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Information Processes, Stimulation and Perceptual Training in Fencing

by

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Learning and development of motor skills and techniques in fencing and other sports with open motor habits are based on perceptual processes involving the senses of vision, touch, and hearing. In fencing, the same stimuli can yield defensive or offensive actions, which are strictly related to the tactics and strategy. Different types of stimulation determine reaction time, movement time, and muscle bioelectric tension (EMG) in fencing. From the training process, controlling the significance of dominant stimuli should be taken into account. The results of presented studies of advanced and novice fencers show that the time of reaction to tactile stimulation is similar or slightly shorter than to acoustic stimuli followed by visual stimuli. The advanced fencers were faster than the novice fencers in all the studied parameters. The EMG signal was significantly lower in case of advanced fencers in all three types of stimulation. It can be a proof that the psycho-motor superiority of elite fencers results in a reduction of the bioelectrical tension of muscles involved in performing the motor tasks. Perceptual skills enable athletes to respond to important signals in sport competition and ignore disrupting ones which lower the effectiveness of sports combat. Time pressure during sports competition makes it necessary to reduce as much as possible the decision-making time and the time of sensorimotor responses in the motor phase. The study results show that experienced athletes make decisions much faster than their novice colleagues. It conforms to the main strategy of perceptual training, (i.e., gaining maximum benefits at the lowest expense). Speed of decision-making is strictly associated with the stimuli detection effectiveness and re-creation of acquired motor patterns.
Key words: *choice reaction, movement speed, tactile stimulus, perception, fencing*

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Background

Traditionally, one of the first actions learned by trainee fencers has been an attack on the opponent's torso in thrusting weapons (foil, epee) or cut on the opponent's head in cutting-thrusting weapons (saber, broadsword, carabella). In modern Olympic fencing, both actions commence from the contact of the fencer's and the coach's blades. The learning of this characteristic fencing technique confirms the significance of tactile stimuli in all fencing weapons. It has given rise to the concept of "feeling the blade", specific to attack au fer or prise au fer. A number of responses in saber, epee, and foil are produced through the sense of touch and pressure, especially during such fencing actions as parries, engagements or blocks.

In general, learning and development of motor skills and techniques in fencing and other sports with open motor habits are based on perceptual processes involving the senses of vision, touch, and hearing. A significant role is also played by proprioceptive mechanisms responsible for static and locomotive balance. The way information is acquired from the environment, as well as different perception speeds of individual senses, affect the efficacy of technical and tactical actions.

Information processes

The significance of tactile stimuli, next to acoustic and visual, as cognitive factors affecting the quality of training motor habits, has been subject to numerous studies in the areas of motor function and sport theory. According to Proctor and Dutta, factors which determine the quality of perceptual processes are stages called: detection (of a stimulus), differentiation, recognition, and identification. The term detection has been discussed in a number of studies only in the context of visual stimuli. This stage of perception determines the moment of appearance of a stimulus. Thanks to its diversity, fencing training makes it possible to reduce the stage of perception and to improve individual capabilities of signal detection. During differentiation of the stimuli types, the athlete's task is to assess the force of stimuli and compare their quality, (e.g., fencers assess the pressure and the spot of the beat parry or engagement in order to respond successfully to the opponent's actions). The recognition stage entails a greater complication of the perception process, (i.e., it involves detection and differentiation of the incoming signals). These learning tasks are of motor character, since at this stage, fencers must display an adequate level of trained responses in order to recognize a correct signal. This type of perception is crucial in most sports, with open motor habits. The ability to recognize signals conditions the linking of movement sequences in order, and allows proper coordination of foot and arm work, which plays the key role in fencing.

Identification is the most advanced stage of the perceptual process. It requires specific responses from fencers, depending on a given combat situation. In fencing, the same stimuli can yield defensive or offensive actions, which are strictly related to the tactics and strategy of sport combat as well as fencers' individual preferences. Identification as a perceptual process is linked to motor training and is a process of making constant sensory corrections following the principles of extrinsic feedback (resulting from a coach's corrections and motivational actions) and intrinsic feedback (resulting from an athlete's knowledge and acquired motor habits and skills).

An original concept of the significance and interpretation of perceptual processes based on coaching practice at the highest sport level was suggested by Czajkowski (2001). Accordingly in learning new actions and developing common motor patterns, the most important variable is selectivity of the perception process. Not only should the athlete's perception of stimuli be selective but also conscious. The processing of external information should be time-conscious, (e.g., before choosing and executing an action or, in some situations, remembering a pattern of response and recreating it later). The process of perception of information allows anticipation of the course of events and proper decision making. The most frequently used information channel is the sense of vision, followed by hearing and touch. An athletes body movements and position are assessed via such sensory parameters as kinesthesia and proprioception for maintaining a sense of balance and equilibrium. Therefore, a significant part of training is teaching an athlete selective perception, proper understanding, and subtle differentiation of stimuli, as well as ignorance of non-significant and false signals, (e.g., discriminating between real actions and feints).

Many other authors (Abernethy 1996; Williams, and Grant 1999) have stressed the significance of the visual strategy. There have been many studies of visual perception among novice and expert athletes. The latter use strategies based on central vision and imaging of mastered vision patterns, which greatly reduce the processes of perception. On the other hand, novice athletes start perceiving using peripheral vision, which extends visual perception and causes redundant fixations. Knowledge and experience improve the effectiveness of perception processes through filtering information which is most appropriate for a given situation. Furthermore, the strategy of choice permits reception of only the most essential amount of stimuli which are of key significance. In case of novice athletes, it poses serious difficulty.

There has been a strong emphasis on comparisons of perceptual processes between novice and expert athletes in experimental research. Analyses of cognitive processes in young athletes, and studies of developmental profiles of novice and experienced athletes, constitute at present one of the key research areas in teaching motor control and sports technique. Czajkowski's study (2005) showed that the speed of complex information processing (motor memory, concentration, choice of motor programs) is significantly slower in novice athletes in comparison with advanced athletes. However, the peripheral factors related to the speed of dispatching executive commands in novice athletes are close to those of advanced ones.

Cognitive processes should be analyzed from the standpoint of speed of processing information from the environment. Some sports regarded as sensorimotor (golf, bowling), as well as endurance (track and field), do not require fast processing of external signals. It is quite opposite in the case of combat sports and team games in which the speed of processing information is often crucial.

According to Knudson and Morrison (2002), perceptual processes and information processes constitute the basis of all cognitive processes in motor control and training. The continuity of information processing must be emphasized, since identification of stimuli, being the highest stage of perception, is linked to information processes, which precede the choice and programming of sensorimotor responses. These processes require a comprehensive research approach and allow a qualitative diagnostic analysis of motor tasks. The analysis of perceptual processes is an introduction to the description of information processes using the basic indices of information processing speed, such as reaction time (RT) and movement time (MT).

According to Luce (1986), the identification stage is a transformation of physical stimulation into biological codes followed by their identification. In sport practice, possibly the most instant recognition of the right stimuli is highly significant. In combat sports it is important to discriminate between initial signals of real threat from feints, (e.g. in boxing or fencing). Sport research and practice show that the efficiency of "recreation" of patterns of stimuli identification is related to long-term experiences in different complex situations of combat sports. Keller and Tyshler (1970) confirmed the importance of experience in the speed of information processing between the environment and the commencement of motor activity. Both novice and experienced competitors may experience a similar tactical situation and the same set of stimuli. For the beginners, the multitude of signals is an overburden to the perceptual system, and they are not able to control the vast influx of information. Their actions are incorrect and fail to respond to the rapidly changing situations in combat sports. Experienced competitors ignore a great deal of signals, even those anticipated, and focus on stimuli that determine the effectiveness of technical and tactical actions. By choosing a few signals for processing, they progress immediately to the decision-making stages of the information process. Salczenko's study (1980), on advanced and novice fencers consisted of setting blocks against subjects' attacks and showed that novice fencers failed to notice the initial signals from their opponents' foot movements, and thus their responses were belated. With experienced fencers, their perception of an initial signal (muscle tension in the rear leg) triggered a defensive habit consisting of assuming an appropriate block. The difference in reaction time (RT) amounted to about 120 ms between the two groups of subjects. When the legs were covered, no differences in reaction time between the two groups were observed. The comparative analysis showed that effective anticipation was conducive to the experienced fencers' decision-making as they used signals from these parts of the opponent's body which affected the speed and accuracy of offensive actions. Similar studies of tennis players (Starkes and Ericsson, 2001) showed that experienced players identified initial signals by perceiving tensions and movements of the opponent's torso and shoulders, which allowed them to anticipate the opponent's service or plays. According to Schmidt's (1999) classic model of information processes, the identification stage is followed by the stage of response choice and the stage of response programming.

Stage of response choice

The stage of response choice is a logical continuation of the stage of identification during which a complex assessment of information takes place. Such information is recognized and processed for making appropriate decisions. The athletes choose the type of response or no response. The stage is a kind of transformation of receptor stimulation into a specific activation in time. Sequences of events evoke appropriate responses in fencers from among the plethora of possible behavior patterns they have acquired during their training. It is the process of identification of stimulation associated with motor memory in a given time (Keele and Hawkins 1982). According to the ideomotor theory, specific stimuli evoke specific responses from among many potential stimuli. In combat sports (fencing, taekwondo, karate, boxing) the changeability of situations evokes simple reactions and choice reactions in competitors in conditions of time deficit. In one type of choice reaction – differential reaction (Czajkowski, 2001) – an athlete responds differently to similar stimuli, (e.g., a boxer ducking a hook or countering to a hook with a slow swing; or a sabreur parrying an attack on the head or counter riposting an attack with a bent arm). Another type of differential reaction consists of refraining from actions being tactical traps and giving the opponent an advantage. Empirical data (Borysiuk, 2000) show that choice reactions are two-times longer than simple reactions in combat sports athletes (180-220ms and 380-410ms, respectively). Moreover, observations made by coaches seem to confirm that increasing task difficulty by increasing the number of alternatives significantly extends the stage of response choice. In laboratory studies this stage is described using the choice reaction paradigm formulated by Keele (1986), which states that the correlation between choice reaction time (RT) and the number of possible responses is curvilinear.

In their discussion of different studies on choice reactions, Klapp and Erwin (1976) confirmed that reaction time increased along with the number of sent stimuli in a linear way (proportionately to $log^2(N)$; N – the number of extra stimuli) up to about 600ms. Above this level, an increase in the amount of information does not significantly affect the extension of reaction time. Their research showed that extra information delayed reaction time from 100 to 150ms. The great variety of offensive actions in karate or fencing offers a number of technical possibilities, often unpredictable for the defending opponents who need more time to choose appropriate responses. In sport practice, when reaction time for a punch in boxing or a thrust in fencing is estimated at about 50ms, an increase in information processing time for more than 100ms has definitely a negative impact on competitors who are not prepared to respond to such fast reactions. Studies examining the effects of motor training (Quesada and Schmidt 1970) demonstrated that multiple repetitions of tasks with four alternatives reduced the time of response choice to the time of choosing between two possibilities. It should be emphasized that elite athletes also sustain substantial motivational factors which play important roles in the process – as shown by Żukowski (1995) in his study of taekwondo practitioners. The Polish Taekwondo National Team achieved similar or slightly worse results in simple reaction and choice reaction tests. A possible interpretation of these results might be that more difficult tasks were an additional factor motivating them to perform the tests more effectively. Similar conclusions were drawn from the studies of simple and complex reactions of elite and novice Polish epeeists (Borysiuk, 2006).

The speed of choice of motor responses is not a matter of individual predisposition, but it is strictly linked to subjects' age. Welford's (1980) longitudinal studies showed that the stage of response choice was greatly reduced in ontogenesis – from puberty to adulthood. In general, the aforementioned authors observed that training determined the speed and effectiveness of perceptual processes in association with information processes in ontogenesis, (i.e., they depended on acquired motor habits and skills). Experience is part of complex knowledge, whereby novice athletes develop their anticipatory competences much faster. Thanks to systematic training, young athletes achieve better results in particular components of the decision-making process than their older counterparts who gave up their active lifestyle.

Stage of response programming

The choice of a motor response results in an appropriate re-organization of the motor system to ensure efficient and successful execution of a given task. From the neurophysiological standpoint, the key role in this process is played by the brain which programs a desired movement by stimulating lower levels of the central nervous system, mostly the cerebellum, to effectively control and coordinate the work of skeletal muscles in terms of contraction speed and force. In other words, response programming is the stage of movement initiation, (i.e., transition from the stage of an abstract idea to the stage of activation of appropriate muscles). It is a complex process affected by memory mechanisms, and the duration of motor responses as illustrated by the course of EMG curves (Borysiuk and Zmarzly, 2005). They demonstrated that longer motor tasks demand an increase in programming time. Response programming is thus the final stage of information processes, which allows communication with the environment. Studies on response programming were carried out by Zelaznik, Schmidt and Gielen (1986), as well as Schmidt and Wriesberg (2004) and concentrated on relations between reaction time (RT) and movement time (MT) as functions of complex motor responses. These authors observed that subjects' time of reaction to the same light signals varied depending on duration of different complex motor tasks with the use of tennis balls. The RT amounted to 159ms (first trial with no balls), 195ms (second trial with catching a ball) and 208ms (third trial with hitting the ball twice). The MT amounted to 0. 95 and 465 ms, respectively. Similar tests were carried out by Sternberg (1969) who specialized in assessment of the time of reaction (RT) to a number of uttered words and letters set in a designated sequence. A greater number of words and letters resulted in an increase in reaction time and decrease in subjects' typing efficacy. In the aforementioned research cases, the obtained results were interpreted as effects of complex responses on reaction time (RT). The increase in reaction time resulted from the necessity to prepare an appropriate motor program, (i.e., create a feedback network).

The above cases can be neurologically explained. It can be assumed that the complexity of motor tasks require more complex commands which are necessary to control a number of movements at different levels of their coordination with the central nervous system. Practicing combat sports involves a direct confrontation with the opponent. In order to take the opponent by surprise it is necessary to constantly vary tactical intentions using appropriate timing. Therefore, the time of motor responses is essential. For instance, a sabreur feinting an attack can dodge the opponent's block and hit the side of his valid target area. The correct programming of his action makes the defending opponent respond to the attacker's feint by assuming the quarte parry with no possibility of effective defense against the cut on the side. This is an illustration of how well-trained competitors can control the opponent's reactions and prevent effective counters. Pashler's (1994) laboratory research, which focused on these issues, led to formation of the so-called double-stimulation paradigm. His results showed that competitors were able to respond within one second (1000ms) only two or three times to sequential stimuli. Like in the case of the sabreur above, it can be concluded that in the course of multi-feinted attacks, an attack marked too explicitly may not produce a desired response from the opponent, and that the programmed attack will fail, (e.g., hit the defender's block). Similar situations occur during bouts involving novice fencers whose reactions are usually belated, opposite, or premature due to excessive stimulation. One should also be aware that standard responses, which are well-known and described in motor function sciences, do not apply to elite competitors, whose speed of information processing can be remarkably astonishing. For instance, saber is a conventional weapon in which the referee's interpretations give priority to attack over the defensive actions performed at the same time (right-of-way). The electronic scoring equipment registers the timing of hits within 125ms of each other, which in practice, determines the result of the entire saber bout. The defending fencer must be ahead of the attacker for at least 125ms to get a single light on the scoring apparatus. Otherwise, the fencer is judged as hit and loses a point. During fencing training, sabreurs learn to differentiate such short time intervals and be ready to receive stimuli in conditions of time deficit. Long-term training makes a number of motor habits automatic. They become mastered with a limited involvement of awareness processes. Fencing training at the specialist level focuses on vivid changes of situations, which makes it possible to re-program intended movements during their execution.

Stimulation types (tactile, acoustic, visual, kinesthetic) and time of sensorimotor responses

From the standpoint of the training process control, the significance of dominant stimuli in each sport or sport event should be most definitely taken into account. Team games and combat sports generally involve visual and kinesthetic stimulation. In running, swimming and ice-skating, perception and quick identification of acoustic stimuli are of key significance. Some sports (e.g., tennis, fencing) feature a wide spectrum of requirements in terms of visual and sensorimotor perception. For instance, in fencing, reactions to tactile stimuli ("feeling the blade") are immensely significant along with the most obvious reactions to visual stimuli. Similarly, in lawn tennis, "feeling the ball on the racket" is one of the determinants for playing effective tennis. Acoustic stimuli are also important. For example, the fencer's footwork rhythm allows evaluation of the distance between the fighting opponents, whereas the sound of the tennis ball informs the player about the opponent's hit strength. The time of reaction to kinesthetic, acoustic, and visual stimuli has been subject to different studies (Enoka, 2000). All the authors have assumed that the time of simple reaction to exteroceptive stimulation ranges from 90 to 130ms. However, with acoustic stimuli, this range is extended another 20-50ms, which amounts to 180-200ms with visual stimuli. It should be remembered that the expression of all types of stimuli (visual, tactile, acoustic, olfactory) takes place simultaneously (Schmidt and Wrisberg, 2004), and after the identification and choice stages, a program considering only selected "filtered" information is launched (Fig. 1).

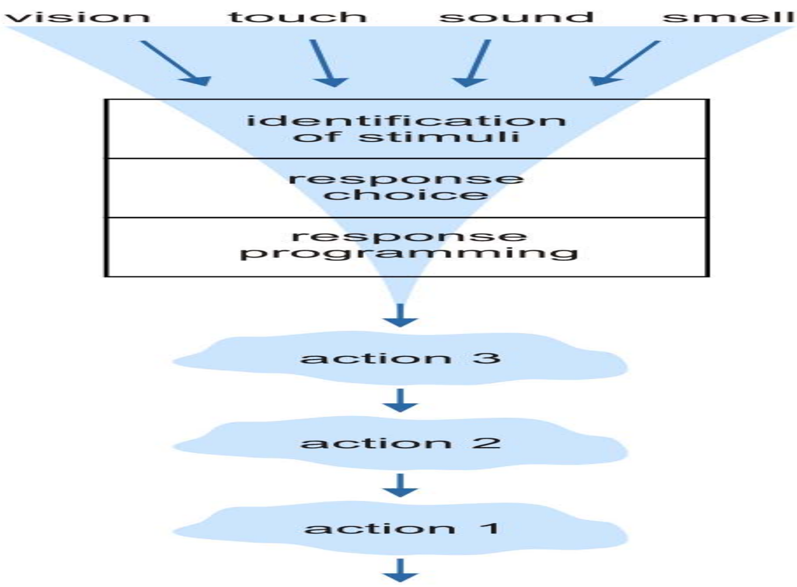

Fig. 1

Model of expression of sensory stimuli and consecutive responses (Schmidt and Wrisberg 2004)

In most combat sports, including fencing, the most significant sensory system is visual stimulation. Two types of visual stimulation can be distinguished:

focal vision and ambient vision (McCormick and Sanders, 1982). Focal vision concentrates on registering detailed information about the observed object, mostly with postural balance in a two-dimensional plane, and involves static visual acuity (SVA). Ambient vision is responsible for such factors as differentiation of stimuli, contrasts, colors, color saturation, movements and time. It is three-dimensional and features dynamic visual acuity (DVA). Both visions interact in the process of stimuli perception; however, in the case of an athlete in motion the DVA is decisive. According to Kluka (1987), if both opponents are in motion in a combat sport then the time necessary for assessment of the situation (focusing attention on the moving object) decreases rapidly. According to Wood and Abernethy (1997), the dynamic visual acuity decreases from 60 to 70 degrees per second. This can be explained by the fact that the retina is not able to acquire and store a changing image of an object in conditions of increasing time deficit. Moreover, both kinds of visual perception are only moderately correlated, whereas the development of dynamic visual acuity (DVA) is greatly affected by training. Focal vision identifies the object and it involves an insignificant part of the retina in the process of image reception. It is estimated that a small point on the retina confines the visual angle to merely 3 degrees. Ambient vision locates the object and assesses its motion and distance from the observer. It receives information using the entire retina and it encompasses both central and peripheral vision. The aforementioned authors consider both types of information to be integrated. Their significance and application in motor control encompass the assessment of:

1. Movement speed.
2. Direction of movement in relation to the observer's position and changes of the object's position.
3. The object's movement in relation to the observer.
4. Time of contact between the object and the observer.

The above information is extremely useful in motor training and development of fencing technique. It allows preparation of an appropriate strategy of perception of the position of the opponent's blade, in particular the point and the bell guard, for one's own offensive actions. The knowledge about the opponent's movements, distance evaluation, and visual concentration on the most useful signals, provides the fencer and the coach with valuable feedback. It permits a strategy of switching from focal vision to ambient vision and vice versa. It develops concentration, ability to react to initial signals, and anticipation of the opponent's actions. It allows recognition of significant signals and rejection of misleading information, (e.g., opponent's feints).

Another type of stimulation is acoustic. Following the data of Borysiuk and Zmarzly (2005), the time of reaction to acoustic stimuli is the shortest and ranges between 140 and 160ms. It is commonly thought that the reason for such fast processing of acoustic signals is the rapid of activation of receptors in both ears, and a very short time of transmission of the afferent signal to the brain along the nervous pathways (8-10ms). In terms of cognitive processes in sports with open motor habits, acoustic perception is the fastest, and enables the entire movement structure. Acoustic information includes such aspects as perception of the fencing tempo, movement frequency, timing, as well as sound pitch and amplitude. The significance of hearing in sports has been widely discussed in literature. In fencing (Szabo, 1988), (Ewangelista, 2000), footwork training is based on the sense of rhythm which is related to the fencing tempo. Losing the tempo during an attack in conventional fencing weapons (epee, foil) results in the loss of right-of-way and exposes fencers to hits in individual engagements. The sense of rhythm and movement frequency registered by the auditory system determines the feeling of distance awareness between the fencers, and thus, about the overall effectiveness of offensive and defensive actions.

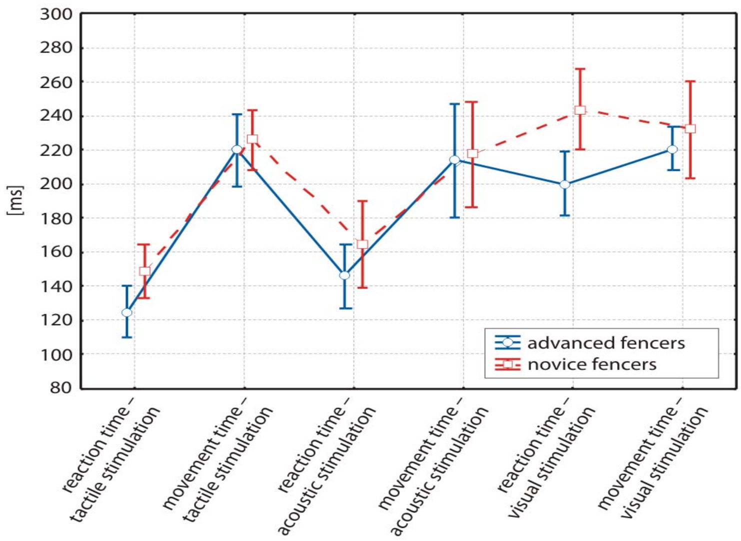

Fig. 2

Reaction time and movement time to the three types of stimulation by novice and advanced fencers.

Similar observations about the speed of information processing (RT) are associated with the sense of touch. However, according to Luce (1986), the time of reaction to tactile stimuli is 20-40ms longer than to acoustic stimuli. The results of own study on advanced fencers (Fig. 2, 3) using an EMG system show that the time of reaction to tactile stimulation is similar or slightly shorter than to acoustic stimuli. The tactile system delivers data gathered by tactile receptors (Meissner's and Ruffini corpuscles) and deep pressure receptors (Pacinian corpuscles). When the stimulation exceeds the activation threshold of the sensory nerves, the signals are activated and transmitted directly to the brain. The pressure receptors have a higher activation threshold than tactile receptors, which is why tactile reactions are faster than pressure reactions. Therefore, a subtle use of the blade and the point can provide a fencer with a number of technical and tactical possibilities, making the contact with the opponent's blade more effective.

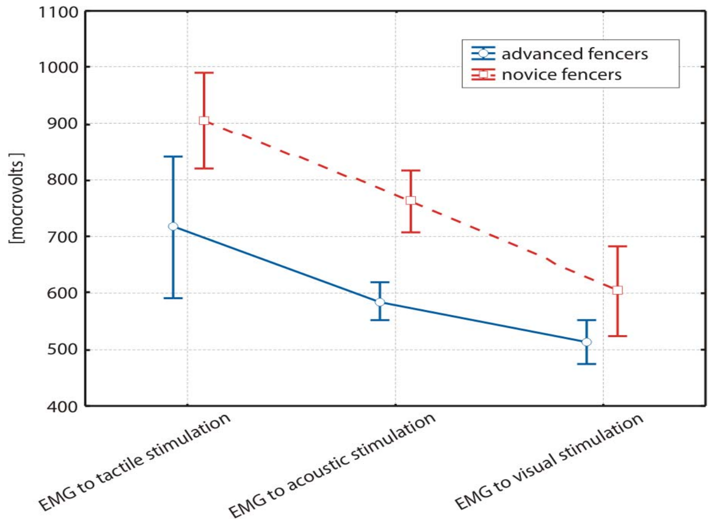

Fig. 3

The EMG signal in response to the three types of stimulation in novice and advanced fencers.

The impact of different types of stimulation on reaction time, movement time, and muscle bioelectric tension (EMG) was subject to a number of own laboratory studies. The research sample consisted of 15 novice fencers (at the introductory stage of their training) and 12 advanced fencers (at the specialist stage of their training). Figure 2 shows that fencers from both groups responded fastest to tactile stimuli, followed by acoustic stimuli and visual stimuli. The advanced fencers were faster than the novice fencers in all studied parameters. The time differences were statistically significant in reaction time (RT), understood as the latency stage of the sensorimotor response without the MT component. As responses to acoustic stimuli failed to produce any significant differences between both groups of subjects, it can be assumed that fencers' responses to tactile and visual stimulation can be learned to a great extent. On the other hand, novice fencers compensated for their longer latency phases of information processing with MT, which was identical in both groups of subjects in response to acoustic stimulation.

In a neurophysiological perspective, the above differentiation is related to nerve conduction. It is estimated that the process of triggering responses to visual stimuli is linked to the great number of synaptic connections with the retina. It can be assumed that the significantly faster responses to tactile stimuli are associated with the concentration of about two thousand receptors in the digital pulp, as well as with the speed of activation of the sensory cortical areas (Enoka, 2000). The effectiveness of the auditory system depends on the receptors in the cochlea, from which the impulses are transmitted along nervous pathways to the temporal lobes of the cerebral cortex. This distance is covered within 10-15ms.

The analysis of the EMG signal also yields interesting results (Fig. 3.). It shows that the fencers who focused on tactile stimulation generated higher bioelectrical tension than those focusing on acoustic stimulation. In responses to visual stimuli, the EMG signal was the lowest, which may be an indication that the response, and sheer anticipation of this type of stimulation, reduced the level of muscle tension. The EMG signal was significantly lower in the advanced fencers in all three types of stimulation. It can be argued that the psycho-motor superiority of expert fencers results in a reduction of bioelectrical tension in muscles involved in performing the motor tasks. These correlations confirm results of studies carried out by a number of experts on combat sports (Lukovich, 1997, Pitman, 1990).

Integration of data from different senses

The understanding of perception and processing of information from four senses (vision, touch, hearing and kinesthesia) as well as their mutual interactions, is the prime objective of any coach. Various observations made by coaches confirm that the brain automatically integrates all types of sensory information and gives priority to those stimuli which are significant for a given competition. According to Marino (1982), there is a similarity between the process of linguistic perception and cognitive processes in motor learning. Marino claims that language skills acquisition takes place on two levels: [1]introductory or pre-linguistic phase, in which the information is merely registered; and [2]linguistic-semantic phase, in which the information is encoded and put into semantic order. Certainly, the information is processed faster in the introductory phase than in the semantic phase. It is similar in sports. For instance, in direct-contact combat sports (e.g., judo, wrestling), tactile information is processed faster, whereas in karate and boxing, visual stimuli is followed by acoustical information as the priority senses. It is also similar in individual fencing bouts involving au fer attacks, where tactile stimulation is an integral part of information that must be taken into account by the fencer.

From a cognitive point of view (Seat and Wrisberg, 1996), combining different types of sensory information occurs within three categories: detection, spatial stimulation, and temporal situation. The reaction time (RT) for particular types of stimulation was discussed above. It should be emphasized that responses to different stimuli, with the exception of acoustic stimuli, can be learned in the course of training. The sequence of stimuli detection depends on its strength, and usually an athletes' perception is focused on stronger stimuli. Shiffrar and Freyd (1990) described the phenomenon of inhibition of information with weaker expression. It can be explained psychologically as subject to selective concentration of attention, and physiologically as muscle tension which can be detected in some sensory organs and inhibited in others. If the initial stimulation is of high intensity, it can inhibit the expression of other sensations. To optimize the different effects of stimulation, sensory expressions should occur simultaneously. That is why synergy and mutual enhancement of muscles of auditory ossicles and papillary muscles have been observed. A similar process can be noticed with mutual synesthesia of the senses of touch and hearing enhanced by the sense of vision. This synesthessia simultaneously broadens and improves the reception of stimuli, as the receiver uses at least two types of stimulation. Moreover, one does not exclude selective processing of information. With regard to spatial stimuli, according to Rhodes, Courney, and Hajduk (2002), the dominant sense is vision, followed by hearing, proprioception, and touch. They noted a close interaction between visual and acoustic perceptions in processing spatial information. They also observed differences between the perceptions of acoustic stimuli, which is horizontal, and of visual stimuli, which is vertical. The visual perception serves as a sort of framework for acoustic information. In other words, the visual memory is a map for acoustic expression in relation to motor proprioception. In regard to temporal information, when temporal stimuli are emitted in short intervals, the acoustic information dominates over tactile and visual. Faster perception of acoustic stimuli makes it possible to process tactile and visual stimuli more slowly. It can be concluded that visual information is complementary to the decision-making process. Coaches taking an active role in training (e.g., fencing or boxing tutorials) should recall the importance of acoustic signals as determining stimuli within the feedback processes (Tyszler and Tyszler 1995), (Cheris, 2002).

Perceptual training

Perceptual training is - next to physical, technical and tactical training - the main component of preparation of athletes to achieve high sports results (Williams and Grant, 1999), (Czajkowski, 2005). Perceptual skills enable athletes to respond to important signals in sport competition and ignore disrupting ones which lower the effectiveness of sports combat. Time pressure during sports competition makes it necessary to reduce as much as possible the decision-making time and the time of sensorimotor responses in the motor phase. The study results (Fig. 2, 3) show that experienced athletes reached decisions much faster than their novice colleagues. Furthermore, the advanced fencers featured better efficiency and economy in their motor actions, which was reflected in lower muscle bioelectric tension to all types of stimuli. It conforms to the main strategy of perceptual training, (i.e., gaining maximum benefits at the lowest expense (Williams, Davids, Burwitz and Williams, 1992). Quick decision-making is strictly associated with the stimuli detection effectiveness and re-creation of acquired motor patterns. A successful choice of responses depends on proper assessment of the space-time relationships, which enables anticipation and making appropriate decisions. Of significant importance are the specialized types of perception, such as "feeling the blade" and spatial-temporal orientation of the fencing hand-weapon position. The organs of perception, in particular vision, can then focus on receiving possible the largest amount of information for immediate processing. Numerous studies have demonstrated that athletes of sports with open motor habits, who follow the target strategy, rely on their perception of long time memory (LTM). This strategy, although extending the phase of stimuli detection, in fact reduces the time of information processing. A number of studies of fencers have pointed to significant differences in simple and complex reactions in novice and advanced fencers. They have been concerned with difficult visual tasks and their results correspond to those obtained by Keller and Tyszler (1970) and Salczenko (1980). These observations are also confirmed by mildly significant differences in simple reactions based on short time memory. Between the two groups of subjects, the advanced fencers were not significantly better than their novice counterparts, which can be an indication that at this level of reaction complexity the responses were automatic.

A significant factor in further reduction of the information processing time in the choice phase is perceptual anticipation. Following the opinions of fencing experts (Szabo, 1998, Lukovich, 1997), the unique anticipatory efficiency of expert fencers is a result of their capabilities of attention splitting. They are 50% more effective in perception of signals which are significant for victory than novice fencers. The timing effectiveness is crucial. Information acquired at the right time allows for making an optimal decision and executing the intended action. This is conditioned by selective perception of stimuli to avoid incorrect or delayed reactions. According to Ericsson, Kilbom, Wiktorin and Winkiel (1991), the key elements in developing perceptual skills in sports with open motor habits should include:

- development of abilities to recall and recreate technical and tactical patterns specific to a given sport;
- fast detection of temporal-spatial intervals of moving objects, competitors, weapons, etc;
- development of the ability to extend visual perception in response to specific signals related to the opponent's postural orientation;
- application of focal and ambient vision;
- differentiation of stimuli and selection of information that can be effectively used in sport competition;
- preservation of sensorimotor patterns and their execution, regardless of the emotional pressure during sport competition;
- matching the temporal structure of motor patterns with individual psychomotor predispositions and combat styles preferred by different temperamental types of fencers.

With regard to perceptual training, a unique problem in fencing is the over-representativeness of left-handed competitors among the world elite foil fencers, epeeists, and sabreurs. Quite interesting results were demonstrated by Borysiuk and Zmarzly (2005), in their study of choice reaction time with regard to ocular dominance, using surface electromyography. The measurement used in the study consisted of two parallel control panels with screens transmitting light signals either directly opposite (compatible reaction) or laterally to the subject's eyes (incompatible reaction). In the former case, the subjects needed only 40ms to make a decision; in the latter the reaction time was 110ms. Possible interpretations of these results may contribute to explaining the phenomenon of the left-handed dominance in competitive fencing, (e.g., Olympic champions Victor Sidjak and Victor Krovopuskov; three Olympic foil champions from the same team Witold Woyda, Lech Koziejowski and Marek Dąbrowski; Olympic epee champion, Laura Flessel and many others. The Polish National Epee Team – the current European Champions – consists of left-handed fencers only). A student of mine, Dariusz Gilman, Cadet World Champion, Junior European

Champion, and Senior Team World Championships bronze medalist is also a left hander. It appears that the left-handed fencers, who most often compete against their right-handed counterparts, acquire an ability to process compatible signals (directly opposite of their eyes) much faster, since their opponent's right weapon arm is the closest target area to them. The dominance of left-handed fencers can be additionally confirmed by the difficulties experienced by right-handed fencers with blade work, blocks and parries in combat with left-sided opponents.

However in our previous study with surface electromyography, results produced insignificant effects of functional hand asymmetry, (i.e., left-hand or right-hand dominance in terms of reaction time). Observed differences included increased bioelectric tension in the non-dominant arm, sensorimotor facilitation of impulse transmission along nervous pathways, and improvement of reaction time of the non-dominant arm following a series of tests using the dominant arm.

The uniqueness of fencing is based on the fact that the key to fencing training consists of individual coaching lessons. In methodological terms the fencing coach's task is to incorporate perceptual training, such as learning responses to an array stimuli, utilizing tactical training, and combining it with the development of such psychical properties as concentration, attention divisibility, and attention shifting. In order to meet these challenges, fencing coaches should be highly skilled in fencing and create training conditions as close as possible to real combat, (i.e., fencing tempo, speed, rhythm, quick changes of decisions during performance, as well as provide diverse exercises and multiple repetitions).

With reference to the issue of functional asymmetry, coaches should not only apply asymmetric exercises but also act as left-handed or right-handed opponents, depending on their fencers' dominant hand. It has been observed that exercises involving both sides of the body not only develop motor habits but may also correct motor habits acquired earlier by the dominant arm. Such exercises improve one's own fencing technique, functional ambidexterity, and – which is also significant – compensate for the osteomuscular system.

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