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Research article

Effect of Uncertainty during the Lunge in Fencing

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Abstract
The aim of this study is to determine the effect that uncertainty, in relation to the probability of error, exerts on the reaction response and speed during the lunge in fencing. The participants were 18 regional-level fencers with over five years' experience. Force platforms under the feet recorded the horizontal components of the reaction forces, from which the kinematic parameters of the center of mass were calculated. An electronic system to present stimuli, controlled by a programmable clock, projected a target onto a screen that represented a plastron. In situations without uncertainty, the fencers had to lunge as swiftly as possible when a circle (the target) appeared in the center of the plastron, trying to touch the center of the circle with the tip of the sword. In situations with uncertainty, the fencers had the same target as in the previous situation but they received the information that they had to change the lunge into a defensive move if the target disappeared from the plastron during the action. The results indicate that the reaction time and the movement time increased with uncertainty. Although there were no differences for the horizontal velocity of the center of mass at the end of the acceleration phase, the mean horizontal velocity of the lunge was reduced by the effect of the uncertainty. Prior knowledge of the opponent´s possible action implies a reduction in uncertainty, reducing movement time as well as meaning faster execution, thereby increasing the success of the lunge in fencing.

Key words: Motor control, biomechanics, neuropsychology, fencing, reaction response, uncertainty.

Introduction

Previous studies, where high-level fencers changed targets during the lunges showed that when the number of possible responses is increased during attacks (uncertainty), simple reaction times (RT) and choice reaction times (CRT) also increase, but do not affect the coordination of the movement pattern (Gutiérrez-Dávila et al., 2013a; 2013b).

In both studies, we have confirmed that the velocity of the center of mass (CoM) at the end of the horizontal acceleration phase decreased as uncertainty increased. Despite this, we should exercise caution when making this statement, since the reduction in speed of the CoM could be related to the adjustments made when increasing the CRT. We should indicate that the CRT required to process the target change occurs during the acceleration phase.

The protocols used in the two mentioned studies do not permit us to confirm the independent effect of the uncertainty regarding the speed of the CoM, in addition to the methodological drawbacks posed by the fact of comparing velocity values among different movement patterns (with or without a target change). In this work, the methodology was designed to test the independent effect of uncertainty on the velocity of the CoM. To do this, under the two experimental conditions, we used attack actions where no target change occurred and uncertainty was considered to be the level of probability that an error might result from that attack action, implying an inhibition of the planned movement pattern.

This type of uncertainty, due to the probability of error during the execution of the planned movement pattern, is common in fencing and is related to the tactical component whereby is possible to reduce uncertainty and execute a rapid and precise movement pattern (Borysiuk and Waskiewicz, 2008; Czajkowski, 2009).

The relevance of the tactical component in fencing goes far beyond trying to reduce the uncertainty prompted by the stimuli that trigger the response and thereby shorten the time to process information (Schmidt and Lee, 2011; Stein, 2008), as the fencer also uses tactics to predict the defensive action of the opponent during the attack. In this way, it is possible to reduce uncertainty during the movement time and execute a predetermined attack action meant to mislead the opponent.

In view of the above, when we analyze attack actions in fencing against distant targets, the concept of anticipation refers to a conscious action, as part of the tactical component or strategic expectancy, through which the opponent's defensive movements are predicted during the attack (Gao et al., 2009). In this predictive sense, we could consider that the attacker's probabilities of anticipating the defender will depend on the level of uncertainty that the fencer has before beginning the attack.

The influence that this type of uncertainty has during attack actions in fencing could be explained by certain findings in cognitive neuroscience. Currently, two main pathways are believed to transmit the visual information gathered through the primary visual cortex to other cortical areas. Each of these routes provides information with different uses and functions for the visual perception of objects (Goodale and Westwood, 2004; Milner and Goodale, 1995; Ungerleider and Mishkin, 1982). The dorsal pathway or system (directed towards the posterior parietal lobule) identifies the location of objects and their movements while the ventral visual pathway or system (directed towards the cortex of the inferior temporal lobule) is responsible for identifying objects.

For sports movements requiring anticipation, Van der Kamp et al., (2008) have described how the visual

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perception of information sources that regulate the reaction response (RR) require the synchronized interaction of the two visual systems, each serving its respective function. Both systems work at different points in space and time. That is, the information used by the dorsal stream is immediate, relatively rapid, and associated with automatic movements in which it is not necessary to be conscious of how the movement is made or of what type of information is used (Goodale and Westwood, 2004). In contrast, the ventral stream is associated with explicit consciousness, enabling the identification of the action most appropriate to reach the target. The ventral stream can also at times have a certain control over movement when the situation is not completely favorable to the dorsal system, as may occur in situations involving uncertainty during an action (Goodale and Westwood, 2004).

Despite the above-mentioned differences, the two systems work in close coordination (Glover, 2004; Van der Kamp et al., 2008), although, depending on the situation, the control of the movement can be dominated more by one visual stream. Therefore, when an attack action has a high probability of beating the opponent (without uncertainty), the movement pattern is made automatically without the need for conscious movement (Gao et al., 2009). In this situation, the dorsal visual system would control the movement. In contrast, uncertainty in the attack (the probability of error due to an unexpected defensive action by the opponent) would require continuous visual information concerning the defensive actions of the opponent. This situation would require mastery of the ventral system and thus a reduction in the speed to maintain the precision of the action.

The aim of this study is to determine the effect that uncertainty due to the possibility of error caused by an unexpected action by the opponent during the simple lunge in fencing exerts on the temporal parameters of the reaction response as well as on the speed of the execution. According to the above-mentioned researchers, the hypothesis is that the uncertainty due to an unforeseen action by the opponent during the execution of a programmed movement pattern will increase the temporal patterns of the response reaction and reduce the speed of the center of mass.

Methods

Participants

The participants were 18 fencers (14 male and 4 female) with over five years' competitive experience at regional level. Ten of them were specialists in epée and the other eight were specialists in foil (age 25.1 ± 6.5 years; height 1.75 ± 0.08 m; mass 70.5 ± 10.9 kg). All of the participants were informed about the study and their participation and gave their written consent to participate in this study, following the guidelines of the Ethics Commission of the University.

Experimental set-up

Two Dinascan/IBV force platforms, A and B, (Instituto de Biomecánica de Valencia, Valencia, Spain) were used, operating at 500 Hz, permitting the recording of the horizontal component of the reaction force from each force platform, (F_{AX} and F_{BX}). A video camera, Casio EX - FH20, at 70 Hz recorded the sagittal plane of the fencers, from which the position of their CoM was determined before starting the movement. A projector connected to a computer with an external programmable card projected a black circle (the target), 0.1 m in diameter onto the geometric center of a white screen of 0.7 x 0.55 m, which acted as a plastron. The geometric center of the screen was situated at a height corresponding to 70% of the height of the fencer. The weapons were fitted with an electronic chronometer (1/1000 s), adapted to the wired system that recorded the reaction-response time (RRT), this being considered as the time period from the instant when the circle appeared (S_1) until the tip of the sword struck the plastron. An electronic signal was used to start the recording of the two platforms using the chronometer at instant S_1. This same signal was used to synchronize the camera by the lighting of a LED.

Procedures

Following the protocol of Williams and Walmsley (2000), after a prior 15-min warm-up the fencers received instructions to remain motionless in their habitual *en garde* position, placing their feet on the two force platforms, A and B. The big toe of the rear foot was situated at a distance of 1.5 times the fencer's height away from the plastron. When the circle (target) was projected onto the plastron (S_1), the fencer had to make a direct long lunge as quickly as possible, in a reaction time situation, to place the tip of the sword inside the circle. After various long lunges towards the plastron at the pre-established distance, the fencers were allowed to adjust the distance until they felt comfortable at the new distance. The participants reduced the initial distance of the plastron by a mean of 0.001 ± 0.069 m. Before beginning the recording trials, the fencers completed a session of several attacks against the plastron until they became accustomed to the system.

For the records of the first experimental condition, where there was no uncertainty, the fencers had to make a simple straight lunge when the circle appeared in the center of the plastron (S_1). Five valid trials were conducted for all the subjects, and the reaction-response time (RRT) was recorded. The errors were noted when the point of the sword did not reach the circle. Using the methodology of Gutiérrez-Dávila, et al., (2006), the beginning of the movement was determined from the instant when the net force of the horizontal component (forces under each foot, $F_{AX} + F_{BX}$) reached a value of greater than or equal to 1% of the fencer's body weight. When this time was less than 100 ms, the trial was repeated.

Next, the trials with uncertainty during the lunge were recorded. As in the previous situation, beginning in the *en garde* position, the fencers lunged as swiftly as possible trying to place the sword point inside the circle that appeared within the plastron (S_1). In this experimental condition, the fencer was instructed to convert the attack to a defensive move if the circle disappeared during the lunge (S_2). The defensive movement, an alternative to the attack action, consisted of striking the sword against a blade attached to the left side of the plastron (Figure 1),

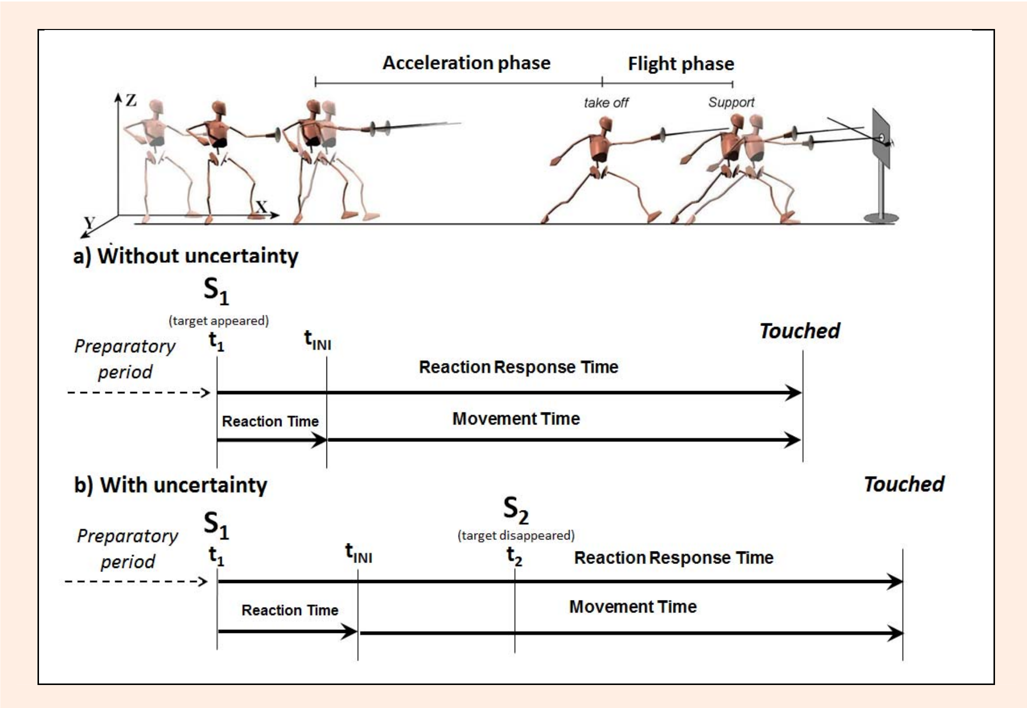

Figure 1. Movement sequence of the lunge (upper) and time scheme of the two situations: without uncertainty (a) and with uncertainty (b).

using a "parry". To determine the instant (t_2) when the target disappears in the course of the lunge (S_2), the time components of the median reaction response time of 5 valid trials of straight thrust were used (t_2 = Reaction Time + ¼ Movement Time). 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 change the attack to a defensive move (Osman et al., 1986).

The learning factor was prevented by the performance of 10 trials in which the two conditions were presented at random: five valid trials where the target disappeared during the lunge and five trials where the target remained projected until the point of the sword touched the plastron. In this second experimental condition, with uncertainty, only five valid trials where the target remained projected until the sword touched the plastron were recorded and only the trial in which the RRT reached the median value was analyzed. Figure 1 shows the sequence of movement together with a time scheme of the two experimental conditions. The experimental conditions were in a random counterbalanced order among the participants.

Data analysis

In addition, the two temporal components of the reaction response time (RRT) were recorded: 1) the reaction time (RT), defined as the period from the appearance of the stimulus (S_1), until the movement began in the force plate (t_{INI}), and 2) the movement time (MT), defined as the period from the initial movement until the instant when the point of the sword touched the plastron and the switch stopped the digital timer. The horizontal acceleration phase, ($\mathbf{t}_{ACCELERATION}$), was defined as the time period between the start of the movement (t_{INI}), and the instant when the horizontal force became lower than 4N (take-off).

The force-platform data were used to determine the records of the velocities and displacements of the center of mass (CoM) of the fencer plus the sword arm. To do this, the horizontal acceleration was calculated from the net horizontal force of the two platforms (F_{AX} + F_{BX}) and the mass of the fencer, by applying Newton's second law, $ax_{(CoM)} = F_{RX}/m$, where $ax_{(CoM)}$, F_{RX}, and m are body CoM horizontal acceleration ($m{\cdot}s^{-2}$), horizontal ground reaction forces (N), and the fencer's mass (kg), respectively, (Do and Yiou 1999). Next, the horizontal component of velocity ($\boldsymbol{v}_{x(CoM)}$) was determined as well as, the displacement of the CoM ($\boldsymbol{s}_{X(CoM)}$), through the integration of the acceleration-time function, using the trapezoidal method (Robertson, et al., 2004). The integration constants were determined from the video images. To do this, five images were digitalized at a frequency of 30 Hz, from the beginning of the movement (t_1), using the 14-segment coordinate model plus two markers situated on the sword blade (the handle and just at the tip), together with the inertia parameters proposed by Zatsiorsky and Seluyanov (1983) and adapted by Leva, (1996). For the conversion of the data to a real scale, a reference system of 1.58 x 1.58 x 1 m was used. Finally, the integration constants were determined by calculating the mean of the plane coordinates of the CoM position of the five digitalized images, considering the origin to be the tip of the trailing foot. The initial positions of the CoM and the sword´s handle were calculated.

The possible differences in the horizontal displacement and velocity of the CoM ($\boldsymbol{s}_{X(CoM)}$ and $\mathbf{v}_{x(CoM)}$) were evaluated in the two experimental conditions by blocking the time factor. Therefore, the horizontal displacement and velocity of the CoM ($s_{X(CoM)}$ and $v_{x(CoM)}$) was recorded at 0.2 s from the start of the movement and in the final phase of horizontal acceleration. We considered the possibility that there might be some differences between the two experimental conditions of uncertainty in regard to the duration and to the horizontal displacement of the CoM during the acceleration phase. To facilitate comparisons, the final part of the longer of the two selected trials of each fencer was truncated to make both trials have the same time during the acceleration phase ($t_{ACCELERATION}$). This produced "time-equated" trials.

Statistical analyses

Results were analyzed using the Statistical Package for the Social Sciences, SPSS v. 20.0 software for Windows. For each variable and experimental condition, the mean and standard deviations were calculated. The differences between the means of the variables were determined in the two experimental conditions (with and without uncertainty during the action) using a repeated-measures analysis of variance (ANOVA). The level for acceptance of significance (α) was set at 0.05. Mean differences between conditions and 95% confidence intervals (CI) were calculated. Effect-size statistics were assessed using Cohen's d. Taking into account the cutoff established by Cohen, the effect size could be small (<0.2), medium (< 0.5), or large (<0.8). The reliability of the tests was assessed by a repeated-measures analysis of variance applied to all the trials in the two experimental conditions (5 trials), taking the reaction-response time (RRT) as a dependent variable. No significant differences were found between the tests. The intraclass correlation coefficients were 0.915 for the trial without uncertainty, and 0.900 (all $p < 0.001$) with uncertainty.

Results

Figures 2a and 2b show the net horizontal forces ($F_{AX}+F_{BX}$) exerted by two participants, as representative of the sample. The values are expressed as a percentage of body weight. It was found that, when the lunge was made with uncertainty due to the possibility of error during the action, the time of starting to apply horizontal forces, (t_{INI}), was delayed, implying a longer reaction time. During the first instants, after t_{INI} (between t = 0 and t = 0.15 s), the values of the horizontal force increased in the absence of uncertainty. The mean horizontal force applied during the acceleration phase was higher for the attacks made without uncertainty, while the time of applying horizontal forces was longer with uncertainty. Therefore, following Figure 2, without uncertainty, the horizontal impulse was less in some cases (a) and greater in others (b). The maximum values of horizontal force were determined at the middle-end phase of the impulse for the two conditions.

The data are presented in Table 1. Before the start of the movement (t_{INI}), during the *en garde* phase, no statistically significant differences were found between the two attack situations proposed (with and without uncertainty) in the position of the CoM and the marker situated on the hand guard of the foil. The mean reaction time was greater for the situation with uncertainty (0.174 ± 0.016 s vs. 0.193 ± 0.041 s; $p < 0.05$). After 0.2 s from the start of movement (t_{INI}), the horizontal displacement of the CoM ($s_{X(CoM)}$) was significantly greater without uncertainty (0.026 ± 0.008 m vs. 0.022 ± 0.009 m; $p < 0.05$). A similar statistical trend was found for the horizontal velocity ($v_{X(CoM)}$) reached at 0.2 s from the start (0.380 ± 0.105 $m·s^{-1}$ vs. 0.325 ± 0.131 $m·s^{-1}$; $p < 0.05$). Figure 2 shows typical biomechanical examples for the

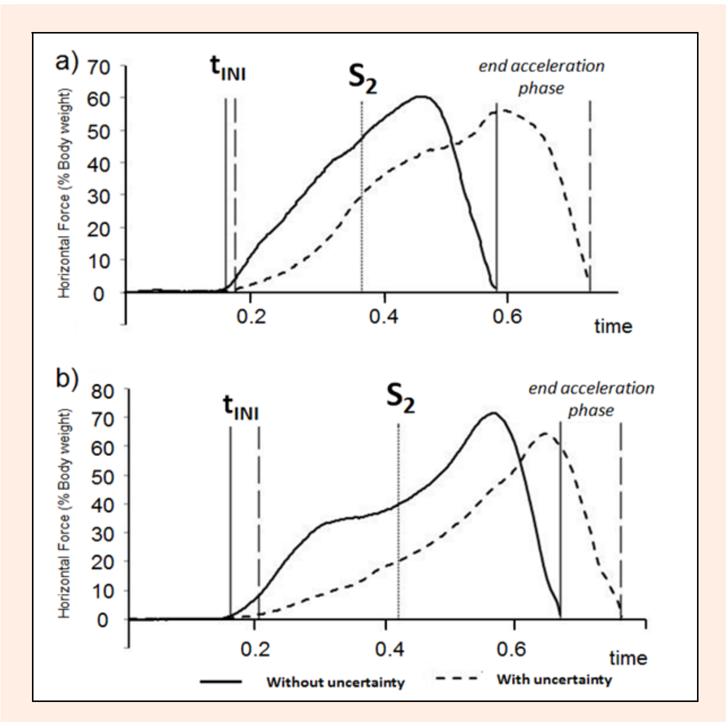

Figure 2. **Net horizontal forces ($F_{AX}+F_{BX}$) exerted by two participants (a and b, respectively) during the lunge, with uncertainty and without uncertainty during the action. The values (N) are expressed as percentage of body weight.**

Table 1. Descriptive statistics and repeated-measures ANOVA for the most significant variables related to the lunge without and with uncertainty during the action, respectively.

Variables	Without uncertainty	With uncertainty	Mean Differences	95% CI	Effect Size d
	Mean (±SD)	Mean (±SD)	Mean (±SD)		
Initial en garde position (t_{INI})					
Vertical position CoM (m)	.898 (.072)	.897 (.081)	.001 (.031)	-.014 to .016	0
Horizontal position CoM (m)	.360 (.078)	.361 (.089)	-.001 (.039)	-.020 to .018	0
Vertical position of the sword´s handle (m)	1.122 (.071)	1.100 (.072)	.019 (.045)	-.003 to .041	.4
Horizontal position of the sword´s handle (m)	.992 (.100)	.998 (.110)	-.006 (.061)	-.036 to .023	.1
Reaction Time, RT(s)	.174 (.016) *	.193 (.041) *	-.019 (.035)	-.037 to -.017	.5
0.2 s from the start of the movement					
Horizontal Displacement, $\mathbf{s}_{X(CoM)}$ (m)	.026 (.008) *	.022 (.009) *	.004 (.007)	.000 to .007	.6
Horizontal Velocity, $\mathbf{v}_{X(CoM)}$ ($m \cdot s^{-1}$)	.380 (.105) *	.325 (.131) *	.055 (.102)	.004 to .106	.5
Final phase of horizontal acceleration					
Acceleration Time, $\mathbf{t}_{(ACCELERATION)}$ (s)	.525 (.052) *	.550 (.069) *	-.025 (.416)	-.045 to -.005	9
Horizontal Displacement, $\mathbf{s}_{X(CoM)}$ (m)	.404 (.089)	.383 (.092)	.020 (.083)	-.021 to .062	.2
Horizontal Velocity, $\mathbf{v}_{X(CoM)}$ ($m \cdot s^{-1}$)	1.737 (.249)	1.690 (.250)	.047 (.172)	-.039 to .132	.3
Time-equated acceleration phase					
Horizontal Displacement, $\mathbf{s}_{X(CoM)}$-truncated (m)	.366 (.085) **	.329 (.078) **	.045 (.063)	.133 to .076	.7
Horizontal Velocity, $\mathbf{v}_{X(CoM)}$-truncated ($m \cdot s^{-1}$)	1.720 (.259) **	1.601 (.250) **	.119 (.163)	.038 to .200	.7
Contact with the plastron					
Reaction Response Time, **RRT** (s)	.716 (.052) ***	.770 (.098) ***	-.055 (.063)	-.087 to -.023	.9
Movement Time, **MT** (s)	.542 (.051) *	.581 (.091) *	-.039 (.060)	-.069 to -.093	.6

* $p< 0.05$; ** $p< 0.01$; *** $p < 0.001$

two participants of the sample, where the increase in the horizontal force in the first instants was greater when the action was made without uncertainty.

Below, Table 1 lists the data for the end of the acceleration phase. The mean time used for this phase ($\mathbf{t}_{ACCELERATION}$), was significantly shorter when the lunge was made without uncertainty (0.525 ± 0.052 s vs. 0.550 ± 0.069 s; p < 0.05). However, the horizontal displacement of the CoM during the acceleration phase ($s_{X(CoM)}$) was similar for both conditions. Some data were expected, as the distance of the plastron was the same in both conditions for each subject. The horizontal velocity of the CoM at the end of the acceleration phase ($v_{X(CoM)}$), the peak of CoM velocity, was similar for the two conditions.

The most relevant data of this work are the "time-equated" trials (Table 1), where for each fencer the longer of the two times reached in the acceleration phase was truncated to match the shorter one. The data indicate that the horizontal displacement of the CoM ($s_{X(CoM)}$-*truncated*), was significantly greater in the absence of uncertainty (0.366 ± 0.085 m vs. 0.329 ± 0.078 m; p < 0.01), implying that the mean horizontal velocity of the CoM during the acceleration phase was greater when the lunge was made without uncertainty during the action. A similar statistical trend was found for the horizontal velocity of the CoM ($v_{X(CoM)}$-*truncated*), at the end of the two times recorded in the acceleration phase (1.720 ± 0.259 $m \cdot s^{-1}$ vs. 1.601 ± 0.250 $m \cdot s^{-1}$; p < 0.01).

Finally, Table 1 presents the temporal data related to the contact of the sword with the plastron. It was found that the reaction-response time (RRT) was shorter when the lunge was made without uncertainty (0.716 ± 0.052 s vs. 0.770 ± 0.098 s; p < 0.001). Although the movement time (MT) maintained the same trend, the statistical significance between means was reduced (0.542 ± 0.051 s vs. 0.581 ± 0.091 s; p < 0.05), maintaining a similar trend as the time used for the acceleration phase ($t_{ACCELERATION}$).

Discussion

The reaction time (RT) and the movement time (MT) increased with uncertainty due to the possibility of error during the fencing lunge. Consequently, the reaction response time was longer with uncertainty. These results confirm previous studies (Gutiérrez-Dávila et al., 2013a; 2013b). The mean RT recorded in this study was lower than the one reported by Gutiérrez-Dávila, et al. (2013c) for fencers of higher competition levels under the same experimental conditions (0.174 ± 0.016 s vs. 0.188 ± 0.022 s). This is one aspect that confirms the findings of Gutiérrez-Dávila, et al. (2013c), where RT is not a key performance factor of fencers with different performance levels.

In both experimental situations, the simple reaction time was used to process the information, i.e. with the same stimulus, and there was only one response. Therefore, the explanation for the longer RT in the situations with uncertainty may be only because, after beginning the movement, there was the possibility that the initial target (the circle) would disappear, requiring a change to another movement pattern. According to the above, the RT was affected only by the information after the start of the movement. This result could be explained by recent theories proposed in cognitive neuropsychology (Desmurget and Sirigu, 2009; Duque, et al., 2010; Gao, et al., 2009; Schluter, et al., 1998).

Therefore, when there was confidence of successfully reaching the target (without uncertainty), the pattern of reaction times is called a benefit-only pattern and is ascribed to automatic facilitation (Gao et al., 2009). This movement pattern develops implicitly, unconsciously, and automatically, offering an advantage when making rapid responses. However, in the situation with uncertainty during the execution of the movement, the fencer developed another type of facilitation, known as strategic expectancy or high-order facilitation, which induced the fencer to restrain the first attack action in order to switch to another (Gao et al., 2009). According to Duque et al., (2010), this restraint process involves two closely related mechanisms. The first inhibits the activation of the possible responses selected at the spinal level (control of impulses) to avoid errors while the second makes the decision of whether to continue the direct lunge or curtail it and shift to another action at frontal cortex level (conflict resolution). Therefore, before the beginning of the movement, the two possible responses are activated, requiring inhibitory signals at the spinal level and awaiting external information to make one response prevail over the other. This second inhibitory mechanism occurs at the frontal cortex, causing a certain delay in the response (Ivanoff et al., 2009).

The horizontal displacement of the CoM during the acceleration phase was similar for the two conditions (with and without uncertainty), although the time in this phase was shorter without uncertainty, confirming that uncertainty, due to the possibility of error during the lunge, caused the movement of the CoM to be slower. The consequence was that the horizontal displacement of the CoM became slower, due to the possibility of having to inhibit the attack action planned in order to change the target during the movement.

The data on the space and horizontal velocity reached for the lunging times (truncated values) confirm that the movement is slower when there is uncertainty. This fact confirms the theories based on the model proposing two streams of visual perception (Goodale and Westwood, 2004; Milner and Goodale, 1995). Therefore, when a lunge is made in fencing, without detecting defensive actions of the opponent, the dorsal stream would be the dominant one from the beginning of the movement. As the stream collects visual information implicit in movement, the action can be executed rapidly and automatically, while maintaining good precision of movement to reach the target. In contrast, with a possibility of error during the attack, the situation would favor the dominance of the ventral stream, associated with explicit consciousness (Van der Kamp et al., 2008). The result is that the lunge slows until the uncertainty disappears, this occurring at the middle-late phase of the movement.

In fact, although the participants had no information about the instant when the target (the circle) might disappear, the uncertainty disappeared at the middle-late phase of the movement, when the fencer felt that there was no longer time to change to another alternative action, the point of no return, (Osman et al., 1986). From this instant on, the situation favoured the dominance of the dorsal stream, which operates relatively quickly (Van der Kamp et al., 2008). The graphs of horizontal force represented in Figure 2 show that in the uncertainty condition, the peak value, reached at the middle-late phase of the movement, is lower and delayed in regard to the no-uncertainty condition. However, there were no significant differences between the two situations with regard to the mean horizontal velocity at the end of the acceleration phase, where the horizontal force became zero.

Conclusion

This research indicates that the confidence in events occurring as programmed before executing a lunge in fencing affects the temporal parameters of the reaction response and the velocity of execution. The results show that the reaction time and the movement time increase when doubts arise about being able to reach the target as planned during the lunge.

No differences in horizontal velocity of the CoM were found at the end of the acceleration phase, because uncertainty disappears when the fencer perceives that the target will be reached. This occurs at the end of the movement, when the possibility of switching to another action is no longer possible, i.e. after the point of no return. However, the mean horizontal velocity decreases by the effect of uncertainty due to the possibility that the events might not occur as planned.

These results highlight the importance that tactical intent plays in fencing in successfully predicting the defensive movements of an opponent before an attack. Therefore, the prediction made by the tactical component will determine the processing time and the execution velocity during the lunge.

References

Borysiuk, Z. and Waskiewicz, Z. (2008) Information processes, stimulation and perceptual training in fencing. *Journal of Human Kinetics* **19,** 63-82.

Czajkowski, Z. (2009) Tactics in fencing – Preparatory actions. *Studies in Physical Culture and Tourism* **16(4),** 371-377.

de Leva, P. (1996) Adjustments to Zatsiorsky-Seluyanovs segment inertia parameters. *Journal of Biomechanics* **29(9)**, 1223-1230.

Desmurget, M. and Sirigu, A. (2009) A parietal-premotor network for movement intention and motor awareness. *Trends in Cognitive Sciences* **13(10)**, 411-419.

Do, M.C. and Yiou, E. (1999) Do centrally programmed anticipatory postural adjustments in fast stepping affect performance of an associated “touché” movement?. *Experimental Brain Research* **129**, 462-466.

Duque, J., Lew, D., Mazzocchio, R., Oliver, E. and 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. and Cohen, J.D. (2009) Sequential effects in two-choice reaction time tasks: Decomposition and synthesis of mechanisms. *Neural Computation* **21(9)***,* 2407-2436.

Glover, S. (2004) Separate visual representations in the planning and control of action. *Behavioral and Brain Sciences* **27,** 3-78.

Goodale, M.A., and 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. and Campos, J. (2006) The effect of muscular pre-tensing on the sprint start. *Journal of Applied Biomechanics* **22(3)**, 194-201.

Gutiérrez-Dávila, M., Rojas, F.J., Antonio, R. and Navarro, E. (2013a). Effect of uncertainty on the reaction response in fencing. *Research Quarterly for Exercise and Sport* **84***,* 16-23.

Gutiérrez-Dávila, M., Rojas, F.J., Caletti, M., Antonio, R. and Navarro, E. (2013b) Effect of target change during the simple attack in fencing. *Journal of Sports Sciences* **31(10),** 1100-1107.

Gutiérrez-Dávila, M., Rojas, F.J., Antonio, R. and Navarro, E. (2013c) Response timing in the lunge and target change in elite versus medium-level fencers. *European Journal of Sports Science* **13(4)**, 364-371.
Ivanoff, J., Branning, P. and 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.
Milner A.D. and Goodale, M.A. (1995) The visual brain in action. Oxford: Oxford University.
Osman, A., Kornblum, S. and 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.
Robertson, D.G.E., Caldwell, G., Hamill, J., Kamen, G. and Whittlesey, S.N. (2004) *Research Methods in Biomechanics.* Human Kinetics. Champaign, Illinois.
Sanderson, F.H. (1983) The effect of directional uncertainty on reaction time and movement time in a fencing task. *Journal Sports Sciences* **1(2)**, 100-105.
Schluter, N.D., Rushworth, M.F., Passingham, R.E. and 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. and Lee, T.D. (2011) *Motor control and learning: A Behavioral Emphasis.* 5TH edition. Champaign, IL: Human Kinetics.
Stein, J.F. (2008) Factors influencing the initiation, performance and precision of the hit in fencing. In: *Proceedings of the 1st International Congress on Science and Technology in Fencing, Barcelona, Spain.* Ed: Iglesias, X. 7-13.
Ungerleider, L.G. and Mishkin, M. (1982). Two cortical visual systems. In: *Analysis of visual behavior*. Eds: Goodale, M. and Mansfield, R.I. Massachusetts Institute of Technology Press, Cambridge, MA.
Van der Kamp, J., Rivas, F., Van Doorn, H. and 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. and Walmsley, A. (2000) Response amendment in fencing: Differences between elite and novice subjects. *Perceptual and Motor Skills* **91(1)**, 131-142.
Zatsiorsky, V.M. and Seluyanov, N.V. (1983) The mass and inertial characteristics of the main segments of the human body. In: *Biomechanics VIII-B.* Eds: Matsui, H. and Kobayashi, K. Champaign, IL: Human Kinetics. 1152-1159.

Key points

- Reaction time (RT) and the movement time (MT) increase when doubts arise about being able to reach the target as planned during the lunge.
- The horizontal velocity of the lunge decreases by the effect of uncertainty due to the possibility that the events might not occur as planned.
- These results highlight the importance that tactical intent has in fencing for successfully predicting the defensive movements of the opponent during the attack.

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