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Czas reakcji i czas ruchu, typy odpowiedzi czuciowo--ruchowych, tempo szermiercze / Reaction time and movement time, types of sensorimotor responses and fencing tempo

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The tactical requirements of fencing combat involving dozens of unexpected situations force fencers to master a great number of movement patters. These movement patterns appear in the form of motor habits which become highly automated, even in complex technical actions, after a long-term training. The crucial timing components of individual sensorimotor responses in combat sports are reaction time and movement time. Making quick and right decisions in fencing depends on a combination of such factors as concentration, selective perception of stimuli and the choice of sensorimotor responses in rapidly changing combat situations.

Timing in fencing is also very significant. Thanks to one's ability to feel the so-called fencing tempo a fencer can take his or her opponent by surprise at the most convenient moment. Through adjusting the distance to the opponent and the positioning of the fencing weapon, fencers try to achieve tactical superiority by invoking their opponents' uncontrolled reactions. The knowledge of timing and formation of proper movement patterns as well as the fencing tempo is very significant in the training process and affects fencers' individual combat styles. It is also ontogenetic as in their sports careers fencers develop different types of reactions and shift the emphasis from strictly movement factors to neuro-psychical factors. A thorough analysis of these processes requires application of research methods from movement control theory as well as research results achieved by top fencing coaches.

Reaction time and movement time

The measurement of timing of sensorimotor responses is, next to assessment of movement precision, another fundamental way to evaluate the quality of motor behavior. It is assumed that an athlete who processes information faster is more efficient in different types of motor behavior [Schmidt 1991]. Reaction time and movement time are the basic correlated measurements in [ms] of information processing. Reaction time (RT) is the interval between the occurrence of an unexpected stimulus and the beginning of a response. The development of fencing technique is, in particular, subject to accurate and quick execution of technical and tactical tasks. One of the best specialist fencing speed tests is "pinning down" a falling fencing glove. It is a hybrid test as it requires from fencers a combination of such skills as high speed of response, movement precision and spatial anticipation of the dropping spot of the glove.

During competition combat sports athletes and team players deal all the time with different types of reactions which are hard to measure, as sports regulations do not allow placing the measuring equipment on the athlete's body. The measurement tests can be carried out during training or in laboratory conditions. Thanks to the use of EMG in laboratory tests it is possible to record the reaction time (RT), i.e. the latency phase, and movement time (MT) of sensorimotor responses.

A thorough analysis of reaction time and movement time can yield important information about their variability depending on the type of movement. Latash [1993] noted that fast and dynamic sequential movements should be subject to peripheral rather than central interpretation. It can be thus assumed that fast movements lack the full effect of feedback. In performing difficult, complex movements the time of information processing is crucial, especially at the stage of response choice. Generally, all studies of RT have been carried out for two important reasons: firstly, RT is a component of a real motor task to be performed by the subjects; secondly, it is a measure of mental processes (stimuli processing, decision making and response programming). The obtained study results make it possible to understand the nature of information processes leading to the adoption of appropriate patterns of motor behavior.

Movement time (MT) is defined as the interval between the commencement of a response (the end of reaction time) to the completion of a particular movement, e.g. pressing a panel button during a lab test. In combat sports, the movements are very short, e.g. a sabreur's cut on the opponent's head or a karate hit, lasting from about 30 to 50 ms. In saber fencing a cut following a single feint may be 100–120 ms long. Apart from relatively simple actions, fencers or boxers use complex movements in combat, e.g. a series of hits, feinted counters or parries, which can last from a few hundred milliseconds to a few seconds. In laboratory EMG tests consisting of pressing panel buttons with one's hand the MT may be from 40–50 ms to 150–180 ms; in anticipatory tests it can be reduced to a few dozen ms.

Highly automated movements (boxing and karate hits, fencing cuts and thrusts) are based on a closed-loop control system of M2 type [Schmidt, Wriesberg 2004]. Thus acquired motor habits can be controlled with some degree of consciousness at the spinal cord level. However, in coordination with motor programs learnt earlier the latency phase for M2 responses amounts from 50 to 80 ms.

A more complex movement of the M3 type based on complete feedback, e.g. a series of karate hits or feinted attack in fencing lasts from 200 to 350ms. This type of response features a longer latency phase (80–120 ms) than an M2 response. It is susceptible to variations and greatly affected by the learning process. Due to multiple repetitions M3 responses can be transformed into regular, well-learnt and highly automated motor habits.

Practical examples of such reactions include a number of daily motor responses following the "wine glass" effect [Johansson, Westling 1984], i.e. the grip force exerted during lifting and holding an object slightly exceeds the minimum amplitude required to prevent the object from slipping. The mechanism of reaction in this case uses the skin receptors which after receiving the vibrations from the object evoke a signal to grasp it firmer. This is an unconscious and fully automated response resulting from earlier experience. The source of response in this case are the tactile receptors. An analogous process can be noted in fencing: in reaction to the opponent's au fer attack, a sabreur or epeeist instinctively counters the pressure of the blade and while attempting to parry performs a pre-emptive hit.

It should be noted that some fencers and fencing theorists underestimate MT, emphasizing RT instead as a component which decides about the quality of a sensorimotor response. Such fencers overemphasize the effect of genetic predispositions on the movement time. The movement time also determines the type of feedback-induced corrections and significantly affects the latency phase, i.e. RT, mainly at the stage of sensorimotor response programming. The knowledge of the above relations in combination with the fencers' psychological types as well as the correlation between reaction time and movement time are crucial in fencing training.

Individual characteristics point to significant differences between fencers in terms of the speed of their responses (latency phase) and their movement. The Olympic and world saber fencing champions have included individuals featuring instant responses, fast movements and relatively simple actions based on simple reactions, e.g. Wojciech Zabłocki, Felix Becker Jean Francois Lamour, Aldo Montano. Fencing champions such as Pal Gerevich, Imre Gedovari, Damien Touya display excellent anticipatory capabilities without any extraordinary speed of movements. On the other hand, fencers like Jerzy Pawłowski, Grigorij Kirienko, Janusz Olech, or Stanisław Pozdniakow have featured all the above characteristics and also used a number of complex actions with great anticipatory capabilities. Fencers with low reaction times, i.e. slowly processing information in time, are difficult to find at the championship level. The fencing coaches with a thorough knowledge of the timing of information processes are able to adjust the training structure to the fencers' individual predispositions, in particular, in terms of development of their technical and tactical skills.

This timing of information processing in fencing is strictly related to the concept of sensorimotor responses and development of simple and complex fencing motor habits. It has been known that fencers with capabilities of instant improvisation rely on recreation of simple movement patterns, while more versatile fencers acquire the motor habits through complex, interlinked motor programs. The discussed differences in the ways of learning and developing technical elements in fencing should be considered in application of training methods related to fencers' specific capacities to master and execute individual movement patterns in competition. The best forms of training of timing of fencing movement patterns include individual tutorials with the coach and exercising in pairs aimed at the mastery of tactical set pieces of a fencing bout.

Classification of sensorimotor responses

Different types of reactions correspond with decision-making processes, which have been a subject of extensive research for over one hundred years. The term "reaction time" was coined by Austrian physiologist Sigmund Exner [1873]. The present-day separation of reaction time from movement time was suggested by E. Bernstein [1967]. The classification of different types of reactions was then developed by Luce [1986] and Sage [1984]. Three basic types of sensorimotor responses can be distinguished:

- simple reaction – a response to a single unanticipated stimulus;
- choice reaction – a response to stimuli using acquired movement patterns;
- differential reaction – a type of choice reaction consisting in identifying similar stimuli, responding to proper signals and ignoring interfering ones.

One of the most interesting and scientifically justified concepts of different types of reactions in sport and motor function was developed by Czajkowski [2001], who expanded the classic three-fold division of sensorimotor responses to seven. Apart from simple reaction, choice reaction and differential reaction Czajkowski distinguishes reaction to an initial signal of movement, reaction to an object in motion, switching reaction and intuitive reaction. This extended classification has proven very useful in fencing training.

Simple reaction time. A great number of motor habits in sport are present in the form of sensorimotor responses. A simple reaction is a response to a stimuli with a well-mastered movement, e.g. a sprinter's or swimmer's starting reaction, or a boxer's straight punch at the coach's signal. A simple reaction in fencing can be a fencer's response to a known stimulus (coach's movement) with a simple thrust or cut. What the fencer does not know is the time of the coach's signal. This model of simple reaction is the basis for one of the most commonly used training methods in combat sports, i.e. exercising a chosen action in response to an expected trainer's movement [Borysiuk 2000]. Accordingly, simple reaction time can be divided into three stages:

1. Preparatory – from the signal of attention to the occurrence of the stimulus;
2. Latency – from the occurrence of the stimulus to the commencement of a movement;
3. Executive (final) – from the beginning to the completion of the movement.

Choice reaction time. A choice reaction time is a response to an unknown stimulus with a different action every time. In other words, we know all the answers but we do not know the question. Choice reactions involve a greater deal of information an athlete must process in the latency stage of his or her reaction: stimulus identification, response choice and response programming.

In their lab tests on choice reactions Rosenbaum [1989] and Keele [1986] confirmed the well-known Hick's law that the reaction time was extended with the number of provided stimuli in a linear way up to 600 ms. Above the limit of 600 ms the increase in the number of stimuli affects the extension of reaction time insignificantly. A choice reaction differs from a simple reaction in its prolonged latency stage consisting of five components:

a. sensory part of the reaction latency stage,
b. isolation of the stimulus from other concurrent stimuli,
c. recognition of the stimulus and its proper classification,
d. differentiation of the stimulus and the choice of response
e. motor part of the reaction latency stage.

The significance of choice reaction in combat sports derives from the fact that these sports always involve two contestants. A karate fighter, boxer or fencer in possession of valuable information about the opponent is not able to anticipate fully all possible moves of the latter. Fencers must recognize their opponents' action and choose an appropriate reaction within a second snap – an attack, counter or block [Richman, Rehberg 1986]. The changing situations during a bout make fencers constantly adjust their previously learnt motor programs.

Differential reaction time (reaction of recognition). A differential reaction consists of identification of correct signals from among many similar stimuli. This reaction type is very common in team games and combat sports and is the foundation for technical and tactical actions [Kurian, Catering, Kulhavy 1993]. A feinted throw in basketball followed by a pass to a team mate in a better position on the pitch, or feinted cut on the head in saber fencing followed by a thrust are actions which high-level competitors must recognize immediately. Another type of differential reaction is a motor response in which a competitor reacts to some stimuli and refrains from reacting to others. This type of reaction is important in combat sports tactics as competitors try to conceal their intentions and evoke their opponents' reactions which can be then effectively countered.

Reaction to an initial signal of movement. This type of reaction is very common in combat sports and team games. It features a longer latency stage than movement stage. Examples of such reactions include goalkeepers' responses in soccer, hockey or team handball. The speed of the ball or the puck moving towards the goal is much higher than the goalkeeper's capacity of information perception and processing [Shestakov, Averkin, Molchanov 2002]. The goalkeeper's successful reaction is possible if it commences earlier following his or her observations of the initial signals of movement. A goalkeeper responds correctly to a "sign" of movement. A study by Salczenko [1980] showed that even the most experienced fencers commenced their responses to the opponent's lunge for about 40 ms earlier before the opponent began his or her attack. The time analysis of these reactions was possible thanks to the use of an oscilloscope and surface EMG. It turned out that, despite the commencement of the attack by the fencing hand, in a classic lunge the highest bioelectric tension in muscle is generated in the fencer's rear leg 100–120 ms earlier. It is observation of the opponent's rear leg which triggers the fencer's earlier responses. The obtained results were confirmed in the second part of the study, during which the attacker's legs were covered. The defender who could not identify the initial signals of a movement reacted in a regular way, with his or her responses belated for over 100 ms. The effectiveness of reaction to the initial signals was also found to be statistically correlated with the fencer's sport experience and rank. Champion fencers responded significantly faster and their success was determined by their ability to effectively process the initial signals of the opponent's actions.

Reaction to an object in motion. According to Evangelista [2000] the sensorimotor responses to moving objects are objective indices of athletes' abilities and level of training and condition in combat sports. In this type of reactions a competitor perceives a moving object (ball, opponent's blade, etc.) instantly (and subconsciously) anticipates its course and the speed and reacts in time by catching or hitting the ball or parrying the opponent's thrust. The reactions to an object in motion, when the distance between the competitors is rather short, are facilitated by the observation of the initial signals of movement, e.g. sweeping arm movement, swinging the body, and not the movement of the fencing hand or weapon. These reactions are effective due to the interaction of spatial anticipation and proper timing of particular movement patterns (fencing techniques).

Switching reaction (changing intentions in the course of action). A switching reaction occurs when a competitor performs an intended action but due to the opponent's unexpected movement switches the course of his or her action and pursues another movement pattern [Tyshler, Tyshler 1995]. Situations involving switching reactions dominate in combat sports [Dryukov, Pavlenko, Shadrina 2003]. For instance, a sabreur who commences a feinted attack notices the opponent's intention to counterattack with a thrust, parries the opponent's blade and performs a cut on the head. The effectiveness of such responses depends on the reaction time and movement time, but also on movement precision. There have been cases of outstanding sabreurs, whose movement stage of the response was relatively slow but compensated for with the response speed. On the other hand, faster anticipation of the opponent's intentions gives the fencer's the comfort of longer information processing and responding at the last moment to prevent the opponent's effective defense. This factor along with movement precision plays a crucial role in all combat sports, and is inherently connected with reaction time. The speed of reaction is known to be negatively correlated with movement precision, thus switching exercises in actions with unpredictable outcomes should be developed as part of fencing training besides free exercises following instant improvisation.

Intuitive reaction. A number of decisions in sport combat are not made after a thorough analysis of a given situation but on the basis of the so-called statistical intuition. If a fencer faces certain situations hundreds or thousands of times, he or she can most likely predict the opponent's movement and action using long time memory and his own experience [Fig. 1]. Experience plays a significant role in making decisions in sport combat.

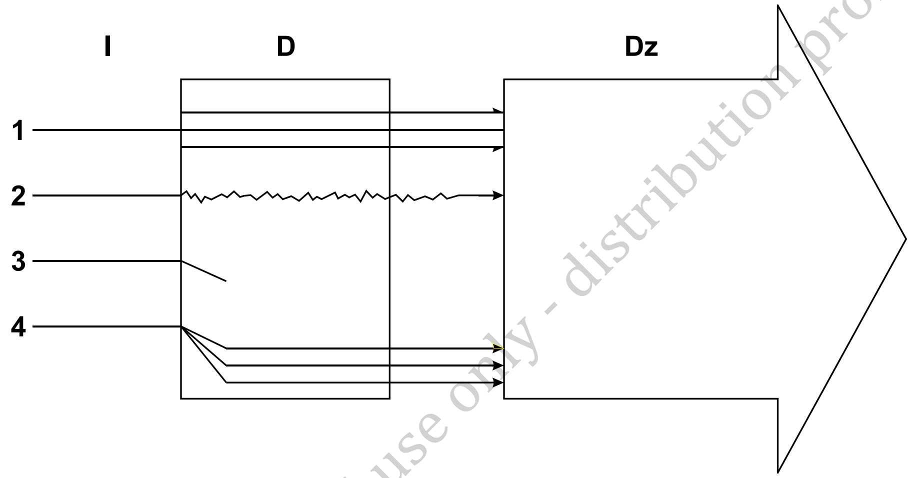

Fig. 1. Significance of experience in sport [Czajkowski 2005]. I – information, D – experience, Dz –action through experience; 1 – information enhanced with experience, 2 – information transformed by experience; 3 – information expired through experience as incorrect or redundant, 4 – information creating the need for further information /
Ryc. 1. Znaczenie układu doświadczeń w sporcie [Czajkowski 2005]. W ramach schematu struktury poziome tworzą; I – informacje, D – układ doświadczeń, Dz – działanie kształtowane pod wpływem informacji. W strukturze pionowej znajdują się: 1 – informacje wzbogacone przez doświadczenie, 2 – informacje przekształcone przez doświadczenie, 3 – informacje wygaszone jako błędne lub niepotrzebne, 4 – informacje wzbudzające potrzebę nowych informacji.

In real sport combat intuitive reactions are intermingled with reactions to initial signals of movement. The latter and anticipation can also enhance the intuitive reactions. Planning fencing training on the basis of intuitive reactions is, however, very difficult. Fencing exercises aimed at training of this type of reactions were developed by L. Borsodi [Czajkowski 1970]. A fencer is to execute a planned action intuitively anticipating the coach's intentions. To complete such exercises both the coach and the fencer must play fair and not bluff or hide their real intentions. In this way, parts of a fencing bout are enacted in the coach's and fencer's mind before the actual enactment during exercise. Such fencing exercises are of great methodological and diagnostic value. As it has been observed in numerous training sessions a high level of sport efficiency is correlated with a good sports condition, thus fencers at the championship level achieve the best sports results.

The above classification of sensorimotor responses is a result of experts' competences and wide coaching experience. It has been accepted by the coaching community and as a concept can be very useful in creative and systematic fencing training. In particular, the reactions to initial signals of a movement, reactions to an object in motion and switching reactions correspond to the scientific concept of anticipatory responses developed and analyzed by Richard Schmidt in his publications.

Anticipatory responses

Anticipatory responses are strictly connected with the stage of response choice in information processing. Thanks to anticipatory mechanisms during this stage the reduction of the standard time of information processing becomes possible. According to Rosenbaum and Patashnik [1980] a significant reduction in reaction time (RT) is due to a bypass of the stage of response choice followed by the immediate commencement of the stage of response programming.

In laboratory tests of different types of reactions unexpected stimuli are used in order to avoid the effect of anticipation. This includes also timing tests using randomly emitted signals. The simple and choice reactions are precisely responses to unexpected (unanticipated) stimuli.

Different sport studies [Ward, Williams, Bennett 2002; Borysiuk 2007; Cynarski 2007] using EMG and video footage show that athletes at the championship level with a long sport experience greatly benefit from the use of anticipatory responses. They apply anticipatory strategies consisting of concentration on the initial signals, i.e. movements frequently unnoticed by novice athletes, and are able to prepare adequate responses in advance. The process of anticipation can be spatial and temporal. The former aims at prediction of what would actually happen; in the latter the time of happening is anticipated. In real sport combat the separation of the two types of anticipation is often impossible. A karate fighter who recognizes a series of the opponent's kicks anticipates the precise timing of the opponent's attack and prepares a block leading to a counter-attack. A fencer who identifies the opponent's feinted lunge anticipates the moment of the thrust completion, extends the distance by stepping backwards, prepares a block and counters with a thrust at an unguarded valid target area. In the case of overlapping of spatial and temporal anticipation the latter becomes dominant and decides about the effectiveness of the anticipatory response. These observations have been confirmed by empirical studies and experts' opinions in such sports as karate or fencing.

When a contestant is able to use a wide spectrum of technical skills in attack, it is very difficult for his or her opponent to identify correctly and explicitly the type of attacking technique, but he or she can – to a great extent – anticipate the timing of the attack completion. The essence of combat sports is a rivalry of anticipated actions and exchange of anticipatory responses between the contestants. In practice, a great deal of such anticipatory actions are countered by the opponent, which forces the attacker to adjust their original plans. Incorrect anticipatory responses may slow down a contestant's reactions. For instance, a boxer expecting a right hook from his opponent who notices a change in his opponent's intentions adjusts his guard against a left hook and block the unexpected attack. Posner [1978] developed the concept of cost-benefit analysis of erroneous anticipatory responses. He showed that correcting missed anticipatory responses extends the time of motor reaction from 40 to 83 ms. Providing the gains from anticipatory responses amount from 40 to 100 ms, it can be concluded that the time necessary for correction of missed responses is relatively short, comparable with the results of anticipatory responses in general. It can be stated that, depending on the type of sport, the use of anticipatory responses and their subsequent adjustment can be very effective in the final analysis. A conservative combat style not justified by tactics and waiting for the opponent's movements often results in losing the initiative. In combat sports featuring a great speed of action three strategies are used. On the one hand, contestants can follow their opponents' initial signals using anticipatory responses. In anticipating of the opponent's movements a contestant risks a belated response in situations in which the adjustment of sensorimotor responses is necessary. On the other hand, it is worth waiting for the opponent's completion of a movement, avoiding feints and respond to real threats. In practice, experienced contestants reduce the negative aspects of these two tactics and use a more versatile combat style combining the two, depending on immediate tactical goals. The above consideration is presented in a diagram illustrating the decision-making process in sport (Fig. 2). It shows that the source of correct anticipatory responses is comprehensive training practice with spatial anticipation as the dominant factor of effectiveness. According to the researchers temporal anticipation is auxiliary, i.e. if a contestant interprets the opponent's action in a wrong way, an appropriate timing will not adjust the incorrect response.

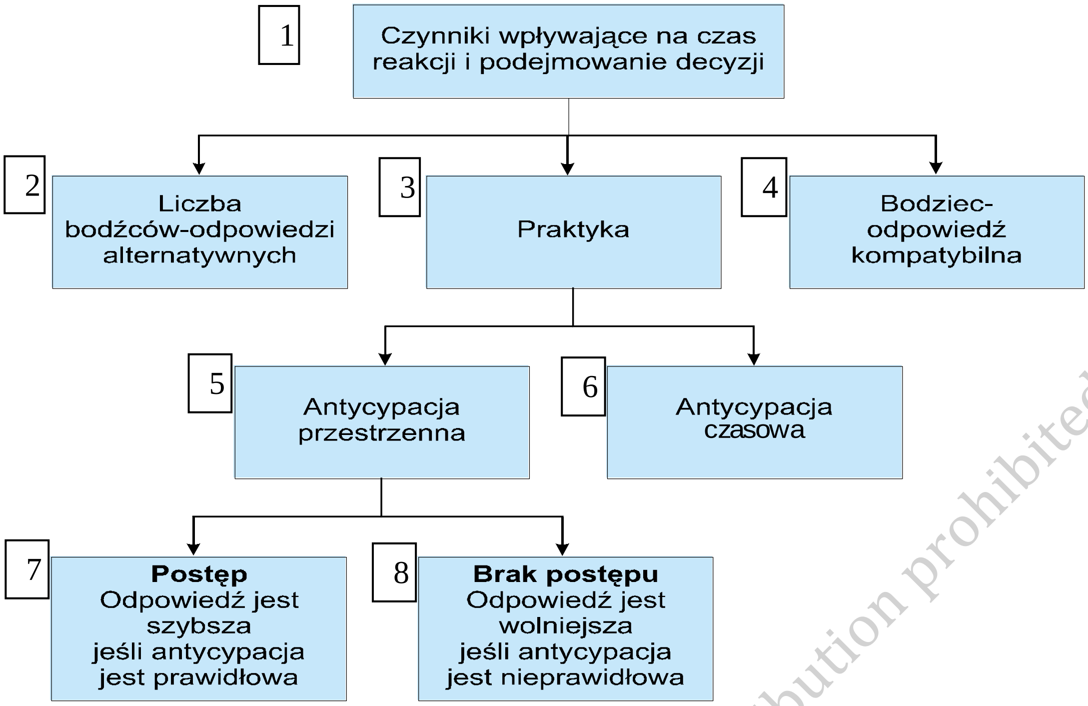

Fig. 2. The influence of the type of anticipation on reaction time [Schmidt, Wriesberg 2004] /
Ryc. 2. Wpływ różnych rodzajów antycypacji na czas reakcji [Schmidt, Wriesberg 2004]

1. Czynniki wpływajace na czas reakcji i podejmowanie decyzji – Factors affecting reaction time and the decision-making process
2. Liczba bodźców – odpowiedzi alternatywnych – The number of stimuli – alternative responses
3. Praktyka – Training experience
4. Bodziec – odpowiedź kompatybylna – Stimulus – compatible response
5. Antycypacja przestrzenna – Spatial anticipation
6. Antycypacja czasowa – Temporal anticipation
7. Postęp. Odpowiedź jest szybsza, jesli antycypacja jest prawidłowa – Success. The response is faster if anticipation is correct
8. Brak postępu. Odpowiedź jest wolniejsza, jesli antycypacja jest nieprawidłowa – Failure: Response is slower if anticipation is incorrect.

Many studies have also been concerned with movement precision in relation to the duration of motor responses. These studies usually encompass an assessment of the variability of movement time (MT) and precision aiming at an electronic target. The results of these studies show that movement precision is inversely correlated with reaction time (RT). This can be explained by the fact that the improvement of aiming effectiveness is a result of the extension of the stage of programming of a complex response. It also shows that MT is a determinant of reaction time (RT). The author's long-term study of 127 fencers at different levels of sports experience [Borysiuk 2006] revealed that fencers featured extraordinary concurrent movement speed and precision as compared with athletes representing other sports. Studies using the Vienna Test System showed that during visual-motor coordination, special orientation and movement precision tests their speed did not affect their precision in a negative way. The fencers displayed much better movement speed and precision parameters than badminton players, gymnasts, soccer players and taekwondo practitioners.

Novice-expert paradigm

Reaction time and movement time are two components of sensorimotor responses, which constitute a valuable source of information about changes during long-term training. The relations between reaction time and movement time are very significant for training, and are best usually examined by way of comparative analysis between novice and advanced fencers. Coaches have extensively pointed out to the growing significance of reaction time, i.e. shortening the decision-making time thanks to longer experience. The question remains how big is the gap between the novice and expert fencers.

A study was carried out on a sample of 22 novice and 16 advanced fencers representing all the three fencing weapons: epee, saber and foil. The research procedures were selected to test three different types of reaction: simple reaction, choice reaction and spatial anticipation reaction (Fig. 3a, 3b, 3c). The study used an EMG system for testing psychomotor responses, differentiation between the latency stage and movement time of complex sensorimotor responses [Borysiuk, Zmarzły 2005].

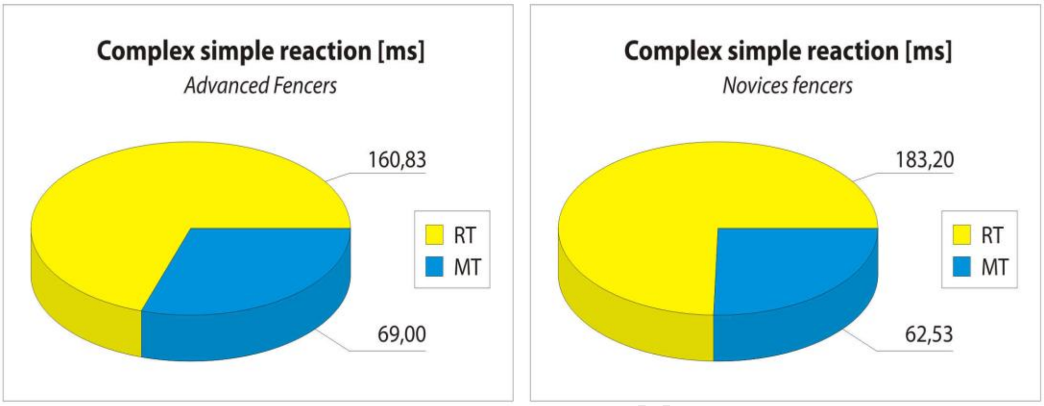

Fig. 3a. Reaction time RT and movement time MT in simple reaction test /
Ryc. 3a. Czas reakcji RT i czas ruchu MT w teście reakcji prostej

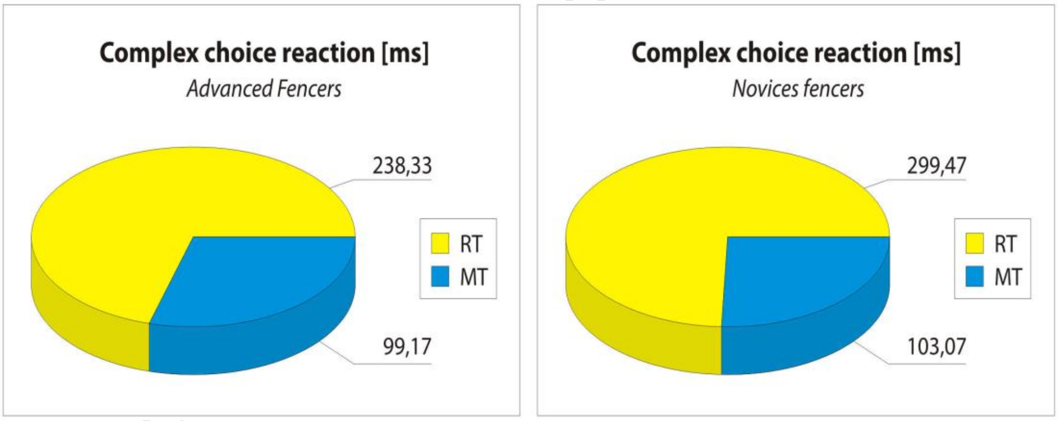

Fig. 3b. Reaction time RT and movement time MT in choice reaction test /
Ryc. 3b. Czas reakcji RT i czas ruchu MT w teście reakcji z wyboru

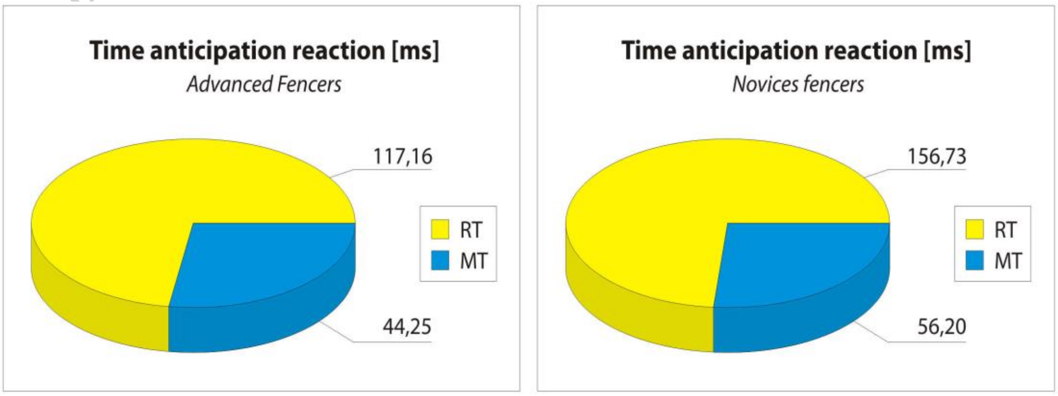

Fig. 3c. Reaction time RT and movement time MT in spatial anticipation reaction test /
Ryc. 3c. Czas reakcji RT i czas ruchu MT w teście reakcji antycypacyjnej

1. The study revealed significant differences between the times of simple reaction and choice reaction to visual stimuli as well as the superiority of experienced fencers over the novice ones. The assessment of RT and MT of information processes in simple reaction and choice reaction tests showed that advanced fencers tend to shorten the time of their sensorimotor response, mostly during the central stage, thus they perceive and make decisions much faster than the novice fencers. This tendency should be seen as a constant process of shortening the latency stage of reaction time inherent in the development of sports championship and as the impact of specialist training on the effectiveness of perception processes in advanced fencers.
2. The effectiveness of anticipatory responses to signals of spatial anticipation was far greater among the advanced fencers who processed the signals at the early stage of signal perception. The system registered premature responses as incorrect.
3. Anticipatory responses based on the identification of the opponent's initial signals of movement are a major feature of champion class competitors in sports with open motor habits as opposed to competitors on an intermediate level. The results of the conducted study point out to a similar distinction between novice and advanced fencers. The effects of anticipatory responses are characteristic of combat sports. They serve as indications that a properly structured perpetual training affects the sensory system and allows for a prompt input into the neuronal representations. Anticipatory information is a pathway for a more speedy and accurate choice of sensorimotor responses. The advanced fencers have a great superiority over the novice fencers in both spatial and temporal anticipation. The obtained lower EMG values also demonstrated that the efficiency and certainty of anticipatory responses were characteristic of the advanced fencers.

The above observations do not explain the entire complexity of the process. The novice-expert research paradigm confirms the reduction in the time of sensorimotor responses, mostly during the latency stage, due to the superiority in training experience of advanced fencers. However, some individual cases show that fencing champions have a tendency to consciously extend the decision-making stage counting on the opponent's unexpected actions in order to gain enough time to correct the response. This tendency was observed in laboratory tests and it shows that a long-term fencing training has an real impact on the timing of movement patterns and makes the RT more flexible. The comparative analysis between advanced and novice fencers showed that the former tended to program their responses longer and then instantly react during the MT stage. This may partially contradict the results obtained above. It might be concluded that this process concerns only the most highly talented fencers, or that fencing champions are so versatile so that they can extend the latency stage depending on a tactical situation.

This observation confirms the important role of the developed open motor habit and inventive ability of fencer [Czajkowski 2001; Cynarski 2006]. This verifies the correctness is also evident in other combat sports.

Fencing tempo

For decades the concept of fencing tempo has been undergoing a number of alterations. The most fundamental understanding of fencing tempo remains the same and is still the essence of competition in fencing. The development of fencing training methods and electronic scoring apparatuses made the fencing intervals much shorter than before in saber, foil but also in epee. In saber fencing the lockout times were reduced to necessitate the separation of the guard phase from the riposte stage and to avoid turning on two lights on the apparatus at the same time, which poses interpretation problems for the referees and unprepared spectators. The lockout time in saber fencing is currently 125 ms. This interval reflects the quality of speed training of present-day sabreurs. Thanks to its length simultaneous hits, which can make a bout boring to the spectators, are avoided. What is stressed by fencing experts is the fact that the mentioned timing is felt better by female sabreurs. This is manifested in girls' bouts with longer fencing times, and more frequent exchanges of parries and counterattacks. In this context the bouts of female sabreurs are better understood and more exciting to the audience. Perhaps, the fencing regulations should account for the sex differences in determining the lockout time, but on the other hand the adjustment of the electronic scoring apparatus in relation to the fencers' sex might lead to a paradox. Research has shown [Borysiuk 2001] that in terms of fencers' psychomotor predispositions sexual dimorphism plays a marginal role in fencing.

The correct interpretation of the concept of fencing tempo in saber and foil is far more complex than in epee. In epee the scoring apparatus can register double-touches, although the touches must be within 40 ms of each other. Hits which are not within this interval are blocked. Unlike sabre and foil, in épée there are no right-of-way rules regarding attacking, i.e. touches are awarded solely on the basis of which fencer makes a touch first. In sabre attacking always takes precedence before defending, unless the counterattacks are faster than the lockout time of 125 ms. In his context belated hits are not considered valid by the referees. In sabre fencing a number of winning actions performed according to the classic sabre bout regulations might not be properly registered by the scoring apparatus. Most frequently two tactical situations can cause this problem. The first is when fencers make technical errors in offensive actions, which then leads to a loss of the fencing tempo – e.g. starting footwork without appropriate offensive action of the fencing hand – and of the right-of-way. Sometimes fencers complete hits despite losing the tempo, but this results in two simultaneous light signals on the apparatus. Such situations are often controversial in terms of refereeing. The other situation occurs when fencers while performing a parry-riposte produce the effect of two lights on the apparatus, which may result in the referee's erroneous decisions. These two situations reveal the significance of fencing tempo in modern competition and the necessity of its precise definition and understanding.

There is no doubt that the fencing tempo is mostly an abstract concept strictly related to saber fencing tactics and depends on the fencers' age. The classic definition of the fencing tempo is the time required to complete a single fencing action and it works as such for novice fencers. This definition also involves the flexibility in understanding of the tempo in terms of a fencer's speed of movement. The fencing tempo can be thus different for advanced and novice fencers, although the lockout time on the scoring apparatus is the same all the time, e.g. 125 ms. The referee's interpretations are essential in such situations and consist of perceiving the moment of surprising the opponent, i.e. "winning" his fencing tempo. In this context the fencing tempo should be trained along with exercises involving elements of surprise.

Final remarks

The above problem is associated with the correct evaluation of technical and tactical of actions, including referee's identification of feints. According to fencing regulations an offensive action is made by extending the sword arm and continuously threatening the valid target of the opponent. Many fencers feint their attacks, however, in order to obtain the right-of-way.

Training and development of the fencing tempo has a motor context and is related to the concept of sensorimotor responses discussed above. It seems that the training of abilities of choice reaction and spatial and temporal anticipation is truly decisive. The basis of good decision-making is the choice of the least expected response by the opponent, i.e. the surprise factor. Secondly, by identifying initial signals of the opponent's intentions a fencer can shorten the time of response choice for about 80–100 ms, i.e. close to the lockout time in sabre.

The psychological dimension of fencing tempo is also important. During a bout fencers often experience shifts of concentration owing to fatigue and emotions. Taking advantage of the opponent's moment of low concentration is a surprise factor. It requires careful tactics and patience and great skill to use a situational advantage resulting from imposing one's own style of combat on the opponent. On the other hand, difficult situations and experiencing of failure require stimulation, inhibition and maintenance of the psychological function in order to be ready to overcome temporary failures.

A fencer's footwork plays a very significant (but often underestimated) part in development of the sense of fencing tempo. The essence of surprise is to maintain a proper distance from the opponent to be able to perform an unexpected attack and, at the same time, avoid being hit. Effective footwork is based on constant maneuverability, mobility as well as changes of the pace and direction. It is important to use the widest possible spectrum of footwork techniques to pose a constant threat to the opponent. The key methodological activity in tempo training is imposing one's own pace of movement. It creates numerous possibilities of establishing one's superiority and taking the adversary by surprise. The highest level of footwork quality is featured by those fencers who can throw their opponents off balance and decide themselves about the choice of the time of attack. In fencing the most effective is footwork training carried out by the fencing coach using mirrors for correction of technical errors.

Modern saber fencing is extremely dynamic. The average time necessary to complete a single fencing action is merely a few seconds. Practically, sabreurs do not have much time for maneuvering on the piste thus the margin for errors and their correction is very small. Sabreurs' decisions must be quick and firm. The fencing referees have been recently allowed to record fencing actions and play them back in slow motion. If in doubt a referee can check the video footage before making his or her decision. Such new developments have been aimed at the maximum reduction of referees' errors and enhancement of correct assessment of even the most dubious fencing actions.

Many components of the saber fencing tempo, surprise and the sense of timing should be perfectly trained and automated. Fencers who execute tactical tasks and get to know the opponent's favorite movements do not have to analyze every fencing situation. The effectiveness of some of their actions can be based on anticipation and earlier visualization of a given situation, which would automatically trigger a given motor program.

Modern science and technology can be very useful in fencing tempo training, e.g. fencers can train and develop their sense of timing with the aid of simulators emitting programmed signals corresponding to the intervals of the fencing tempo. Thanks to such devices fencers can develop their motor memory and precisely recreate the timing of movement patterns. New technologies in fencing training will never replace the fencing coach but they could be useful supplements to individual fencing classes and training bouts.

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Słowa kluczowe: czas reakcji z wyboru, szermierka, timing, wzorce ruchowe

Streszczenie

Bogactwo wymogów taktycznych walki szermierczej, składającej się z dziesiątków niespodziewanych sytuacji, nakłada na zawodników konieczność opanowania wielu wzorców ruchowych. Występują one w formie otwartych nawyków ruchowych, które po długotrwałym treningu osiągają wysoki poziom zautomatyzowania nawet w dość złożonych działaniach technicznych. Kluczową rolę, swoistych ram czasowych poszczególnych składowych odpowiedzi czuciowo-ruchowych, pełni czas reakcji i czas ruchu. Podejmowanie szybkich i właściwych decyzji zależy od koincydencji takich czynników jak: koncentracja uwagi, wybiórcze postrzeganie bodźców, wybór odpowiedzi czuciowo-ruchowych w zależności od zmienności akcji i sytuacji taktycznej walki szermierczej.

Specyfiką szermierki jest znaczenie timingu rozumianego jako czucie tempa, czyli zdolność zaskoczenia przeciwnika w najbardziej dogodnym momencie. Zawodnicy podejmując własne działania poprzez odpowiednie manewrowanie dystansem i położeniami broni (floretu, szabli, szpady), by uzyskać przewagę taktyczną, dążą do wymuszenia niekontrolowanych reakcji swoich oponentów.

Praktyczny, trenerski aspekt głębokiej znajomości procesów prowadzących do formowania właściwych struktur czasowych wzorców ruchowych i tempa szermierczego ma znaczenie indywidualne i wpływa na styl walki poszczególnych zawodników. Posiada również kontekst ontogenetyczny, bowiem w trakcie rozwoju kariery sportowej szermierze doskonaląc różne odmiany reakcji przesuwają akcenty z uwarunkowań *stricte* motorycznych na czynniki neuro-psychiczne. Pogłębiona analiza tych zjawisk wymaga oparcia się o metody badawcze wyniesione z teorii sterowania i kontroli motoryczności skonfrontowane z badaniami eksperckimi czołowych trenerów szermierki.