

Effect of target change during the simple attack in fencing

¹University of Granada, Faculty of Sport Sciences, Department of Physical Education and Sports, Granada, Spain,

²University of Granada, Faculty of Psychology, Granada, Spain, and ³Technical University of Madrid, Faculty of Physical Activity and Sport Sciences, Madrid, Spain

(Accepted 9 January 2013)

Abstract

The aim of this study was to test the effect that changing targets during a simple long lunge attack in fencing exerts on the temporal parameters of the reaction response, the execution speed, and the precision and the coordination of the movement pattern. Thirty fencers with more than 10 years of experience participated in this study. Two force platforms were used to record the horizontal components of the reaction forces and thereby to determine the beginning of the movement. A three-dimensional (3D) system recorded the spatial positions of the 9 markers situated on the fencer plus the epee, while a moving target was projected on a screen, enabling the control of the target change. The results indicated that when a target change is provoked the reaction time (RT), movement time (MT), and the time used in the acceleration phase of the centre of mass (CM) increases significantly with respect to the attack executed with a straight thrust. The speed and horizontal distance reached by the CM at the end of the acceleration phase ($V_{X(CM)}$ and $S_{X(CM)}$, respectively) significantly decreased, while the errors increased. However, the temporal sequence of the movement pattern did not appreciably change.

Keywords: motor control, biomechanics, fencer, reaction response

Introduction

The lunge is one of the most frequently used actions during the attack in fencing. This technical action is executed in an uninterrupted way with a temporal sequence that begins with the acceleration of the epee arm, then the back foot becomes active followed by the front foot, and ends when the point of the epee touches the target. During the movement, a horizontal thrust phase can be distinguished, when the centre of mass (CM) of the fencer accelerates forwards, leading to a flight phase that ends when the front foot makes contact with the floor (Stewart & Kopetka, 2005). The movement pattern is based on a model of pushing kinetic chain (Kreighbaum & Barthels, 1996), which facilitates the change in the trajectory of the weapon at any instant during the action.

Following classical fencing manuals, the lunge can be executed by a straight thrust or by disengagement, changing the target during the action (Thirioux, 1970). Sometimes, the disengagement is used to change the target during the attack in response to a defence action. In this case, the fencer

must wait until the opponent starts the defensive action (Movement Time (MT)-stimulus change). Then, when the defensive action is detected (S_2), the attacker should inhibit the initial attack, process the information, and make the most appropriate decision while accelerating forwards, this being considered “choice reaction time” (CRT). Finally, the fencer needs sufficient movement time to change the aim of the epee and reach the target (MT-target change). Figure 1 shows a sequence of a simple attack together with the movement phases (upper part), as well as a simplified time model of the simple attack with only a direct thrust (A) together with a simple attack involving a target change (B).

In the practice of fencing, the simple attack with target change, described in Figure 1 (B), is usually trained for individually, with the coach (master) acting as opponent and attempting to simulate a real action (Czajkowski, 2005). Recently, automatic systems that permit a simulation of this situation through randomised control of stimuli (Electronic Training Target, Favero Electronic Design - Italy) have been used. Besides the acquisition of a certain functional variability in movement patterns, this type

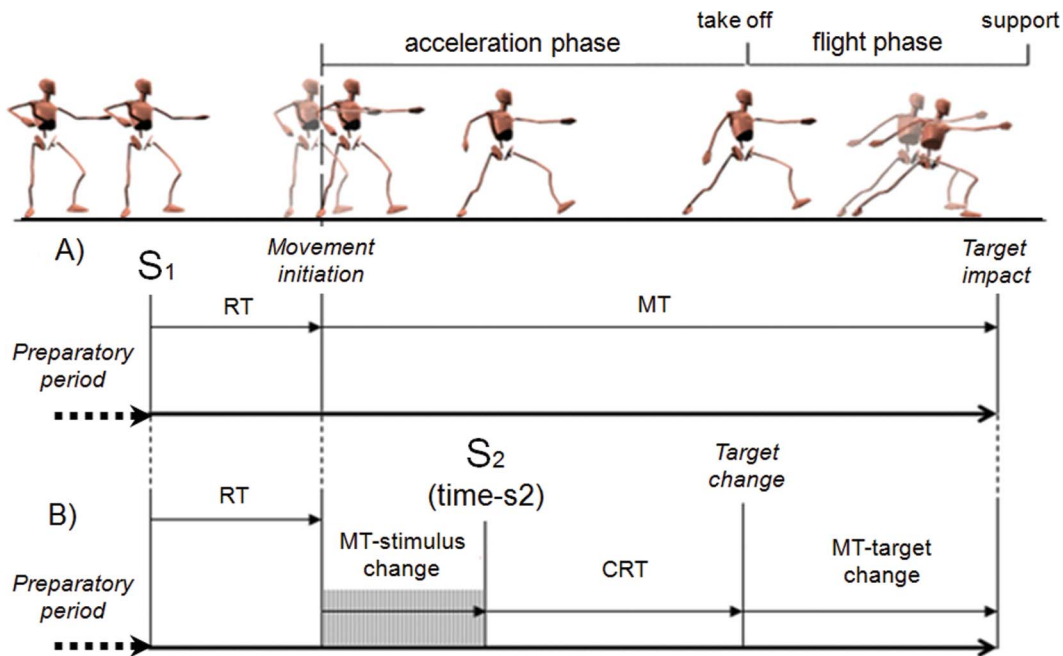


Figure 1. Schematic representation of the simple attack sequence together with the movement phases (upper part), as well as a simplified temporal model of the simple attack executed with a direct thrust (A) and of the simple attack with a target change (B). (RT = reaction time.)

of training is intended to help the fencer reduce their choice reaction time, attempting to associate every response with a stimulus. However, studies carried out that entail varying levels of uncertainty of response for the fencer (Borysiuk & Waskiewicz, 2008; Sanderson, 1983), along with certain explanatory theories discussed below, cause us to suspect that the uncertainty produced by target change during the execution of a movement may reduce the velocity of displacement and modify the coordination of the movement pattern, approximating the context of real competition.

From the dual-visual-system model, the reaction response requires the contribution of the two visual processes that have different functions. A ventral current, associated with explicit awareness, provides information on the probabilities to execute the action (affordable perception), while a dorsal current gathers visual cues implicit in movement control, immediately and relatively quickly (Goodale & Westwood, 2004; Milner & Goodale, 1995). Following Van der Kamp, Rivas, Van Doorn, and Savelsbergh (2008), the ventral current would be more involved before starting the movement, while the dorsal would dominate over the ventral during movement execution. Accordingly, in the case of a target change during a simple attack, the dominance of the dorsal current would be delayed until the instant at which the target change occurs, thus slowing down the initial movement.

In another sphere, cognitive neuropsychologists recognise that the motor planes and their sequencing arise in an implicit, unconscious, and automatic way, whereas the intentions of the movements are conscious and can be influenced by prior information, giving rise to simple facilitation or priming, which favours rapid responses (Desmurget & Sirigu, 2009). However, to guarantee adaptability in the responses when a target change is required during an action, a facilitation or high-order strategy is necessary to enable the inhibition of the first action triggered by a stimulus to refine the precision of the response (Gao, Wong-Lin, Holmes, Simen, & Cohen, 2009).

According to Duque, Lew, Mazzocchio, Oliver, and Ivry (2010), this inhibition process develops by two closely related mechanisms. The first inhibits the activation of possible responses selected at the spinal level (impulse control to avoid premature reactions) and the second determines one response among the most relevant options (conflict resolution). Thus, before the movement starts, all the possible responses are activated, requiring inhibitory signals at the spinal level, anticipating external information that would cause one response to prevail over all others. This second inhibitory mechanism would occur at the upper cortical levels, causing a certain delay in the response (Ivanoff, Branning & Marois, 2009; Schluter, Rushworth, Passingham, & Mills, 1998). This aspect could be related to the findings of Di Russo, Taddei, Apnile, and Spinelli (2006),

who compared high-level fencers with non-athlete university students, and showed that the capacity that fencers have to change one target to a more appropriate one is the result of greater inhibitory activity by the prefrontal cortex over motor processes.

According to the above-mentioned researchers, the target change in response to the opponent's defensive action increases uncertainty, delays the dominance of the dorsal current during the attack, and activates the inhibitory mechanism of conflict resolution before spurring movement. This research suggests the hypothesis that, in the situation of simple attack with target change, there will be an increase in the two temporal components of the reaction response time (RRT): a) simple reaction time (RT) and b) movement time (MT) as consequence of the reduction in horizontal velocity of the centre of mass (CM).

Methods

Participants

A total of 30 fencers participated, each with experience in national competition for more than 10 years. Of these, 13 were members of the National Spanish Fencing Team and the other 17 were participants of national ranking in Spain (age = 35.2 ± 10.4 years old; height = 1.79 ± 0.05 m; body mass = 82 ± 10 kg). All procedures were conducted according to the ethical guidelines of the university. All fencers were thoroughly informed about the study and their participation, and gave their written consent prior to commencement.

Procedures

The fencers used their personal epee equipped with an electronic chronometer with a precision of 1 ms (0.001 s), adapted to a system that recorded the time needed in each trial for the point of the epee to touch the plastron. The fencers adopted their customary on-guard position, placing their feet on the two force platforms (0.6×0.37 m), Dinascan/IBV (IBV, Valencia, Spain), which operated at 500 Hz, enabling us to record the horizontal component of the reaction force (F_{AX} and F_{BX}). A three-dimensional (3D) movement-recording system VICON-460, (Vicon Motion Systems, Oxford, UK), with 6 infrared video cameras, functioning at 500 Hz recorded the spatial positions of 8 body markers situated on the two heels, the points of the shoes, the knee (epicondylus fibularis femoris), the hip (trochanter major), the shoulder (tuberculum majus) and the elbow (epicondylus radialis) of the epee arm, plus a marker situated at the beginning of

the forte of the epee blade (near the hilt). A projector connected to a computer with a programmable external card enabled the timed projection of a circle of 0.09 m over a white surface of 0.70×0.55 m representing a plastron, after a random period of 0.5 s to 1.2 s, from the starting cue. After this period, an electronic signal was used to synchronise all the recording systems mentioned.

Following the protocol used by Williams and Walmsley (2000), for a long lunge the plastron was situated at a distance of 1.5-fold the height of the fencer, with respect to the big toe of the back foot. After several simple attacks with a straight thrust at the pre-established distance, the plastron was moved to a distance at which the fencer felt comfortable. After the projection of the circle was set to the established diameter, the distance chosen by each participant was maintained for all the trials in the two experimental situations (straight thrust and target change). After the adjustment, the fencers reduced the distance to the plastron by 0.013 ± 0.2 m. The fencers received instructions to remain still in the on-guard position until the circle was projected on the plastron. From this instant, they were instructed to make a simple attack with a straight thrust as rapidly as possible, touching the point of the epee within the circle. Before recordings began, the fencers made several thrusts until becoming completely familiar with the measurement system. In order to maintain the level of activation of the participants, they were informed of the times obtained after every trial. To confirm the effect exerted by target change in fencing, we compared two types of simple attack (direct thrust and target change).

Direct-thrust attack. In the first recording phase, the fencers had to respond with a simple attack of a straight long lunge when the circle appeared, stimulus 1 (S_1), in the centre of the plastron. Five valid trials were made for all the participants in which the reaction response time (RRT) was recorded, the errors being recorded when the point of the epee did not reach the circle. Following the method of Gutiérrez-Dávila, Dapena, and Campos (2006), the start of the movement was determined from the instant at which the net force of the horizontal component ($F_{AX} + F_{BX}$) reached a value greater than or equal to 1% of body weight. When this time was less than 100 ms, the trial was repeated.

Target change attack. After the recording of 5 valid trials corresponding to the first phase, the tests were made for the simple attack with a target change, stimuli 2 (S_2). As in the previous situation, beginning from the on-guard position, the fencer lunged as swiftly as possible, seeking to touch the point of the epee within the circle that appeared in the centre

of the plastron. The participants were aware from the beginning of the second phase that the target might move, but they did not know what the nature of those movements might be. The target could move to three equidistant positions situated on both sides of and below the starting position (circle situated at the centre of the plastron) at a distance of 0.25 m from the initial target.

To determine the instant at which the position of the circle would change (time- S_2), the time components of the median reaction response time of the 5 valid trials of the simple attack with a straight thrust were used (time- S_2 = Reaction Time + $\frac{1}{4}$ Movement Time; see Figure 1). S_2 appeared once the fencer began his/her movement and then had time to change the trajectory, before the “point of no return.” Once thought has passed this point, there is no turning back; the action is inevitable and it is not possible to measure reaction time (Osman, Kornblum, & Meyer, 1986).

To avoid the factor of learning, 9 trials were carried out under different conditions: 5 valid trials where the stimulus was changed at a pre-established instant (time- S_2), 2 trials where no change was made, and 2 trials where the stimulus was changed at a random time between the reaction time (RT) and time- S_2 . The order of the trials was random and a trial was repeated when the target was not reached, misses being noted as errors. Only the 5 valid trials were recorded, in which the target change was made at time- S_2 , and only the trial with the median reaction response time (RRT) of the 5 was analysed.

Data analysis

For an evaluation of the results when the target was changed, in comparison to the simple attack with a direct thrust, the reaction response time was recorded, as were its two most significant components: a) reaction time (RT), defined as the period from the appearance of the stimulus (S_1) until movement begins; and b) the movement time (MT), defined as the period from beginning the movement until the instant that the point of the epee touches the plastron. Choice reaction time (CRT), was defined as the time period between S_2 and the instant when the fencer changes (*Target change*) the transverse or vertical component of the acceleration of the marker situated at the second third of the epee. For the calculation of the acceleration components, the second derivative of the movement vector was used through fifth-grade splines without applying the smoothing function (Figure 1). For the temporal analysis, the time needed by the fencer during horizontal acceleration (time-acceleration phase) and the time during which the fencer is in flight (time-flight phase) were recorded. For the analysis

of the movements of the centre of mass (CM) of the fencer system plus the epee, the velocity and distance of the horizontal component travelled by the CM during the first 0.2 s of the acceleration phase were measured ($V_{X(CM)}$ and $S_{X(CM)}$ respectively). For the analysis of movement, we have used a system of inertial references associated with the ground, where the horizontal axis (X) has been identified with the principal direction of movement (Figure 1).

With the aim of determining the possible changes in the starting position (on-guard), the positions were recorded by the markers situated on the hip, shoulder and epee, with respect to the position of the big toe of the back foot. To determine the sequence of the segmentary participation, the time of lifting the front foot was measured (time of lifting the front foot) and the maximum horizontal velocities of the markers situated on the heel of the front foot and at the beginning of the forte section (lower third) of the blade ($V_{X(MAX)}$ foot and $V_{X(MAX)}$ epee, respectively), as well as the timing of these velocities, expressed as percentages with respect to the acceleration time (Time $V_{X(Max)}$ foot and Time $V_{X(Max)}$ epee). Finally, the length of the long lunge was recorded under the two experimental conditions defined as the distance between the marker of the toe of the back foot in the on-guard position and the marker situated on the heel of the front foot fully planted on the floor after a lunge.

From the force-platform data, the records for velocities and movements of centre of mass (CM) were determined following the method of Gutiérrez-Dávila et al. (2006). The horizontal acceleration (a_x) of the CM was calculated from the net horizontal force of the two platforms (F_{AX} and F_{BX}) and the mass of the fencer. Progressive horizontal velocities ($V_{CM(X)}$) and displacements ($S_{CM(X)}$) were calculated from the horizontal acceleration-time values using trapezoidal integration. For the calculation of the horizontal velocity of the markers, the horizontal component was used after having been filtered by fifth-order spline functions. The smoothing factor was calculated by the method known as cross-generalised validation (Woltring, 1985). Then, the first derivative was applied with respect to time, using the fifth-order spline function without applying the smoothing function.

Statistical analyses

For the statistical treatment of the data, the software used was SPSS v. 20.0 software for Windows (SPSS, Inc., Chicago, IL). The mean and standard deviation were calculated for the variables in each experimental condition. To calculate the differences between means of the variables in the two types of simple attack (simple thrust and target change), a multifactorial analysis

of variance for repeated measures (ANOVA) was used. Mean differences between experimental conditions and 95% Confidence Interval (CI) were calculated. Effect size statistics was assessed using Cohen's d , taking into account the cut-off established by Cohen, 0.20, 0.50, and 0.80, constitute small, medium, and large effect sizes, respectively (Nakagawa & Cuthill, 2007).

To evaluate the reliability of the trials, an analysis of variance for repeated measures was applied to all the trials under the two experimental conditions (5 trials), taking as the dependent variable the reaction response time (RRT). No significant differences were found between the two tests. The intraclass correlation coefficient was 0.934 ($P < 0.001$) for the simple attack with a straight thrust and 0.909 ($P < 0.001$) for the attack with a target change. A P -value of $P < 0.05$ was considered to correspond to statistical significance.

Results

Figure 2 presents a typical example of the horizontal-force values for one of the fencers during the acceleration phase. The upper part of the figure (a) shows separately the horizontal forces recorded in the two platforms, while in the lower part (b) appear the results of the horizontal forces exerted by the two supports under the two experimental conditions. The movement starts with the increase in force of the back foot and the reduction of the force of the front foot. When the simple attack is executed with

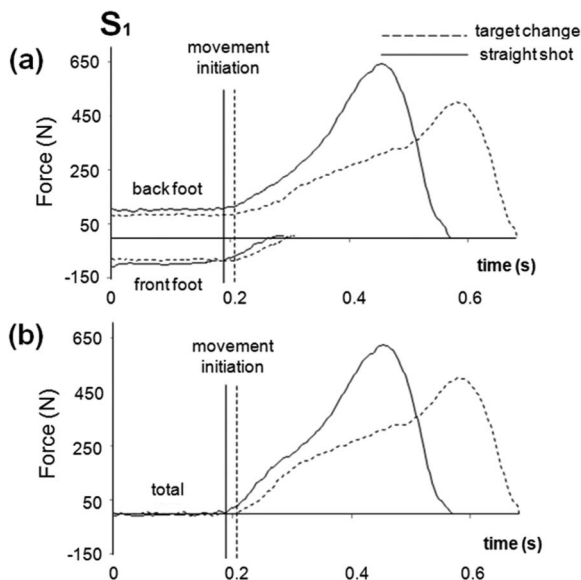


Figure 2. Horizontal forces for one of the fencers during the acceleration phase. In the upper part (a) appear the horizontal forces recorded in the two platforms and in the lower part (b), the resulting horizontal forces.

the target change, the peak of the force is lower, whereas the time needed for the acceleration is greater than that needed for the straight thrust. The reaction time (RT) is shorter when the attack is made with the straight thrust (Figure 2(b)).

Table I lists the numerical data corresponding to the temporal parameters of the RT and certain kinetic factors related to the centre of mass (CM). It was confirmed that the mean RT and the movement time (MT) were significantly less when the attack was made with the straight thrust ($P < 0.001$). As a result, the mean reaction response time (RRT) was also significantly shorter for the straight thrust. Both $V_{X(CM)}$ and $S_{X(CM)}$ decreased significantly during the first 0.2 s of the acceleration phase when the attack was realised with a target change ($P < 0.001$), which indicates that the horizontal velocity of the CM, at the beginning of the phase of acceleration, is lessened when the simple attack is realised with a target change conditioned to represent the defence of an opponent. The mean horizontal velocity of the CM at the end of the acceleration phase ($v_{CM(X)}$) was significantly greater ($P < 0.001$) when the attack was a straight thrust and the mean displacement of the CM ($s_{CM(X)}$) presented a certain significance among the means ($P < 0.05$), being greater when the attack was a straight thrust. With respect to the phases in which the movement was divided (acceleration impulse and flight) significant differences were only seen in the mean time of acceleration impulse ($P < 0.001$), while no differences were found in flight time. Table I also presents the errors made under the two conditions, expressed in percentages of all the trials carried out. The results indicate that when the attack was a direct thrust, the errors significantly diminished ($P < 0.001$).

Table II contains the data of the markers on the hip, shoulder, and the beginning of the forte of the epee blade (near the hilt), with respect to the big toe of the back foot in the on-guard position. None of the positions registered statically significant differences between the means of the two conditions. Consequently, the mean starting position was similar in both cases. Below, data are presented to describe the characteristics of the movement pattern utilised in both conditions. The time of lifting the front foot was significantly greater when the attack was made with a target change ($P < 0.001$). No statistically significant differences were found for the times at which the front foot and epee reached maximum velocity (Time $V_{X(MAX)}$ foot and Time $V_{X(MAX)}$ epee, respectively) and therefore, in the two conditions, the foot attained its maximum velocity before the epee did. Finally, we should indicate that the maximum velocity of the epee was significantly greater when the attack was direct ($P < 0.001$).

Table I. Descriptive and inferential statistics of the temporal parameters of the response and reaction as well as other relevant variables for the attacks made with direct thrust or target change.

Variables	Direct-thrust attack	Target-change attack	Mean differences		
	$N = 30$ Mean \pm s	$N = 30$ Mean \pm s	Mean \pm s	95% CI	Effect size d
Reaction Resp. Time, RRT (ms)	710 \pm 82***	807 \pm 81***	-97 \pm 60	-119 to -74	1.6
Reaction Time, RT (ms)	188 \pm 22***	216 \pm 28***	-28 \pm 32	-40 to -16	0.9
Movement Time, MT (ms)	523 \pm 74***	591 \pm 76***	-69 \pm 50	-87 to -50	1.4
Choice React. Time, CRT (ms)	-	234 \pm 36			
Time-acceleration Phase (ms)	505 \pm 68***	548 \pm 72***	-43 \pm 49	-62 to -25	0.9
Time-flight Phase (ms)	28 \pm 29	21 \pm 33	7 \pm 20	-0.9 to 14	0.3
Errors (%)	20 \pm 17***	38 \pm 15***	-18 \pm 19	-25 to -11	0.9
$V_{X(CM)}$ first 0.2 s of acceleration phase ($m \cdot s^{-1}$)	0.52 \pm 0.11***	0.36 \pm 0.13***	0.16 \pm 0.14	0.11 to 0.21	1.1
$S_{X(CM)}$ first 0.2 s of acceleration phase (m)	0.04 \pm 0.01***	0.02 \pm 0.01***	0.01 \pm 0.01	0.01 to 0.02	1
$V_{X(CM)}$ end of the acceleration phase ($m \cdot s^{-1}$)	1.72 \pm 0.36*	1.60 \pm 0.38*	0.11 \pm 0.20	0.03 to 0.19	0.5
$S_{X(CM)}$ end of the acceleration phase (m)	0.39 \pm 0.08*	0.35 \pm 0.09*	0.04 \pm 0.08	0.01 to 0.07	0.5

*** $P < 0.001$; * $P < 0.05$.

Table II. Descriptive and inferential statistics of the main kinematic variables for the situations of direct attack and target-change attack.

Variables	Direct-thrust attack	Target-change attack	Mean differences		
	$N = 30$ Mean \pm s	$N = 30$ Mean \pm s	Mean \pm s	95% CI	Effect size d
On-guard position					
Horizontal position hip (m)	0.38 \pm 0.06	0.36 \pm 0.07	0.01 \pm 0.05	-0.01 to 0.03	0.3
Horizontal pos. shoulder (m)	0.49 \pm 0.08	0.49 \pm 0.09	0 \pm 0.07	-0.02 to 0.02	0
Horizontal position epee (m)	1.06 \pm 0.10	1.04 \pm 0.12	0.02 \pm 0.08	-0.01 to 0.05	0.2
Movement time (MT)					
Time lifting front foot (s)	0.039 \pm 0.001***	0.083 \pm 0.023***	-0.04 \pm 0.02	-0.05 to -0.03	2
Time $V_{X(MAX)}$ foot (%)	68 \pm 7	66 \pm 10	2 \pm 9	-50 to 1	0.3
$V_{X(MAX)}$ foot ($m \cdot s^{-1}$)	4.10 \pm 0.80	3.98 \pm 0.71	0.12 \pm 0.62	-0.1 to 0.36	0.2
Time maximum velocity epee, $V_{X(MAX)}$ epee (%)	84 \pm 6	87 \pm 9	-3 \pm 9	-6 to 1	0.3
Maximum velocity epee, $V_{X(MAX)}$ epee ($m \cdot s^{-1}$)	2.49 \pm 0.40***	2.15 \pm 0.56***	0.33 \pm 0.35	0.20 to 0.46	1
Lunge length (m)	1.37 \pm 0.19	1.34 \pm 0.19	0.03 \pm 0.35	-0.10 to 0.16	0.1

*** $P < 0.001$.

Discussion and conclusions

The data show that when a target change is made during a simple attack in fencing, the movement time (MT) increases. The velocity (V_x) and the horizontal distance (S_x) travelled by the CM at the end of the acceleration reduces, while the time needed for acceleration impulse increases (see Table I). Consequently, when the target changes due to an action of the opponent, the displacement is slower than when the attack is a straight thrust. This aspect is confirmed by the results of Sanderson (1983) and Borysiuk and Waskiewicz (2008), which show that uncertainty caused by target change during the attacking action in fencing reduces velocity. The graph in Figure 2 for one of the participants approximates a typical example.

In both experimental situations, the lunge length was similar; the weapon reaches maximum velocity after the foot has attained its maximum velocity. This data suggests that the movement pattern was similar for the two experimental conditions, corroborating the findings of Williams and Walmsley (2000), who suggested that the target change did not pose overwhelming technical difficulties.

The time of the phases increased in the target-change attack except for the time-flight phase because the uncertainty led to the fencer putting his/her foot on the floor faster and reducing the velocity of movement. If the time of the phases are analysed in percentage (%) of the reaction response time (RRT), the phases diminish in a similar percentage (Table II), what is considered an invariant of the movement (Schmidt & Lee, 2011), with the

exception of the flight phase. Taking these considerations into account, the velocity of the movement is a variant of the same pattern.

The high level of variability in flight time phase is justified by the initial position of the fencer in the experimental set up. Initially, all the fencers placed themselves on the platform at a distance which was 1.5 times their height. After that, with the same procedure as Williams and Walmsley (2000), the plastron was slightly moved so that the fencer could feel comfortable and could proceed with the lunge following the technique normally used. The fencers reduced the distance to the plastron by 0.013 ± 0.2 m. The distance chosen by each participant was maintained for all the trials in the two experimental situations (direct-thrust attack and target change).

The results presented can also be explained using the dual-visual system proposed by Milner and Goodale (1995). Thus, when an attack is made with a direct thrust, the dorsal current would be the dominant one, from the start of the movement (S_1). Being a current that takes visual information implicit in the movement, it enables the movement to be executed swiftly and automatically while maintaining good precision of the motion until reaching the target (Goodale & Westwood, 2004; Van der Kamp et al., 2008). On the contrary, when the attack is made with the target change, the ventral current, associated with explicit awareness, dominates over the dorsal until after the information of the stimulus change (S_2) has been processed. The result is that the movement starts more slowly, increasing in velocity only during the MT target change, when the dorsal current already assumes dominance over the ventral. Although we cannot confirm that this is the cause of the increase in the errors when a target change is undertaken (see Table I), the lack of synchronisation and the possible interference in the contribution of the two currents (Schneider & Deubel, 2002), together with the fact of having less time to make the precise adjustments that would enable the target to be reached and the small diameter of the circle (target) 0.09 m, could be responsible for increased error. The high level of variability in each experimental condition was due to the variability of the distance to the plastron (target); each fencer felt comfortable and was able to proceed with the lunge following the technique normally used.

Despite the above, the fact that the reaction time was significantly greater when the attack involved a target change is difficult to explain using theories related to visual information processing. It bears pointing out that in both conditions the fencers had to respond initially to the same stimulus (S_1). The difference that arises between the two situations was the complexity of the task after the initial stimulus. From cognitive neuropsychology, it is known that

when an attack is executed with no expectation of a response from the opponent (direct thrust) the motor planes and their sequencing arise by a pattern of only benefit, known as automatic facilitation (Gao et al., 2009). However, when there is an expectation of a response from the opponent (target change), the use of automatic facilitation could become a liability more than an advantage and lead to errors. To guarantee the adaptability of the actions involved in target change, the fencer develops another type of facilitation, known as strategic or high-order facilitation, which enables the fencer to inhibit the first action of attack to refine the precision of the response during choice reaction time (CRT).

According to the above explanation and the precepts of Schluter et al., (1998) as well as Duque et al., (2010), the anticipation of acting by an inhibition process to resolve conflicts would account for the slower movement during a target change and, especially, the delay encountered in reaction time. The findings of Praamstra, Kourtis, Fei Kwok, and Ooterveld (2006) support this contention by demonstrating that in multiple-choice tasks with a reaction time, participants tend to anticipate implicitly or unconsciously the time intervals, delaying the reaction time.

In conclusion, when a target change results from or may prevent the defensive action of the opponent, we find that the reaction response time increases, the execution velocity diminishes, and errors increase. However, we did not detect changes in the temporal sequence of segmentary participation.

According to the practical applications of the present study, the movement time (MT) that a fencer takes for a direct thrust would be greater than the reaction time that the opponent would need to respond to this attack. It appears improbable that with the distance to the target established in this study the attack with a straight thrust would be successful. Therefore, these types of actions should be trained for with closer objectives (the arm or leg of the opponent), or this attack should be preceded with a certain tactical intent to delay the opponent's response.

According to the above, considering that the target change results in a reduction in velocity of the CM and an increase in MT (591 ± 76 ms), the simple attack with a target change does not appear to be a basic attack option, but rather would constitute a resource that is determined by uncertainty, the choice reaction time (CRT), and the time needed to execute the target change (MT target change). Therefore, the practical utility for training for high-level competition should be understood as an element within the general attack strategy, with the aim of obtaining from the opponent a predictable erroneous response towards the first objective (S_1). The fact of knowing beforehand the possible

response of the opponent constitutes a tactical element of special relevancy in fencing, that allows a reduction in uncertainty and this is related with the ability to switch, a reaction with a movement pattern acquired with similar characteristics to a direct thrust situation, despite the realisation of a target change.

Acknowledgements

The authors wish to thank Cristina López de Subijana for her invaluable help collecting data and the Spanish Royal Federation of Fencing for its collaboration in this project, providing access to the fencers of the National Epee fighting Team.

References

- Borysiuk, Z., & Waskiewicz, Z. (2008). Information processes, stimulation and perceptual training in fencing. *Journal of Human Kinetics, 19*, 63–82.
- Czajkowski, Z. (2005). *Understanding fencing: The unity of theory and practice*. Staten Island, NY: SKA Swordplay Books.
- Desmurget, M., & Sirigu, A. (2009). A parietal-premotor network for movement intention and motor awareness. *Trends in Cognitive Sciences, 13*(10), 411–419.
- Di Russo, F., Taddei, F., Apnile, T., & Spinelli, D. (2006). Neural correlates of fast stimulus discrimination and response selection in top-level fencers. *Neuroscience Letters, 408*, 113–118.
- Duque, J., Lew, D., Mazzocchio, R., Oliver, E., & Ivry, R. B. (2010). Evidence for two concurrent inhibitory mechanisms during response preparation. *Journal of Neuroscience, 30*(10), 3796–3802.
- Gao, J., Wong-Lin, K., Holmes, P., Simen, P., & Cohen, J. D. (2009). Sequential effects in two-choice reaction time tasks: Decomposition and synthesis of mechanisms. *Neural Computation, 21*(9), 2407–2436.
- Goodale, M. A., & Westwood, D. A. (2004). An evolving view of duplex vision: Separate but interacting cortical pathways for perception and action. *Current Opinion in Neurobiology, 14*, 203–211.
- Gutiérrez-Dávila, M., Dapena, J., & Campos, J. (2006). The effect of muscular pre-tensing on the sprint start. *Journal of Applied Biomechanics, 22*(3), 194–201.
- Ivanoff, J., Branning, P., & Marois, R. (2009). Mapping the pathways of information processing from sensation to action in four distinct sensorimotor tasks. *Human Brain Mapping, 30*(12), 4167–4186.
- Kreighbaum, E., & Barthels, K. M. (1996). *Biomechanics. A qualitative approach for studying human movement* (4th ed.). Boston, MA: Allyn & Bacon.
- Milner A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford: Oxford University Press.
- Nakagawa, S., & Cuthill, I. C. (2007). Effect size, confidence interval and statistical significance: A practical guide for biologists. *Biological Reviews Cambridge Philosophical Society, 82*(4), 591–605.
- Osman, A., Kornblum, S., & Meyer, D. E. (1986). The point of no return in choice reaction time: Controlled and ballistic stages of response preparation. *Journal of Experimental Psychology: Human Perception and Performance, 12*(3), 243–258.
- Praamstra, P., Kourtis, D., Fei Kwok, H., & Ooterveld, R. (2006). Neurophysiology of implicit timing in serial choice reaction-time performance. *Journal of Neuroscience, 26*(20), 5448–5455.
- Sanderson, F. H. (1983). The effect of directional uncertainty on reaction time and movement time in a fencing task. *Journal of Sports Sciences, 1*(2), 105–110.
- Schluter, N. D., Rushworth, M. F., Passingham, R. E., & Mills, K. R. (1998). Temporary interference in human lateral premotor cortex suggests dominance for the selection of movements. A study using transcranial magnetic stimulation. *Brain, 121*, 785–799.
- Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning: A behavioral emphasis* (5th ed.). Champaign, IL: Human Kinetics.
- Schneider, W. X., & Deubel, H. (2002). Selection-for-perception and selection-for-spatial-motor action are coupled by visual attention. A review of recent finding and new evidence from stimulus driven saccade control. In W. Prinz & B. Hommel (Eds.), *Attention and performance XIX: Common mechanisms in perception and action* (pp. 609–627). Oxford: Oxford University Press.
- Stewart, S. L., & Kopetka, B. (2005). The kinematic determinants of speed in the fencing lunge. *Journal of Sports Sciences, 23*(2), 105.
- Thirioux, M. P. (1970). *Escrime moderne aux trois armes*. Modern fencing to three weapons Paris: Amphora.
- Van der Kamp, J., Rivas, F., Van Doorn, H., & Savelsbergh, G. (2008). Ventral and dorsal system contributions to visual anticipation in fast ball sports. *International Journal of Sport Psychology, 39*, 100–130.
- Williams, L. R. T., & Walmsley, A. (2000). Response amendment in fencing: Differences between elite and novice subjects. *Perceptual and Motor Skills, 91*(1), 131–142.
- Woltring, H. J. (1985). On optimal smoothing and derivate estimation from noisy displacement data in biomechanics. *Human Movement Science, 4*, 229–245.