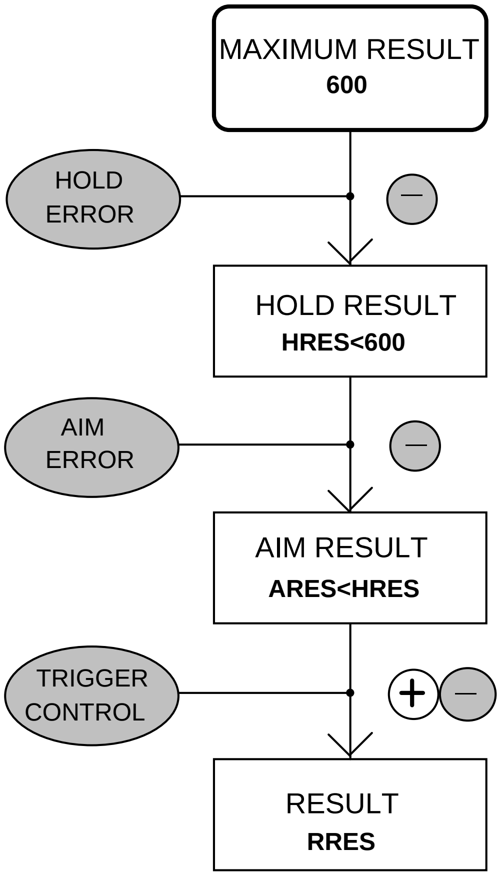


Figure 3. Effect of success factors on the shooting result

2.3.1 Hold Result, HRES

The above figure can be interpreted in the following manner. In a set of 60 shots the shooter **has the opportunity to score** a total of 600 points. Given that he has a non-ideal hold, i.e. the gun is in continuous motion, he will lose points in accordance with the degree of this movement, which will reduce the **actually achievable** score. This 'intermediate result' is referred to here as the **hold result, HRES**, and can be calculated mathematically from the hold values, i.e. the calculated deviations from the gun orientation path, assuming that the shooter has aimed each shot at the target centre on average (i.e. the shooter's aiming ability is not included in this measure). A top-class air pistol shooter, for example, will 'lose' approximately 10 points out of 600 on this basis, and the holding result for a person who habitually scores nines (540 points) will be approximately 550 points, i.e. he will 'lose' 50 points on account of inadequate holding alone. The average hold error in the pistol series analysed here was 27.6 points, which yields an average HRES of 572.4 points, while the corresponding figures for rifle shooters were 23.6 and 576.4 points. Thus at the individual level, a top-class rifle shooter will have a slightly better hold ability when measured in terms of rings on the target. This can be attributed to the smaller extent of vertical movement because of the support available.

Holding results corresponding to the various hold values are presented in Table 4 on page 22, together with an approximate formula which enables the holding result to be calculated easily.

2.3.2. Aim result, ARES

No shooter is able to aim each shot in such a way that the centre of gravity of the holding area lies precisely at the centre of the target, and consequently the **achievable** score will decline further. This result is known as the **aim result, ARES**, which will thus always be smaller than HRES. The aim result can be calculated mathematically on the basis of holding values calculated from the path and the holding area location data, i.e. the centre of gravity (**COG)**. The average centre of gravity for a top pistol shooter in a set of 60 shots is of the order of 10.60 at best, rarely higher. Assuming that the shooter has a 590 point holding result, he will 'lose' another 5 points or so due to incorrect aiming, i.e. his aiming result will be 585 points. The typical centre of gravity for a person with an average score of 9 over a series is 10.00, which with his holding ability will mean an aiming error of some 16 points. The average '**aim error**' in the air pistol sets was 18.0 points, which indicates that the shooter had 'lost' 45.6 points due to a defects holding/ aiming and will thus have had an average aiming result of 600-45.6 = 554.4 points. This aiming error is equivalent to an average centre of gravity of 10.19. The centre of gravity over a whole series for a top rifle shooter is of the order of 10.60 at best, i.e. the same as for a pistol shooter.

The holding and aiming values are both also dependent on shooting style. We have divided shooters into three groups: **hold shooters, optimising shooters and reaction shooters** (i.e. highly optimising shooters). The calculating of holding and aiming ability from values recorded at the holding stage in the manner described in the model means that the hold shooters naturally obtain the best values and reaction shooters the poorest ones. The eventual result may in any case be the same, as reaction shooters tend to gain additional points by virtue of their good trigger control. The classification of shooters will be discussed in Section 2.5.

The formation of the aiming result is shown in Table 7. on pages 28-29, which also demonstrates that the magnitude of the aiming error in points is dependent on the shooter's holding ability, i.e. the better the hold, the more points the shooter will lose on account of aiming error! Fortunately it is also the case that a shooter with a good holding ability will automatically achieve a better centre of gravity, other things being equal (aiming, repeatability of performance etc.).

2.3.3. Trigger result, RRES

As mentioned above, trigger control is a factor which enables the shooter to 'compensate' for score losses arising from holding and aiming errors. This compensation is mainly based on timing, in that the shooter tries to **optimise** (see Section 2.4.) the triggering point relative to either the aiming picture and/or hold, bearing in mind the average state of these two during the aiming/hold sequence. Even the benefits gained from good timing may be wasted, however, if the actual triggering is not performed properly. The measurements indicate that practically **all** shooters make use of optimisation either consciously or subconsciously, although this is particularly the case with reaction shooters. Trigger control contributed to the fact that the average **net benefit** observed in the series shot with an air pistol in the present data was as much as 9.6 points, yielding an average final result of 564.0 points (600-27.6-18.0+9.6 = 564.0). The main factor accounting for this positive effect at the trigger stage was optimisation.

2.4. Temporal history of a shot

The above model is based on the idea that a shot can be divided temporally into two stages, the preparatory, or **hold stage**, and the actual shot, or **trigger control stage**. The hold stage occurs between -3 s and -1 s on the time scale for a shot, the last second preceding triggering being assigned to the trigger control stage. It should be noted, however, that this pattern does not apply when shooting at rapid intervals, an activity which is not based on hold techniques. This temporal division of shooting performance into hold and trigger control stages is based on actual measurements. Average **time curves** for **all** the shots considered here are indicated in Fig. 4. below.

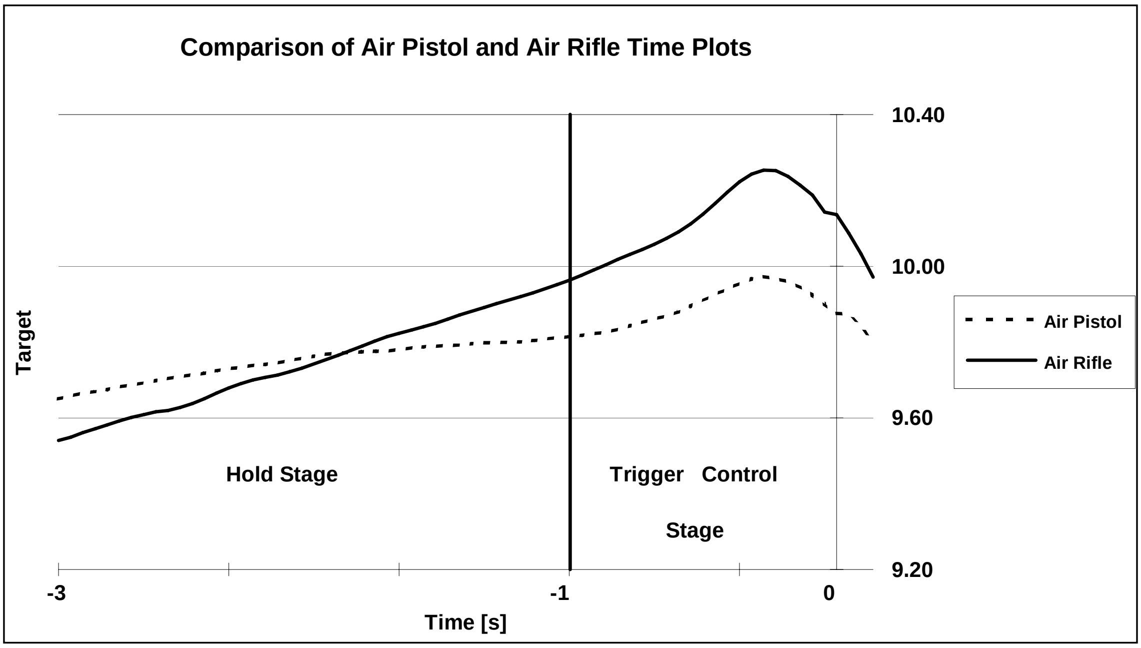


Figure 4. Temporal history of air pistol and air rifle shots

Figure 4 indicates how an average air pistol or air rifle shot originates during the last three seconds. The vertical axis shows the result and the horizontal one time. The holding and aiming errors referred to in the model for shooting performance are thus calculated for the hold stage, and the hold result is calculated on the basis of hold ability only, while the aiming result also involves the average aiming point. The total effect of trigger control can be obtained by subtracting the real result from the aiming result.

The figure clearly indicates that shooters try to benefit, either consciously or subconsciously, from the timing of triggering, a process referred to here as **optimisation**. The diagram also confirms our impression of the finite nature of human reaction time, which in this case is an average of approximately 0.3 seconds. When a visual cue is obtained that the direction of the gun, i.e. the aim, is good, the shooter 'decides' to squeeze the trigger, whereupon it will take approximately 0.3 seconds for the forefinger to bend and the gun to go off. Unfortunately, the gun will have already left its ideal position even within such a short period of time, and the result will thus be poorer than expected. This movement is also attributable to the fact that triggering is on average not absolutely clean, as indicated by the fact that the 'optimisation peak' is not fully symmetrical. Optimisation is present at all levels of performance, and is considerably greater among rifle shooters, due to the fact that a larger part of the movement of a rifle occurs in the low frequency range (less than 3 Hz), which is easier to control, whereas 40-50% of pistol movement occurs at the extremes of the shooters' reaction ability or completely beyond it. It should be noted, however, that considerably less test data were available for rifle shooters than for pistol shooters.

Evolution patterns for good and poor shots with time are shown below. The diagram is based on the 18 best and 18 poorest results in each series.

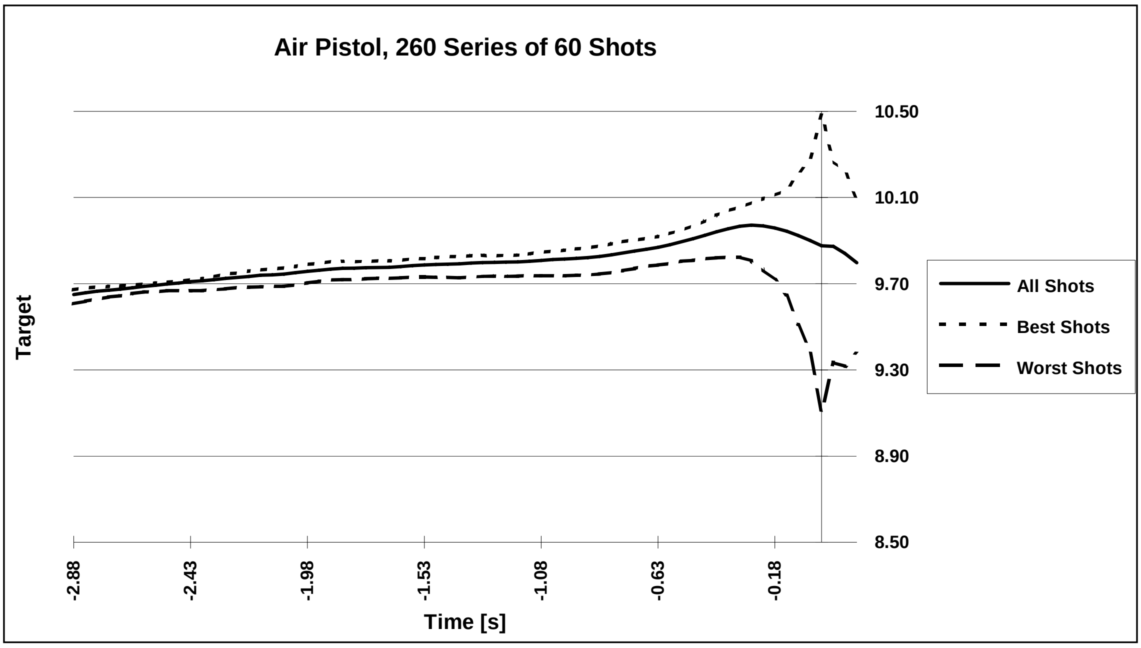


Figure 5. Evolution of good and poor air pistol shots with time.

As seen in Figure 5, the difference a good shot and a poor one arises at the holding stage. The most important factor, however, is the timing of triggering, as the poor scores can be attributed to late triggering.

The corresponding patterns for air rifle shots are presented in Fig. 6.

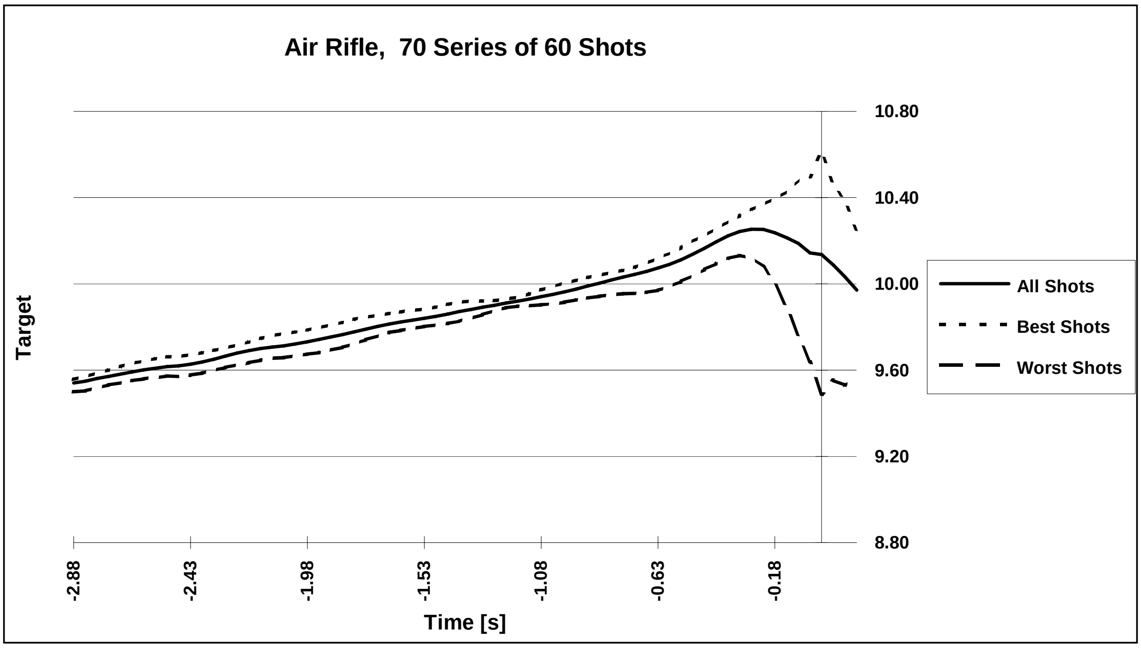


Figure 6. Evolution of good and poor air rifle shots with time.

The 'good' rifle shots proceed in a straightforward manner, whereas in pistol shooting the slope of the curve increases during the last half second, possibly due to more high-frequency vibration of the pistol. Again a difference between the good and poor shots can already be observed 3 seconds before triggering! It was found in a Finnish study by Niilo Konttinen that such a difference between good and poor scores could be observed in electroencephalogram curves as early as 6 seconds before the shot!

2.5. Classification of shooters

We classified the shooters in two ways, according to shooting style and according to level of performance. Let us first look at shooting styles.

2.5.1. Shooting styles

The shooters can be divided into groups according to their manner of performance, most conveniently on the basis of the time curve. Air pistol shooting styles are presented in Fig. 7.

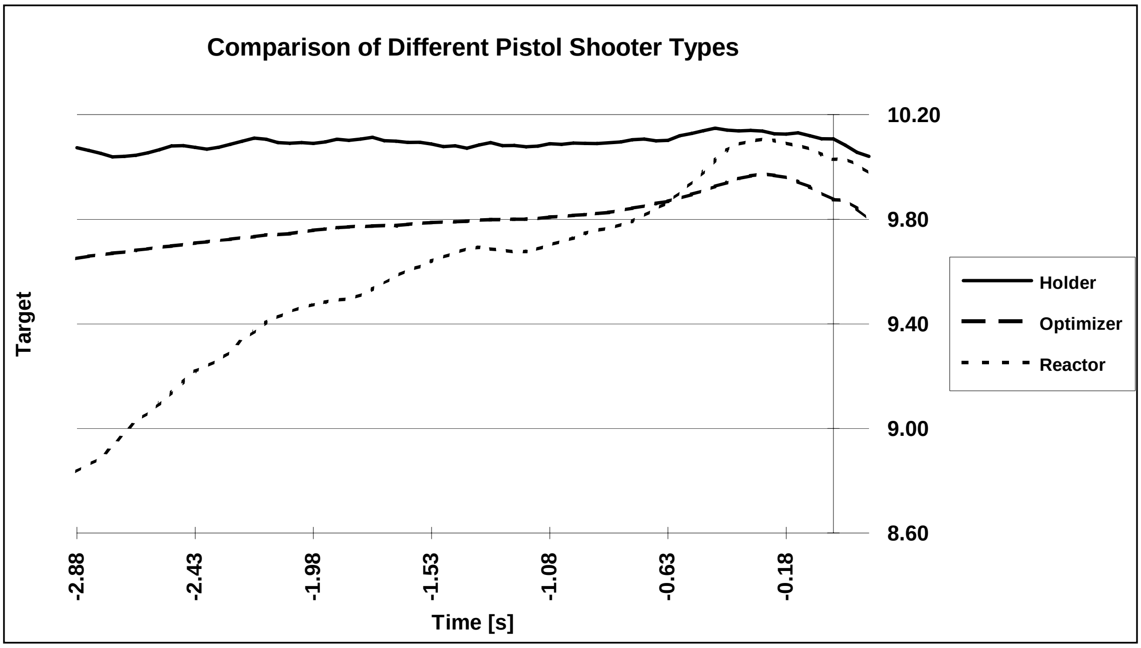


Figure 7. Basic air pistol shooting styles.

Three groups can be distinguished:

*** Hold shooters**

*** Optimising shooters**

*** Reaction shooters**

*This division is based on the amount of **relative optimisation**, i.e. the **optimisation resources** that the shooter makes use of. Optimisation resources can be calculated by subtracting the ARES score from 600. The average relative optimisation for the air pistol series was approximately 47%, the maximum 84% and the minimum 13%. A shooter with a relative optimisation of under 20% per series is defined here as a hold shooter, and a person with a value >=75% as a reaction shooter.*

The same groups could also distinguished among the rifle shooters.

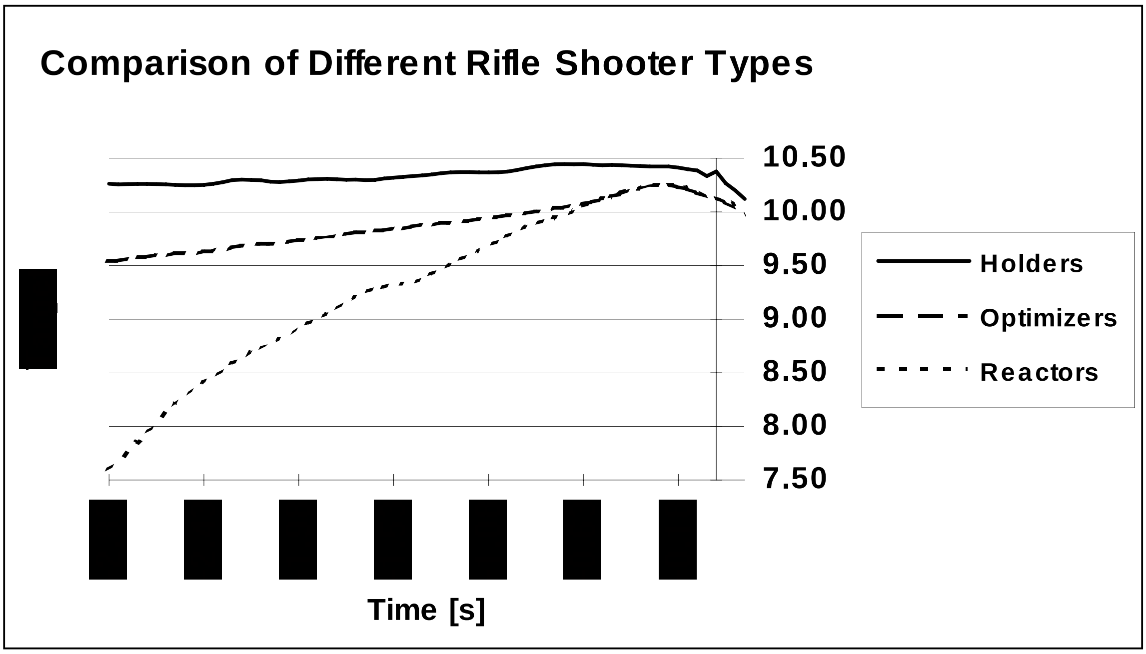


Figure 8. Basic rifle shooting styles.

Higher relative optimisation values were recorded among the rifle shooters, however, i.e. most of them made use of timing to compensate for inadequate holding. On the other hand, an evident group of hold shooters was also identified in this case. It would seem on the basis of the test material that the best female shooters have a better hold ability than male shooters, the difference being a matter of vertical hold. This point will be taken up again later.

2.5.2. Competence groups

The shooters can also be grouped in a natural manner on the basis of the results they achieved. The air pistol shooters were classified as follows:

Competence group	**Result**	
Competence group	>=580	Top marksman
Competence group	570-579.9	Very good
Competence group	560-569.9	Quite good
Competence group	540-559.9	Good
Competence group	510-539.9	Satisfactory
Competence group	<510	Poor

Table 1. Air pistol competence groups.

The corresponding groups can be obtained for air rifle shooters by adding 10 points to each of the boundary values:

Competence group	**Result**	
Competence group	>=590	Top marksman
Competence group	580-589.9	Very good
Competence group	570-579.9	Quite good
Competence group	550-569.9	Good
Competence group	520-549.9	Satisfactory
Competence group	<520	Poor

Table 2. Air rifle competence groups.

We should remember that this kind of grouping is always more or less arbitrary. Other group limits could also be justified.

2.6. Summary of the model

The purpose of **NOStat** is to describe the shooting event in a simple, illustrative manner. The model is based on three basic performance factors, or **success factors, hold, aim and trigger control**, the first two of which are determined relative to time during the **hold stage** and the third at the **trigger control stage**. Extensive measurements have confirmed that the model is indeed illustrative of the shooting event and can be used effectively for training purposes.

The statistical calculation time usually employed in practical systems is the three final seconds preceding the shot, whereas the hold and aim values in the model are calculated over two seconds. Thus the figures obtained differ slightly, the three second hold values being slightly higher (a longer time involves more movement) and the centre of gravity (COG) slightly better, on account of factors such as optimisation. The differences are quite small, however.

3. Measurement of holding ability

The results obtained indicate that the most important success factor is holding ability. In fact, since the research covers shooters of varying quality, they can be ranked in an reliable manner solely on the basis of the **scope** of the holding area. Thus the hold results (**HRES**) explained more than **80%** of the variance in the results recorded for the air pistol shooters over all the test series and those for the air rifle shooters **60%**. The distribution of holding results among the competence groups of air pistol shooters is indicated in Table 3 below.

Competence group	**Result, RRES**	**Mean HRES**
Competence group 1.	**583.0**	**583.5**
Competence group 2.	**575.2**	**579.6**
Competence group 3.	**565.9**	**572.1**
Competence group 4.	**552.6**	**565.2**
Competence group 5.	**529.3**	**545.7**
Competence group 6.	**503.9**	**515.9**

Table 3. Holding results for the competence groups of air pistol shooters.

This table points to the paramount importance of holding ability from the point of view of the result, in that the mean holding result improves with the competence of the shooter.

Hold is a more crucial factor for pistol shooters than for rifle shooters, as is quite natural, since it is more difficult to control a pistol, the movements being more rapid and the gun being triggered and held with one hand. The situation with the rifle is quite the opposite, as the triggering hand does not hold the rifle. An important factor contributing to the result in pistol shooting is minimisation of large, slow movements, whereas vibration is more damaging to the result in the case of rifle shooting.

The figures contained in Table 3 require some additional comments. Since most extensive material was available for groups 1-4, their means can be regarded as highly reliable in a general sense, whereas the holding results for groups 5 and 6 are higher than they should actually be, due to the fact that the measurement range of the ST-1000 PC, with which the tests series were shot, is fairly small and yields slightly too good holding results for poor shooters, i.e. those with a poor holding ability. The ST-2000 has a considerably broader measurement range, however, and is capable of measuring the entire range of movement among poor shooters. This is illustrated in Fig. 9.

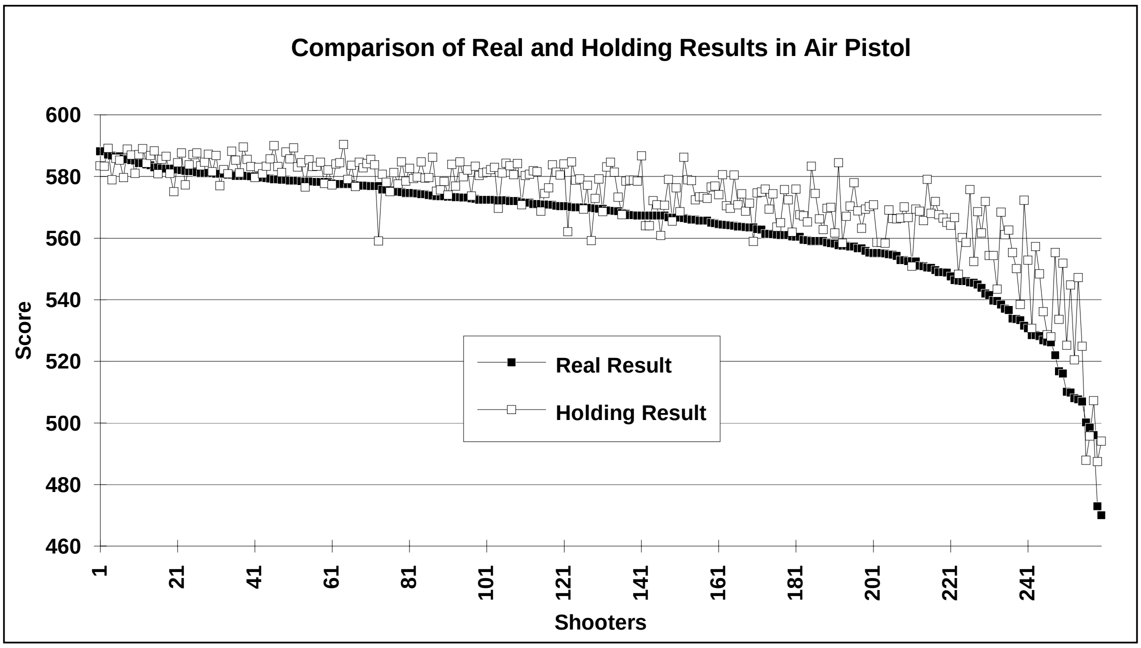
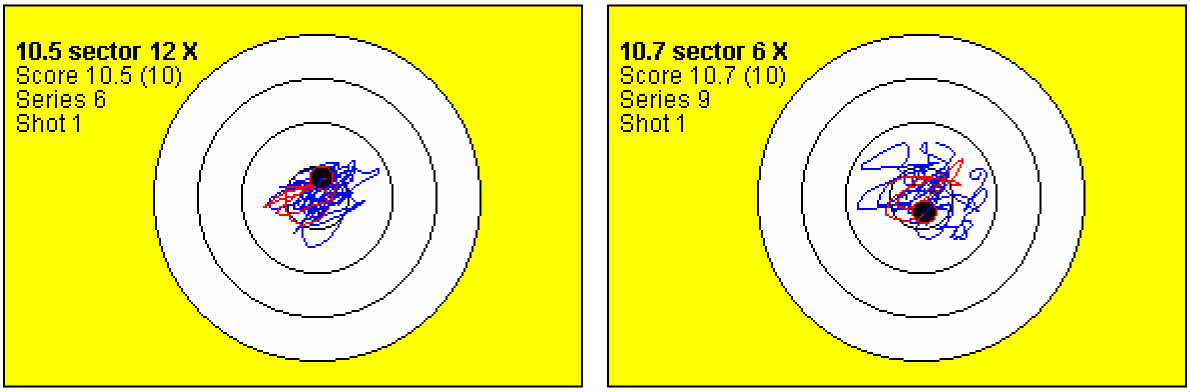


Figure 9. Comparison between real scores and holding results in air pistol shooting

The diagram also indicates that the better the shooter is, the closer to his score will come to his 3 s holding result. This tells of the important role of the holding ability for the trigger control. It should be noted, however, that interpretation of the curve is hampered by the measurement error mentioned above.

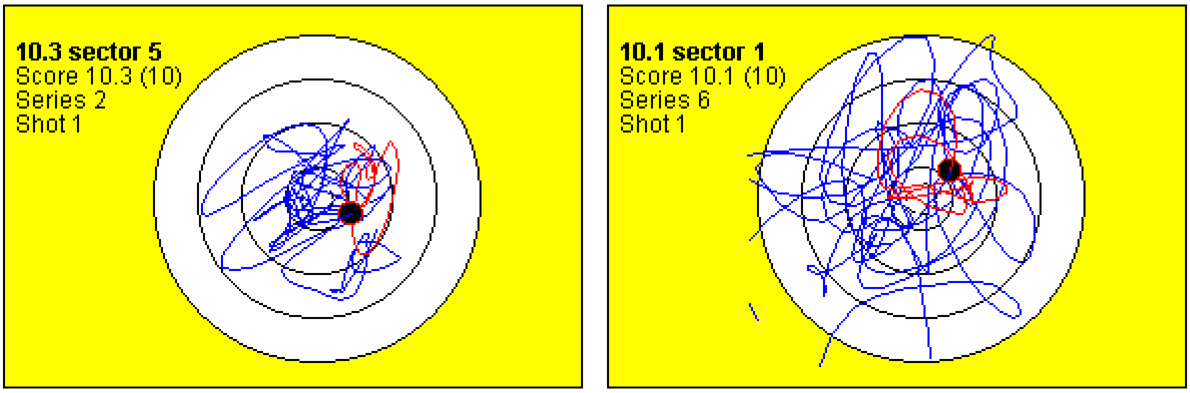
3.1. Extent and shape of the holding area

Examples of holding paths on target surface are shown in Figs. 10 and 11.



(a) **(b)**

Figure 10. Two examples of 3 s holding paths for air pistol shooters. Left, the work of a top-class shooter; right, that of an very good shooter.



(a) **(b)**

Figure 11. Two additional examples of air pistol holding paths. Left, the hold is still good; right, it is quite poor.

All four paths in the above illustrations are relatively symmetrical, i.e. the x and y hold components are of almost equal magnitude, and aiming was good in all cases. It is obvious, of course, that a small holding area will facilitate the obtaining of good results. The matter can be simplified by stating that the path represents all the points at which the gun could have gone off. The 'random' element still plays a major part in the case of an individual shot, but its role is almost non-existent in a series of 60 shots, for instance. In the case of the last shot illustrated above a score of ten was achieved thanks to accidentally correct timing of triggering. Maybe 10 out of the 60 shots in a series produced by a person with such a holding pattern will give a score of ten, while some will fall into the white area of air pistol target.

Two examples of air rifle shots are shown in Fig. 12 below.

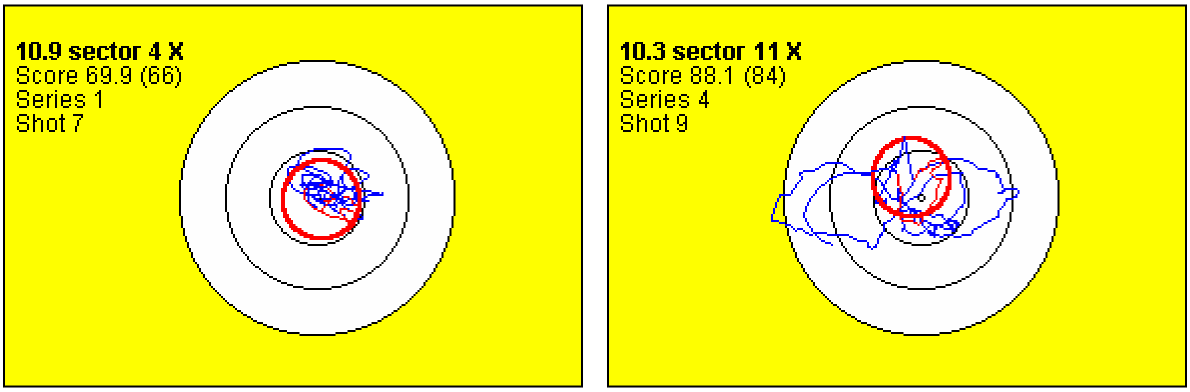


Figure 12. Left, an excellent symmetrical hold on the part of a rifle shooter; right, a poorer, asymmetrical holding path.

The most important measure of holding ability is thus the **extent of the holding area (1)**. This means that the smaller the path area, the better the holding ability. In everyday terms, holding ability is equivalent to the extent of the holding area, although it is only one of the criteria on which holding ability is evaluated. The **shape (2)** of the path area describes another important measure, i.e. the **symmetry of the hold**. A circular area indicates a symmetrical hold, i.e. horizontal and vertical movements are of the same magnitude, while an elliptical pattern indicates that the hold is asymmetrical, i.e. horizontal and vertical movements are of different magnitude. The third measure, **repeatability of hold (3),** indicates the extent to which the extent of the holding area varies between shots within the set. We can also examine the **frequency content (4)** of the hold, i.e. we can explore the frequency components of which the movement is composed (swaying vs. vibration etc.). The movement of the aim point on the target surface is a combination of components arising from the shooter and is particular to each shooter. In fact, each shot carries a frequency content of its own, which can also be detected in the time curve.

Holding ability is always determined over a certain time interval, referred to here as the **statistical time.** It is obvious that the average path area will be larger if traced over 5 seconds than over 1 second, for example. The statistical time usually employed is 3 seconds, i.e. holding values are calculated for the last 3 seconds. It should be remembered, however, as noted above, that in the actual investigation, holding ability was calculated for the **hold stage**, i.e. **-3s --> -1 s** before the shot, so that the fact that the hold values are slightly below the normal for 3 s intervals can mainly be attributed to the 1 s time difference. **Trigger control**, which also plays a role in this, though admittedly a very minor one, can thus be treated for calculation purposes in isolation from the hold/aiming process.

The extent of the holding area can be determined by a number of means. Noptel's basic systems employ two types of calculation: **deviations** and **percentages**.

3.1.1. Determination of the extent of the holding area from deviation figures

The extent of the holding area within the selected statistical time can be indicated separately for the horizontal and vertical axes by means of the deviations **Sx** and **Sy** respectively. The unit of deviation is the interval between two consecutive rings, and the figure can be converted to millimetres by multiplying it by the width of a ring on the target. Thus the coefficient needed for this purpose is 8 for air pistol shooting and 2.5 for air rifle shooting, for instance. Sx and Sy values can also be presented graphically in the form of a rectangle (deviation box) on the target surface display (X-Y display), where the length of the rectangle is 2 * Sx, the height 2 * Sy and its centre the COG. It is immaterial, in fact, what point is used as the reference for calculating the deviations, as they in any case describe the extent of movement in an absolute manner.

3.1.1.1. Deviations and the size of the holding area

*The proportion of the total extent of movement expressed by the deviation is dependent on the distribution of the movement. Thus it would be approximately 29% if the movement were distributed evenly and 68% if it conformed to a normal Gaussian distribution, bearing in mind that the movement may be either horizontal or vertical. This distribution varies at the shot level as a function of holding ability and type of hold, but at the series level it does approach the Gaussian model, thus becoming normalised, for reasons well known to statisticians. It can be stated quite reliably for a set of 60 shots, for example, for which the average deviations are Sx=Sy=S, that approximately 39.3% of the movement will have taken place within a circle of radius S around an average centre of gravity (COG), some 86% within a circle of radius 2*S and 99% within a circle of radius 3*S. This is illustrated in Fig. 13.*

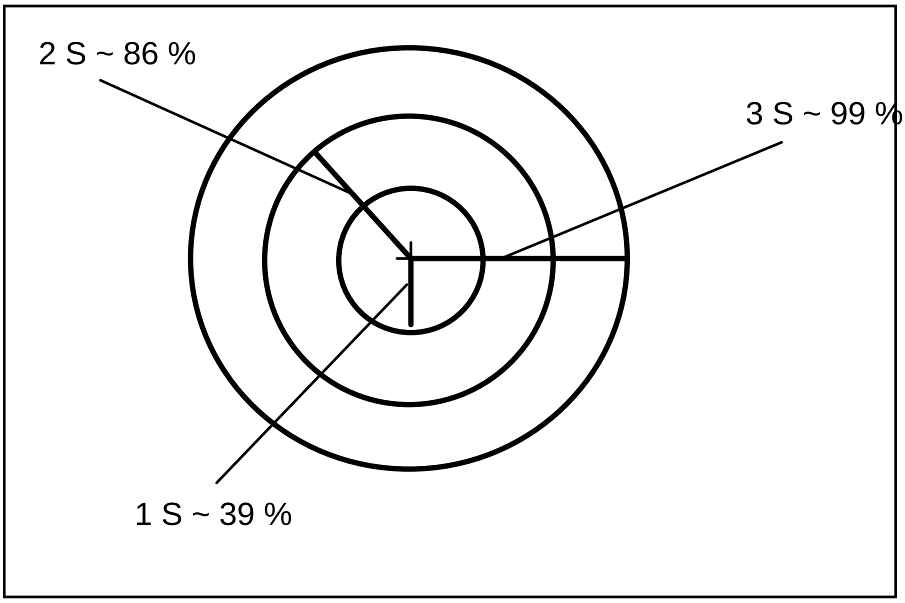


Figure 13. Deviations and their coverage of the total path area, given a hold with a normal distribution.

As we do not know the form of the distribution for an individual shot, it is impossible to determine the coverage percentage. The deviation can still be taken to describe the extent of movement in the case of individual shots, however, but should be interpreted in a slightly different manner. If the shooter's hold value is 1.0 rings and he aims at the centre of the target, the probability of his hitting the ten despite random movement is 39.3%, the probability of a nine being 47.2%, that of an eight 12.4% and that of a poorer score approximately 1%. Correspondingly, if the hold value in such a case were 0.5, the likelihood of a ten would be 86.5% and the rest of the movement would occur within the nine.

Let us illustrate this by considering what the holding area on an air pistol target would look like at different levels of hold ability. It is assumed here that 39% of the gun movement will occur in the smallest circle, 86% within the next circle and 99% within the largest one.

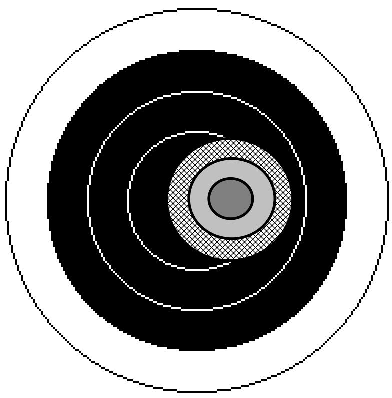


Figure 14a. Deviations Sx=Sy=0.5, symmetrical

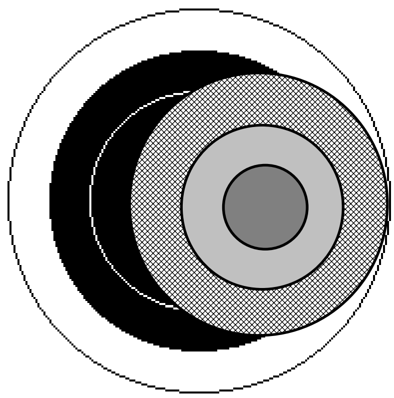


Figure 14b. Deviations Sx=Sy=1.0, symmetrical

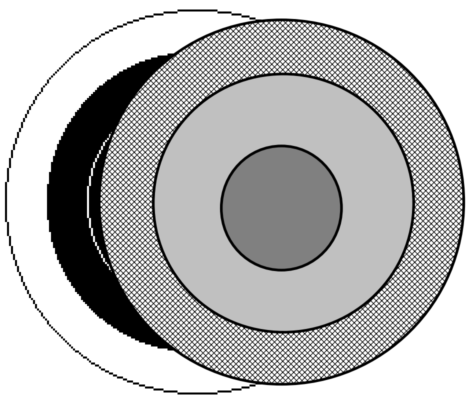


Figure 14c. Deviations Sx=Sy=1.5, symmetrical

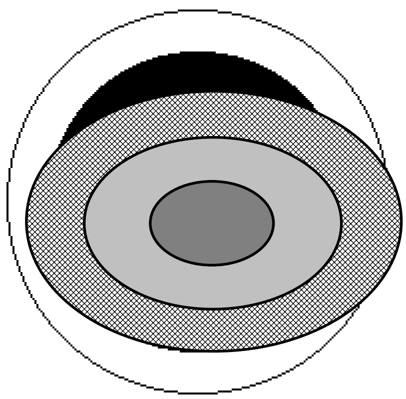


Figure 14 d. Deviations Sx=1.5;Sy=1.0 asymmetrical

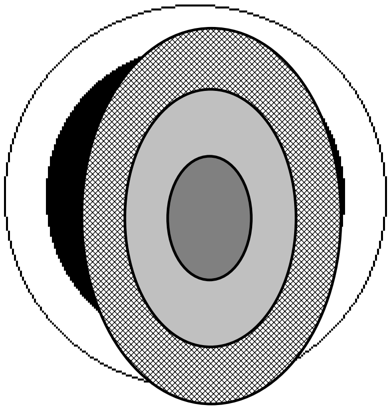


Figure 14e. Deviations Sx=1.0; Sy=1.5, asymmetrical

3.1.1.2. Deviations and the hold result, HRES

The relation between deviation and the hold result in the symmetrical case (Sx = Sy) is presented in the table below. The hold result can be calculated from the deviation by assuming that the path area has a normal distribution and that the shooter has always been aiming precisely at the centre of the target (no aiming error).

DEVIATION	HRES		DEVIATION	HRES		DEVIATION	HRES
0.45	594.9		1.00	554.8		1.55	513.4
0.50	591.9		1.05	551.0		1.60	509.7
0.55	588.4		1.10	547.3		1.65	505.9
0.60	584.8		1.15	543.5		1.70	502.2
0.65	581.1		1.20	539.8		1.75	498.4
0.70	577.4		1.25	536.0		1.80	494.6
0.75	573.6		1.30	532.2		1.85	490.9
0.80	569.8		1.35	528.5		1.90	487.1
0.85	566.1		1.40	524.7		1.95	483.4
0.90	562.3		1.45	521.0		2.00	479.6
0.95	558.6		1.50	517.2			

Table 4. Relation between deviation and the holding result at given hold values.

The average hold deviations recorded for top-class pistol shooters over 3 s vary between 0.5 and 0.6 per series, in which case the hold result will be between 592 - 585, even though the deviations for individual shots may be in the range 0.4-0.5. The deviations for the air rifle shooters are slightly smaller, particularly in the vertical direction, as the vertical deviation for a top rifle shooter is 0.3 rings or perhaps less and the horizontal holding values typically vary between 0.50 and 0.60.

Deviations for a shooter with an average score of 9 per shot (total 540 points) will be slightly over 1 and the corresponding hold result approximately 550 points, i.e. the average total effect of aiming and trigger control will be -10 points.

It can be stated by way of summary that holding ability can be illustrated by means of a single figure, the **hold result, HRES,** which can be used to account not only for the extent of the holding area, but also its symmetry and repeatability, provided that calculation of the hold result takes the actual hold values of the individual shots into consideration in a statistically correct manner. The content of the above table is displayed in graphical form in Fig. 16.

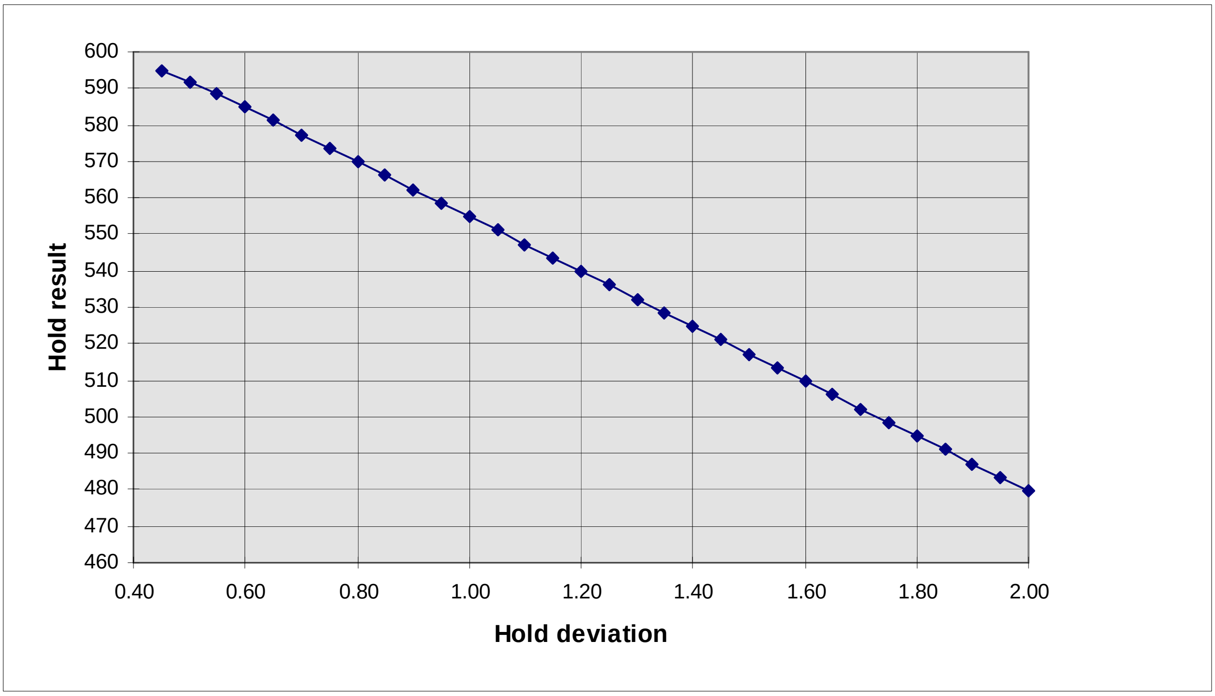


Figure 15. Dependence of HRES on holding ability

As seen in Figure 15, there is a linear relation between deviation and the holding result, which can be represented by the following rough equation:

HRES = -75*S+630

Hold deviation figures can be obtained from the ST-1000 and ST-2000 statistics. The shooter should first fire a series of 60 shots and then calculate the mean values for Sx and Sy over this series and take the mean of these. He can then read off his holding result roughly from Table 4 or calculate it using the above formula. It should be noted, however, that the holding result calculated in this way will be slightly better than the actual one, as the calculation of means cannot be regarded as a mathematically correct method. The result is nevertheless a good preliminary indicator.

3.1.2. Determination of holding area as a percentage

Noptel's statistical programs can also be used to calculate holding ability in percentages in the following manner. The shooter has access to two hold boundaries, a rough one and a fine one, which are normally the 9 ring and the 10 ring respectively. The device will in a sense draw a new target around the shooter's centre of gravity (COG) and calculate the percentages of the selected statistical time for which the gun was aimed within the above boundaries. This will enable the shooter to see directly for what percentage of the time the gun was directed at an area of the size of the 10 or 9. In this sense, percentages can be regarded as more illustrative than actual deviations. It should be noted, however, that they are slightly less useful, as they do not tell the shooter anything about the symmetry of the hold.

3.2. Symmetry of hold

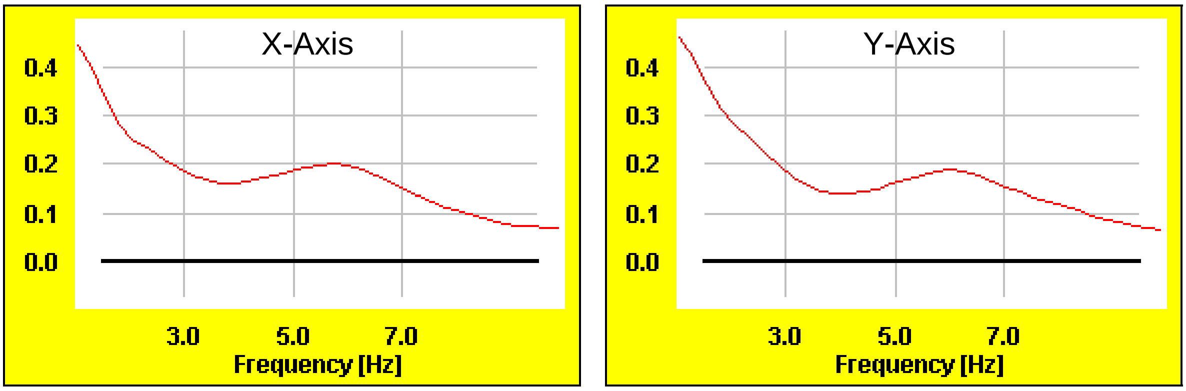
Deviations are a good way of illustrating hold ability, as the method also reveals the **symmetry/asymmetry** of the hold. Symmetry denotes the relation between the horizontal and vertical hold values, so that Sx=Sy implies a symmetrical hold and inequality an asymmetrical hold. Asymmetry in the case of pistol shooting may be due to errors in position or grip, or inadequate muscle condition, while horizontal deviation will be larger than vertical in the case rifle shooting in a standing position, as the gun has a better vertical support. Asymmetry in pistol shooting can be regarded as considerable if the difference between the deviations calculated as means for a series of 60 shots is more than 5%. Thus deviations of 0.50/0.55 recorded for a top pistol shooter, for example, would imply a degree of asymmetry which should be investigated further. The present test series for rifle shooters indicate that the difference between the horizontal and vertical deviations varies considerably from one shooter to another, the average horizontal deviation being some 40% greater than the vertical one. It should be noted, however, that top rifle shooters similarly have a good hold in both directions.

3.3. Repeatability of hold

Valuable information on shooting performance can also be obtained from the hold variations observed during a series. The HRES calculated here takes this aspect into consideration, enabling a coefficient of variation, CVAR, to be calculated separately by dividing the scatter in the deviation over the series by the mean deviation. The greater this result, the more the hold varies from one shot to the next.

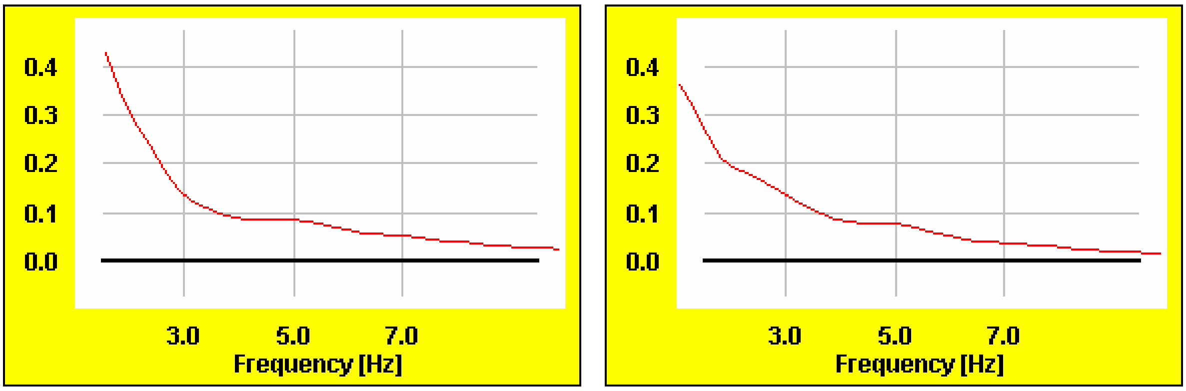
3.4. Hold amplitude spectrum

We have also examined the frequency distribution of gun movements by means of an amplitude spectrum which indicates the role of the various frequency components. Some examples of this will be given below.



(a) (b)

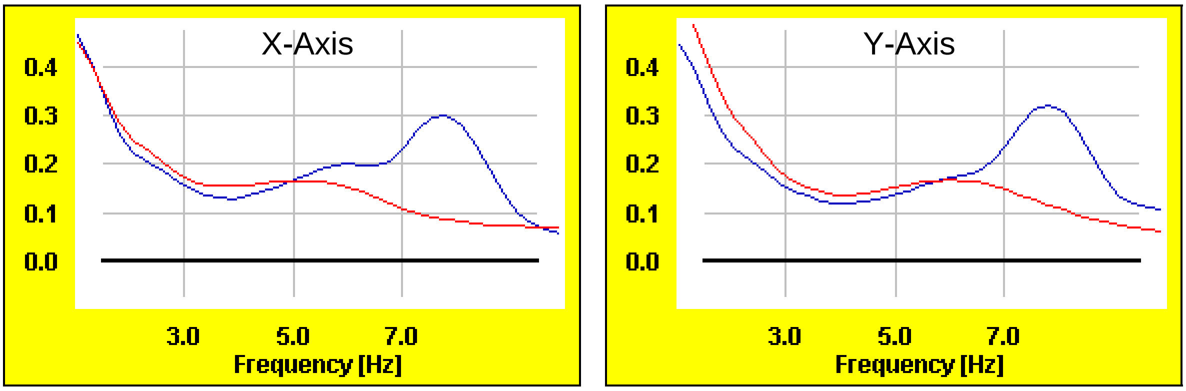
Figure 16 a and b. Amplitude spectrum for horizontal and vertical movement in pistol series.



(a) (b)

Figure 17a and b. Amplitude spectrum for horizontal and vertical movement in rifle series.

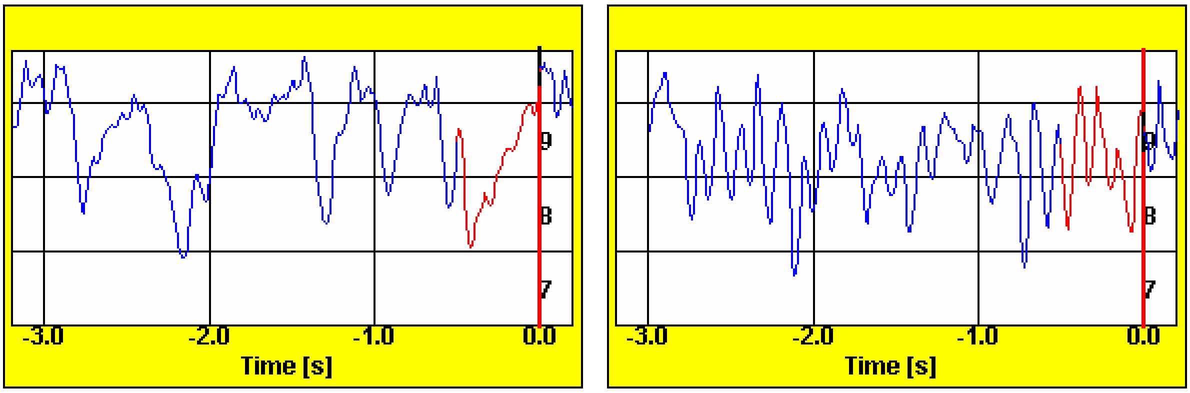
The horizontal axis in the above figures denotes frequency and the vertical one amplitude. The spectra recorded on the x and y axes are highly similar for the pistol shooters, whereas the y axis is a supported direction in rifle shooting, so that low-frequency movement in particular (swaying or shaking) is less than on the x axis. Movement on the y axis is in general smaller than that on the x axis in the case of rifle shooting, while a local amplitude maximum can be observed in the 4-8 Hz range in the horizontal direction in rifle shooting and to a more marked extent still in pistol shooting. As this is a question of muscle vibration, the maximum frequency will vary on an individual basis, the lowest values being slightly over 4 Hz and the highest almost 8 Hz. The guideline is that an improvement in holding ability tends to shift the frequency of the local maximum amplitude to the right. Two styles of shooting are compared in the following figures:



(a) (b)

Figure 18 a and b. x and y amplitude spectra for two pistol shooters representing the same performance level but different styles.

Gun movement as a function of time, R(t), is indicated for a 'lower frequency shooter' in Fig. 19a and for a 'higher frequency shooter' in Fig. 19b.



(a) (b)

Figure 19 a and b. Examples of individual frequency characteristics.

As the high frequency component of the shooter's total movement pattern increases, his control over triggering decreases. There is a high inverse correlation between this proportion and the net benefit to be gained from trigger control.

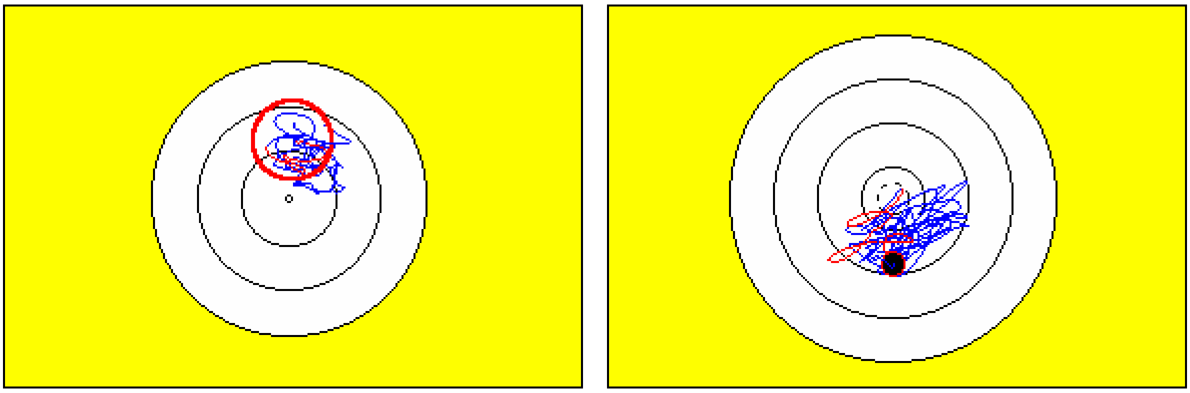
4. Measurement of aiming ability

4.1. Centre of gravity, COG

From the point of view of the shooter, aiming denotes directing the gun at the desired point on the target by means of the **sight picture** formed by the sights and the target itself. As the gun is in continuous movement, the shooter will recognise the 'correct' picture only occasionally. Aiming ability is measured here on the basis of the **central point** of all the orientations of the gun recorded within the given statistical time. This is normally the last 3 seconds preceding the shot, although aiming ability was defined for the present purpose over the 2 s interval comprising the holding stage (-3 s --> -1 s). The central point referred to is termed here the **COG (Centre of Gravity)**.

Aiming ability is very much dependent on holding ability, i.e. the better the hold, the better the preconditions for accurate aiming. On the other hand, the better the hold, the more important it is to aim accurately. This means that a poorer hold will reduce the relative role of aiming in the final result.

The importance of accurate aiming when the shooter has a good holding ability is illustrated in a concrete manner by the following two example shots. The shot tends to 'lie' in the average area aimed at.



(a) **(b)**

Figure 20 a and b. Poor aiming and its consequences in air rifle (a) and air pistol shooting (b)

4.2. Centre of gravity and aiming result, ARES

The behaviour of the aiming result as a function of hold with the centre of gravity varying between 11.00 and 9.70 is presented in the tables on pages 28 and 29. The same situation is illustrated graphically in the following figure.

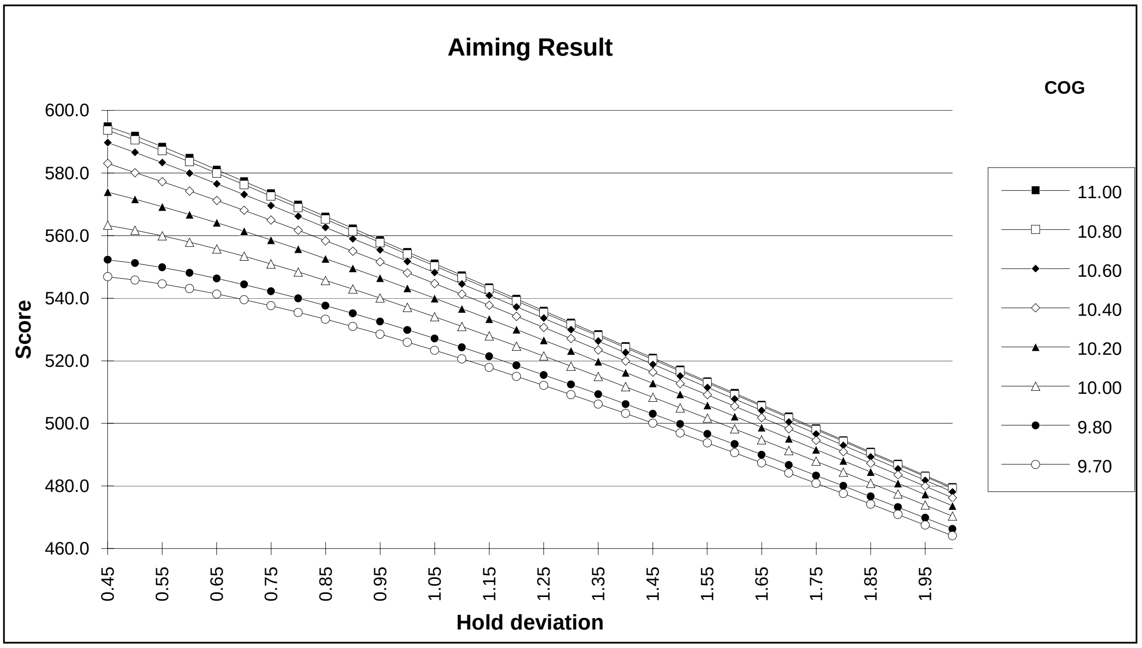


Figure 21. Aiming result as function of holding ability at COG values varying from 9.70 to 11.00.

The above figure clearly indicates how the relative importance of aiming declines with holding ability. Let us take an example. Shooter 1 has a holding value of 1.0 and Shooter 2 0.5. If the average COG declines from 10.30 to 10.20, Shooter 1 will lose 2.5 points in a series of 60 shots and Shooter 2 as many as 4.5 points.

The average COG for the pistol series at the holding stage was 10.20, and the best mean for the 60 shots was 10.55, which gave a total score of 580. Since the aiming values recorded 3 seconds before the shot were slightly better than this, the shooter had a corresponding 3 s aiming result of 10.60.

Aiming results for the various categories of air pistol shooter are presented in the table below. The better the level of competence, the greater the accuracy of aiming.

Competence group	Result	COG	ARES
Competence group	>=580	10.37	572.5
Competence group	570-579.9	10.32	567.5
Competence group	560-569.9	10.16	555.8
Competence group	540-559.9	10.08	547.9
Competence group	510-539.9	9.87	524.8
Competence group	<510	9.65	493.4

Table 6. Aiming abilities of the competence groups.

The relation between the aiming result and the eventual score is shown in the following figure.

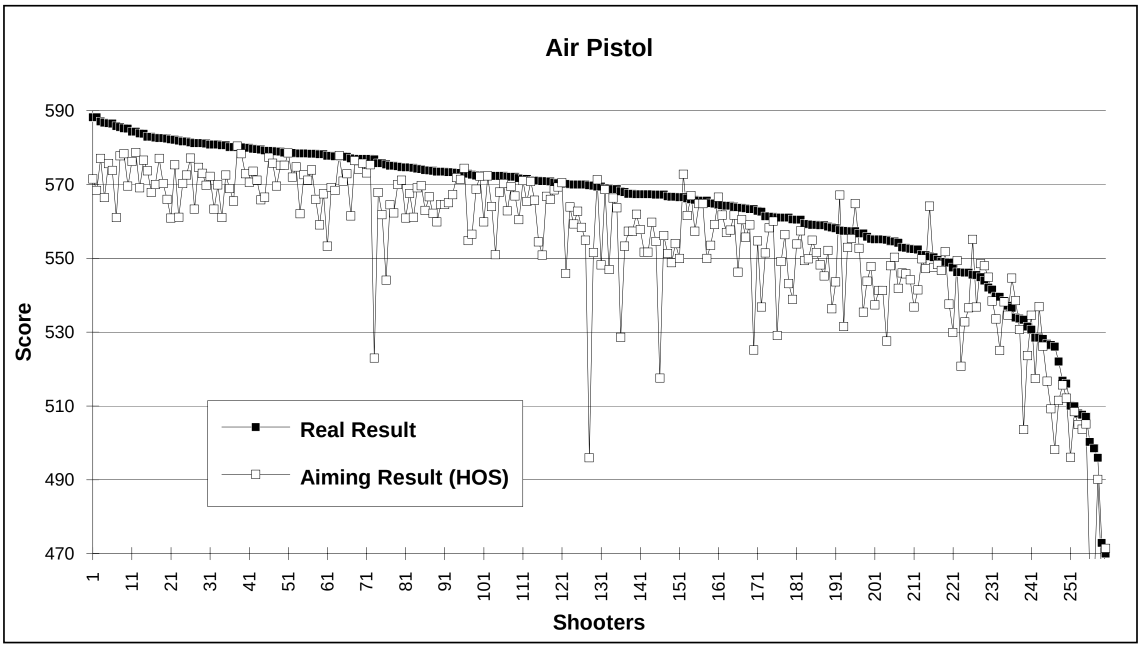


Figure 22. Correlation between aiming result at the hold stage and the eventual score in air pistol shooting.

The figure also contains some reaction-type series in which the correlation between the aiming result and the eventual score is poor. In these cases the shooter held the gun slightly to one side and then brought it into line at the right aiming point for triggering. The correlation between the statistical result at the trigger control stage and the actual score is presented in Fig. 23.

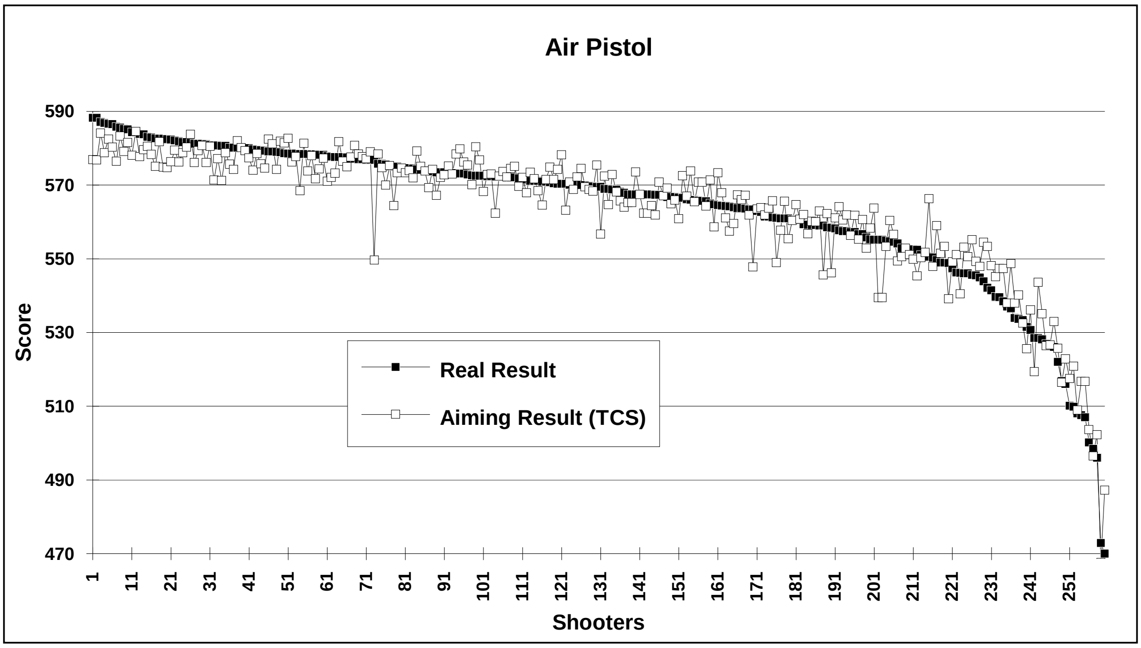


Figure 23. Statistical result for the last second before firing vs. the eventual score in air pistol shooting.

As expected, the statistical result for the last second correlated more closely with the eventual score than did the result obtained at the hold stage. The main guideline would seem to be that the better the shooter, the better the score he will obtain relative to the statistical result. This means that good shooters are able to make use of elements of trigger control better than do poor shooters, as is quite natural, of course.

Corresponding figures for air rifle shooting are presented below.

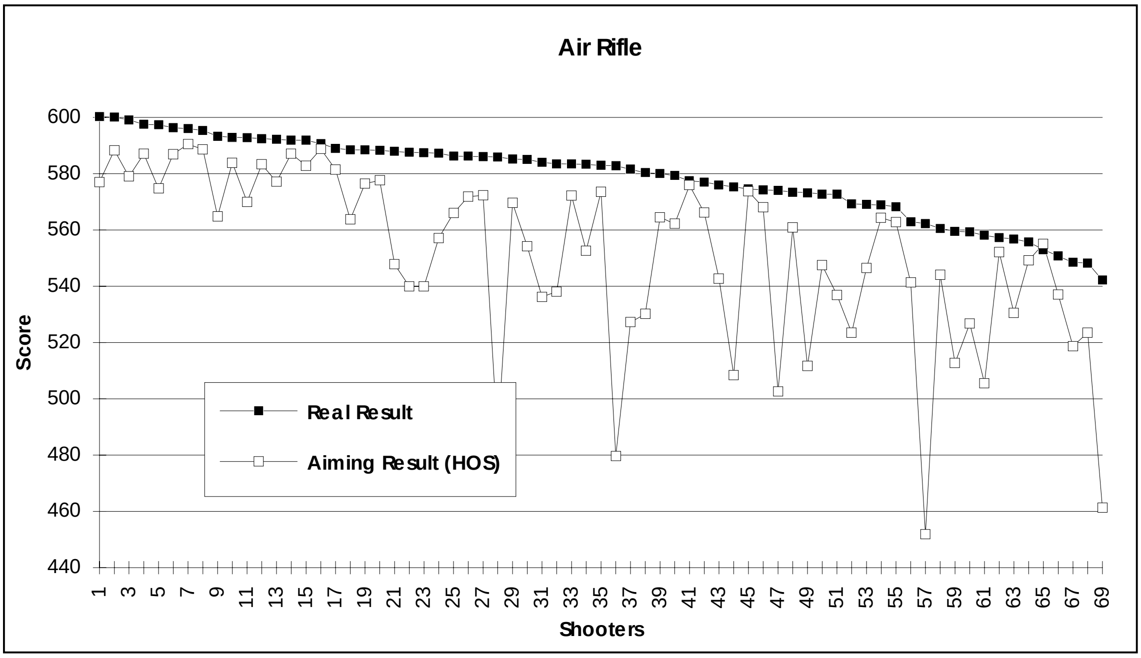


Figure 24. Correlation between aiming result at the hold stage and the eventual score.

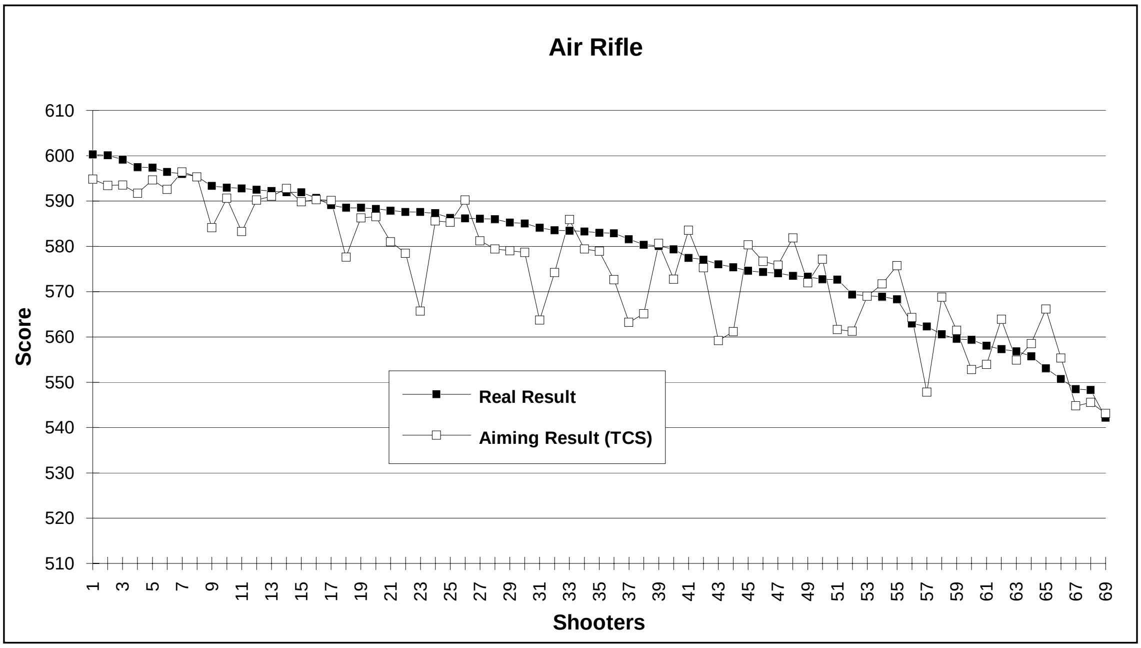


Figure 25. Statistical result for the last second before firing vs. the eventual score in air rifle shooting.

As shown in Fig. 25, rifle shooters may approach their actual result from a very 'deep' position at the holding stage, some of them making considerable use of trigger control to compensate for a poor holding ability, whereas good shooters, at least those in the test group, rely more on the latter.

The same applies to both rifle and pistol shooting, so that the better the shooter is, the better he will be able to raise his performance relative to the statistical result, i.e. the better trigger control he will have. In fact, the difference between the statistical result for the last second and the real result could well be taken as an index of trigger control, as it would balance out the difference observed between hold and reaction shooters.

4.3. Practical questions connected with aiming

There are two main schools of thought among pistol shooters regarding aiming. One is that aim should be taken at a point close to the lower edge of the black area of the target, and the other that one should aim somewhat lower down. It is likely that the accuracy of aiming will be better when focusing on a point below the black area, although some shooters find that aiming further into the white area is helpful from the point of view of trigger control. It is really a matter of personal preference. Aiming is more straightforward with a rifle, as this will have ring sights for competition use.

One further short comment should be made regarding the sights on air pistols. Some shooters prefer tight sights and others loose ones. As very tight sights tend to strain the eyes, hamper trigger control and even impair the hold, it is preferable for the back sight to be fairly loose. What does this 'fairly loose' mean? There is unfortunately no uniform answer to this question as it depends on the shooter's personal characteristics and preferences and the type of shooting concerned. Shooting at a rapid tempo requires looser sights than for slow training purposes.

5. Trigger control

The act of shooting culminates in triggering. Although the action itself is technically highly simple, i.e. a slight bending of the forefinger, **trigger control** can be regarded as a complex chain of events which are difficult to explain or measure. The basic difficulty lies in the fact that it is at least partly a subconscious process which includes many overlapping events and in which there are considerable personal differences. An additional difficulty is introduced by the fact that some of the events are so rapid that the shooter cannot observe them consciously, let alone be able to react or act rapidly enough.

Trigger control and factors contributing to it

Trigger control comprises triggering and the process leading to the decision to pull the trigger. It can be divided into two parts:

- **timing of triggering**
- **cleanness of triggering**

The timing of triggering denotes the state of aiming and holding at the moment of triggering in relation to both the target and the hold stage. The cleanness of triggering can be used to measure the effect of the triggering event on the gun path. Timing and cleanness are interdependent, and consequently they are difficult to measure, and care should be taken to ensure that the results are interpreted correctly. An attempt will be made below to examine the essence of trigger control through practical examples.

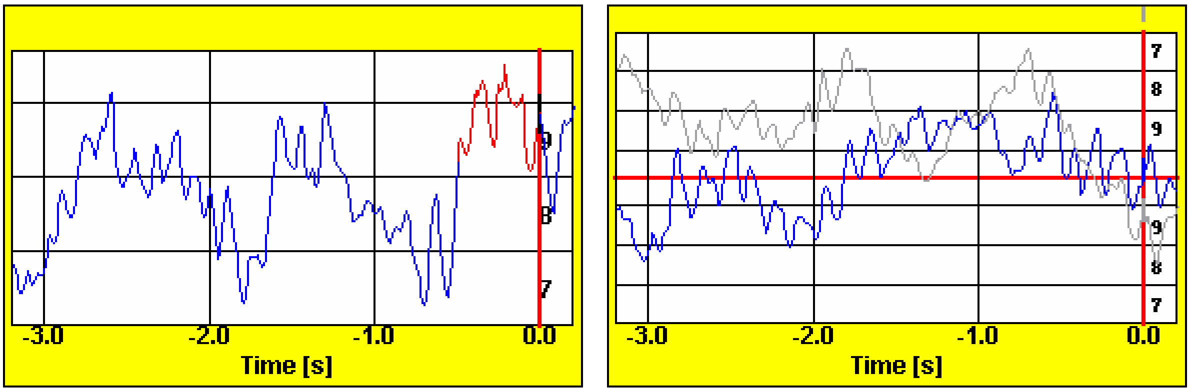
5.1. Timing of triggering

The timing of triggering is a major factor contributing to the eventual score. It is in fact the only means by which the shooter can 'fool' the statisticians, i.e. he can try at this stage to compensate for holding or aiming errors arising from his inadequate holding ability.

Timing can be examined from the point of view of either holding or aiming. In the ideal case, the shooter will be able to 'find' a moment of minimal gun movement when the sight picture is maximally correct (**optimisation**). In principle, the same situation would arise if the shooter were able to 'stop' the movement of the gun in a controlled manner instead of just 'finding' the optimal point, but this is very difficult, of course, as the hold is the result of a number of factors, some of which are beyond the shooter's control.

In practice, the shooter cannot distinguish very well between the state of his hold and the sight picture, and tends to see them as one and the same thing. This is quite natural, as the sight picture is one of the factors on the basis of which he perceives the state of his hold. How he crosses the threshold which inevitably leads to triggering is undoubtedly a highly individual matter, and yet all this takes place in accordance with the psychological regularities governing practical skills and through habits learned by constant practice. If and when these regularities could be investigated, it might be possible to develop effective means of providing training in trigger control.

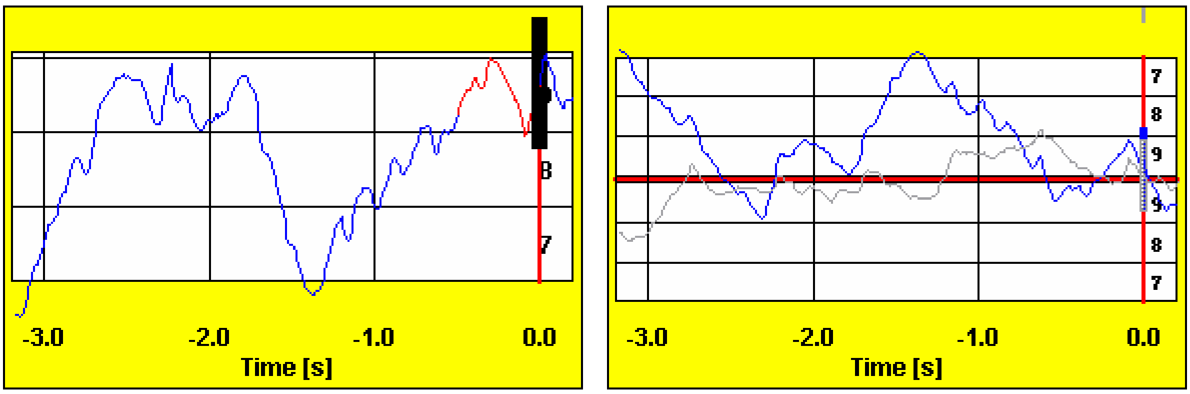
One of the groups into which the present shooters were divided according to their manner of shooting in Section 3.5 was **reaction shooters**, who consciously try to control the moment of triggering through their aiming, to the extent that they move the gun from one aiming position to another by means of a 'pumping' action (Figure 26).



(a) (b)

Figure 26. A 'pumping' style of trigger control in air pistol shooting.

The advantages of the method lie in the fact that if the gun is deliberately moved along one axis its movement on the other axis will decrease and that the method allows for active anticipation. The drawback is that trigger control involves not only observations but also action, and since there is always a great danger of the shooter not being able to control his movements, particularly under great pressure, he may fail to shoot cleanly enough. The corresponding path for an air rifle shooter might be of the following form:



(a) (b)

Figure 27. Example of the action of a reaction rifle shooter.

As seen in Fig. 27, the shooter has a fairly poor horizontal hold, or else he intentionally moves the gun horizontally, but he manages to keep the gun still in the vertical plane.

Our model enables simple calculation of the joint effect of holding and aiming. This requires only selection of the time interval over which the hold values and centre of gravity are to be determined, after which the statistical result can be calculated. The **time curve** employed in the model is created in this way.

The time curve can be used to evaluate certain important elements connected with the timing of triggering, while another important source of information for this evaluation is the shot-specific R(t) curve (distance from the centre of the target as a function of time). As the time curve is integrative in nature, it will reveal **trends** in performance, whereas the shot-specific R(t) is merely a time-based presentation of the aiming procedure and thus involves the entire **dynamics** of the shot process.

The timing of triggering can also be divided into elements. As no established routine is available for this yet, Noptel Oy have developed the following division criteria:

*** optimisation**

*** reaction**

*** anticipation**

The same difficulty, i.e. overlapping, arises when one wishes to distinguish between the elements of timing as are encountered when distinguishing between timing and the cleanness of triggering. This means that it is extremely difficult if not even impossible to find completely unambiguous, mutually exclusive measures on the basis of path data alone.

5.1.1. Optimisation

As discussed at a number of points above, **optimisation denotes seeking/finding an optimal state of holding or aiming in order to guarantee correct timing of triggering**. It can be evaluated qualitatively by comparing the events of the trigger control stage (2) relative to the target and to the preceding hold stage (1). A case of ideal optimisation is described in the following figure.

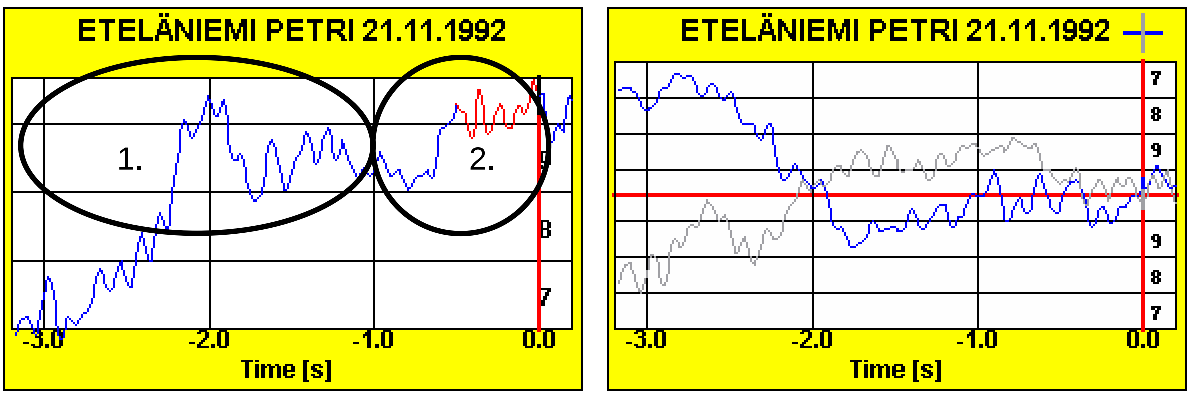


Figure 28a. R(t). **Figure 28b. XY(t).**

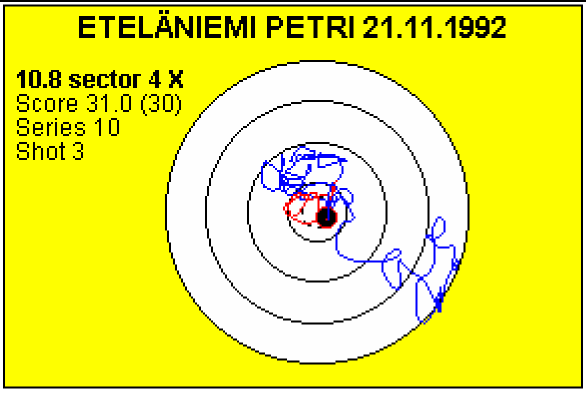
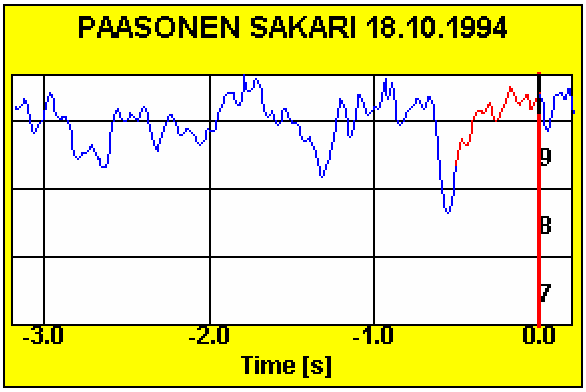


Figure 28 c. X-Y.

Figure 28. Ideal optimisation I.

The figure shows an ideally timed shot. The shooter has optimised the moment of triggering excellently with respect to holding and aiming. An almost **perfect sight picture** and **maximum** hold lasted approximately half a second, during which the shooter had sufficient time to fire. This represents an ideal performance by a **reaction shooter**.

The following figure shows a shot by a top marksman.



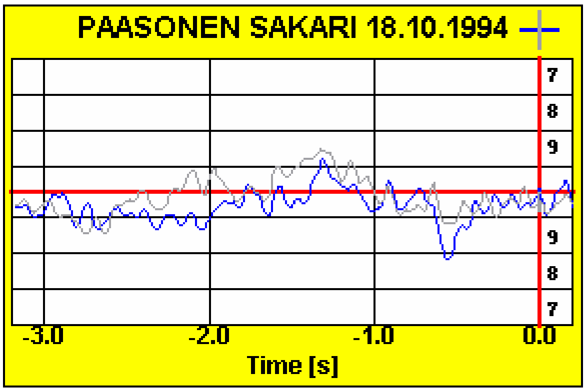


Figure 29a. R(t). **Figure 29b. XY(t).**

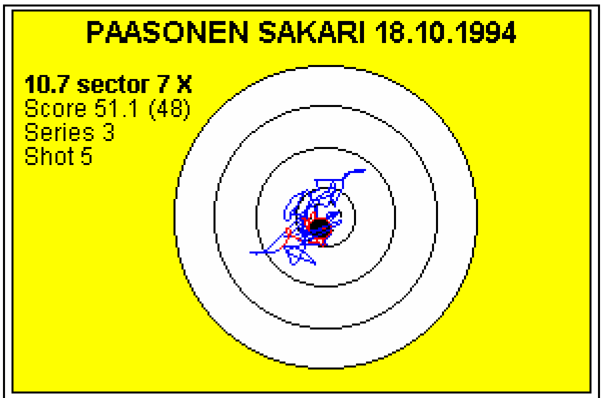


Figure 29 c. X-Y.

Figure 29. Ideal optimisation II.

The starting point for a hold shooter differs from that of a reaction shooter. His gun has been aimed at almost the correct point throughout the hold stage, so that optimisation is more a matter of final adjustment than of radical change. The example shows that the gun was aimed at the ten for half a second, whereupon the shooter sensed that the time was right and began the triggering process, leading to an almost perfect shot.

The number of suitable moments for triggering is in fact larger among hold shooters than among reaction shooters, as the gun is constantly within the area of accurate aiming. Two examples of rifle shots are presented below.

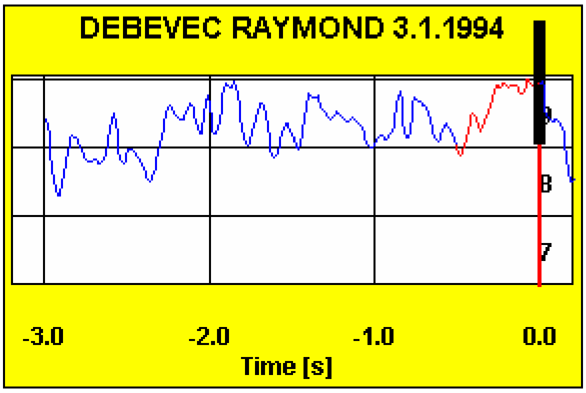


Figure 30a. R(t).

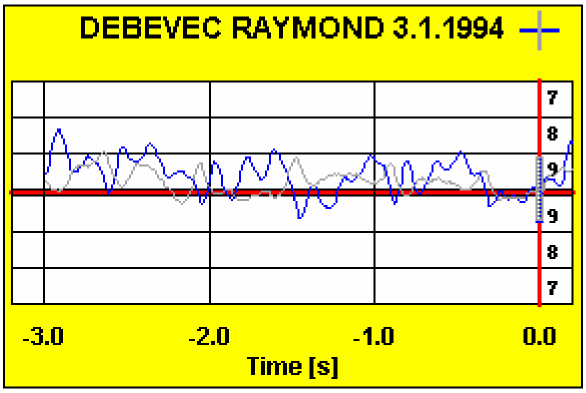


Figure 30b. XY(t).

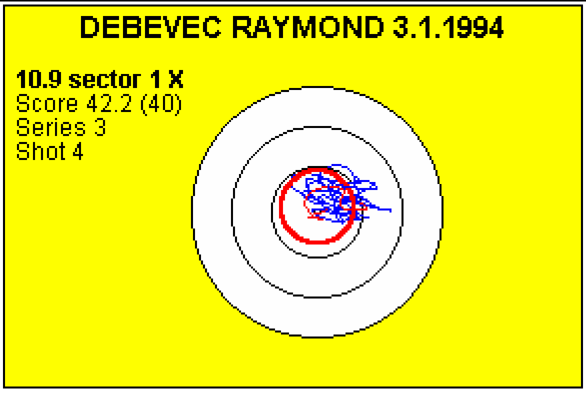
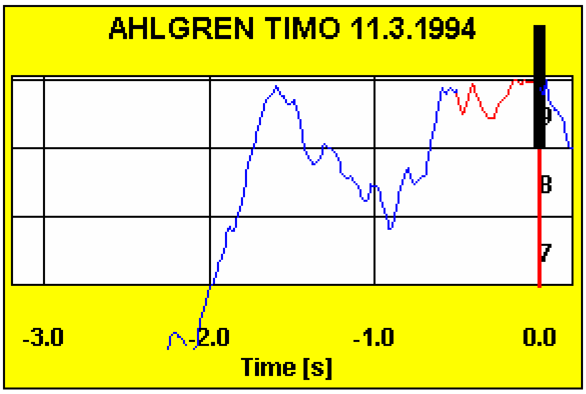


Figure 30c. X-Y.

Figure 30. Excellent optimisation with the rifle.

Debevec is a typical hold shooter, and his holding area is symmetrical, as he also masters the horizontal component. The gun finally stops at the centre of the target for approximately 0.25 seconds, at which point he initiates the triggering process, producing a perfect shot. Although he has an excellent hold, the holding state, like the sight picture, exhibits different levels of accuracy.

The second rifle example illustrates the performance of a reaction shooter.



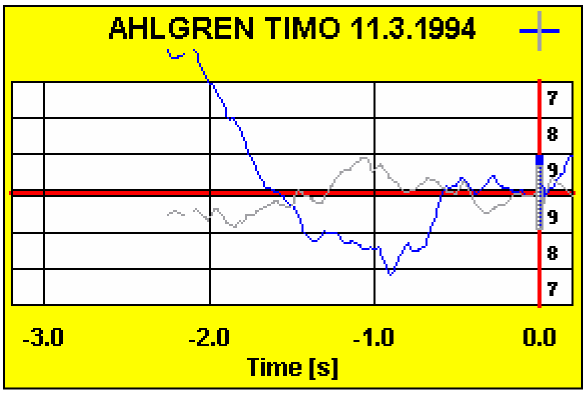


Figure 31a. R(t).

Figure 31b. XY(t).

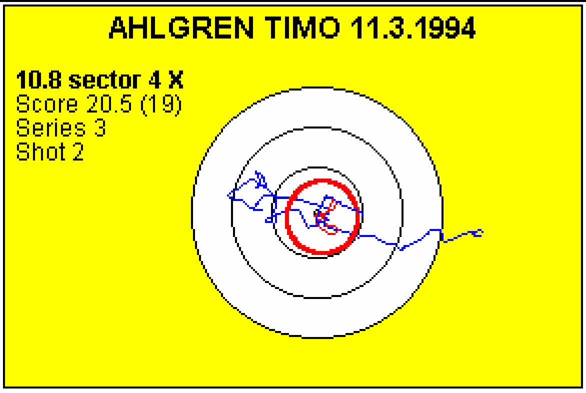
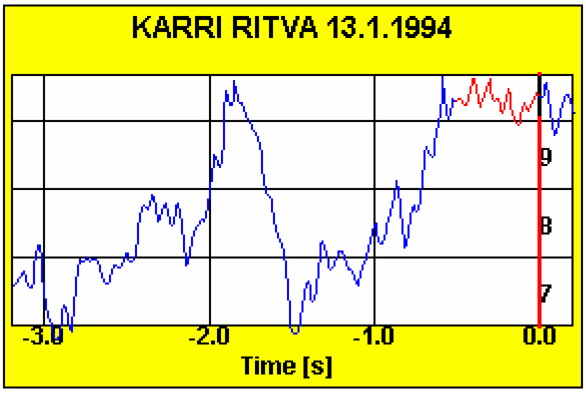


Figure 31c. X-Y.

Figure 31. Performance of a reaction rifle shooter.
In the above example the shooter moved his gun into the area of accurate aiming from further away and, having recognised an ideal sighting image and hold state, pulled the trigger. There is no actual hold stage at all! Note, too, that he achieved this ideal situation 'at the second attempt'. On the other hand, the situation lasted for more than half a second, so that he had plenty of time for triggering.

Some rifle shooters may have a maximal hold stage lasting more than a second, but then there is a danger of becoming completely paralysed and failing to deliver the shot. It is thus not surprising that such shooters in particular try to develop a reaction type of trigger control, although others do so on account of inadequate holding ability.

Let us take as our next example a shot by one of the best female pistol shooters in Finland.



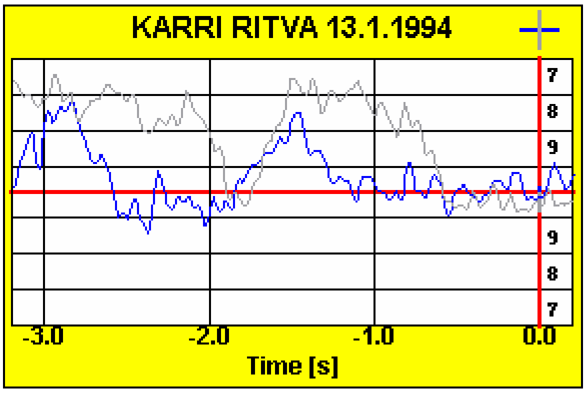


Figure 32a. R(t). **Figure 32b. XY(t).**

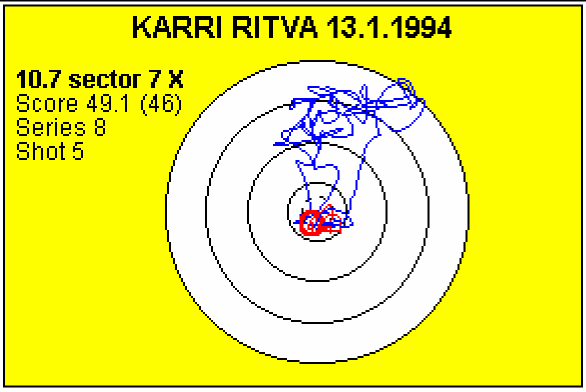


Figure 32c. X-Y.

Figure 32. An excellent reaction shot.

This leading Finnish female pistol shooter has produced an almost perfect reaction shot. In her usual way, she first held the gun at around the 7-8 areas in the upper part of the target, from where she brought it to the ten. She failed to hold this position at first, but managed to do so for more than half a second in her second attempt, whereupon triggering gave her a score of 10.7. It is difficult to imagine a better performance.

The shots in the above examples are almost ideal ones produced by top-ranking shooters, the common denominator being that they were able to **optimise** the moment of triggering with respect to holding and aiming. It should be noted, however, that the examples represent extreme cases of a kind which are infrequent in a series. Fortunately, a good shot can be achieved from slightly poorer beginnings as well. Let us look at some examples in which optimisation has been only partly successful.

Cases with slightly unsuccessful optimisation

An attempt at optimisation may fail with respect to either holding or aiming. This can be illustrated with a couple of examples:

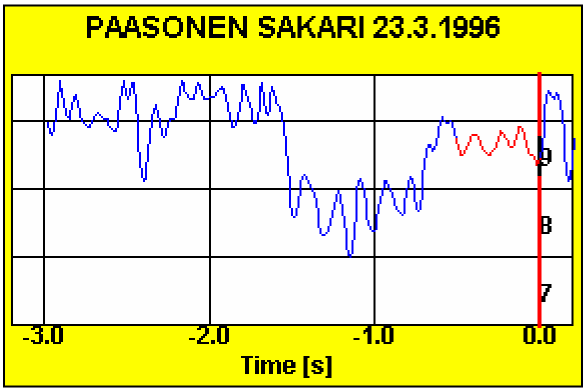


Figure 33a.R(t).

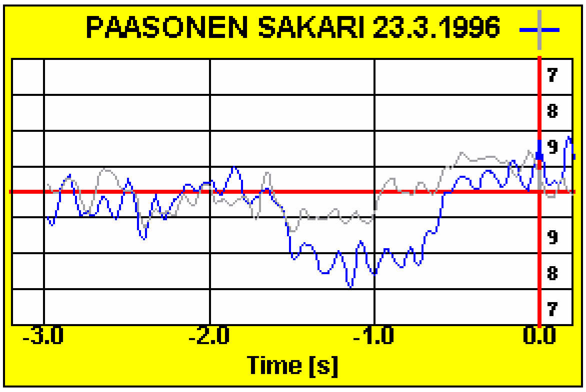


Figure 33b. XY(t).

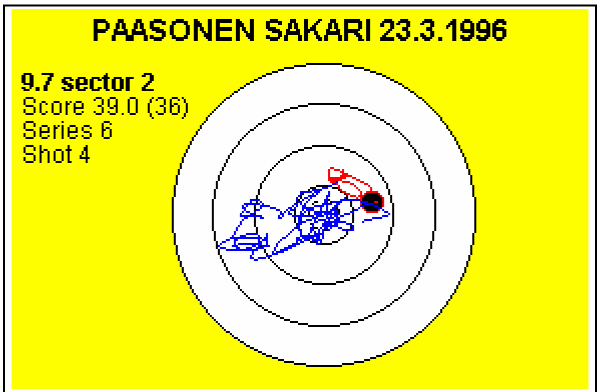


Figure 33c. X-Y.

Figure 33. Problems for a hold shooter.

Sakari Paasonen had his aim settled on the 10 for almost 1.5 seconds but did not proceed to the triggering stage. It then moved slightly to the left, towards the 9 or 8, returned, went slightly beyond the 10 and stopped there for more than half a second. He was 'almost' satisfied with this and started to prepare for the triggering process, but decided to adjust his position very slightly at the same time, with the result that he scored a 9.

The second example is another shot by Ritva Karri.

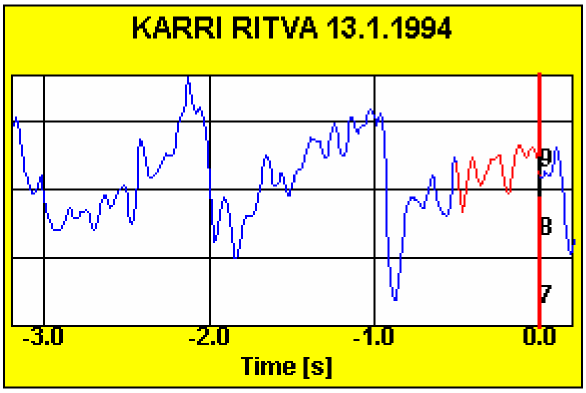


Figure 34a. R(t).

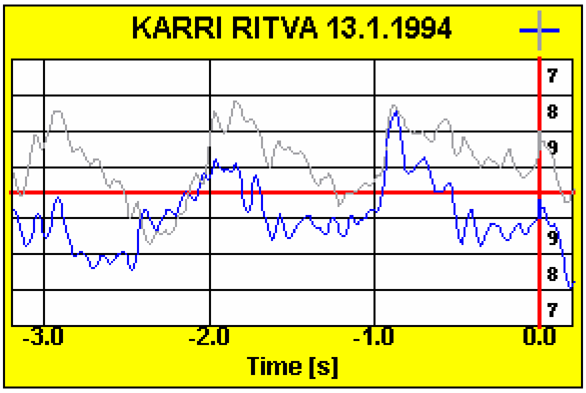


Figure 34b. XY(t).

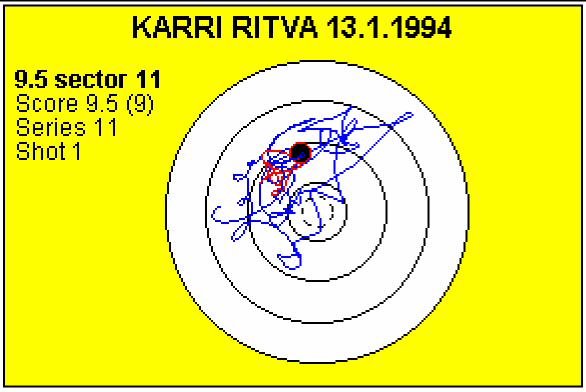


Figure 34c. X-Y.

Figure 34. Triggering problems of a reaction shooter.

She tried three times to achieve the correct position but ended up further away from the 10 each time. When the shot was finally fired it scored 'only' a 9.5.

Two optimisation attempts by rifle shooters are presented below.

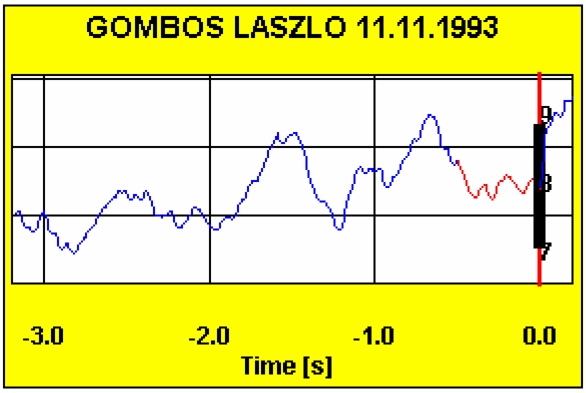


Figure 35a. R(t).

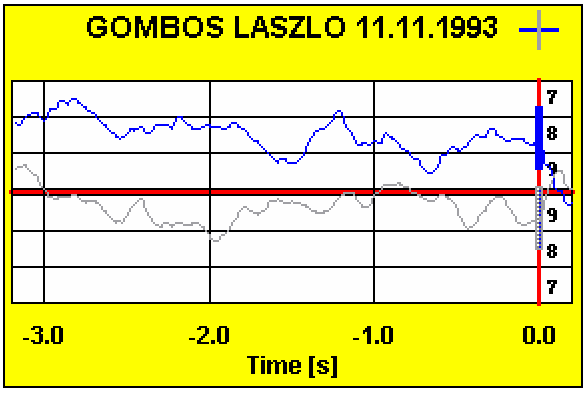


Figure 35b. XY(t).

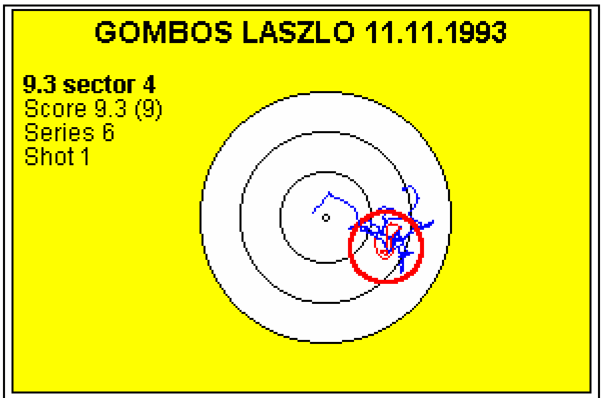


Figure 35c. X-Y.

Figure 35. Optimisation problems in rifle shooting, I.

The shooter tried to correct his aim but was not entirely successful in this. He was evidently moving towards the ten, but the shot came while the movement had paused for approximately 0.4 seconds. This once again illustrates in a concrete manner how important it is for the centre of gravity to be as close to the centre of the target as possible.

Here is another example:

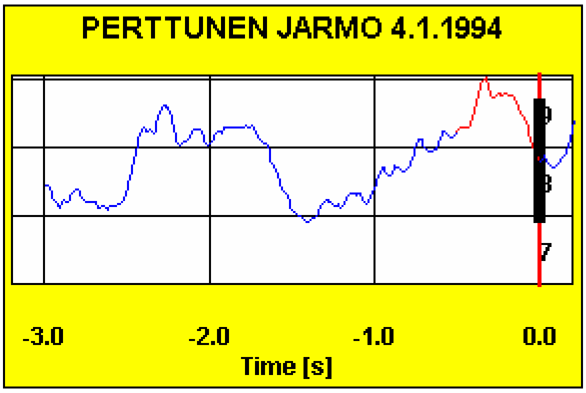


Figure 36a. R(t).

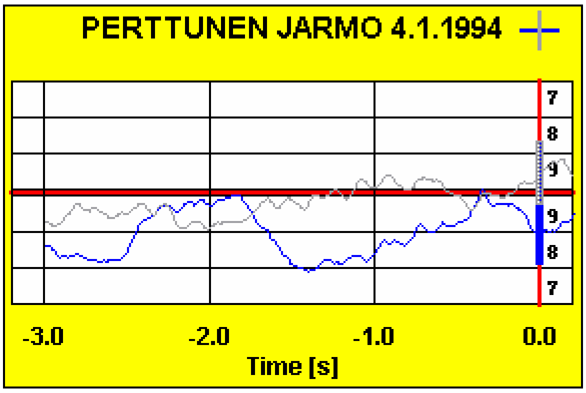


Figure 36b. XY(t).

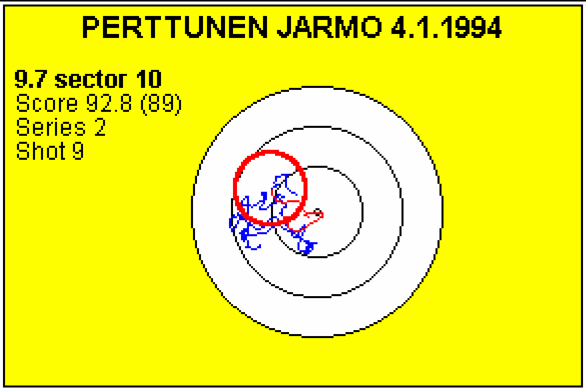
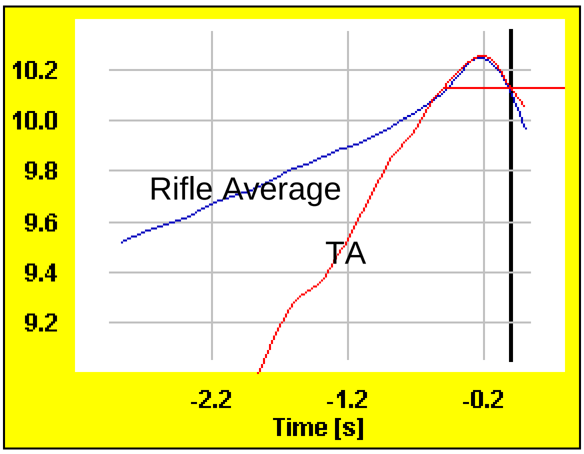


Figure 36c. X-Y.

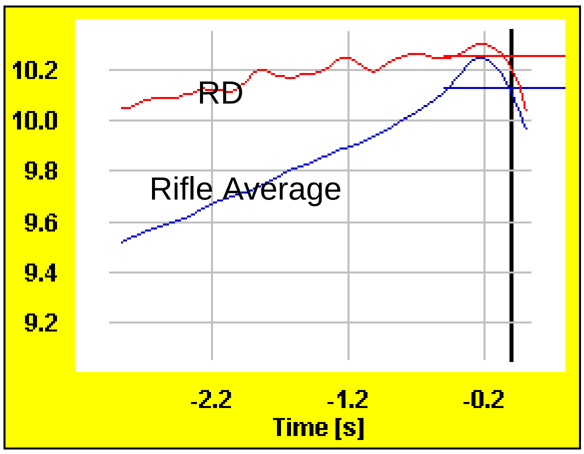
Figure 36. Optimisation problems with the rifle II.

The shooter achieved a perfect sight picture but was unable to stop the movement of the gun for a sufficiently long period of time. By the time triggering finally took place, it was already pointing wide of the 10, i.e. the shot was either **too late** or the gun deviated during triggering (which did not take place cleanly). A shooter of this type should concentrate on developing his anticipation and prepare for triggering at the closing-in stage.

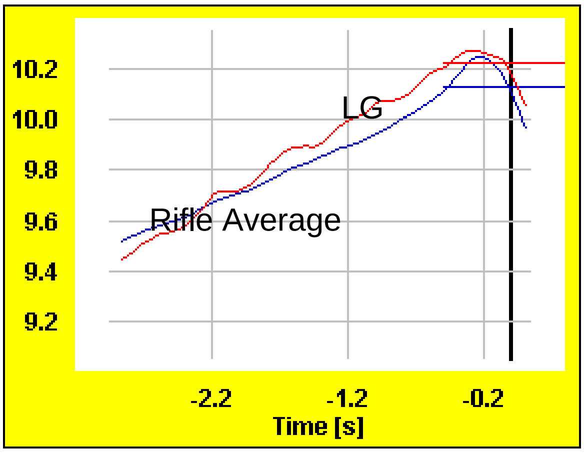
Let us now take a look at the average time curves for all the shots delivered by the above shooters and comparing them with those for the total group of shooters.



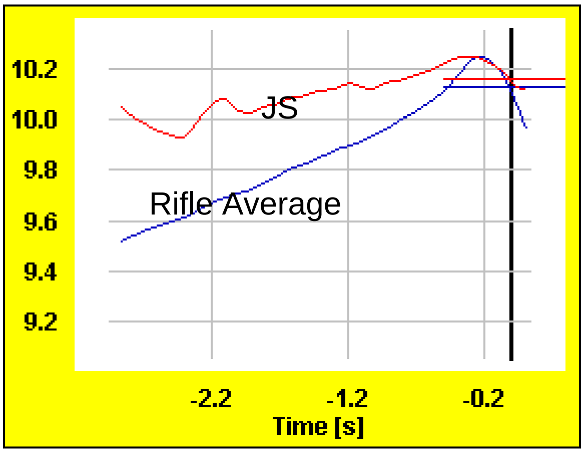
Kuva 37. Timo Ahlgren, TA



Kuva 38. Raymond Debevec, RD



Kuva 39. Laszlo Gombos, LG



Kuva 40. Jukka Salonen, JS

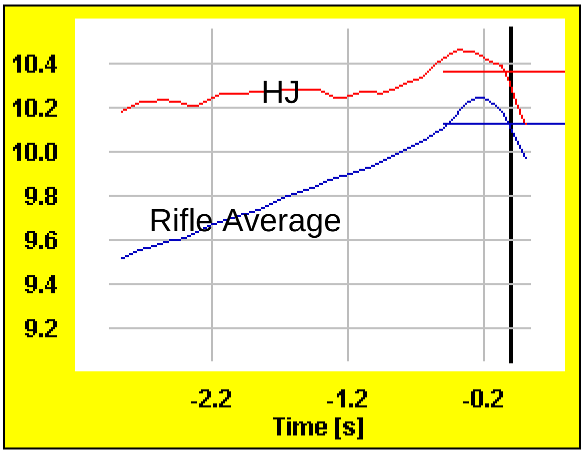


Figure 41. Helena Juppala, HJ

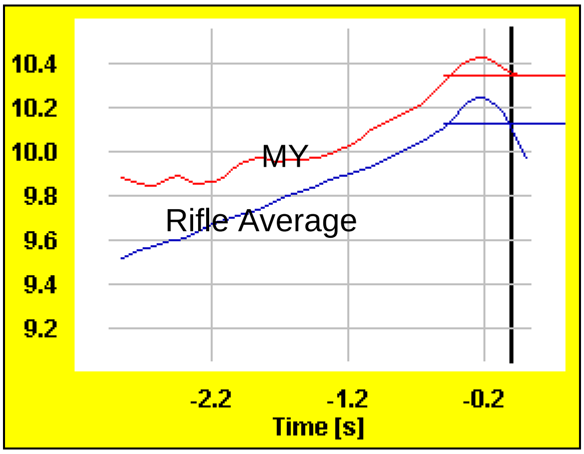
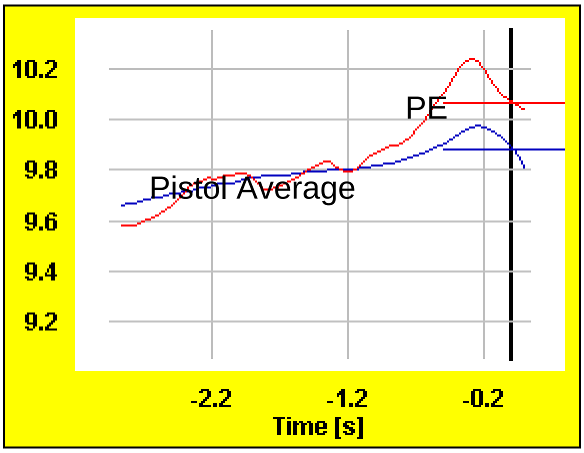
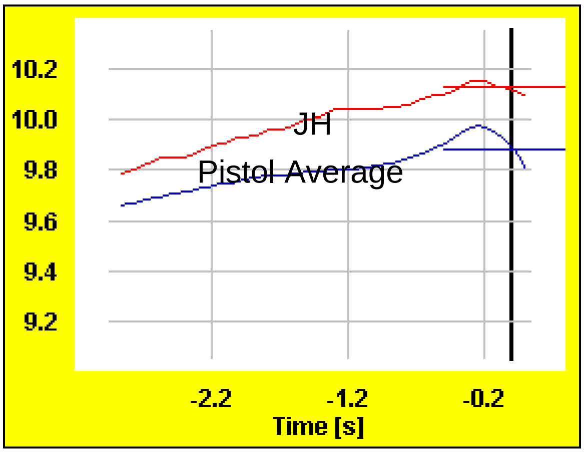


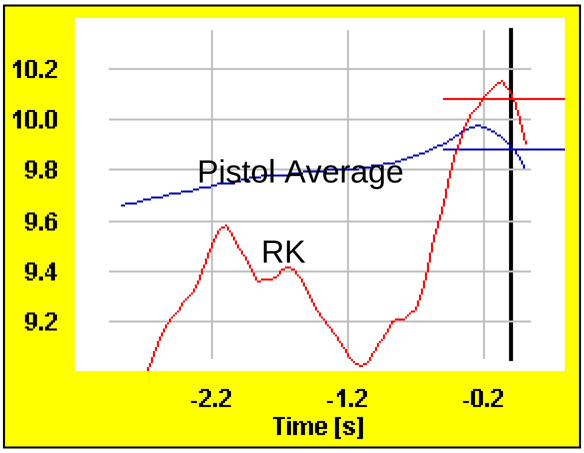
Figure 42. Marjo Yli-Kiikka, MY



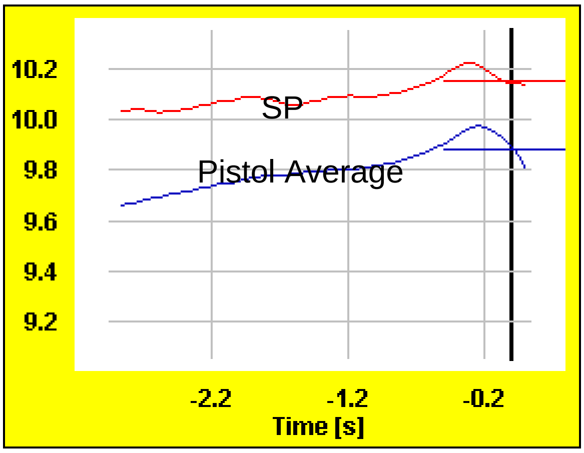
Kuva 43. Petri Eteläniemi, PE



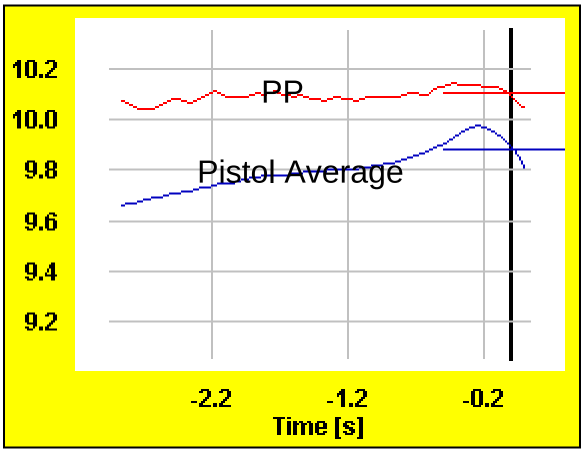
Kuva 44. Jarmo Hokkanen, JH



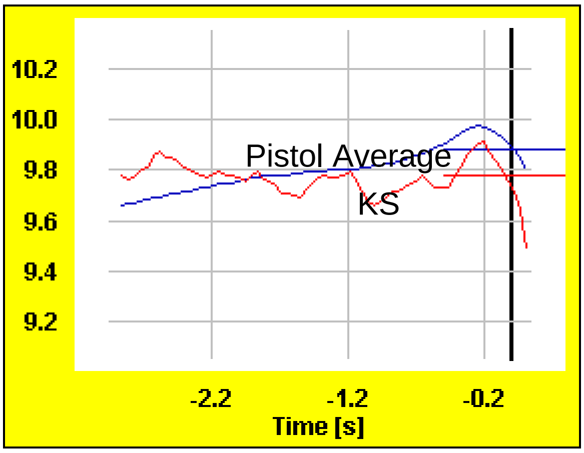
Kuva 45. Ritva Karri, RK



Kuva 46. Sakari Paasonen, SP



Kuva 47. Paavo Palokangas, PP



Kuva 48. Katja Salo, KS

The time curves testify to the fact that shooters try to optimise their aiming rather than just 'holding and squeezing', as previously thought. These time curves for individual shooters 'reveal' their shooting styles in a highly illustrative manner. As shooting style is inevitably a part of the person's own character, however, it is difficult to say that any one particular style is best in any general sense. Experience has shown that hold shooters have the best chances of success even under pressure, as there are no extra tricks that they have to pay attention to and their style is consequently less sensitive to the tension caused by competition pressure. Our basic advice is thus **'Get your hold right!'**

The purpose of the following figures is to indicate that when the shooter is capable of selecting a triggering moment which is ideal from the point of view of his hold, he will achieve better scores. They show relative amplitude spectra, i.e. the relations between the various frequency components in the movement that occurred during the last second before firing (the trigger control stage) and the corresponding components of the holding stage. The relation is 1 on the central line, >1 above it and < 1 beneath it.

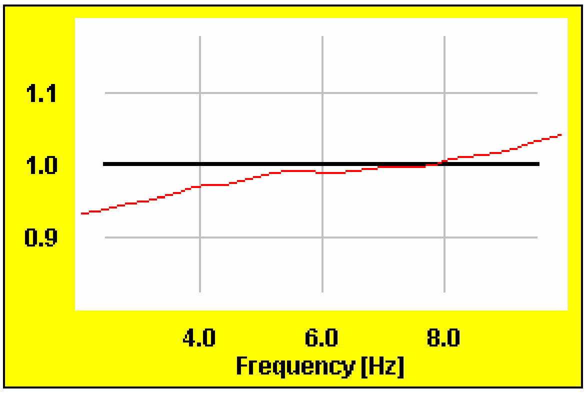


Figure 49a. Pistol, best shots, x.

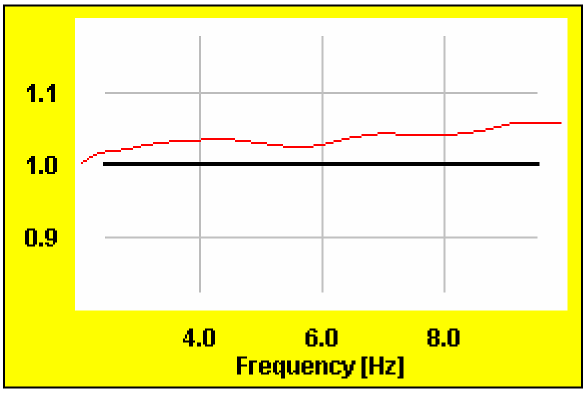


Figure 49b. Poorest shots, x.

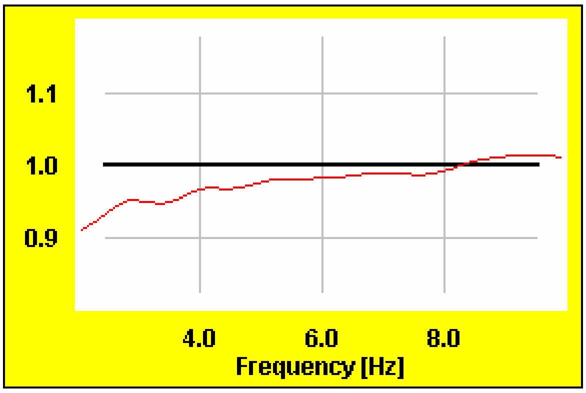


Figure 50a. Pistol, best shots, y.

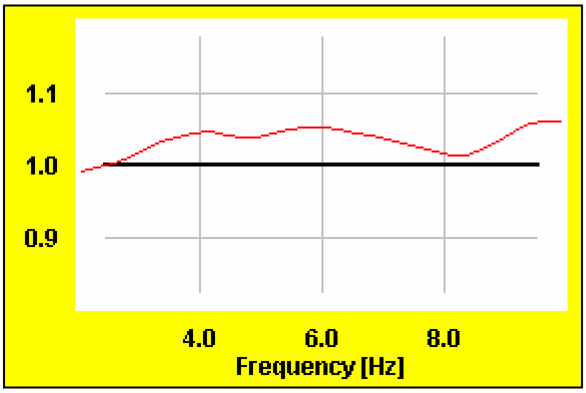
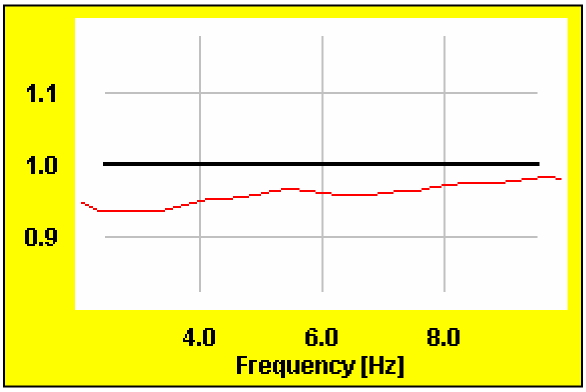


Figure 50b. Poorest shots, y.

The above figures indicate that in the case of good shots (the 18 best shots in the series), the hold state is evidently optimised in the x and y directions at almost all frequencies, whereas in the poorer shots there is an increase in movement at all frequencies during the last second. This is confirmed by the following two figures which show relative spectra for good and poor shots during the last second.



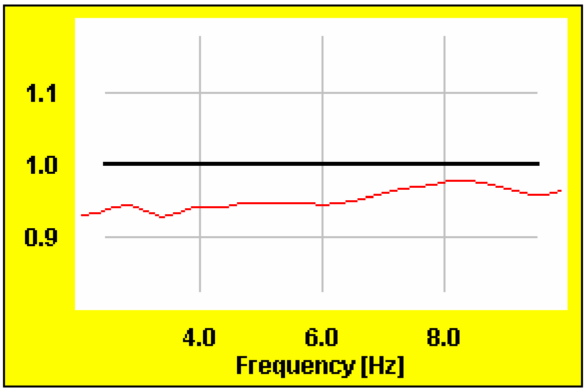
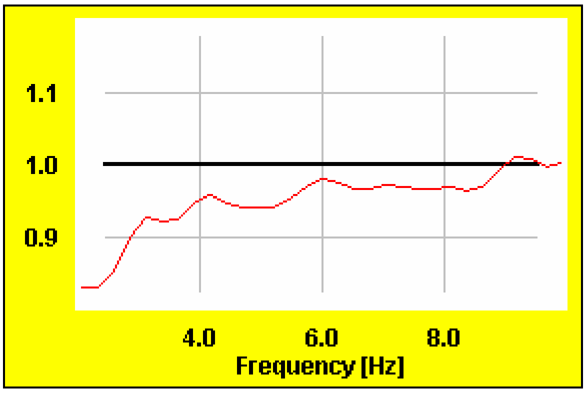


Figure 51a. Good vs. poor shots, x. **Figure 51b. Good vs. poor shots, y.**

The corresponding graphs for rifle shots are shown below:



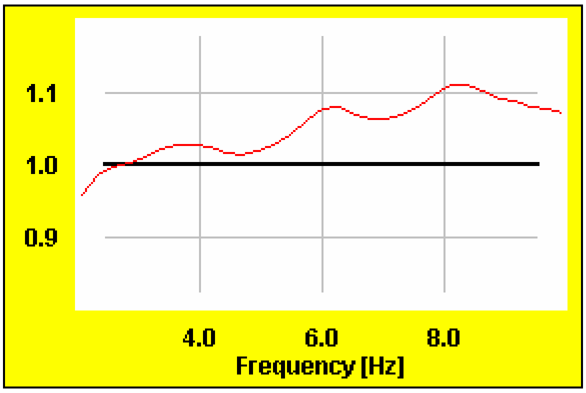
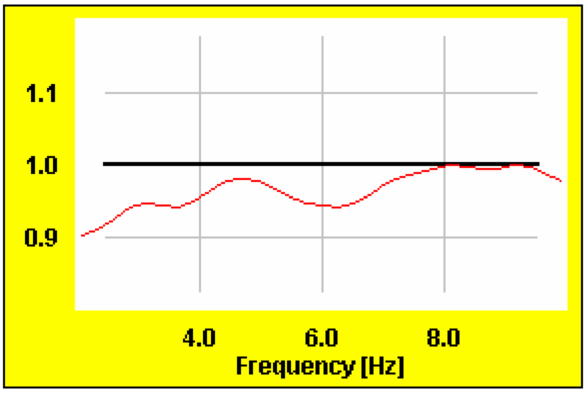


Figure 52a. Rifle, best shots, x. **Figure 52b. Poorest shots, x.**



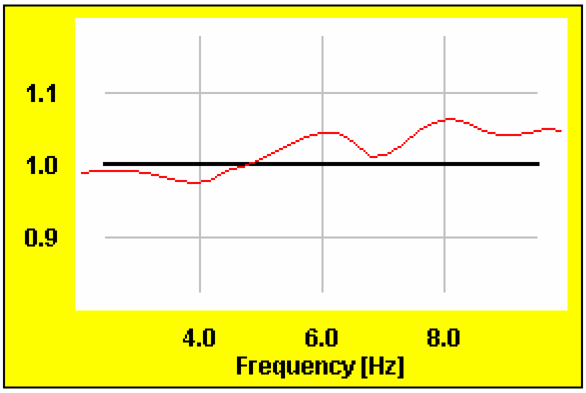


Figure 53a. Rifle, best shots, y. **Figure 53b. Poorest shots, y.**

Optimisation in the x and y directions occurs at almost all frequencies in the good rifle shots, whereas in the poorest shots movement increases at the higher frequencies. Some optimisation on both axes can also be seen at the lower frequencies in the case of the poor shots, however. Let us finally compare the good and poor shots during the last second before firing.

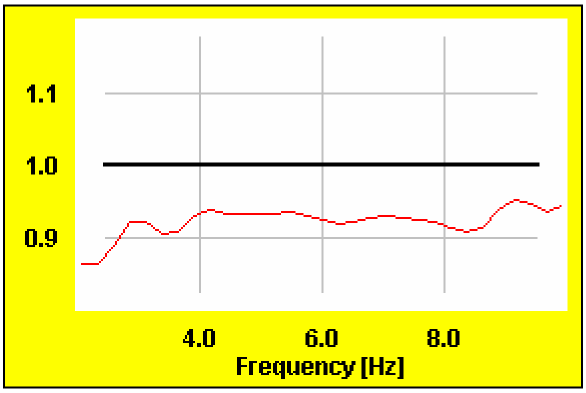


Figure 54a. Good vs. poor shots, x.

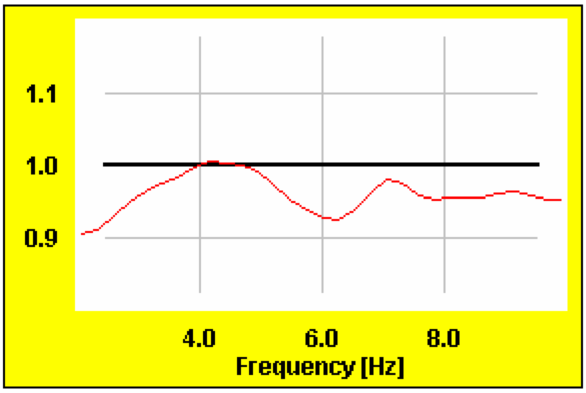
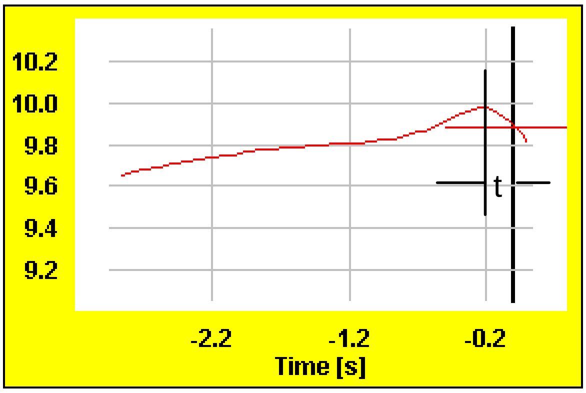


Figure 54b. Good vs . poor shots, y.

5.1.2. Reaction (time) and anticipation

We shall now discuss the shooters' **reaction ability**. We know on the basis of psychological investigations into the performance of certain skills that human reaction speeds vary between 100 ms and 700 ms from one individual to another. The times recorded for events requiring simple reactions such as the start in a sprint race are shorter than those obtained for situations which call for more complex decision-making. It is also emphasised in the literature that reaction speed is a highly innate ability and is difficult to improve by training. The reaction times under 0.1 seconds occasionally recorded for sprinters are usually regarded as the result of **anticipation** (tantamount to a false start). The situation is the same with shooters, so that it is likewise impossible to distinguish it entirely from reaction on the basis of path data only. We have been able to simplify the situation, however, by defining **reaction time** as **the time interval between the optimisation peak and the moment of triggering** (Figure 36). This time will in any case measure the shooter's reaction ability, particularly in the case of hold shooters.



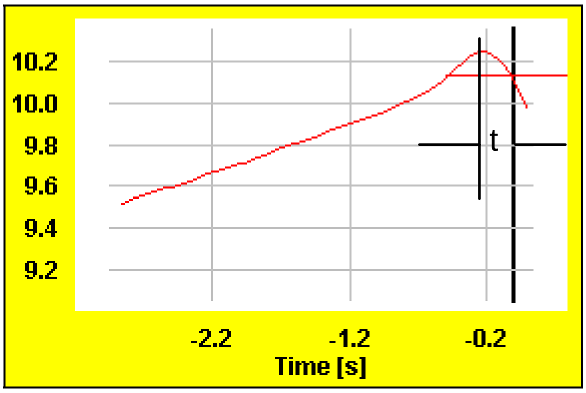


Figure 55a. Reaction time for a pistol shooter. **Figure 55b. Reaction time for the rifle.**

Measurements indicate that the average reaction time for pistol shooters is 288 milliseconds for men and for women 243, the figures for the rifle being 263 for the men and 303 for the women. The shorter time recorded for the male rifle shooters may reflect more extensive use of the anticipation technique rather than faster reactions. It is simply easier to use anticipation in rifle shooting, as the rifle moves more slowly than the pistol. Women in turn appear to be 'faster' with the pistol, as they have to rely more on a reaction style, due to a less satisfactory hold. In rifle shooting, on the other hand, women have a better hold than men and thus anticipate less. No appreciable differences in reaction time could be identified between the competence groups among the pistol shooters, which suggests that it is difficult to improve reaction time by means of training. The average for the pistol reaction shooters was 204 ms, so that the total time difference was less than 100 ms (the overall average of 287 includes the reaction shooters). Assuming that the reaction style is preferred by persons with innately rapid reactions, the role of anticipation remains of the order of some tens of milliseconds.

It should be remembered, however, that the above figures are based only on the material available and conclusions derived from this material, i.e. no in-depth research has been carried out into these matters.

5.1.2.1. Measurement of optimisation by means of the basic ST-2000 software, TIRE

The standard ST-2000 software does not so far possess any specific means of determining optimisation, but it does have one relevant measure, **TIRE**, which is mainly used to measure aiming. The last 600 milliseconds of the trigger control stage are divided into three 0.2 s sequences, as indicated by the following figure.

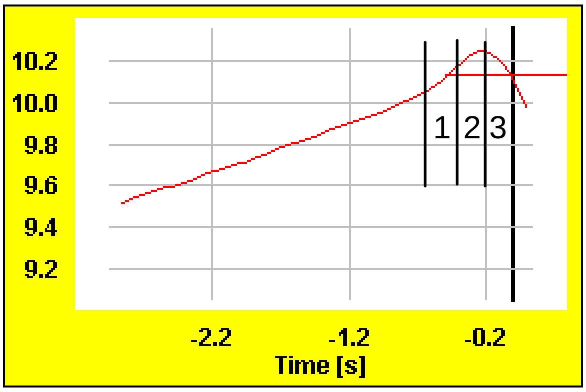


Figure 56. Measurement of TIRE

TIRE is determined for each shot separately by first calculating the average COG for each of the three 200 ms sequences. If the figure for Sequence 1 is highest, the resulting value will be 1, if it is Sequence 2, the value will be 2, and if it is Sequence 3, the value will be 3. Bearing in mind that the optimisation averages for all the shots were -287 ms for pistol shooting and -273 for rifle shooting, the average TIRE will be approximately 2. If the shooter obtains higher values, his timing will be above the average, whereas lower values imply poorer than average timing. The statistical result for each sequence, which would thus also include the hold, should in fact be determined rather than the COG, but this is not yet allowed for in the standard program. The new software will also take the hold stage into consideration.

Let us now look at a situation in which the air pistol shots are grouped according to their TIRE values.

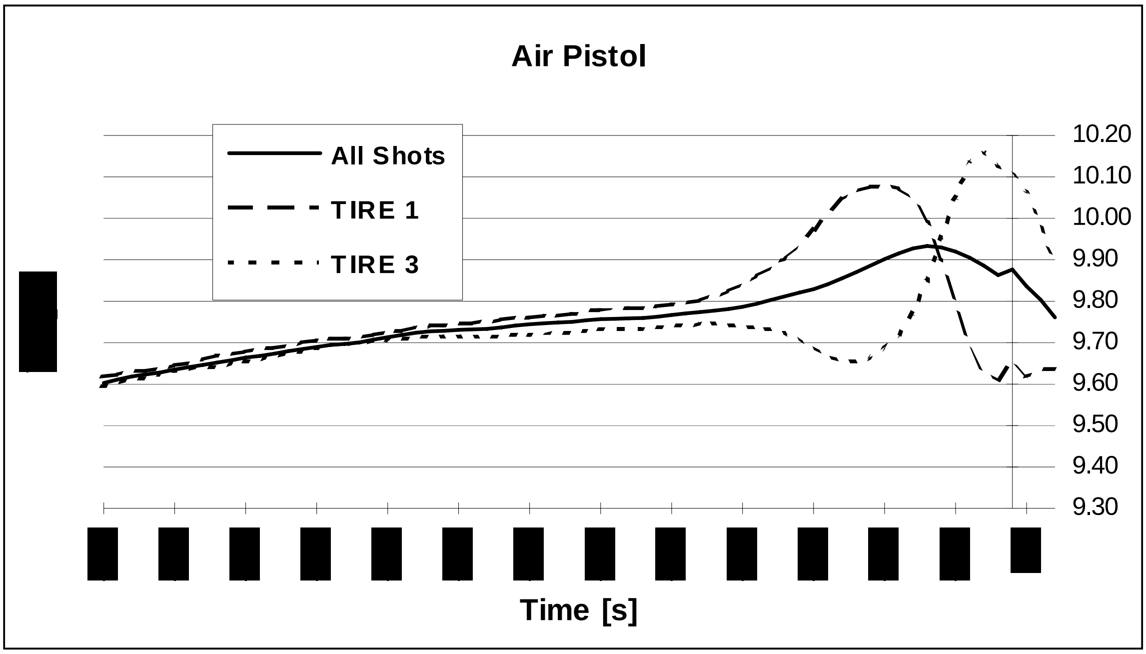


Figure 57. Correlation between TIRE values and the time curve in pistol shooting.

The above figure confirms the existence of a correlation between the TIRE value and the expected result. Even if the TIRE value is 3, the gun may have be moving away from the centre at the time of triggering. Each TIRE group contained about 1/3 of the shots. The corresponding curve for the rifle series is shown in Figure 58.

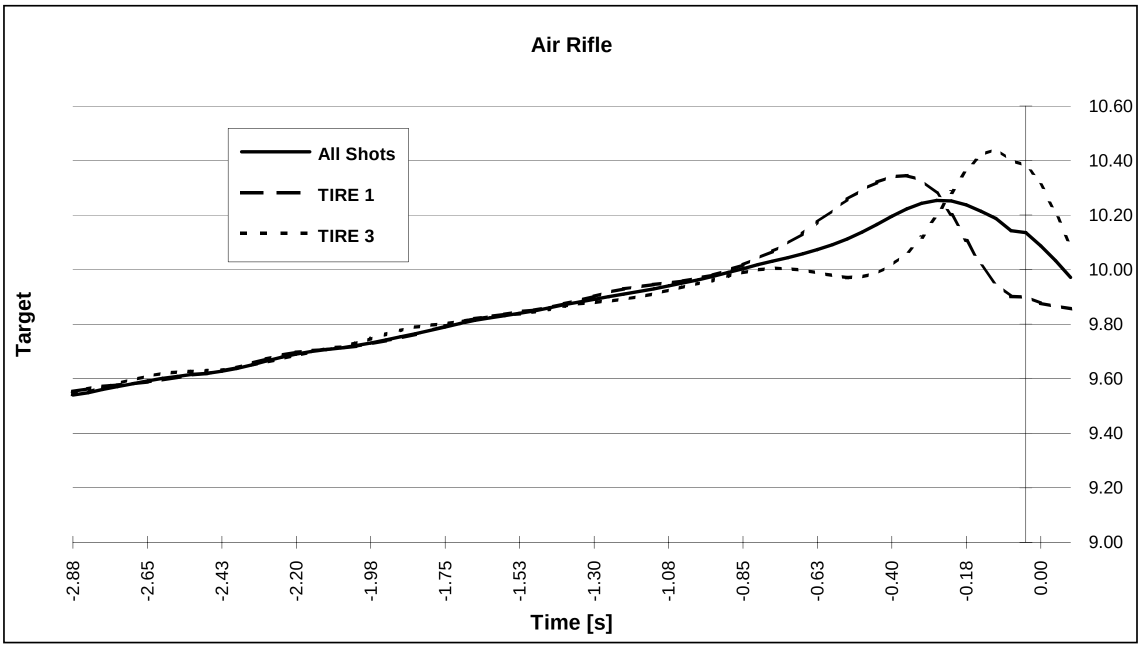


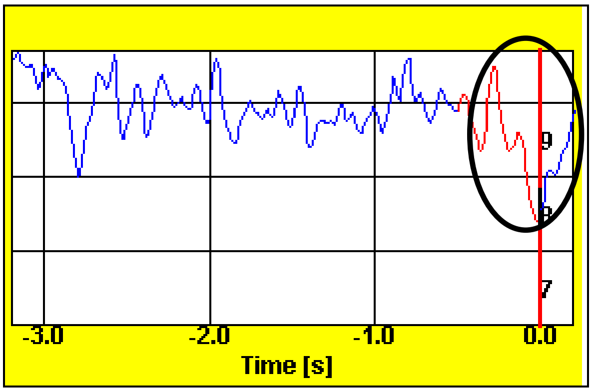
Figure 58. Correlation between TIRE values and the time curve in rifle shooting.

Comparison of TIRE values for individual shots with their path curves may sometimes suggest that the result does not conform to the basic interpretation. This may be for a number of reasons, e.g. situations where the shots are fired rapidly and represent the reaction style of shooting, in which case TIRE calculations are not necessarily applicable, since, being calculated from the average value obtained over 0.2 seconds, it cannot take every aspect of the path dynamics into consideration. This is the same basic problem as is found in the relation between the time curve and R(t), that one yields an average while the other contains the entire dynamics.

5.2. Cleanness of triggering

Evaluation of the cleanness of triggering has been a part of shooters' everyday lives even in the absence of sophisticated measurement devices. Shooters are very familiar with comments such as 'accidental shot' or 'terrible triggering'. They have realised that the cleanness of triggering is connected with the extent to which they feel that they have fired in an abnormal manner relative to the preceding hold or aim stage. It is extremely difficult to identify a small defect in the cleanness of triggering, of course, particularly when the movements taking place in shooting are very rapid, and another problem for shooters is how to distinguish triggering movement from normal gun movement. If the gun happens to go off when the normal sway connected with holding is at its maximum, the shooter may feel that he has actually pulled the trigger with a jerk even though this may not be the case.

Let us look at some examples of shots undoubtedly produced by impure triggering or even jerking.



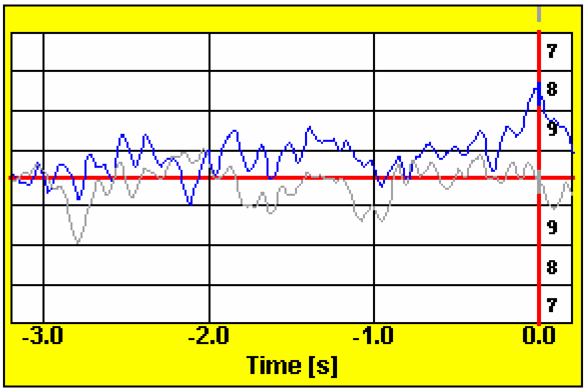


Figure 59a. R(t). **Figure 59b. XY(t).**

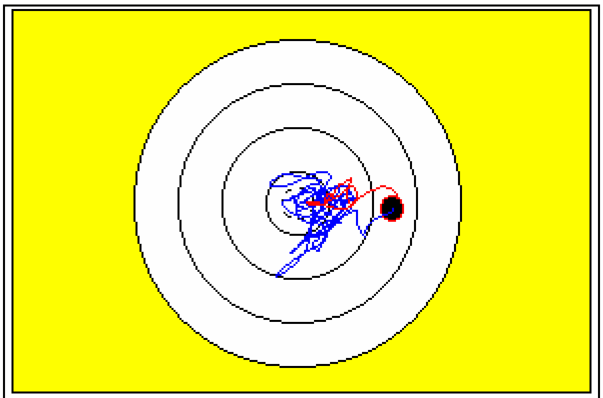
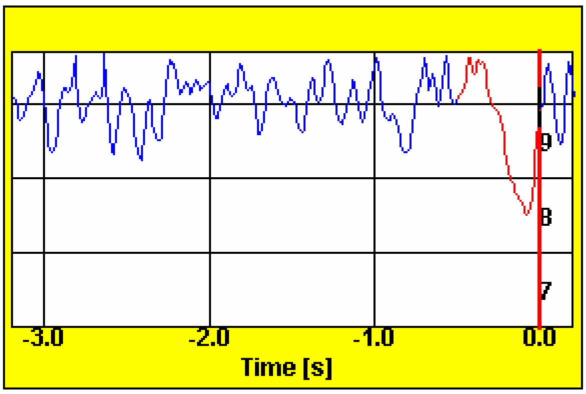


Figure 59c. X-Y.

Figure 59. Jerked pistol shot by a hold shooter.

The encircled area in the R(t) diagram clearly indicates that the shooter has introduced something extra into the normal holding process, as the movement has changed in both **extent and form**. In this case, triggering can be regarded as having involved a jerking action.



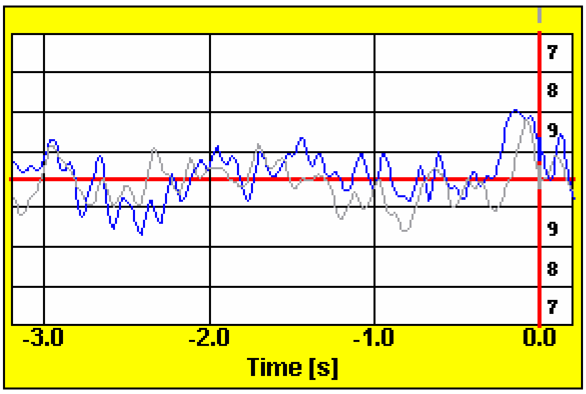


Figure 60a. R(t).

Figure 60b. XY(t).

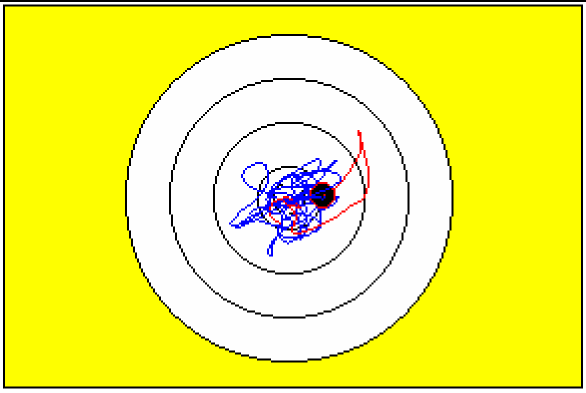
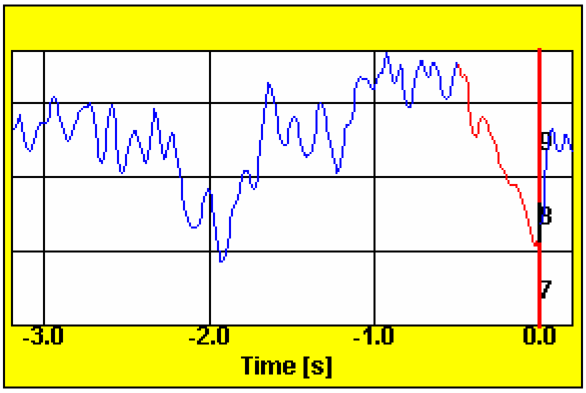


Figure 60c. X-Y.

Figure 60. Another shot not executed cleanly.

Here is an example of an upside-down movement in a sense, a triggering action which does not take place cleanly but scores a ten. Shots of this kind are in fact encountered fairly often.

The above two examples represent the performance of a hold shooter, where the cleanness of triggering can be observed and measured more easily than for a reaction shooter, where the shots automatically involve more movement. Let us finally look at a pistol shot by a reaction shooter.



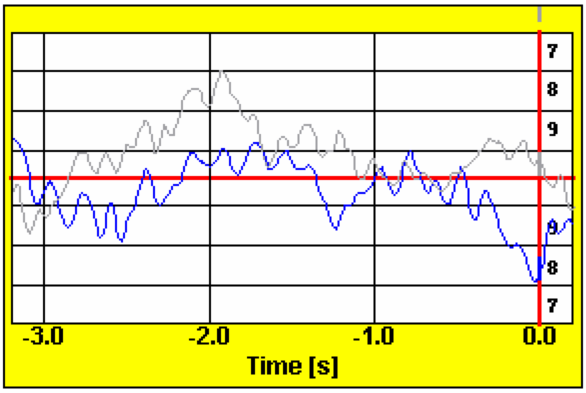


Figure 61a. R(t).

Figure 61b. XY(t).

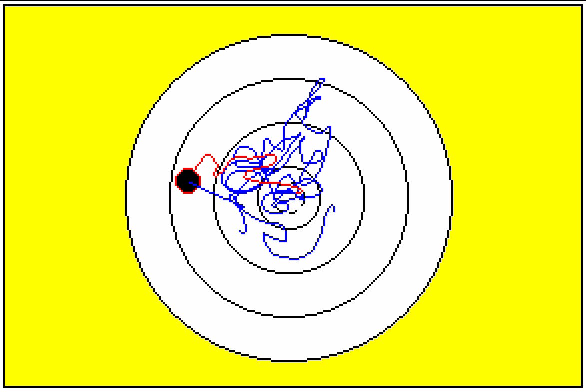
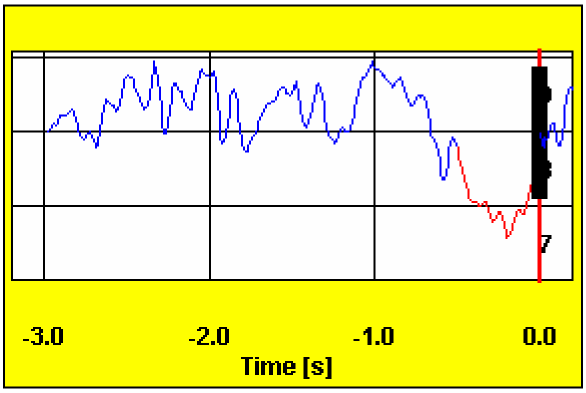


Figure 61c. X-Y.

Figure 61. Shot by a reaction shooter that is not executed cleanly.

The shot serves as a good example of the dangers faced by reaction shooters. This may be partly because the closing-in stage and triggering involve more of a conscious effort than with a hold shooter. The shot can justifiably be regarded as having been produced by a jerking movement.

The same kind of deficiency in the cleanness of triggering occurs in rifle shooting, but as a rifle is heavier, its movements are slightly slower. Differences are also caused by the fact that the rifle is triggered with the free hand whereas pistol is held and triggered with the same hand. The direction of the jerking movement in the case of a pistol is usually to downwards and to the left or upwards and to the right for a right-handed shooter, whereas a right-hand rifle shooter will usually jerk the shot upwards and to the left, as illustrated in Fig. 62.



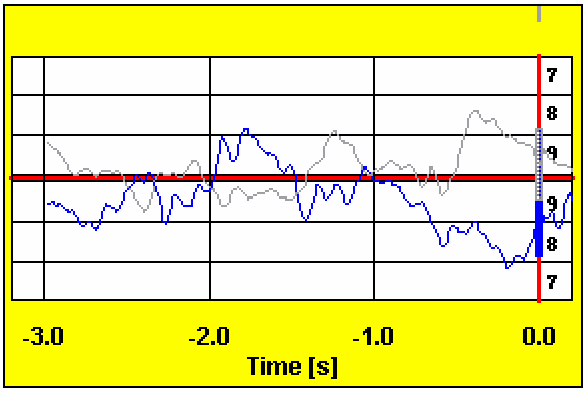


Figure 62a. R(t). **Figure 62b. XY(T).**

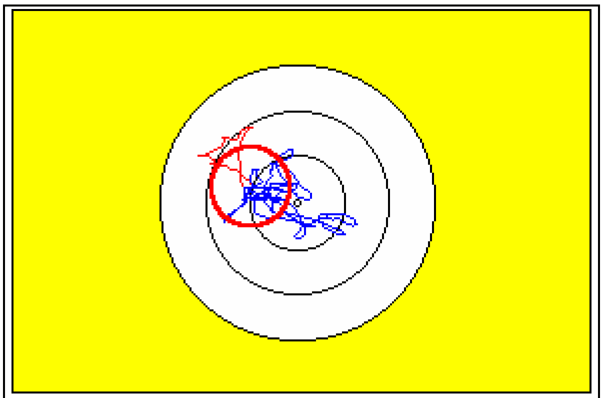


Figure 62C. X-Y.

Figure 62. A typical rifle shot not executed cleanly.

The hold remained good for more than two seconds, but the rifle wobbled badly at the moment of triggering, so that we can talk about quite an obvious jerk. The direction is the typical one: upwards and to the left.

Another typical jerked rifle shot is shown in Figure 63.

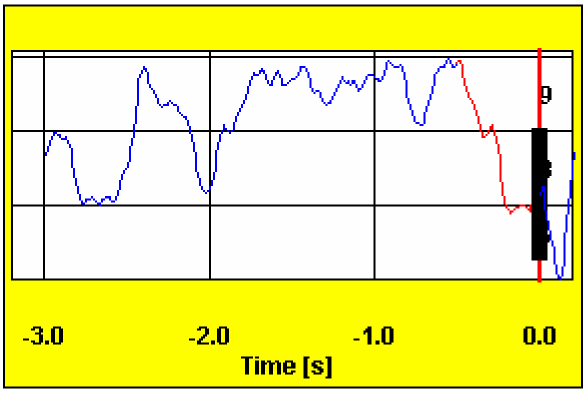


Figure 63a. R(t).

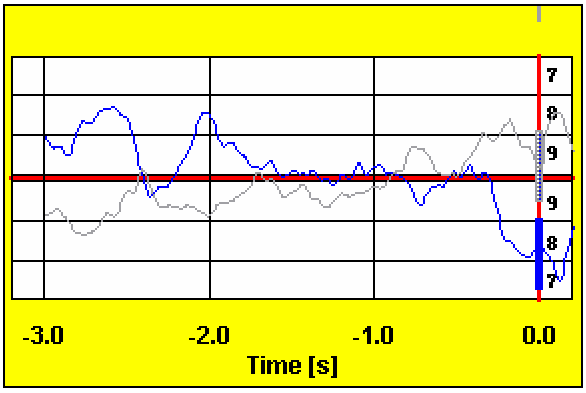


Figure 63b. XY(t).

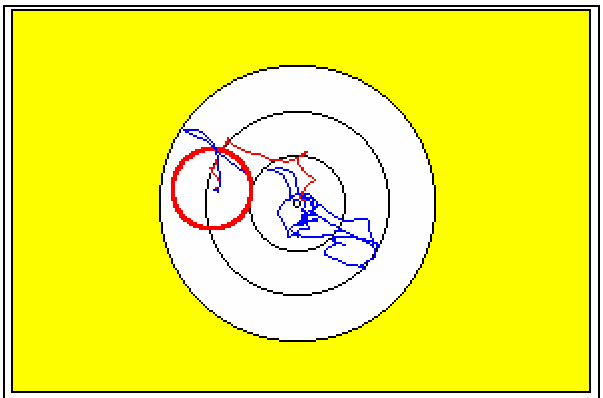


Figure 63c. X-Y.

Figure 63. Another jerked rifle shot.

Another 'good example' of a deficient triggering is shown in Figure 63, where the direction of the jerking movement pull is again the characteristic one.

The lack of cleanness in triggering is so evident in all the above examples (a change in the extent of movement and form of the path) that the problem could be reliably identified by visual inspection alone, but the situation is not always so straightforward, however. A shooter may have a slight tendency not to trigger cleanly which it is difficult to observe on the display but which may result in a considerable loss of points over a series of 60 shots. This means that reliable parameters are required for determining cleanness of shooting.

5.3. Measurement of the cleanness of triggering using the ST-2000 system

Since the gun is in practically continuous movement during shooting, this needs to be eliminated in order to ensure that it will not interfere with the measurement of the cleanness of triggering, that the triggering values for shooters of different levels of competence can be compared and that any extra triggering movement can be distinguished from holding movement. This is implemented in Noptel's standard software by means of RTV, i.e. relative triggering value, which is determined in the following manner:

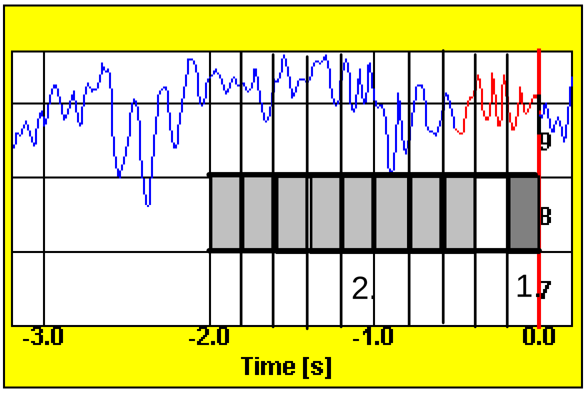


Figure 64. Determination of RTV

The movement taking place at Stage 1 (0.2 s before the shot) and Stage 2 is calculated as an average for 0.2 s sequences, and the RTV can be obtained by dividing the former by the latter. If the RTV is 1.00, movement at the point of triggering was absolutely identical to the average movement at the holding stage. If RTV > 1, the gun during triggering, and if it is < 1 there was less gun movement than average.

The RTV thus measures the movement occurring during the last 0.2 seconds and contrasts it with the preceding holding stage. There are some factors which should be taken into consideration when interpreting the RTV. As indicated above, the shooter can optimise his hold at the trigger control stage, which means that basic movement will already be smaller at this point. The situation may thus be that, given this state of less pronounced movement, the shooter suffers a slight defect in the cleanness of his shot but still records a good RTV! Another aspect which should be borne in mind is timing, i.e. the state of movement at the time when the shot is fired. One might think that averaging over a sufficient number of samples, such as a series of 60 shots, would eliminate random 'interference', so that the only variable to remain would be that indicating triggering. Research indicates that there is an obvious negative correlation between the RTV and the eventual score in pistol shooting, so that approximately 1-1.5% of the result can be explained by the RTV.

The average RTV for the pistol was 1.08, i.e. more or less the same for all the competence groups. The values for the best series were slightly below 1 (even 0.90) and those for the poorest ones of the order of 1.30. The average for all the rifle shooters was close to 1.09, the best values for individual series ranging from 0.80 to 0.90 while the poorest ones were 1.40. The average scores were 564 points for the pistol series and 579 for the rifle series. The lower RTV values obtained by the rifle shooters are attributable to the fact that they are better able to 'remain in place' for triggering so that their total movement was in general smaller. It should be noted, however, that the number of rifle series considered here was markedly smaller than that of pistol series (80 vs. 270) and that all the series were produced by trained shooters, whereas the pistol material can be regarded as more comprehensive.

It is difficult to measure the cleanness of triggering in an unambiguous manner on the basis of path data alone, and a more detailed analysis would require the measurement of triggering pressure. The RTV measures movement at the trigger control stage reliably by comparing it with the hold stage, and in this sense can be regarded as a good aid for evaluating shooting performance.

6. Summary

The findings obtained here clearly indicate that holding ability is of paramount importance in marksmanship, and that it plays a more prominent role in pistol shooting than in rifle shooting, as it is more difficult to control the rapid movements typical of a pistol. Improved holding ability also creates favourable circumstances for accurate aiming, while at the same time the better the hold is, the more important it will be to aim accurately.

An inadequate hold stage can be compensated for by optimisation at the trigger control stage. This optimisation should at best involve both holding and aiming, and can also be seen as being connected with shooting style. It should be noted, however, that extreme emphasis on optimisation may involve a danger of generating uncontrolled movements under competition pressure. How much of the eventual score can be attributed to holding and how much to trigger control must vary from one individual to another. Holding/aiming ability could well be likened to direct current and triggering control to alternating current, the result arising from the combined effects of the two, as illustrated in the following figure:

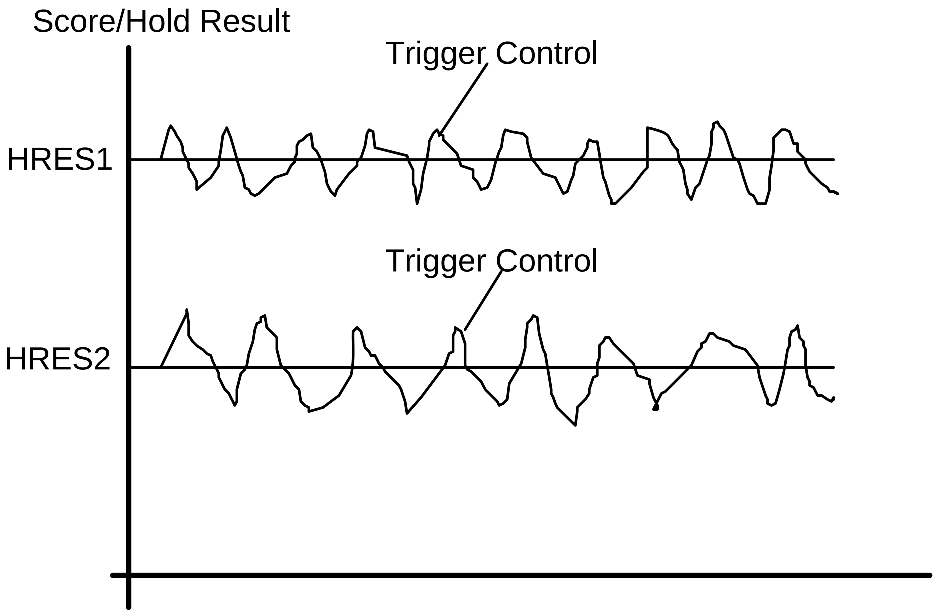
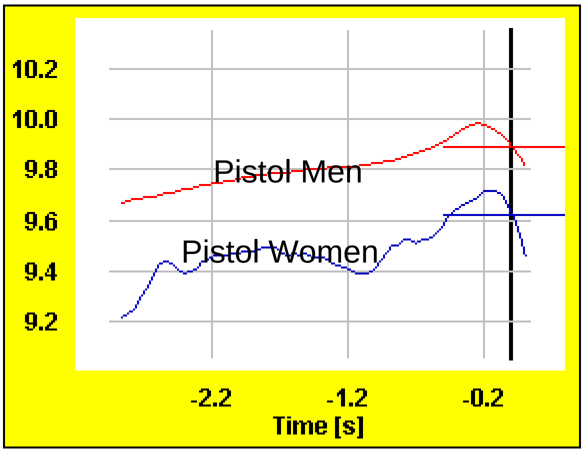


Figure 65. Roles of holding and triggering control in marksmanship.

It is our belief that it is safer to develop a good holding ability than to rely on large-scale optimisation, and that this applies to both rifle and pistol shooting. Personal differences are bound to occur, however.

As pistol shooting is evidently a 'power sport', women are in an inferior position to men as regards the hold stage, whereas in the case of rifle shooters the hold depends mainly based on the skeletal system, so that women are equal to men in this respect. It seems that women in fact have an advantage over men, thanks to their different pelvic structure. This is reflected in the fact that the vertical hold component for the best female rifle shooters is better than that for the best males!

The time curves recorded for male and female shooters are compared in the figures below. The higher the curve at the holding stage, the better the hold.



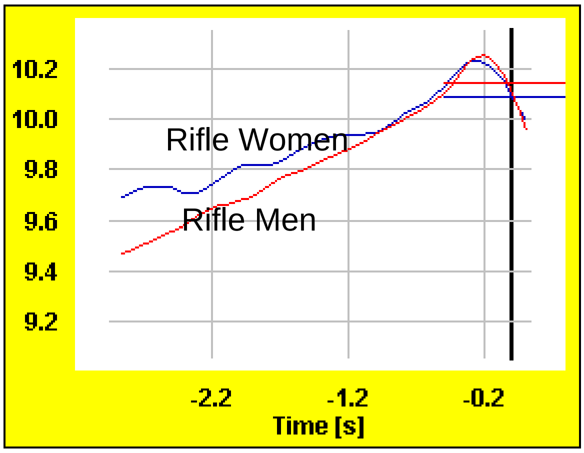


Figure 66. Time curves for pistol shooters.

Figure 67. Time curves for rifle shooters.

Finally we present a table indicating the numerical values for the success factors obtained for the various pistol test groups. As only a small number of test series are as yet available for rifle shooters and their representativeness is poor, the corresponding data will be presented in the next edition of this report. In NOStat we have 4 basic reports: Numerical Aiming, Holding, Triggering and Shooting reports. The reader finds samples of each of these reports for different competence groups for air pistol as follows. Then a glossary of the parameters is presented.

NOSTAT

Glossary of Notation

Notation	Definition
AERR	Aiming Error in the *Hold Stage* The Aiming Error is the difference between the Holding Result *HRES* and the Aiming Result *ARES*. **AERR = HRES - ARES.** See also the *NOStat Model* in **22**.
ARES	Aiming Result in the *Hold Stage*

ARES is a statistical result calculated from the shooter's holding ability (see *S*, *SX*, *SY*) and aiming accuracy (see *COG*).

Amplitude Frequency domain description of the gun orientation path.

Spectrum

The time signal representing the movement of the gun on the target is converted into a frequency domain description using a Fourier transform. Basically, this shows the relative distribution of the amplitude of the movement as a function of frequency.

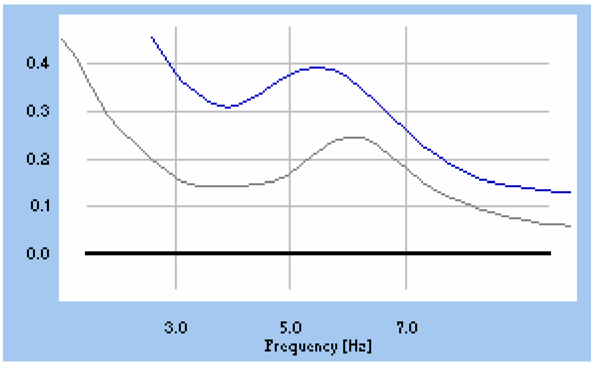


Fig. 1. Comparison of two Amplitude Spectra. The poorer shooter has a greater amplitude at all frequencies.

ATI Aiming Time in seconds.
B Best 30 % of the shots in each session.

COG Centre of Gravity of Aiming in the Hold Stage.

COGX Horizontal Centre of Gravity of Aiming in the *Hold Stage.*

COGY Vertical Centre of Gravity of Aiming in the *Hold Stage.*

CVAR* Coefficient of Variation, obtained by dividing the deviation in a variable by its average value. Here it is calculated for a session, of 60 shots. The coefficient of variation is a numerical indication of the extent of variability of a variable in a certain set. CVAR* makes it

possible to compare the variability of a variable between sessions and shooters.
The greater the CVAR*, the greater is the variability of the variable in question.

CVARATI Coefficient of Variation of *ATI.*

See *CVAR*.*

CVARSX Coefficient of Variation of the holding deviation *SX*.

See *CVAR*.*

CVARSY Coefficient of Variation of holding deviation *SY.*

See *CVAR*.*

CVARCX Coefficient of Variation of *COGX*.

See *CVAR*.*

CVARCY Coefficient of Variation of *COGY.*

See *CVAR*.*

DTRIGR A measure of Trigger Control timing.

A simple way to describe DTRIGR is to think of *R(t),* i.e. the distance from the target centre as a sinus-shaped curve:

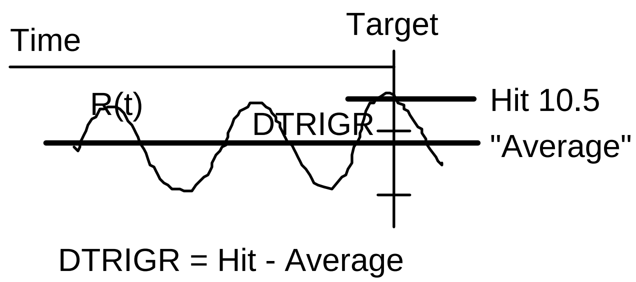


Fig. 2. Calculation of DTRIGR

The actual calculation is more complicated.

FFT10R *Amplitude Spectrum* of *R* for the *Trigger Control Stage.*

FFT10X *Amplitude Spectrum* of *X* for the *Trigger Control Stage.*

FFT10XB *Amplitude Spectrum* of *X* for the best shots in the *Trigger Control Stage.*

FFT10XW *Amplitude Spectrum* of *X* for the worst shots in the *Trigger Control Stage.*

FFT10Y *Amplitude Spectrum* of *Y* for the *Trigger Control Stage.*

FFT10YB *Amplitude Spectrum* of *Y* for the best shots in the *Trigger Control Stage.*

FFT10YW *Amplitude Spectrum* of *Y* for the worst shots in the *Trigger Control Stage.*

FFT31R *Amplitude Spectrum* of *R* for the *Hold Stage.*

FFT31X *Amplitude Spectrum* of *X* for the *Hold Stage.*

FFT31XB *Amplitude Spectrum* of *X* for the best shots in the *Hold Stage.*

FFT31XW *Amplitude Spectrum* of *X* for the worst shots in the *Hold Stage.*

FFT31Y *Amplitude Spectrum* of *Y* for the *Hold Stage.*

FFT31YB *Amplitude Spectrum* of *Y* for the best shots in the *Hold Stage.*

FFT31YW *Amplitude Spectrum* of *Y* for the worst shots in the *Hold Stage.*

HAERR Hold & Aim Error in the *Hold Stage.*

HAERR is the difference between the Maximum Result MXRES (=600) and the Aim result *ARES*, and expresses in terms of a points score the degree of imperfection in holding and aiming in the *Hold Stage.*

HAERR = 600 - ARES.

HERR *Hold Error* in the *Hold Stage.*

HERR is the difference between the Maximum Result MXRES and the Hold Result *HRES*, and expresses in terms of a points score the degree of imperfection in holding in the *Hold Stage*.

HERR = 600 - HRES

Hold Stage

Hold Stage: -3 s --> -1 s before release of the shot .

The last 3 seconds before release of the shot are considered in NOStat to form the Shot Development Stage.The time interval from -3 seconds to -1 second before the shot is called the Hold Stage. It is actually the time of concentration before the actual *Trigger Control Stage*, which in NOStat is the last second before release the shot .

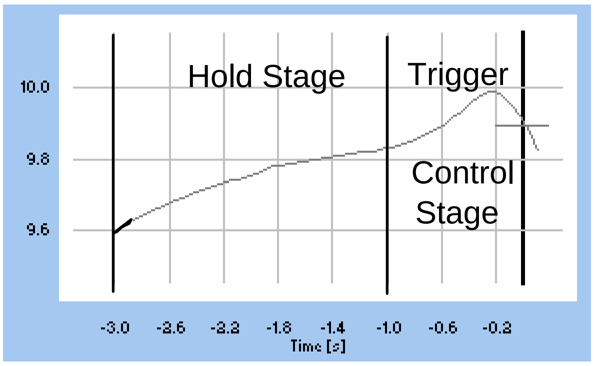


Fig. 3. The Shot Development Stage and its parts

HRES

The Hold Result in the *Hold Stage*.
HRES is a statistical result calculated from the shooter's holding ability (see deviations).

MAXFX

Frequency of the local amplitude maximum in the *Amplitude Spectrum* for horizontal movement.

See also 3: *Amplitude Spectrum.*

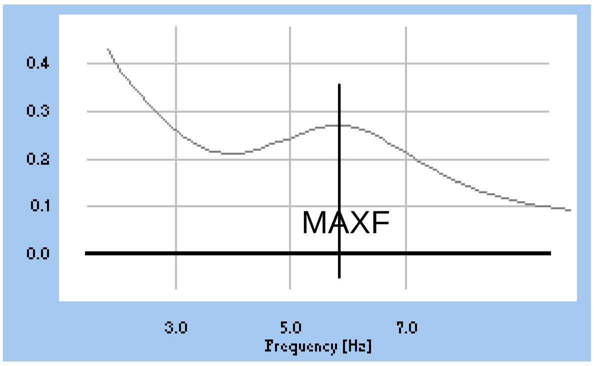


Fig. 4. Definition of MAXF*

MAXFY Frequency of the local amplitude maximum in the *Amplitude Spectrum* for vertical movement (see above).

NAR Numerical Aiming Report in NOStat.

NHR Numerical Holding Report in NOStat.

NOStat Model Model of the shooting process developed by Noptel.

The model is thoroughly described in detail in the NOStat manual. Only some basics are introduced here.

Figure 5. shows how the result is influenced by the fundamental factors in shooting: Hold, Aim and Trigger Control.

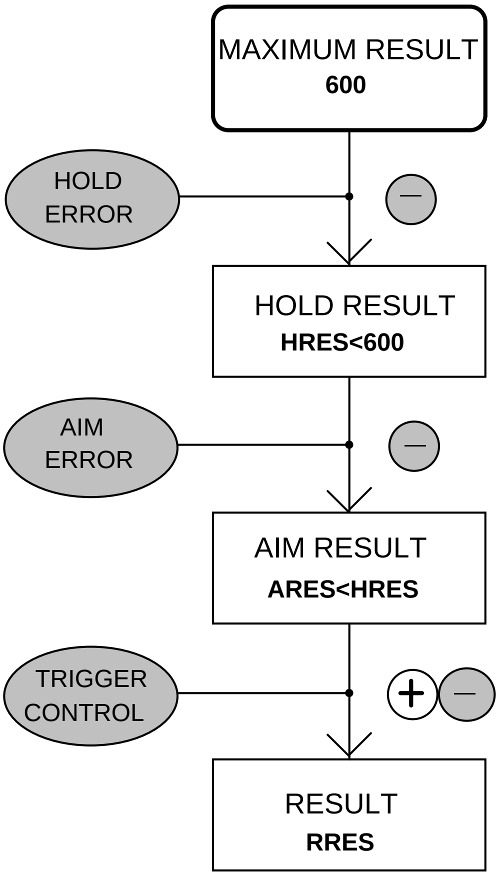


Fig. 5. The influence of Hold, Aim and Trigger Control on the result.

The next figure shows both the connections between the fundamental factors and the result and the connections between the factors.

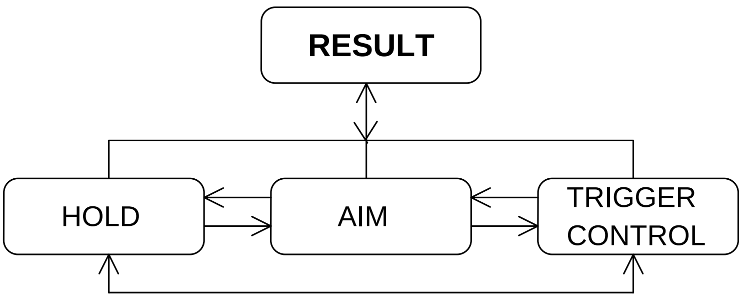


Fig. 6. The result and its factors

NSR Numerical Shooting Report.

Gives the basic set of parameters for Hold, Aim and Trigger Control.

NTR Numerical Triggering Report.

OPT The degree of optimization in the *Trigger Control Stage*.

Figure 7. illustrates the calculation of OPT.

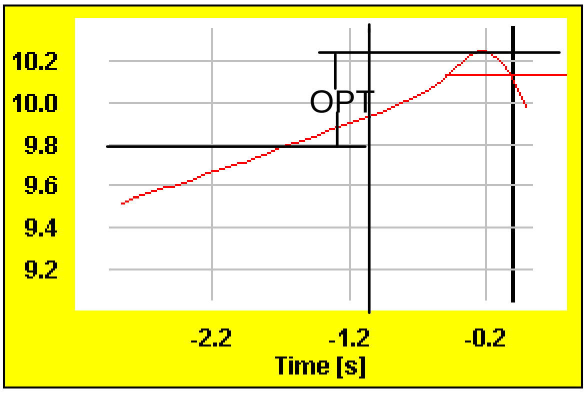


Fig. 7. Calculation of OPT

R The distance of the trajectory from the centre of the target.

R(t) The distance of the trajectory from the centre of the target as a function of time.

R10R31 *Relative Amplitude Spectrum* of *R* for the *Trigger Control Stage* versus the *Hold Stage*.

R10X31 *Relative Amplitude Spectrum* of *X* for the *Trigger Control Stage* versus the *Hold Stage*.

R10XB31 *Relative Amplitude Spectrum* of *X* for the best shots in the *Trigger Control Stage* versus the *Hold Stage*.

R10XBW *Relative Amplitude Spectrum* of *X* for the best shots versus the worst shots in the *Trigger Control Stage*.

R10XW31 *Relative Amplitude Spectrum* of *X* for the worst shots in the *Trigger Control Stage* versus the *Hold Stage*.

R10Y31 *Relative Amplitude Spectrum* of *Y* for the *Trigger*

Control Stage versus the *Hold Stage*.

R10YB31 — *Relative Amplitude Spectrum* of *Y* for the best shots in the *Trigger Control Stage* versus the *Hold Stage*.

R10XBW — *Relative Amplitude Spectrum* of *X* for the best shots versus the worst shots in the *Trigger Control Stage*.

R10YW31 — *Relative Amplitude Spectrum* of *Y* for the worst shots in the *Trigger Control Stage* versus the *Hold Stage*.

R31XBW — *Relative Amplitude Spectrum* of *X* for the best shots versus the worst shots in the *Hold Stage*.

R31YBW — *Relative Amplitude Spectrum* of *Y* for the best shots versus the worst shots in the *Hold Stage*.

Relative Amplitude Spectrum — The relation between two Amplitude Spectra.

The relation is calculated for each frequency component separately, and can be used to detect differences between good and poor shots, between the *Hold Stage* and the *Trigger Control Stage*, or between the *X* and *Y* components of the trajectory. The reference line is drawn to the value 1. If R* is 1, both variables have the same amplitude at that frequency. Sakari Paasonen's *R10XBW* is illustrated in Figure 8.

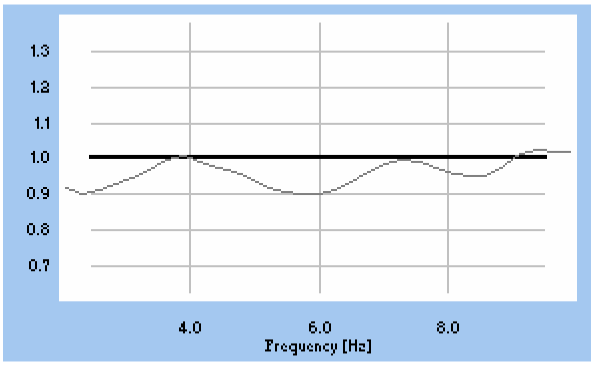


Fig. 8. Sakari Paasonen's average *R10XBW*

The figure indicates that the movement of the gun is smaller for every frequency component in good shots.

RRES The real result shot by the shooter.

RRES is calculated from the decimal sum as follows:

RRES = DecimalSum - 27

RTSDX Relative Trigger Speed horizontally.

The maximum speed of the trajectory during the last 0.3 s for X divided by the respective deviation (in this case *SX*).

RTSDY Relative Trigger Speed vertically.

See *RTSDX*.

RTV Relative Trigger Value for *R*.

RTV is calculated as shown below.

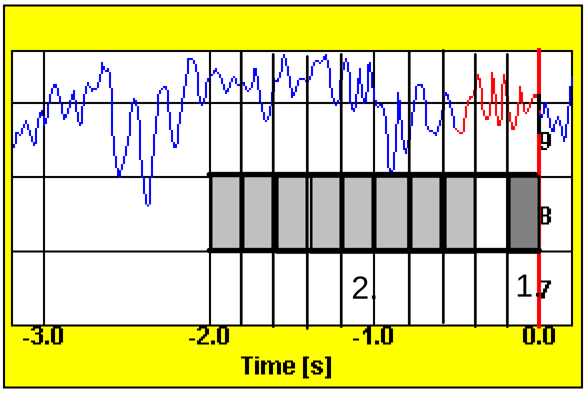


Fig. 9. Calculation of RTV

The movement of the gun during the last 0.2 s is compared with the average movement during the previous time intervals.

RTV2 Relative Trigger Value 2. of *R*.

As above but the last 0.2 s slice is now compared with a previous slice of equal size.

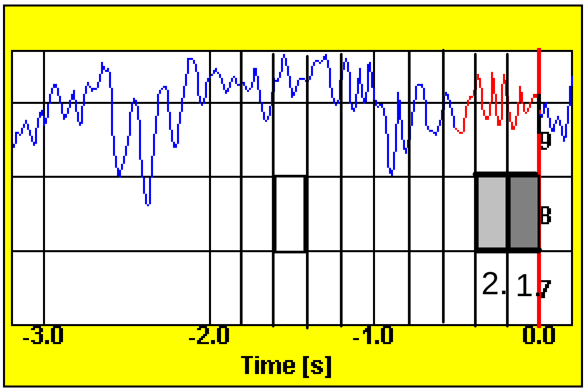


Fig. 10. Calculation of RTV2

RTVX Relative Trigger Value for *X*.

As *RTV* but for the X-component of the trajectory.

RTVX2 Relative Trigger Value 2 for *X*.

As *RTV2* but for *X*.

RTVY Relative Trigger Value for *Y*.

As *RTV* but for the *Y*-component of the trajectory.

RTVY2 Relative Trigger Value 2 for *Y*.

As *RTV2* but for *Y*.

S Standard Deviation of the trajectory in the Hold Stage.

S is one of the most important measures of skill, and is the basic measure of the Holding skill of the shooter. *S* is calculated from *SX* and *SY* as follow:

S = SQRT(SX^2 + SY^2).

S02 Average standard deviation of 0.2 s intervals in the *Hold Stage*.

S02 is calculated in order to form an idea of the "high frequency" part of the whole movement in terms of deviation. Its magnitude has an effect on trigger control.

Session A session normally comprises 60 shots.

SRELR The relation between *S02* and *S* for *R*.

SRELX The relation between *SX02* and *SX*.

SRELY The relation between *SY02* and *SY*.

SX Standard deviation of horizontal movement in the *Hold Stage*.

SX02 Average standard deviation of 0.2 s intervals horizontally in the *Hold Stage*.

SY Standard deviation of vertical movement in the *Hold Stage*.

SY02 Average standard deviation of 0.2 s intervals vertically in the *Hold Stage*.

TCNS Trigger Control Net Score.

TCNS is the difference between *RRES* and *ARES*, and is the most important characteristics for Trigger Control.

TCNS = RRES - ARES

TIMING TIMING is a measure of reaction time and anticipation.

TIMING is measured as shown below.

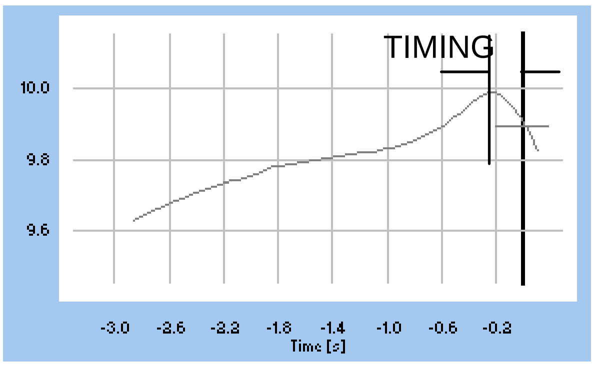


Fig. 12. Measurement of *TIMING*

Thus *TIMING* is the time from the *OPT*- peak to the shot.

TIRE Timing and Reaction.

TIRE is another measure of the timing skill of the shooter. In order to calculate *TIRE* we divide the last 600 ms into three 0.2 second intervals. If interval number 3 is highest the *TIRE* will be 3. If the first interval is highest the *TIRE* is 1.

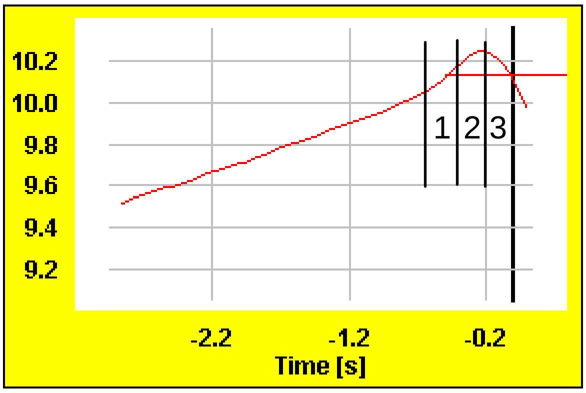


Fig. 13. Measurement of *TIRE*

Trigger Control Stage The last second of the Shot Development Stage.

See also the *Hold Stage*.

TRNDALL Time Plot of the average shot.

TRNDALL is perhaps the most important trend-type description of shooting practice. It allows the shooters to be categorized into three groups:

Holders
Optimizers
Reactors

A typical time plot can be seen in Figure 13.

TRNDALLX Horizontal Time Plot of the average shot.

TRNDALLY Vertical Time Plot of the average shot.

TRNDB30 Time Plot of the best shots in the sessions.

The best 30 % of the scores in each session are included.

TRNDB30X	Horizontal Time Plot of the best shots in the *Sessions*. The best 30 % of the scores in each session are included.
TRNDB30Y	Vertical Time Plot of the best shots in the *Sessions*. The best 30 % of the scores in each session are included.
TRNDW30	Time Plot of the worst shots in the *Sessions.* The worst 30 % of the scores in each session are included.
TRNDW30X	Horizontal Time Plot of the worst shots of *Sessions.* The worst 30 % of the scores in each session are included.
TRNDW30Y	Vertical Time Plot of the worst shots in the *Sessions.* The worst 30 % of the scores in each session are included.
W	The worst 30 % of the shots in a *Session.*
X	X stands for horizontal.
XY	Display of the trajectory on the target surface.
XY(t)	Display of horizontal and vertical movement on the time axis.
Y	Y stands for vertical.