MASTER THESIS

Course code: MKØ210 Candidate name: Kathrine Forfang

The effect of different learning backgrounds on learning an unknown skill

Date: 15.05.17 Total number of pages: 48

NORD University

www.nord.no

Abstract

The purpose of this study was to measure and compare the process of learning an unknown skill based on two different training backgrounds. The unknown skill chosen in this study was pistol shooting. For this purpose, gymnasts (n=5) and non-gymnasts (n=5) were tested by measuring the point of impact during shooting with a laser pistol before and after a training period. The training period consisted of two sessions per week for three weeks where the subjects were shooting 20 times during each session. The pre-test, post-test and retention test also consisted of 20 shots per test. The point of impact was measured for all shots during pre-test, training, post-test and retention test. Mean values and standard deviation was calculated for both groups and Mann-Whitney U was used to detect significant differences between the two training backgrounds. The results showed an improvement for both groups, but there was a significant difference between the groups at training no. 6, post-test and retention test, in which the non-gymnastics group had improved the most. The percentage increase or decrease in performance between tests, showed an increase for the non-gymnastics between all tests, while the gymnastics group showed an increase in performance between pre- and post-tests, but a decrease between the post- and retentions test. A linear regression was also calculated, and the results showed a slope increase for both groups. A higher slope increase was detected for the non-gymnastics group compared to the gymnastics group. As the test subjects in the non-gymnastics group consisted of handball players, this can be explained by the similarity between the eye-hand coordination one develops during handball practice and the eye-hand coordination in pistol shooting.

Key words: Transfer, learning process, gymnastics, handball, pistol shooting.

Sammendrag

Hensikten med denne studien var å måle og sammenligne læringsprosessen for to forskjellige treningsbakgrunner ved innlæring av en ukjent ferdighet, pistolskyting. Turnere (n=5) og ikke-turnere (n=5) ble testet ved å måle treffpunkt ved skyting med en laserpistol før og etter en treningsperiode. Treningsperioden besto av to økter per uke i tre uker, deltagerne skjøt 20 ganger hver økt. Pre-test, post-test og retention test besto også av 20 skudd per test. Treffpunktet ble målt på alle skuddene under pre-test, trening, post-test og retention test. Gjennomsnitt og standard avvik ble utregnet for begge gruppene og Mann-Whitney U ble brukt for å finne signifikante forskjeller mellom de to treningsbakgrunnene. Resultatene viser en forbedring hos begge gruppene, men det var en signifikant forskjell mellom gruppene på trening nr. 6, post-test og retention test, i ikke-turnerne sitt favør. Ikke-turnerne viste en prosentvis økning i prestasjon mellom alle testene, mens turnerne hadde en prosentvis økning i prestasjon mellom pre-test og post-test, men en nedgang mellom post-test og retention test. Lineær regresjon viste forbedring for begge gruppene. En brattere helning på regresjonslinja ble funnet for ikke-turnerne sammenlignet med turnerne. Siden deltagerne i ikke-turn gruppa besto av håndballspillere så kan øye-håndkoordinasjon ved praktisering av håndball ha gitt overføringsverdi til pistolskyting, noe som kan forklare den brattere læringskurven.

Nøkkelord: Overføringsverdi, læringsprosess, turn, håndball, pistolskyting

.

Acknowledgements

The completion of this Master Thesis demanded more than I could do by my self, and I needed a little help. I would therefore like to thank the people who helped and contributed to my work.

I would like to thank my family for supporting and motivating me during this period, specially my big sister who has contributed with helpful tips. My fellow students, in the basement workroom, Veronika Myran Wee, Line Ringseth and Runa Steiro for all the discussions, laugh and support.

Likewise, I would like to thank IL Sverre gymnastics and Nesseguten handball for contributing with subjects to this study. My advisors Rolf P. Ingvaldsen and Tore Kristian Aune for all the help and guidance during this period.

Table of Contents

1. Introduction

Learning is defined by Magill and Anderson (2014) as a "*change in the capability for a person to perform a skill; it must be inferred from a relatively permanent improvement in performance as a result of practice or experience*" (p.257). According to Fitts and Posner (1967), learning involves three stages: the cognitive, associative and autonomous. In the cognitive stage, the learner tries to make sense of the instructions that are given from the instructor. Performance during this stage is highly variable from one attempt to the next, the learner can be aware that they are doing something wrong, but do not know what and how to improve their performance. In the associative stage, practice is required and the learner develops knowledge of what to do. When the learner can perform the skill consistently and rarely are affected by distractions, they have reached the autonomous stage.

Bernstein (1967) wanted to understand how humans coordinate and control their complex system of bone segments, linked together with joints and layers of musculature, and how this system is capable of moving in a variety of different ways. He did not believe that the central nervous system controlled all muscles and joints separately, and he developed a theory that describes how humans could control the degrees of freedom of muscles, joints and motor units are put into a functional unit, in a synergy. Degree of freedom is according to Webster's dictionary (1986, in Rose, 1997) a (limited) number of ways in which a body may move. In the early stages when learning a new and unknown skill, it is necessary to "freeze out" a number of degrees of freedom and later, when the skill has been improved, release them gradually. Vereijken, van Emmerik, Whiting and Newell (1992) investigated Bernstein's idea about the early stages in skill acquisition, where five subjects practiced slalom-like ski movement on a ski apparatus. The result showed that during the early stages of learning, the measured joint angles (hip, knee, ankle and tip of the shoe) had little movement. After significant improvement of the skill during practice, the measured joint angles showed increased movement. This supports the process of freezing and releasing degrees of freedom.

Training and learning implies that one should bring forward what is previously learned and use it at a later time, in another task or situation. Therefore, learning and training skills have an element of transfer.

1.1. Transfer of learning

Transfer of learning occurs when a previously learned skill has an effect on the learning of a new skill (McGeoh, 1953). Magill (2003) describes that transfer of learning distinguishes between three types of transfer;

1. Intra-task: from one environment or situation to another
2. Inter-task: from one technical skill to another
3. Bilateral transfer: improvement in performance in non-trained joint as a result from training the opposite joint

(Magill, 2003)

There are different explanations on why transfer occurs. The traditional view is that transfer occurs due to the degree of similarity between the characteristics of two skills or of two performance situations. This view has its roots in Thorndike's (1914) identical elements theory, where he explains that the similarities must be in the stimulus (S), and/or in the responses (R), or between S and R. In line with Thorndike, Skinner (1938) explained operant conditioning in his approach, where he looked at the causes of an action and its consequences. This is the S-R-S theory, where responses from the environment can affect the probability of an action to be repeated in a positive, negative or unchanged manner. Edelman (1992) explains this within the nervous system, where the nervous patterns are reinforced if the behavior is considered as positive, or are weakened if the behavior is considered as negative.

Another explanation why positive transfer occurs is the transfer-appropriate processing theory that explains the transfer based on the similarity in the cognitive processing characteristics between two skills or two performance situations (Magill & Anderson, 2014). Richard A. Schmidt (1975) proposed a theory where the motor control and motor learning happens through development of motor programs, called generalized motor program (GMP). A GMP controls a class of movements; one class of movements is a set of different movements having the same unique set of characteristics, based on what is stored in memory. In order for a person to produce a specific movement, the person must retrieve the appropriate program from his or her memory and add movement-specific parameters. These parameters are collected through Schmidt's motor response scheme, which is responsible for providing the specific rules for the performance of a skill in a given situation.

1.1.1. General principles in transfer

Early in the 20th century teachers believed that students who studied Latin and Mathematics developed a bigger intellectual ability in other subjects or activities, but later it was proven that special intellectual activities did not have an effect on unrelated subjects or abilities (Oxendine, 1968). Judd's (1908) theory of generalized principles suggests that basic principles and knowledge of one skill is transferred to the performance of another skill. An example of this is the transfer of tennis forehand and backhand skills, as well as the footwork and knowledge of strategy and rebounds, to the similar sport squash. It is assumed that an individual who has learned the basic movements or understands the mechanical principle of the movement is able to apply this knowledge to a wide range of motor skills. According to Oxendine (1968), mental rehearsal aids learning and performance of motor skills if the athlete knows the principle and understands the task, and then it is assumed that the mental rehearsal might be transferred to the appropriate task. However, it is hard to study the mind of athletes and how they might vision a skill or the principle of the skill.

1.2. Motor skills and abilities

Ability is according to Magill and Anderson (2014) "a general trait or capability of an individual that is a determinant of a person's achievement potential for the performance of specific skills." (p.53). But the term motor ability is described as an ability that are underlying, foundational components of a performance of a motor skill. A motor skill is explained as an activity or task that requires a certain amount of control of the movements of the joints and body segments to achieve a goal (Magill and Anderson, 2014). For example, the tennis serve (motor skill) consists of several components, and some of the motor abilities needed to perform those components are the speed of arm movement, aiming and static strength.

The general motor ability hypothesis predicts that a person, who is highly skilled in one motor skill, are expected to be or become highly skilled in all motor skills (Magill and Anderson, 2014). This view got little support from other research, as another perspective came to light, the specificity of motor abilities hypothesis. This hypothesis states that motor abilities are independent and specific, and if there would be any, there would be little relationship between any two abilities. Franklin Henry's (in Magill and Anderson, 2014) research on correlation

between reaction time and movement speed gave evidence that provided most of the support for the specificity hypothesis. But if this is the case, then how can we explain the "all-around-athletes"?

1.3. Gymnastics

According to Cleassens and colleagues (1999) gymnasts are among the strongest and most flexible of all athletes, this is because they have the ability to control bodily movements though a variety of positions. Gymnastics belongs to the group of sports where stabilized kinematic structures of complicated coordination actions are performed. Gymnasts performs bending-straightening movements mainly in the shoulders and hips, these movements must be precise and carefully coordinated in time and space. The gymnasts must possess highly developed physical qualities, such as strength, speed, flexibility and special endurance, with a high performance and love for hard work (Arkaev & Suchilin, 2004). Oxendine (1968) describes how a well-learned habit is easily applied to a new situation or a new activity, and the bodily controlled skills that are developed through gymnastics are easily put to use in other activities such as dancing, diving, or other stimuli situations where the previously learned responses apply. Gallahue and Ozmun (2006) explain that gymnastics belongs to the group of basic sports that develop general characteristics that are fundamental in other sports as well.

Čuljak, Delaš Kalinski, Kezić, and Miletić (2014) studied the transfer between fundamental movement skills to basic gymnastics skills. The result showed that the subjects who had better performance during the pre-test in fundamental movement skills for surmounting obstacles also had better results in gymnastics skills at the post-test. They discussed that the fundamental movement skills for surmounting obstacles are probably more complex skills, which represent basic gymnastics skills in their modified form. Mujanović, Atiković and Nožinović Mujanović (2014) investigated the correlation between gymnastics elements and the parallel turn in alpine skiing, on male students. The presented results displayed that subjects who performed the gymnastics elements on the highest level or the level with minor mistakes, achieved better results of learning the parallel turn in alpine skiing. They explained that the gymnastics elements forward roll, backward roll and dive roll demands coordination and strength of the whole body, which the alpine technique parallel turn also consists of. However, they used male students who studied at the Faculty of sport, and never had

practiced gymnastics before. An improvement of this study design would be adding a group of experienced gymnasts, to see the effect of the subjects' training background on learning another skill. Collard, Ahmaidi and Oboeuf (2007) examined adult specialists in combat sport, team sports, gymnastics and swimming, in three 25 m swimming tasks while "blindfolded", 75 m freestyle and 25 m butterfly. They found that the gymnasts moved easily in the water during the blindfolded tasks and 25 m butterfly swim, whereas the combat and team athletes did not. However, the gymnasts swam more slowly over 75 m freestyle, and the authors discussed this as a result of the gymnasts' height, arm span and the fact that ration of women to men were higher than in the other groups.

It seems like the view of gymnastics as a basic sport is "common sense", and research on this field is minimal. Therefore, the aim of this study is to measure and compare the process of learning an unknown skill based on two different training backgrounds. The unknown skill chosen in this study was pistol shooting.

2. Methods

The primary aim of this study was to compare the process of learning an unknown skill based on two different training backgrounds. The unknown skill chosen in this study was pistol shooting. For this purpose, gymnasts (n=5) and non-gymnasts (n=5) were tested by measuring the point of impact during shooting with a laser pistol before and after a training period.

2.1. Subjects

Ten subjects participated in this study. They were divided into two groups based on their training background. The participants in the gymnastics group (n=5, Table 1) were recruited from the local gymnastics club, where they train gymnastics regularly 4.4 ± 0.5 hours per week on a regional level, in addition to 2 ± 3.3 hours of other types of training. The non-gymnastics group (n=5, Table 2) was recruited from other local teams (handball), where they train regularly 4.5 ± 0.6 hours per week on a regional level in their sport. The present study followed the ethical guidelines for human research given in the declaration of Helsinki and Toronto. Before participating in the study, the subjects and their parents/guardians were informed about the testing protocol and an informed consent was signed. The agreement stated that the subjects could withdraw from the study whenever they wanted.

Table 1. Subject characteristics for the gymnastic group. Standard deviation is given as SD.

	Minimum	Maximum	Mean	SD
Age (years)	13	14	13.6	0.5
Body height (cm)	153.5	164.5	158.8	4.4
Body mass (kg)	35.5	59.5	47.7	8.8
Gymnastic training-hours (per week)	4	5	4.4	0.5
Other training hours (per week)	0	7.5	2	3.3

Table 2. Subject characteristics for the non-gymnastic group. Standard deviation is given as SD.

	Minimum	Maximum	Mean	SD
Age (years)	13	14	13,4	0,5
Body height (cm)	157	174	165,8	6,2
Body mass (kg)	48,2	67	60,7	7,3
Training hours (per week)	4	5,5	4,5	0,6

2.2. Procedures

The presented work was designed as a pretest-posttest and retention test with two groups, where both groups completed the same practice period between pre-test and post-test. The two different groups represent two different training backgrounds that were tested to evaluate which training background could be beneficial for learning an unknown skill.

The experiment started with a pre-test of the participants shooting skills, to determine the baseline. This was followed by a three weeks training period. Right after the completion of the training, a post-test was conducted, followed by a retention test, one month after post-test were completed. All three tests followed the same procedures.

2.2.1. Testing procedures

The subjects were shooting with a laser pistol at an electronic target with their preferred hand. The center of the target was placed 140 cm above ground and the subjects were standing 4.5 m from the target (Figure 1). Each subject had total of 20 shots per test, and got instructions on how to stand, aim and shoot prior to each testing (see 1.2.3 Task). They also got information on the point of impact after each shot, due to lack of visual feedback on the shooting plate.

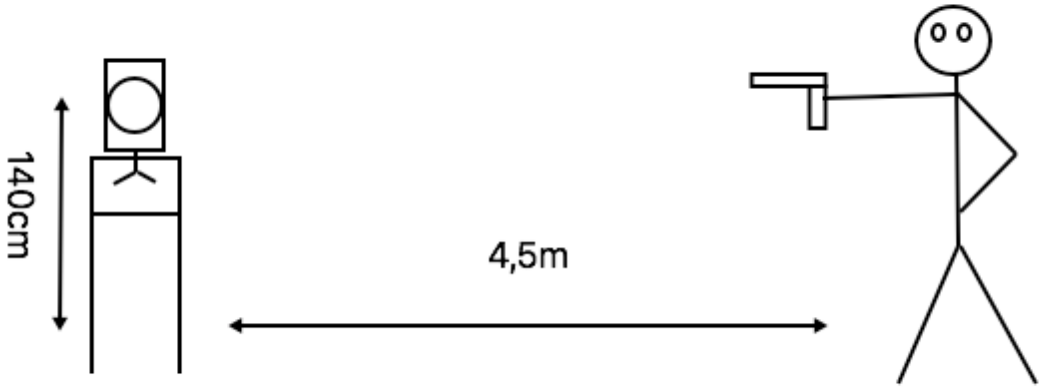

Figure 1. Experimental set-up of the training and test conditions.

2.2.2. Training period

Both groups participated in the same training period for 3 weeks. The training period consisted of two days per week and a total 20 shots per day. The set up for the shooting conditions were the same during both testing and training. Prior to each training the subject was given instruction on shooting techniques and while shooting they were given information on the point of impact.

2.2.3. Task

The subjects were instructed to read a list providing technical clues based on the "pistol Marksmanship Training Guide" manual on how to shoot prior to all testing and training:

1. The body is turned 40-50 degrees from the shooting plate. The shooter's standing position is relaxed, but the bodyweight is pushed forward from the center.
2. The feet are placed with hip width distance and the toes are pointing out.
3. The head is in a neutral position turned towards the pistol. The head should not be tilted to either sides or bend forward.
4. The pistol is held with a firm grip with the middle and the ring finger, while the little finger and thumb are relaxed. The index finger is on the trigger.
5. The pistol is calmly lifted from a resting position straight up to the shooting position. The shooting arm should be extended with a stiff wrist and the elbow locked without any load.
6. While aiming, the front sight is placed in the middle of the rear sight with equal distance on the sides. The top of the front sight is in the same height as the top of the rear sight (Figure 2). The shooter must focus on the front sight when firing the shot (Figure 3).
7. The pressure on the trigger is even using the outer part of the index finger (Figure 4), while focusing on the aim.
8. Lowering of the pistol is done calmly and restrained, as while lifting the pistol.
9. The shooter should perform the shots as similar as possible.

Figure 2. Front sight, rear sight and combined.

Figure 3. Focus on the front sight when firing the shot.

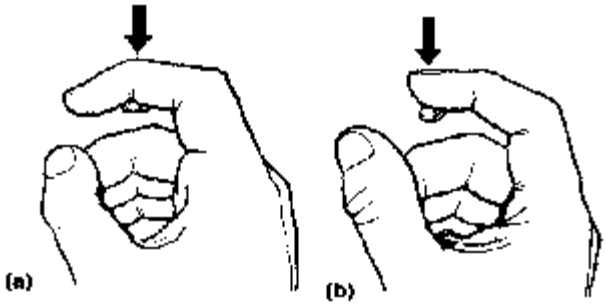

Figure 4. Correct placement of the index finger on the trigger. (a) With the first joint of the index finger. (b) With the first bone section of the index finger.

(U.S. Army Marksmanship Unit, unknown year)

2.3. Apparatus

A caliber 6mm blowback airpistol (ASG, Taiwan) was used to aim and shoot at an electronic target. An optical sensor (WS-03, Scatt WS1, Russia) was attached to the pistol. An electronic target (WT-01, Scatt WS1, Russia), connected to a computer (Samsung, NP355V5C), was used to record the point of impact. All data from the electronic target and the optical sensor

were collected in the software program Scatt Professional (Scatt WS1, Russia). The sensitivity on the electronic target and the optical sensor were put to 2.6%.

2.4. Statistical analysis

All data were collected in the Scatt Professional database directly and transferred into Microsoft Excel (2010, version 14.7.2). SPSS version 23 (IMB, statistic viewer) was used to run the statistical analysis Mann-Whitney U, to find significant differences between the groups between sessions. The average point of impact was calculated for each group on pre-, post- and retention tests. The percentage increase or decrease between tests was also calculated, and presented in charts. A Linear regression was calculated to find the slope increase for both groups.

3. Results

The primary aim of this study was to measure and compare the process of learning an unknown skill based on two different training backgrounds. The unknown skill chosen in this study was pistol shooting. For this purpose, gymnasts (n=5) and non-gymnasts (n=5) were tested by measuring the point of impact during shooting with a laser pistol before and after a training period.

3.1. Learning progress

The learning process was measured by calculating the average point of impact for each shooter during all sessions (see Appendix I and Appendix II).

In the gymnastics group, an 4.16% increase (6.211-5.963=0.248 (0.248/5.963)*100=4.16%) in the average point of impact was calculated from pre-test to post-test, while the non-gymnastics group had an 24.54% increase (6.938-5.571=1.367 (1.367/5.571)*100=24.54%) between the pre-test and post-test. The gymnastics group experienced a 2.4% decrease in average point of impact (6.062-6.211=–0.149 (–0.149/6.211)*100=–2.4%) from the post-test to retention test. At the same time, the non-gymnastics group showed an 12.64% increase in average point of impact (7.815-6.938=0.877 (0.877/6.938)*100=12.64%) between the post-test and retention test. (See figure 5).

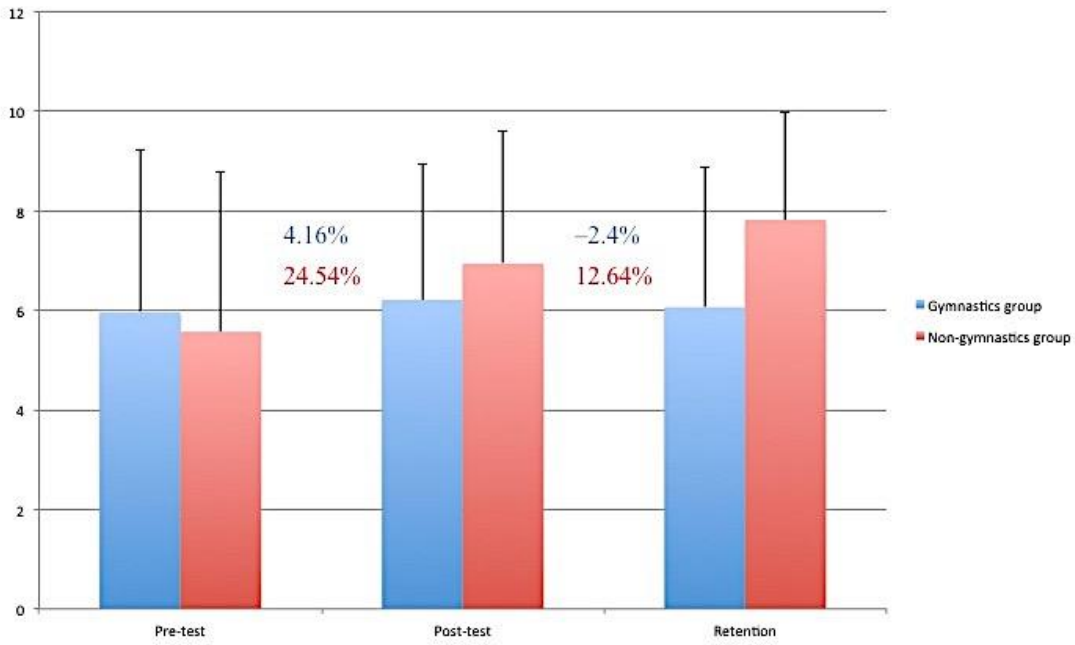

Figure 5. The figure shows the average point of impact (y-axis) and standard deviation for the gymnastics group and the non-gymnastics group. Differences are shown in percentage between pre-, post- and retention tests.

Results given in Figure 6 show the different learning progress in the shooting exercise between the gymnastics group and the non-gymnastics group, displayed by the average point of impact and standard deviation during each test and training. Mann-Whitney U showed no significant difference the two groups at pre-test, but a significant difference was found between the groups on training no. 6 ($p<0.010$), post-test ($p<0.038$) and retention test ($p<0.019$).

Slope increase models the regression between point of impact and sessions. Table 3 describes the constant for the gymnastics group is 5.677, but has a slope increase of 0.077 (b_1). While the non-gymnastics group starts at a constant of 5.410, and has a slope increase of 0.205 (b_1).

Table 3. Parameter Estimates for both groups.

		Parameter Estimates	
Group	Equation	Constant	b_1
1	Linear	5.677	0.077
2	Linear	5.410	0.205

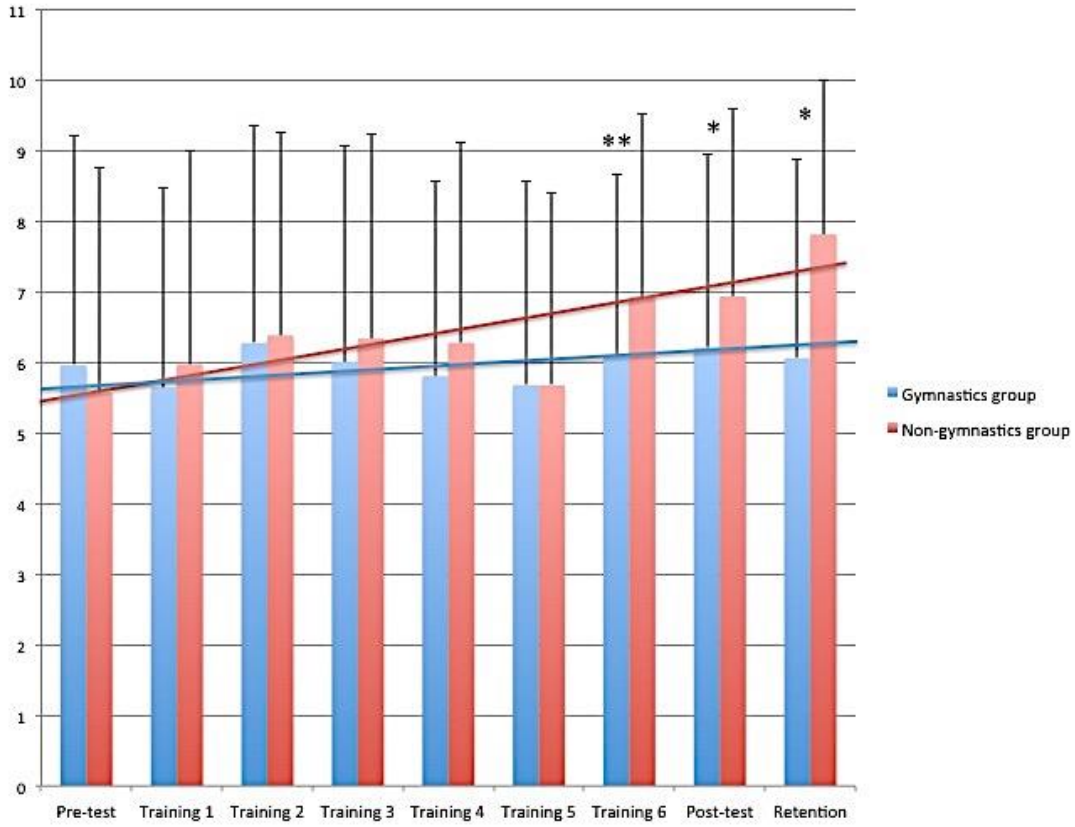

Figure 6. Learning progress displayed by the mean and standard deviation of point of impact (y-axis) during shooting for both the gymnastics group (n=5) and the non-gymnastics group (n=5) during testing and training. The blue line displays the slope increase of 0.077 for the gymnastics group. The red line shows the slope increase of 0.205 for the non-gymnastics group. Star abbreviated bars show Mann-Whitney U significant differences between the two groups. ** Significant differences at the 0.01 level (2-tailed). * Significant differences at the 0.05 level (2-tailed).

4. Discussion

The primary aim of this study was to measure and compare the process of learning an unknown skill based on two different training backgrounds. The unknown skill chosen in this study was pistol shooting. Gymnasts (n=5) and non-gymnasts (n=5) were tested by measuring the point of impact during shooting with a laser pistol before and after a training period of three weeks.

Gymnastics belongs to a group of basic sports, where the learned skills possess general characteristics that are fundamental in other sports as well (Gallahue & Ozmun, 2007). We wanted to study whether previously learned gymnastics skills could be transferable and beneficial for learning the unknown skill pistol shooting. In the present study, the gymnastics group did improve their point of impact throughout the training- and testing period, but a greater, significant improvement was measured for the non-gymnastics group. Collard, Ahmaidi and Oboeuf (2007) explained that gymnasts and swimmers use their body orientation to perform skills within their sports. Gymnasts exploit their proprioceptive information as much as possible. However, in pistol shooting the eye-hand coordination is an important factor of aiming and shooting (U.S. Army Marksmanship Unit, unknown year). The eye-hand coordination is explained by Magill and Anderson (2014) as "the ability to perform skills requiring vision and the precise use of the hands." This specific coordination also exists in handball, and the non-gymnastics group in this study consisted of handball players. Grigore, Mitrache, Predoiu and Rosca (2007) analyzed the eye-hand coordination between sports with contact with their opponents (handball, basket and karate) and without contact with their opponents (gymnastics, dance, athletics and swimming). The subjects had to follow a yellow square with a red square on a screen by pressing buttons, the yellow square moved at a slow speed and a fast speed. Results showed that the subjects who practiced contact sports with their opponents had significantly better eye-hand coordination than the subjects who practiced sports without contact with their opponents. They reasoned that athletes who practice contact sports have the opportunity to develop skills as eye-hand coordination in both the sport and in general. This ability to perform the skill pistol shooting, which requires the coordination of vision and the precise use of the hand, can support the specificity hypothesis that the eye-hand coordination is an independent and specific ability. This will also explain

the fact that the gymnasts with lesser training in coordinating the vision and hand also have a lower improvement in the point of impact during pistol shooting.

The results of the presented study showed a greater learning progress for the non-gymnastics group compared to the gymnastics group. This indicates, in line with Thorndike's theory on identical elements, that the level of similarity between the eye-hand coordination in pistol shooting and handball are high. Handball players have a physical target to aim and shot at, as well does pistol shooters, the differences between them are that the handball players are in movement while the pistol shooters stand still, also the size of the target is different. Clearly, these differences are not as large compared to difference between techniques gymnasts use in their training, proprioceptive information, and the eye-hand coordination needed during pistol shooting.

Even though the Mann-Whitney U analysis showed no significant differences between groups at the pre-test ($p=0.335$), the average point of impact and the constant are higher for the gymnastics group than the non-gymnastics group (average: 5.963 vs. 5.571, constant: 5.677 vs. 5.410). This suggests that the gymnasts had an advantage at the start of the experiment. However, as the training continues this advantage does not weigh up for the specific eye-hand coordination, that are required in pistol shooting, as the resulting change in point of impact between the tests performed in this study (Figure 5 and Figure 6). The gymnastics group had an 4.16% increase from pre-test to post-test, while the non-gymnastics group had an 24.54% increase from pre-test to post-test. If this specific coordination of vision and hand is a crucial factor while shooting, then the non-gymnastics group should have preformed greater at the pre-test.

An interesting aspect that should be studied further is the different movement patterns between the groups, to see what the non-gymnastics group does differently from the gymnastics group. Arutyunyan, Gurfinkel and Mirskii (1968, 1969) compared pistol shooting between skilled shooters and unskilled shooters. Their results showed that beginners keep the bio kinematic linkages of the arm fixed, while the skilled shooters displayed no locking but compensatory actions in the arm link to minimize movement on the pistol. They concluded that this was due to changes in the process of learning, from fixed joints to compensatory synergism, as Bernstein (1967) explained about the early stages in skill acquisition where it is

necessary to “freeze out” a number of degrees of freedom, and when the skill has been improved, release them gradually.

5. Conclusion

The results in the presented study showed a greater learning progress for the non-gymnastics group (n=5) compared to the gymnastics group (n=5). The results showed improvement for both groups, but the non-gymnastics group had a greater learning curve compared to the gymnastics-group. The improvement for the non-gymnastics group in this study could be explained by the level of similarity between the eye-hand coordination in pistol shooting and handball.

6. References

Arkaev, L., & Suchilin, N. G. (2004). *Gymnastics: How to create champions.* UK: Meyer and Meyer Sport.

Arutyunyan, G. H., Gurfinkel, V. S., & Mirskii, M. L. (1968). Investigation of aiming at a target . *Biophysics* (13), pp. 536-538.

Arutyunyan, G. H., Gurfinkel, V. S., & Mirskii, M. L. (1969). Organization of movements on execution by man of an exact postural task. *Biophysics* (14), pp. 1162-1167.

Bernstein, N. A. (1967). *The co-ordination and regulation of movements.* Oxford: Pergamon.

Čuljak, Z., Delaš Kalinski, S., Kezić, A., & Miletić, Đ. (2014). Influence of fundamental movement skills on basic gymnastics skills acquisition. *Science of Gymnastics Journal , 6* (2), pp. 73-82.

Cleassens, A., Lefevre, J., Beunen, G., & Malina, R. (1999). The contribution of athropometric characteristics to performance scores in elite females gymnasts. *Journal of sports medicine and physical Fitnes , 39*, pp. 355-360.

Collard, L., Ahmaidi, S., & Oboeuf, A. (2007). Motor skills transfer from gymnastics to swimming. *Perceptual and Motor skills* (105), pp. 15-26.

Edelman, G. (1992). *Bright air, brilliant fire: On the matter of the mind.* Harmondsworth: Penguin.

Fitts, P., & Posner, M. (1967). *Human performance.* California, USA: Brooks/Cole.

Gallahue, D. L., & Ozmun, J. C. (2006). *Understanding Motor Development: Infants, Children, Adolescent, Adults* (6th ed.). Sydney: McGraw-Hill.

Grigore, V., Mitrache, G., Predoiu, R., & Rosca, R. (2012). Characteristic of instrumental movements - eye hand coordination in sports. *Procedia - Social and Behavior Sciences* (33), pp. 193-197.

Judd, C. H. (1908). The relation of special training and general intellegence. *Educational Review , 36*, pp. 28-42.

Magill, R. A. (2003). *Motor learning and control: Concepts and applications.* USA: McGraw-Hill.

Magill, R. A., & Anderson, D. (2014). *Motor Learning an Control - Concepts and Applications* (10th. ed.). McGraw-Hill international edition.

McGeoh, J. A., & Irion, A. L. (1953). *The psycology of human learning* (2nd. ed.). New York: Mckay.

Mujanović, E., Atiković, A., & Nožinović Mujanović, A. (2014). Relation between acrobatic elements knowledge and alpine skiing parallel turns among physical education students. *Science of Gymnastics Journal , 6* (2), pp. 83-94.

Oxendine, J. B. (1968). *Psychology of motor learning.* New York: Appleton-Century-Crofts, Division of Meredith Corporation.

Rose, D. (1997). *A multilevel approach to the study of motor control and learning.* USA: Allyn & Bacon.

Schmidt, R. A. (1975). A schema theory of discrete motor skill learning. *Psychological Review* (82), pp. 225-260.

Skinner, B. F. (1938). *The behavior of organisms.* New York: Appelton.

Thorndike, E. L. (1914). Educational psychology: briefer course. New York: Columbia University Press.

U.S. Army Marksmanship Unit. (Unkown). *Pistol Marksmanship Training Guide* . Georgia, USA: Fort Benning.

Vereijken, B., van Emmerik, R. E., Whiting, H. T., & Newell, K. M. (1992). Fee(z)ing Degees of Feedom in Skill Acquistion. *Journal of Motor Behavior , 24* (1), pp. 133-142.

Appendix

Table of Contents

A1. Learning process for the gymnastics group

The learning process was measured by calculating the average point of impact for each shooter during all sessions.

Table A1.1. All point of impact for all sessions for subject 1, in the gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	4.5	6.5	10.5	1.2	3.2	0	5	6.1	0
2	0	3.7	1.1	9.1	3.3	7.6	2.8	1.8	3.4
3	1.5	0	2.7	0	1	5.6	6.1	6.3	7
4	4.2	3	7.4	1.9	3.9	1.6	7.4	7	0
5	4.2	2.8	2	7.8	2	4.7	7	4.5	6.6
6	5.1	3.9	3.6	0	5.8	5	2.5	5.2	6.6
7	1.4	3.3	6.8	3	10.5	6.9	4	8.7	3
8	6.3	0	0	3.7	6.6	3.3	5.9	3	3.3
9	2.7	1.9	6.5	9.3	8.4	10	3.9	5.3	0
10	3.1	4	5.5	5.2	9.8	7.3	3.2	4.7	1.1
11	2.6	0	9.4	1.7	1.6	2.8	5.8	7.4	4
12	3.5	4.1	10.2	9.3	6.1	0	5.9	5.5	2.1
13	6.7	2.3	1.9	6.2	9	6	5.9	1.1	3.9
14	0	1.3	0	1	0	6.1	2.8	5.2	7.5
15	0	0	1.3	2	4	4.6	8.4	5.6	6.2
16	0	0	1.7	0	8.2	8.2	4.7	3.4	9.5
17	5.4	0	0	1.1	2.6	4.9	2	3.2	4.9
18	5.8	2.4	6.9	4.3	5.7	3.9	8	9.6	5.9
19	0	4.8	4.6	3.5	3.4	10.3	8.6	6.1	9.3
20	6.6	8.2	0	6.6	5	6.7	2.7	4.6	2.9

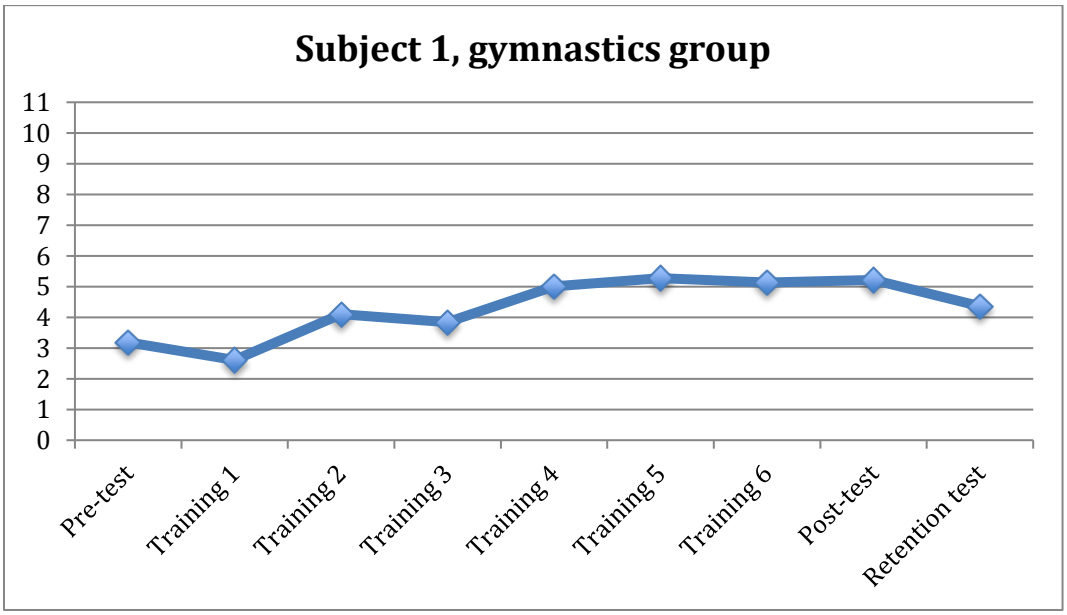

Figure A1.1. Learning process displayed by the average point of impact for subject 1 at all sessions, in the gymnastics group.

Table A1.2. All point of impact for all sessions for subject 2, in the gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	9.2	3.2	9.6	0	8.1	3.8	4.8	3.9	8
2	9.9	2.6	10.8	5.3	7.2	9.6	6.4	8.9	6.6
3	3.8	5	6.8	4.6	8.2	9.3	6.4	4.9	10.3
4	6.9	1.8	4.4	10.4	0	7.6	6.4	7.1	9.6
5	10.1	6.3	9.8	6.9	8.5	6.8	6.1	8.7	9.3
6	5.3	5.6	9.7	9.8	2.2	10.1	0	4.4	7.9
7	9.7	2.7	7.9	4	4.7	6.1	1.8	6.1	8.2
8	9.2	3.5	8.4	4.9	3.3	7.7	7	7.7	9.4
9	6.9	7.8	10	0	2.6	9.1	4.6	10.3	7.2
10	6.9	9.5	8.9	9.7	8.7	7.2	6.4	8.4	8.3
11	8.5	6.9	3.9	3.3	2.7	5.4	1.5	6.8	8.4
12	9.1	10	9.7	5.3	9	6.2	6.2	5.6	9.5
13	10.1	6.9	10.2	8.6	3.8	7.9	8.4	7.8	4.5
14	9.3	6.2	10.3	2	8.7	4.7	6.9	5.6	9.8
15	9.3	7.4	7.4	2.6	6.2	8.8	9.3	5.7	10
16	7.3	8	8.2	10.6	4.7	4.1	7.4	9.7	8.8
17	7.3	7.3	6.7	3.7	6.6	7.9	7.7	8.6	8.5
18	7	8.9	4.8	5.9	8.3	9.8	3.9	8.5	6.3
19	9.3	2	9.1	3.6	7.6	10.2	7.6	7.8	10.8
20	9.7	7.9	6.5	5.3	10	7.6	9.3	4.7	7.8

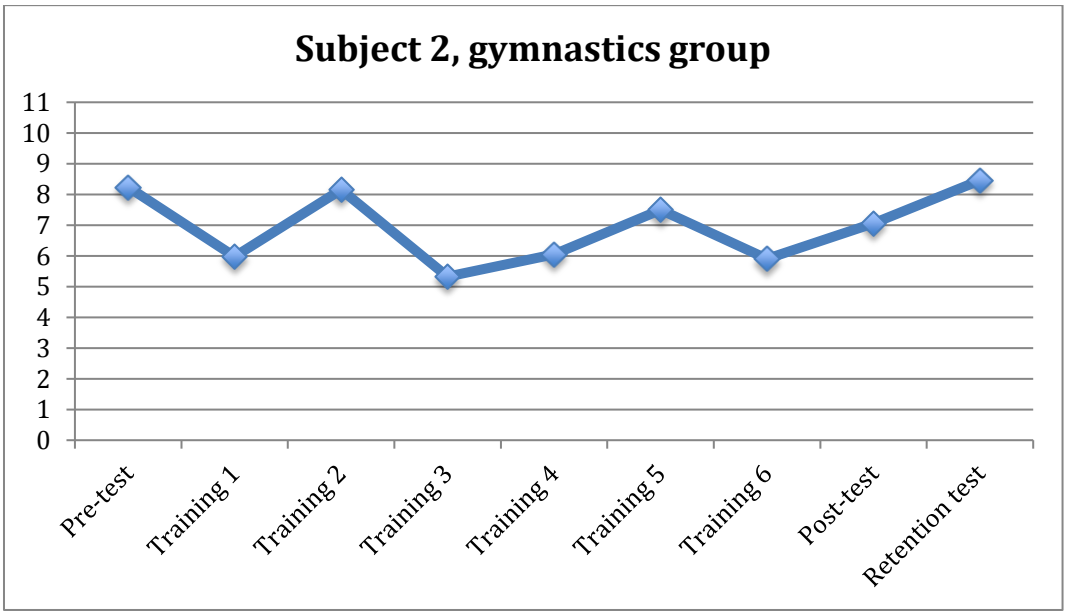

Figure A1.2. Learning process displayed by the average point of impact for subject 2 at all sessions, in the gymnastics group.

Table A1.3. All point of impact for all sessions for subject 3, in the gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	6.1	1.9	7.6	0	5.6	7.2	0	7.9	9.4
2	7.6	4.2	6.9	10.4	10.3	0	7.4	4.7	10.7
3	7.9	7.4	7.6	9.3	2	6.7	5.9	2.7	0
4	9.1	2.3	3.3	7.4	4.9	10.2	10.2	0	9.5
5	7.4	5.1	3.5	4.7	5.5	5.1	4.9	8	2.7
6	0	9.6	9.1	6.4	6.1	3.5	3.4	4.3	7.2
7	6.3	8.9	10.6	9	10	8.5	6.8	7.7	6.1
8	5.3	7.2	6.6	9.7	8.3	6.7	6.5	5.6	8.5
9	4.4	2.8	6.6	5.3	2.4	0	7.5	0	5.5
10	2	10.6	3.8	5.2	6.5	8.1	2.8	10.4	10.4
11	2.9	3.6	3	9.3	5.8	3.6	2.6	9.1	1.1
12	8.4	9.6	6.8	6.2	0	3.4	5.7	9.2	9.3
13	0	4.3	1.4	8.3	7.3	7.4	5.5	3.6	4.7
14	7.4	10.2	7.7	0	6	3.9	2	10.5	9.1
15	5.9	6.9	1.8	10.4	4	7.9	1.4	7.3	10
16	10	4.9	0	6.6	9.8	6.8	8.7	6.4	5
17	9.3	8.9	9.1	3.9	3.7	7.7	6.7	6.2	6
18	5.3	3.9	6.3	8.5	8.8	5.1	10.5	8.1	9.4
19	2.7	3.5	9.6	9.2	6.4	5	8.5	2	9.9
20	0	9.3	8.3	6.4	7.1	6	6.6	9.5	6.9

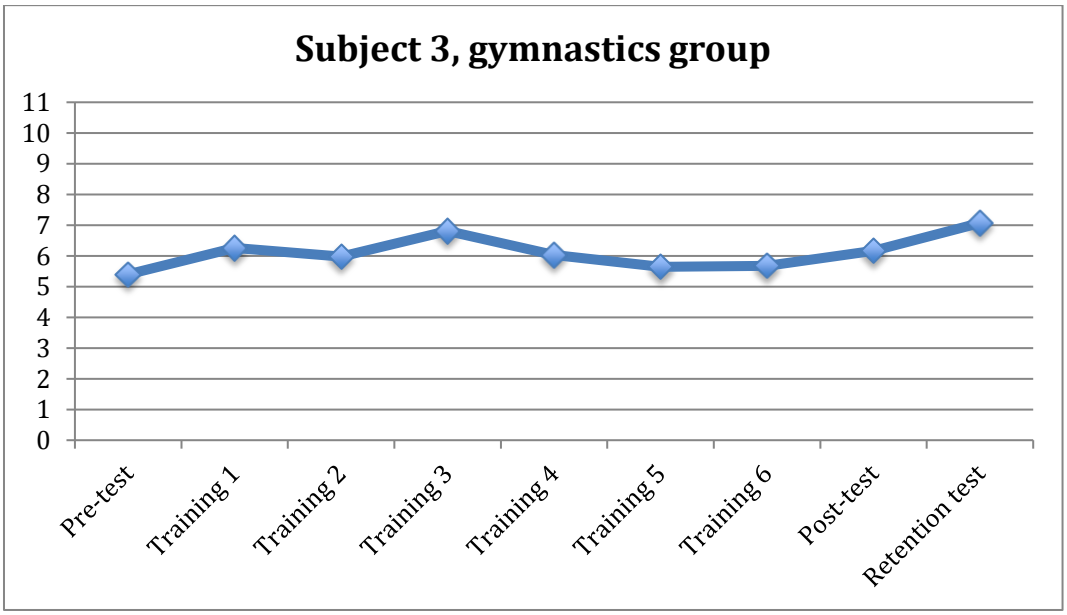

Figure A1.3. Learning process displayed by the average point of impact for subject 3 at all sessions, in the gymnastic group.

Table A1.4. All point of impact for all sessions for subject 4, in the gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	1.9	3.8	9.2	8.1	6.6	7.6	7.2	4.3	6.9
2	7.2	5.4.	3.3	8.5	3.1	0	5.4	2.2	9.6
3	2.6	6.4	9.4	3.3	8.2	4.3	3.2	8.3	9.2
4	0	4.2	7.1	8.7	4	6.8	7.5	9.5	8.4
5	1.2	7.8	1.7	8.9	6.9	7.3	8.8	8	7.5
6	4	4.8	8.3	5.8	6.5	1.5	8.1	0	2.6
7	9.4	8.8	4.8	1.8	8.5	1.9	9.3	8.8	7
8	8.1	3.6	1.6	2.6	2.9	6.3	8.9	8.2	9.1
9	9	9.7	1.6	5.4	7.2	2.9	8.3	6.7	6.4
10	7.5	8.6	4.9	9.1	3.5	8.2	5.3	7.1	3.8
11	6.1	7	4.3	5.6	7.6	7.5	7.2	9	7.4
12	10.6	8.7	5.5	4.4	5.3	5.6	8.5	4.5	5.2
13	9.4	7.1	9.6	7.4	10.8	0	8.3	7.2	7.2
14	9.5	9	8.6	4.9	1.9	5.5	6.1	7.9	2.3
15	9.9	9.9	3.7	9.6	6.5	3.8	10.4	5.1	2.3
16	7.2	3.9	6	9.7	9.3	2.4	5.1	8.4	1.6
17	9.3	7.5	6.9	7.8	0	5.1	7.8	1.4	8.8
18	8.4	1.6	4.9	3.5	9	8.5	2.3	10.7	7.9
19	5.8	7.8	9.4	10.6	4.8	3.4	3.2	0	5.8
20	9.2	5.2	5.7	6.7	9.2	1.7	5.3	9.6	9.7

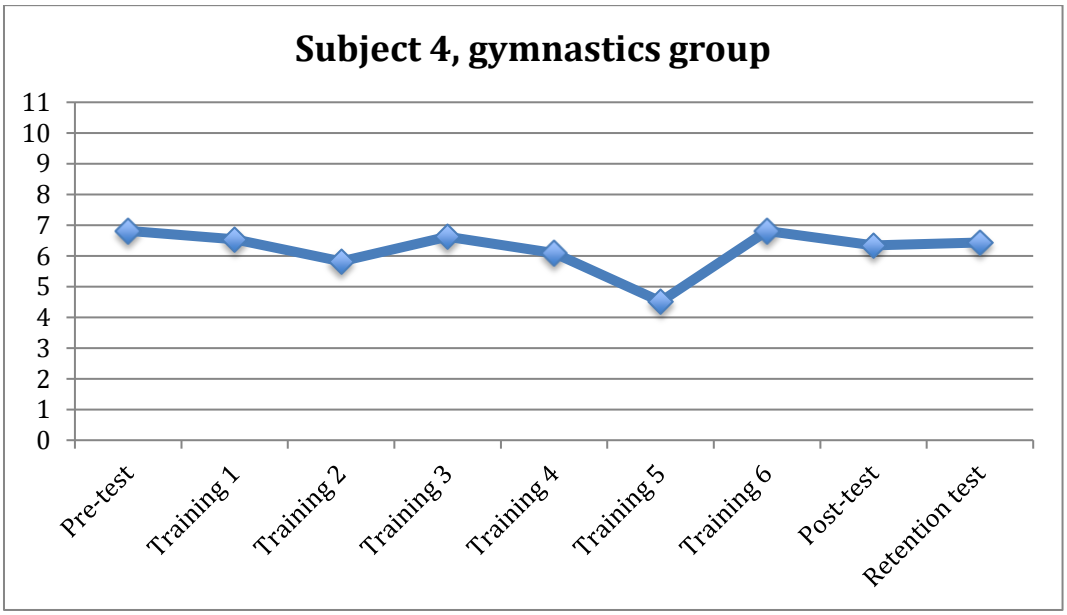

Figure A1.4. Learning process displayed by the point of impact for subject 4 at all sessions, in the gymnastics group.

Table A1.5. All point of impact for all sessions for subject 5, in the gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	5.2	6.4	6.2	5.2	7.2	5.9	1	2.5	6.1
2	8.7	7	9.2	5.1	0	0	8.8	7.4	9.4
3	2.9	6.1	3.9	5.8	6.4	10.4	6.2	1.4	6.8
4	4.4	4.6	7.7	4	3.8	8.5	9.2	4.7	8.3
5	0	8.8	9.2	7.7	6.9	6.3	8.6	3.8	9.6
6	4.5	7.8	3.2	7.2	5.9	0	6.9	8	7.3
7	10	5.9	8.9	6.2	6.1	8	6.9	4.7	8.8
8	7,8	9,2	8,7	9,5	3,9	4,8	7,4	7,9	4,6
9	9,3	7,9	6,5	6,6	7,3	5,1	6,2	1,4	9,2
10	7,8	7,8	7,8	8,5	8,9	3,8	7,3	9,8	10,7
11	0	8,4	9	4	6,5	9,4	3	3,8	8,7
12	5,5	6,3	9,8	8,6	1,6	7	8,7	8,1	5,3
13	5,9	6,2	5,3	8,2	6	2	5,6	9,6	10,2
14	10,1	8,9	9,3	10,4	10	3,9	9,8	5,9	7,8
15	8	7,1	7,2	7	4,8	9,2	10,6	9,2	7
16	9,5	4,8	8,7	7,6	6,1	5,7	6,3	6	8,4
17	7	7,3	0	9,8	6,4	10,7	6,8	10,4	8,2
18	7,4	7	7,9	9,2	2,7	1,3	0	7,5	10,2
19	9,6	1,8	9,1	8,8	8,1	0	9,5	9,4	5,8
20	0	7,9	8,8	9,4	8,8	7,6	9,4	4	8,1

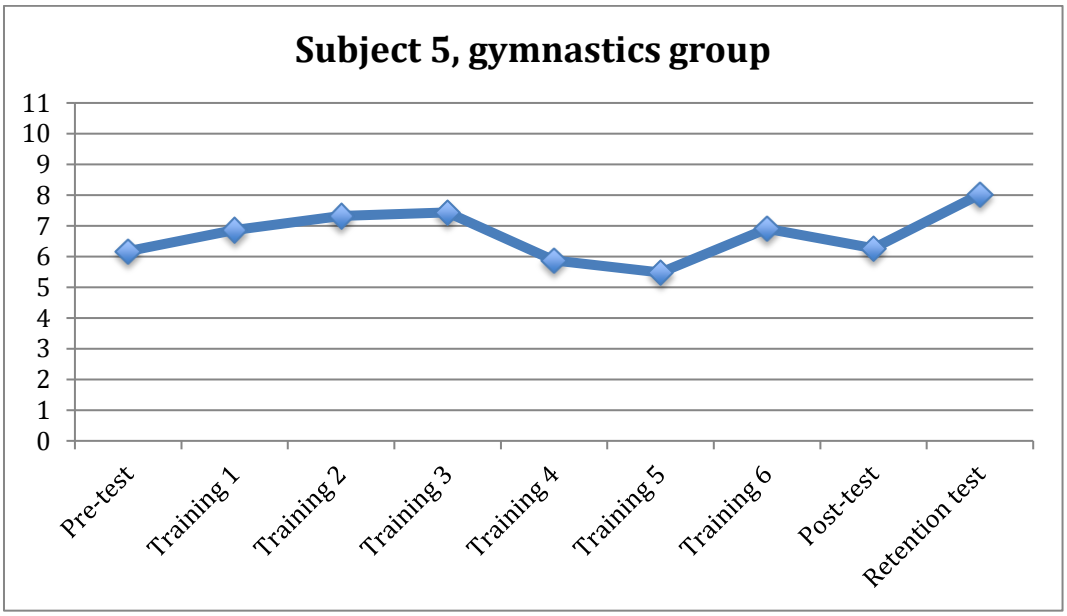

Figure A1.5. Learning process displayed by average point of impact for subject 5 at all sessions, in the gymnastic group.

A2. Learning process for the non-gymnastics group

The learning process was measured by calculating the average point of impact for each shooter during all sessions.

Table A2.1. All point of impact for all sessions for subject 6, in the non-gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	6,3	5,8	7	3,3	5,3	4,9	9,9	8,4	7,9
2	10,1	4	4,3	0	3,7	2,4	3,7	7,1	4,3
3	6,4	6,9	8,1	9,9	6	9,8	8,4	10,3	3,6
4	2,9	3,9	1,7	6,6	1,6	8,5	9,6	7,8	10,3
5	6,5	5,8	9,9	5,7	8,1	6,5	9	9,7	8,1
6	5,1	9,1	5,3	8,9	3,9	5,4	7,6	7,9	8,5
7	6,7	9,1	8,4	8,7	6,7	2,4	9,8	3,7	7
8	8,7	3,3	0	2,7	1,9	6,4	6,2	9,7	5,7
9	4,8	7,3	4,7	0	3,7	10,3	7,8	8	10
10	9,2	1	3	9,5	3	10,2	9,5	5	9,4
11	9,2	7,9	5,6	8,7	5,2	8,5	4,7	8,3	8
12	5,5	0	7	9,5	2,8	9,4	0	7,2	6,8
13	5,7	4,2	8,9	5,4	6	9,4	8,3	7,3	2,1
14	4	2,1	8,5	5,9	2,5	7,5	7,2	6,5	10,3
15	7,7	2,7	3,2	7,1	5	4,4	8,2	10,6	9,2
16	1,2	5,3	7,9	0	5,9	5,7	3	7,8	5,4
17	3,9	6,7	8,9	8,8	4,7	7,1	10,3	9,8	4,7
18	4,5	4	7,3	6,2	8,9	3,4	7,1	8,4	6,7
19	7,1	3,5	10,1	8,2	5,8	9,5	5	10,3	9,8
20	8,7	2,5	3,8	8,5	6,7	4,7	10,1	3,7	7,5

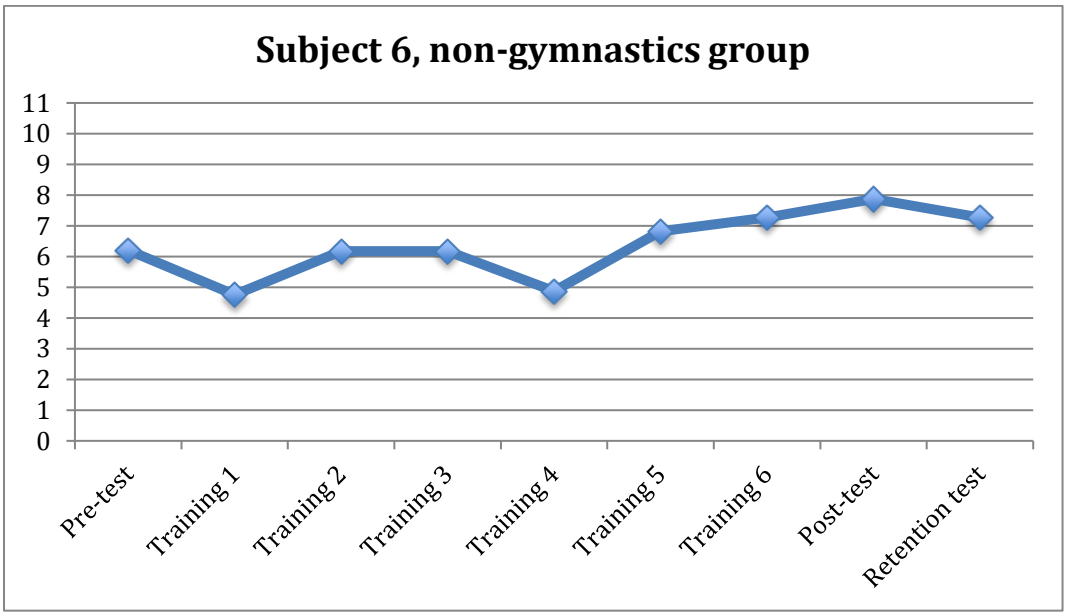

Figure A2.1. Learning process displayed by the average point of impact for subject 6 at all sessions, in the non-gymnastic group.

Table A2.2. All point of impact for all sessions for subject 7, in the non-gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	8,4	5,5	8,4	4,4	10,1	8	6,7	10,2	6,5
2	8	9,1	4,1	5,7	3,6	3,1	3,5	5,5	6,7
3	8	3,9	9,2	3,3	0	8,8	6,6	7,4	7,8
4	8,9	8,4	9,5	9,9	3	8,2	4,8	9,1	3,5
5	0	4,5	0	7,3	9	3,7	9,8	9,5	9,1
6	8,7	0	4,5	9,2	10,1	1,9	9,3	8,6	5
7	7,7	0	8,7	9,9	9,5	8,1	8,4	9	3,5
8	0	9,2	9,6	5,1	6,8	1,9	6,6	6,6	9,9
9	9,7	6,6	5,5	2,6	6,4	7,2	7,6	10	7,4
10	9,2	8,6	6,6	8	7,5	5,9	6	6,1	6,9
11	5,3	0	9,7	5,9	2	6,5	8	9,4	8,3
12	8,6	9,8	4,1	10,1	1	8,6	10,8	7,8	9,1
13	6,5	8,5	7,3	0	0	2,8	0	2,2	1,6
14	9,6	5	10,6	8,7	9	5,6	8,6	9,8	8,3
15	1,3	8,3	7,2	0	0	2,8	8,1	7,1	4
16	10,7	2,4	9,2	8,6	9,8	6,9	6,4	7,8	3,4
17	9,4	9,8	6,5	6,1	6,3	3,6	9,7	9,5	7,4
18	6,4	10,1	5,6	1,9	8,7	3,6	0	8,5	10
19	4,6	4,2	1,1	4,7	5,4	5,1	8,6	5,8	9,1
20	10,3	0	7,9	4	5,3	8,8	1,5	8,5	2,3

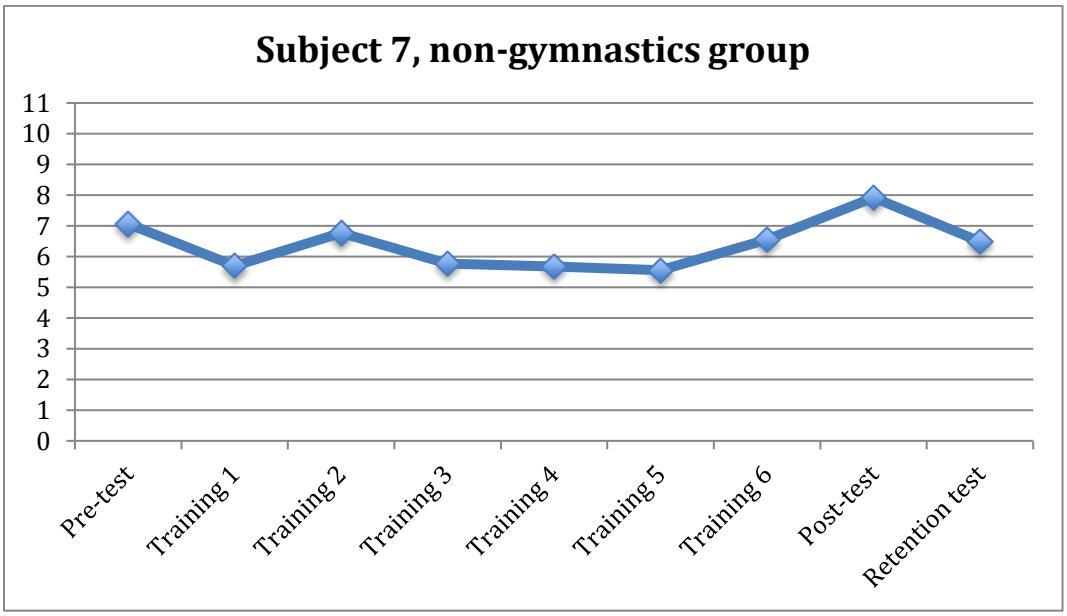

Figure A2.2. Learning process displayed by the average point of impact for subject 7 at all sessions, in the non-gymnastics group.

Table A2.3. All point of impact for all sessions for subject 8, in the non-gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	6,4	5,2	7,3	7,5	5,2	7	7,7	7,1	7,9
2	3	7	7,3	4,7	0	8,5	6,5	6,4	8,1
3	4,1	7,5	9,8	4,2	4,2	7	8,8	6,4	8,6
4	5	9,1	1,5	2,7	7,2	4,6	8,6	6,7	7,2
5	5,9	8,4	9,6	0	8,2	9,9	6,6	5,8	9,5
6	8,8	5,7	4,9	7,1	5,6	5,3	2,1	9,5	9,7
7	10,1	8,8	8,5	6,6	6,9	6,4	4,9	7	10
8	8,7	0	2	5,3	4,7	0	8,2	7,4	9,7
9	2,7	6,4	1,6	9,5	7,8	6,6	3	4	6,3
10	2,9	6,1	7,2	9,8	9,7	7,1	5,7	8,3	8,2
11	7,1	6,4	2,4	9	2,8	6,2	5,4	5,4	7,2
12	8,8	5,2	3	4,1	6,4	8,1	2,5	10	7,1
13	5,4	6,5	6,8	4,4	10	5,6	5,8	10,2	10,6
14	6,2	7,4	0	7,9	8,4	1,4	3,2	9	10,6
15	2,1	3,4	4,4	4,1	7,1	8,7	9,2	9,2	8,4
16	3,3	5,3	10,5	8	7,6	3,2	6,7	3	7,3
17	7,6	8,2	0	3,7	2,7	7,9	7,1	8	9,1
18	2,7	8,2	6,5	0	9,3	3,7	7,6	9,7	8,9
19	5,4	10	8,1	4,1	7,3	7,6	9,8	6,7	7,8
20	2,1	6,5	5,3	6,7	7,7	3,5	8,6	4,8	10,7

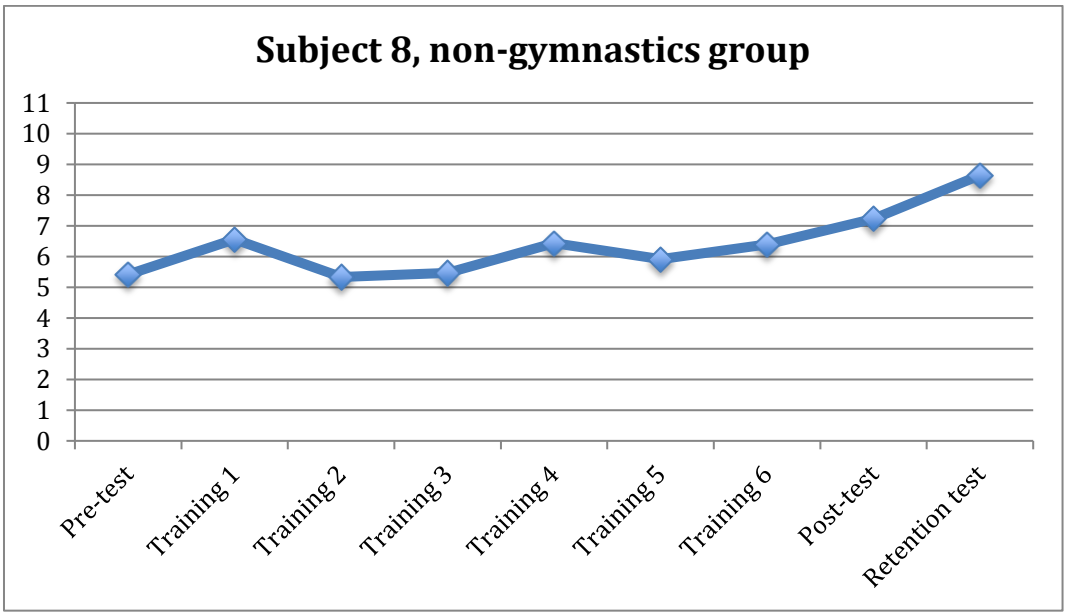

Figure A2.3. Learning process displayed by the average point of impact for subject 8 at all sessions, in the non-gymnastics group.

Table A2.4. All point of impact for all sessions for subject 9, in the non-gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	9,6	6,2	5,1	6,1	2,5	9,6	10,1	3,5	9,9
2	3,5	7,2	7,6	0	5,7	5,3	6	0	9,6
3	8,4	5,9	7,5	6,2	7,6	9,5	7,6	8,4	5,9
4	10,3	9,6	6,4	8,7	3	3,2	8,5	7,2	9,9
5	1	7,3	4,7	7	8,5	6,1	4	0	7,2
6	9,4	8,8	10,1	6	7,7	4,7	9,6	5,9	9,7
7	7	7,3	8,3	7,7	9,8	2,5	5,4	1,9	8,8
8	7,9	8,8	10	7	9,1	6	10,3	3,4	7,5
9	3,2	0	3,8	6,8	10,3	3,9	4,7	7,8	9,2
10	8,5	7,6	9,1	3,9	7,2	7,9	7,9	7,8	9,9
11	9,2	10,2	4,2	7,3	7,4	5,1	1,4	4,8	10,8
12	6,9	4,9	2,4	4,6	1,8	4,7	7	2,9	8,1
13	0	7,5	5,4	8,5	8,8	9,6	9,8	6,8	3,6
14	9,4	9,5	6,4	6,7	7,2	5,9	6,1	8,3	7,2
15	6,7	8,4	3,1	9,9	7,6	6,6	8,9	9,5	10,1
16	6,3	9,4	2,8	9,1	3,4	3,2	8,8	0	8,2
17	6,9	1,3	7,6	6,6	4,3	6,7	10,3	5,7	8
18	8,2	2,3	4,9	0	4	4,8	7,7	4,3	9,7
19	8,6	6,7	6,1	8,1	4,7	9,2	6,1	6,1	8,6
20	5,7	5,4	0	3,5	6,2	7,6	7,1	0	10

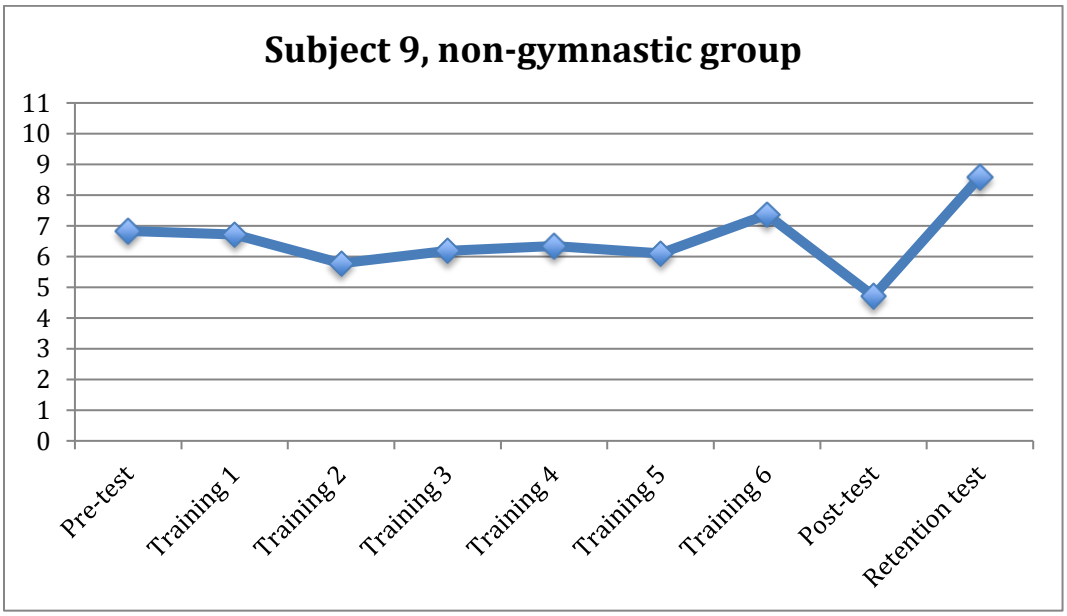

Figure A2.4. Learning process displayed by the average point of impact for subject 9 at all sessions, in the non-gymnastics group.

Table A2.5. All point of impact for all sessions for subject 10, in the non-gymnastics group.

Shot number	Pre-test	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Post-test	Retention test
1	0	0	6,6	7,6	3,2	2,3	3,4	5	9,8
2	1,9	7,5	8,1	9,6	3,8	0	4,4	1,8	8,8
3	8,4	2,9	8,9	9,8	9,2	3	6,7	6,9	9,5
4	5,7	8,7	6,7	8,5	3,8	6,7	10,1	5,5	2,9
5	3,4	9,9	7	8,4	10,4	3,5	1,3	9,1	8,8
6	0	8,3	2,7	8,6	8	4,9	6,2	5,5	10,1
7	0	9,8	8,7	8,3	10,2	4,7	6,6	1,4	9,7
8	1,5	1,6	4,7	7,5	9,5	0	6,2	1,1	9,5
9	2,9	6,4	8,1	8,5	9,7	6,9	7,8	9,7	6,3
10	0	1	9	6,6	10	6,3	8,3	9,8	4
11	3,8	6,2	7,6	10,5	10,2	10,8	7,6	9,3	7,6
12	1,5	6,4	10,1	7,4	8,7	1,2	9	10	9,6
13	6,1	0	9,8	8,6	6,1	0	3,5	7,9	8,1
14	2	8,6	10	10,2	3,8	1	9,3	8	8,1
15	0	2,7	9	6,1	10,1	6,9	6,1	9,7	8,1
16	1,9	10,2	3,6	10,9	8,3	8,5	9	8,8	8,9
17	0	8,1	7,5	10,1	9,6	0	7,3	6,1	7,7
18	0	7	10,3	4,7	8,7	2,9	9	6,9	7,6
19	0	10	10,3	4,5	9,1	6,8	8,9	7,9	6,3
20	7,5	7,6	8,6	5,4	9,1	3,3	10,5	8,6	10,2

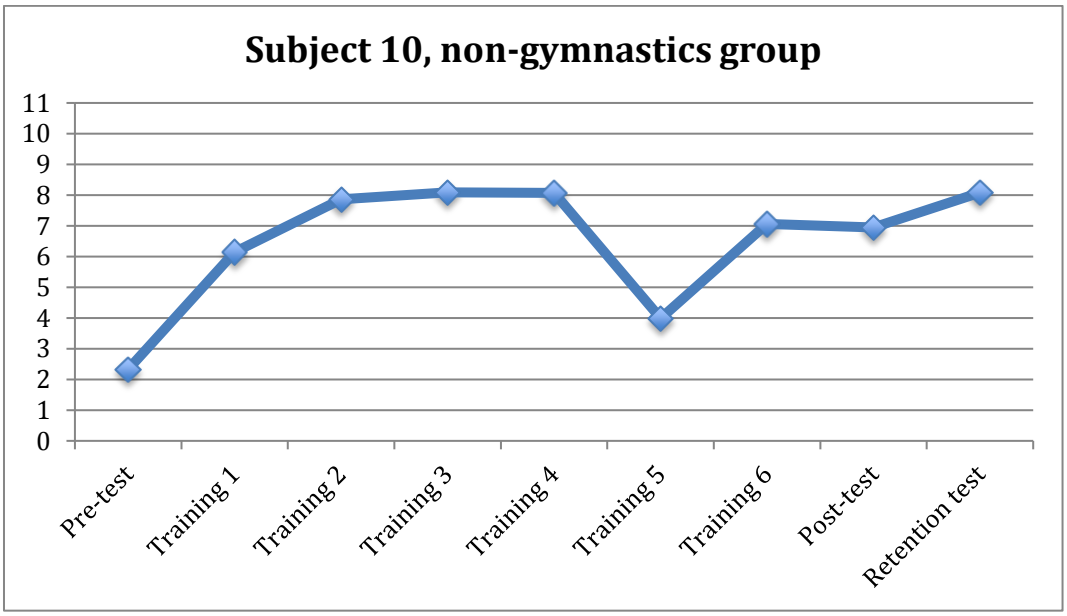

Figure A5.5. Learning process displayed by the average point of impact for subject 10 at all sessions, in the non-gymnastics group.