The ability to correct an on-going action: Accuracy and correction time in elite fencing

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background and Study Aim: Performing an attack in fencing takes fractions of a second implying that there is little time to correct an on-going movement to anticipate the opponent's action. Studies in the lab evaluated correction times in artificial tasks but stand in shrill contrast to elite sports where via extensive training, motor programs are mastered and perfected. This study aim was to expand the knowledge on the capability of elite fencers to correct an on-going attack on a central target when the target suddenly changes position at random time intervals.

Material and Methods: Eight elite fencers (7 males, 18.3 ±4.66 years) performed a *fente* at a target as fast and accurate as possible. In 80% of the trials, a new target light was lit during the *fente*, and the fencers had to adjust their movement to hit the new illuminated target. Correction times were set at 100ms, 170ms, 240ms, 310ms or 380ms before the estimated *epee*-target contact. The number of successful adjustments and the radial error was reported.

Results: With increasing correction times (p<0.01), radial error decreased. Based on the correction times, the inflexion point was determined at 277ms. It was demonstrated that correction time influenced the number of adjusted trials (p<0.01). Fencers were able to adjust more trials when correction times were set at 310ms and 380ms (p<0.01).

Conclusions: Correction times in humans, which are often measured in laboratory settings, appear to apply for sports situations as well. A quarter of a second is sufficient to correct an on-going movement in which the whole body is involved subtle but effectively when the target unexpectedly changes position.

Keywords: epee • feint • *fente* • foil • motor control • on-going attack • prise de fer

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Epee – fencing sword with triangular blade and large bell guard.

Fente – or lunge refers to the attack which is performed by extending the rear leg while landing on the front foot.

Feint – a feint aims to initiate a reaction from the opponent. It is an attacking movement in all but its continuance.

Foil – the blunt-edged, light fencing sword.

Prise de fer – the movement in which the fencer takes the opponent's blade into a line and holds it there in preparation to attack.

INTRODUCTION

Humans are natural born movers, whether it is the simple task of picking up a cup of coffee or the more complex task of kicking a ball to a goal. Given that many movements have extensively been practised extensively, a *blueprint* or motor programme of the particular movement has been developed in the central nervous system [1, 2]. A motor programme refers to a series of memory stored motor commands which are pre-structured at the executive level [1, 3]. However, often the motor programme is not well fit the action we wish to undertake, or suddenly the dynamics of the context necessitate an adjustment which forces us to correct the on-going movement. The time to correct the on-going movement is also referred to as correction time. Paulignan et al. [4] reported in 1991 that it takes nearly 100ms to make the first corrections to an unexpected movement of the target when performing a transport and grasp task, but it takes another 275ms to effectively move the hand in the new direction of the target. Brenner and Smeets [5] demonstrated that in simple motor tasks such as pointing to a target, 100ms to 200ms is enough to make corrections which concurs with the findings of Prablanc and Martin [6] who reported that one could adjust his pointing movement within 155ms to an abrupt movement of the target. However, most studies performed in the lab made use of artificial tasks which can be learned in a short time span and only involve a part of the body. In contrast, elite sports skills involve the whole body and movements are learned and optimised through extensive training. In fencing, for example, the more body mass is involved in the action, the more the inertia of this moving mass will influence the correction of the action.

Fencing is a fast-moving, open skill combat sport that is characterised by sequences of short high-intensity movements, spaced by periods of low intensity and recovery [7]. The elite fencer is obliged to follow offensive and defensive kinetic patterns in which accuracy, fast reaction capacity and visual motor coordination are essential for performance [8]. Similar to fastball sports such as tennis, table tennis or baseball, there is only a very short time interval to prepare a correct motor response to anticipate the opponent's action [9-11]. The execution of an attack only takes fractions of a second [12]. Performing a *fente* in competition, for example, takes about 540ms [13]. When the opponent initiates a countermovement at 200ms after the onset of the attack, is it still possible to correct the on-going attack?

Accordingly, Roi and Bianchedi [14] suggested that the quickness of a fencer's movement in response to the opponent's actions is one the most important characteristics of elite fencing. Controlling and correcting of actions is therefore often of paramount importance. For example, the opponent feints to attack the fencer's arm whereon the fencer will anticipate with an appropriate counterattack. In the meantime, however, the opponent already corrected his attack by taking the foil of the fencer with a *prise de fer* and places a hit on the chest of the fencer before the fencer could realise what has happened. In sports such as fencing or boxing, it is therefore essential for the athlete to think a few steps ahead to respond, anticipate and correct as quickly and as accurately as possible to the behaviour of one's opponent [7]. When a fencer has less time to correct his attack, the faster he has to perform his action. Consequently, increasing the speed of the movement will inevitably compromise the accuracy of the attack, according to Fitts' [15] law of speed-accuracy trade-off [1, 3, 16].

Nevertheless, literature is scarce regarding what extent humans can correct on-going movements, in tasks involving the whole body. The study aim was to expand the knowledge on the capability of elite fencers to correct an on-going attack on a central target when the target suddenly changes position at random time intervals. A group of elite fencers was therefore examined on their capability to correct an on-going attacking action to a central target when the target suddenly changes position at random time intervals. First, correction times of fencers in a real task are compared to correction times in laboratory tasks. Furthermore, it is hypothesised that with decreasing correction time, the accuracy of the action and the amount of successfully adjusted actions will decrease.

MATERIAL AND METHODS

Participants

For this study, eight elite epee fencers (7 males and 1 female) were recruited. Four of the fencers were left-handed while the four others were right-handed. All fencers were competing in national, European and world-level tournaments. The participants signed informed consent prior

Table 1. Specific characteristics of the participants.

Variable	Mean	SD
Age (years)	18.3	4.66
Weight (kg)	67.9	7.90
Length (cm)	180.3	5.39

to the start of the tests, which were approved by the ethical committee of the Ghent University Hospital. Specific characteristics of the fencers are presented in Table 1.

Procedures

Task

The task required the participants to perform a *fente* at the central target as fast and accurate as possible. *Fente* in fencing refers to a lunge, which is performed by stretching the attacking arm so that the fencer can aim at the central target, followed by kicking the front foot forward and pushing the body forward with the hind leg. However, in 80% of the trials, a new target light was lit (below, above, on the left or the right of the target) during the movement. In such occasion, the fencer had to suddenly correct his/her action as accurately as possible to hit the new target. Participants were required to perform 10 series of 10 trials resulting in 100 trials. In total, there were 25 different conditions consisting of five different time intervals and five different targets. Trials were divided into clusters of 50 trials in which each condition was randomly presented two times. The theoretical time intervals or correction times were 100msec, 170msec, 240msec, 310msec and 380msec. Correction time refers to the time between the lighting of the LED in a target and the striking of the target (Figure 1); see *Protocol* for the calculation of the individual delay times.

Apparatus

The participant was asked to stand on a wooden plate in front of a board with five targets (Figure 2). The front foot was placed on a pressure sensor which was embedded in the wooden plate. This light sensor registered when the front foot left the plate when performing an action, e.g. when performing a *fente*. The wooden plate could be placed closer or further from the target to create a comfortable distance for each participant to perform a *fente*.

The target board consisted of five different targets. One was placed in the middle, and the four others were placed above, underneath and one on each side of the middle target respectively. Each target consisted of a black centre. The middle target comprised of 10 concentric circles around the centre while the side target consisted of eight concentric circles. Starting from the inner circle, the radius of each concentric circle increased with 1 cm. The centre was a little larger than the circles since this was the intended target for each *fente*. In the centre of each of the four surrounding targets, a power LED-light (Luxeon Star White) was placed, controlled by a computer. In front of the target board, a plate of Plexiglas was mounted for protection. Also, the construction was suspended so that it could be lowered or heightened in stages of 10 cm to match the participant's profile.

An accelerometer [8302 A (x) S1 (K-Beam), Kistler] was attached to the back of the target board to measure impact and time of the strike. The accelerometer, foot sensor and lights in the targets were connected to a black box PCIMDAS1602/16, in turn, connected to a computer which allowed measuring movement time and impact force of the *fente*. Furthermore, using Labview 7.1, it was determined which light and with which time interval one of the surrounding targets would be lit (correction times: 100msec, 170msec, 240msec, 310msec and 380msec). However, a LED was only lightened when a

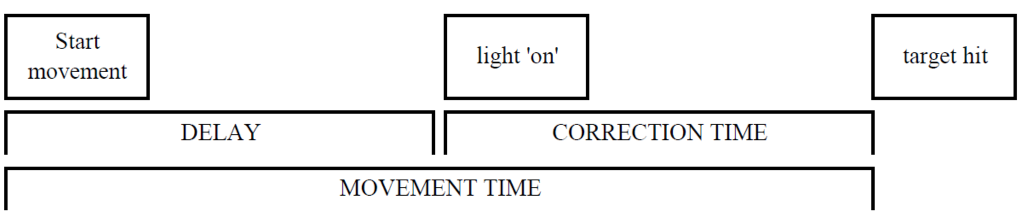

Figure 1. A systematic overview of the delay, correction time and movement time.

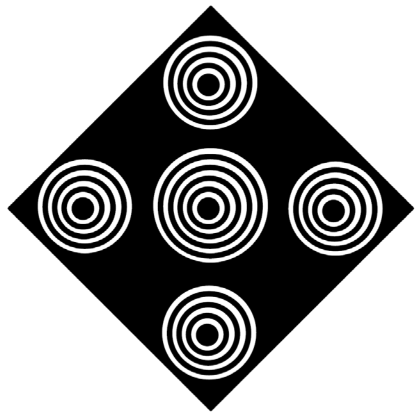

Figure 2. The target, consisting of five of once middle target and four peripheral targets.

participant had initiated his action, and his foot left the foot sensor.

Two Sony handy cams (Sony DCR-HC 19E PAL, 50 Hz) were used to record the performance of the fencers. The first camera recorded the fencer in the sagittal plane for evaluation of the *fente* attack, while the other camera (camera 2) was used to film the target for product scores.

Protocol

Prior to the actual test, participants were allowed to perform a couple of practice trials to get accustomed to the task demands. Then each participant was required to strike ten times as fast and as accurately as possible at the centre of the middle target to measure the mean movement time for a *fente* without choice. The mean movement time, therefore, refers to the time between lifting the front foot from the pressure sensor and the impact of the tip of the foil. Based on these practice trials, it was concluded that 150ms needed to be added to the meantime to create a mean movement time with different choices. The mean movement time, with the addition of 150ms, was used to calculate the delay (time between the start of the movement and lighting of a LED) for each correction time in each condition. For example, in a slower fencer, the light had to be lit later to acquire the same correction time (larger delay; see Figure 3a) while in the fastest fencers, the light had to be lit sooner to acquire a similar correction time (smaller delay; see Figure 3b).

Data analysis

Dependent variables

Based on the images from the witness camera, the following product scores for each trial could be calculated: (1) the radial error, (2) whether the participant attempted to 'adjust' his trial. For the radial error, the horizontal (ΔX) and vertical (ΔY) distance from the point of impact to the target were used to calculate the radial error (Magill, 2007) (Figure 4). A trial was categorised as 'adjusted' if the point of impact was more than 8.32cm (mean radial error ±2 SD in the trials without a peripheral light being lit) away from the centre of the middle target in the direction of the illuminated target. Once the mean radial errors for each correction time were calculated, a 3rd degree polynomial was fitted to the data, resulting in a function f(x) of which the inflexion point, i.e. the moment where the change in radial error in function of the time interval is highest,

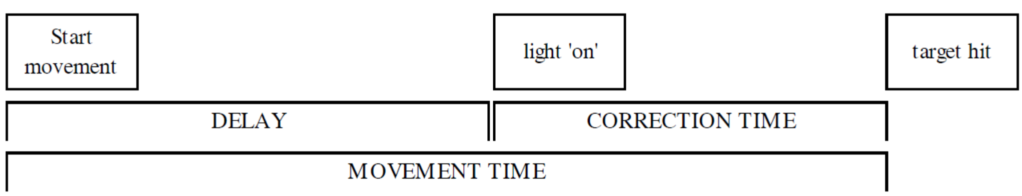

Figure 3a. Schematic overview of delay and correction time with lower movement time in a slower fencer.

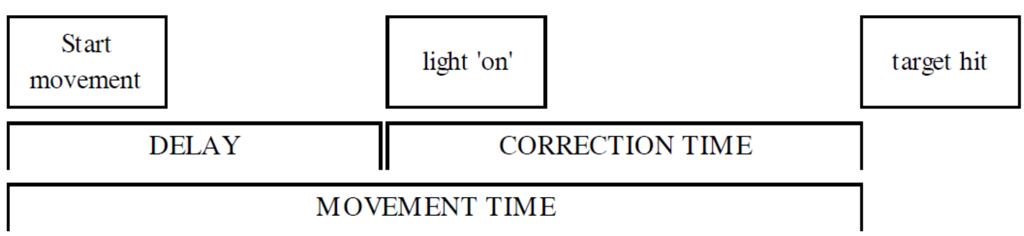

Figure 3b. Schematic overview of delay and correction time with higher movement time in a faster fencer

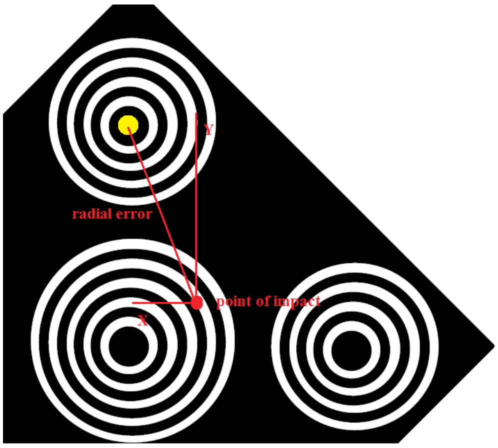

Figure 4. Visual representation is representing the calculation of the radial error. The yellow point represents a LED light, indicating the new target. The redpoint refers to the point where the fencer hit the target.

could be determined.

Movement time was defined as the time interval between the release of the subject's foot from the surface and the impact on the target. Based on the real movement time, the real correction time was estimated for each trial (real movement time – delay).

Statistical analysis

Statistics were performed using IBM SPSS Statistics 20.0. A 5 × 5 repeated measures ANOVA (5 light conditions × 5 correction times) was used to examine the differences in radial errors and adjusted trials. Significance levels were set at $p \leq 0.05$.

RESULTS

The results of the ANOVA indicated that the radial error decreased with increasing correction time ($F = 46.22$, $p < 0.01$) (Figure 5). Fitting a polynomial to the data yielded the following function: from which the radial error could be calculated based on the correction time. This function has an explained variance (R^2) of 0.9946 which implies that 99% of the difference in radial error can be explained by the difference in correction time. To calculate the inflexion point, the derivative f'(x) of the function f(x) was used, and the zero-point of f'(x) was determined at 277 ms.

The radial error for the condition in which the participants did not have to adjust their attack (no light in a peripheral target), was significantly lower compared to the conditions in which the participants had to adjust their attack towards a peripheral light ($t = 3.289$, $p < 0.05$) (Table 2). Furthermore, there was no significant difference in radial error for dominant hand ($F = 1.910$; $p = 0.216$). Some fencers noted that there was visual obstruction due to the bell guard of the foil when a light was lit at the side of the hand holding the foil. However, no significant influence was found on the horizontal radial error (left or right) ($F = 2.46$; $p = 0.168$) when a light was lit at the respective side. Also between the first part of 50 trials and the last part of 50 trials, no significant difference was found in radial error ($t = 1.079$; $p = 0.286$).

Correction time was shown to significantly influence the number of adjusted trials ($F = 16.590$; $p<0.01$) (Figure 6), e.g. the number of adjusted movements increased with increasing correction time. Especially the correction time conditions 310, and 380ms have significantly more adjusted trials compared to the three other conditions ($F = 98.177$; $p < 0.01$) since the inflexion point was situated around 270 ms. There was no significant difference in the number of adjusted trials between the different lights ($F = 1.162$; $p = 0.411$).

Table 2. Mean radial error (cm) and SD for the condition without a light (middle) en for the condition in which a peripheral light was lit.

Target	Radial error (cm)
Peripheral	13.7 ±6.10
Upper target	14.1 ±6.94
Lower target	13.9 ±6.33
Left target	14.0 ±5.44
Right target	12.8 ±5.70
Middle	4.9 ±1.71

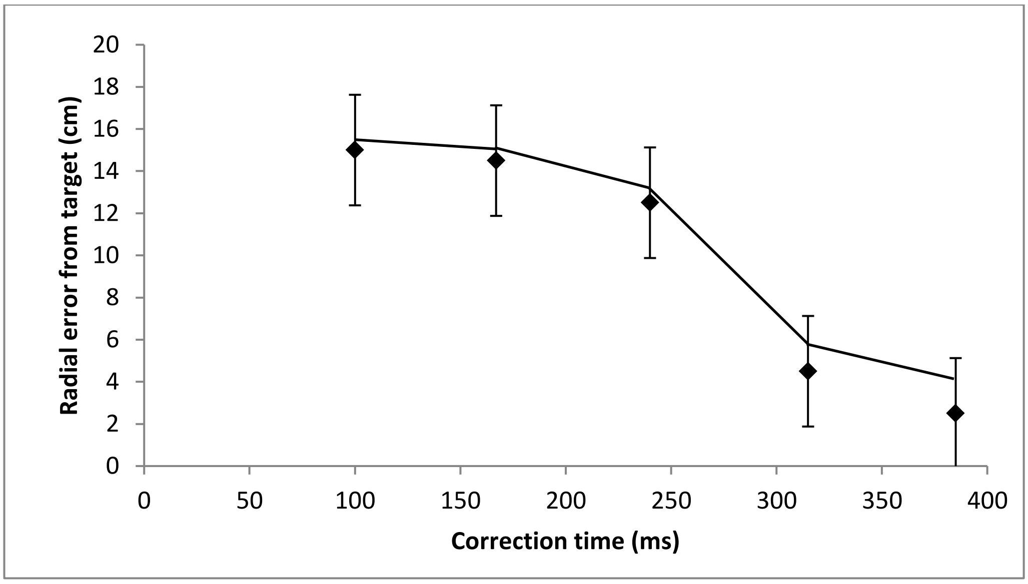

Figure 5. Radial error as a function of correction time.

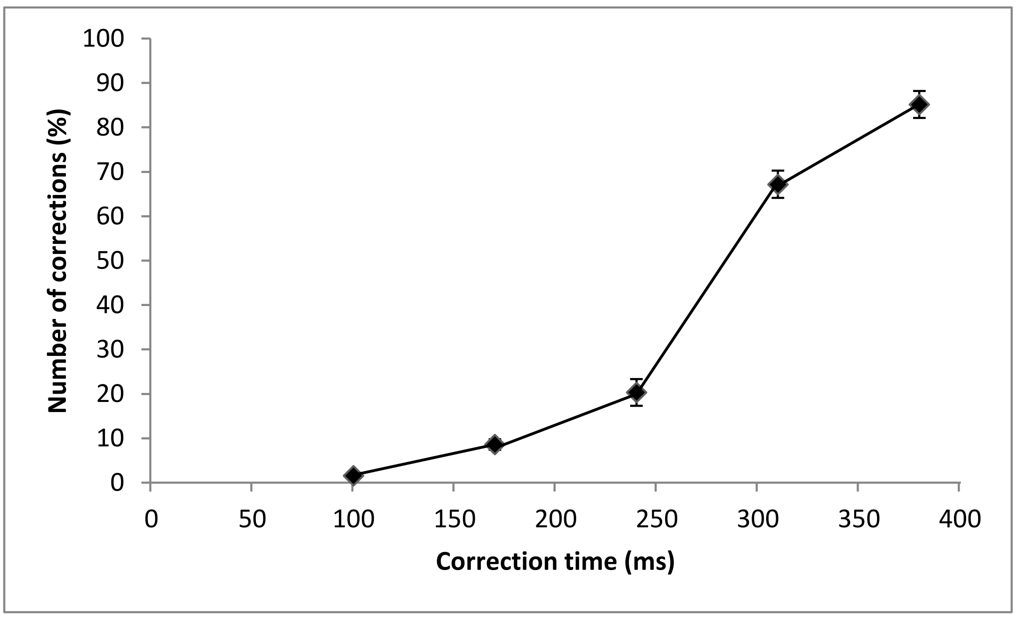

Figure 6. A number of successful corrections as a function of correction time.

DISCUSSION

In this study on the ability of elite fencers to correct an offensive action, the location of the target (five directions) and correction times (five correction times) randomly changed in 80% of the trials after the fencer had initiated the *fente*. The results demonstrated that when a new target illuminated 100ms before the tip of the foil would hit the original target, almost no correction was possible. There was only time for the fencers to realise their action would not be successful. The number of successful corrections only slightly increased for the trials with longer correction times of 170ms (8.5%) and 240ms (20%). Since it has been demonstrated that in simple motor tasks, correction of an on-going movement such as pointing to an abruptly changing target, based on visual feedback could be made within 100ms to 155ms [5, 6], our results demonstrated that when the whole body was involved in the attacking action, correction times increased.

The findings of the current study are therefore consistent with Anson premotor time (PMT) [17] who reported that an increase in the moment of inertia effectively increased simple reaction time and motor time when performing a rapid arm movement, influencing the overall response initiation time. In line with our hypothesis, the number of successfully corrected *fentes* to the target increased with increasing correction time. When the correction time increased up to 310ms, 67% of the attempts were successfully corrected, and for 380ms, elite fencers successfully corrected their *fentes* towards the new target in 85% of the trials. It appeared that the deflection point for this kind of tasks is situated around 277ms, which implies that more than 50% of the attacks can successfully be corrected when the tip of the foil is 277ms away from the target. It can, therefore, be concluded that a time span of 270ms is sufficient to perceive the new situation, to decide which corrections need to be made and to send the appropriate stimuli to the muscle groups involved in the action (Figure 6). Furthermore, the results demonstrated that elite fencers were able to adjust their attack towards the different peripheral stimuli equally well. Furthermore, there was no significant difference between right or left handed fencers [15].

According to the speed-accuracy trade-off [18], when an action needs to be corrected as quickly as possible, this will cause the accuracy of the action to decrease. In line with the expectations, the target was hit more accurately when there was more time to correct the on-going action to the new target. While fencers were able to stab the tip of the foil within a circle of 5cm around the centre of the target when no correction was required, the radial error increased almost threefold when corrections needed to be made very quickly (100ms) (Figure 5). The performance of a fencer who has to adjust his action within a split-second will, therefore, be less accurate the faster the adjustment needs to be made, which is extremely relevant regarding the feinting of movements.

Given that in fencing, movements are performed extremely fast, and accuracy of the action decreases with increasing speed, early recognition of the target area of an opponent's attack can, therefore, be expected a key factor for performance [11]. Indeed, elite fencers can extract significantly more information from the opponent's actions and use that information to anticipate the direction of their attack. Excellent anticipatory skills can thus be considered a factor for success and training [19, 20]. Given that performing a *fente* takes about 539ms and an opponent starts executing a countermovement after 200ms, it is possible for highly skilled fencers to correctly adjust their attack. Future research might aim to explore in detail which areas of the opponent's body are looked at during attacking initiation or preparatory phase in close temporal manner.

The current findings also provide valuable insights and implications for the detection of talent. Skills such as reaction time, accuracy, speed, and the ability to adjust/correct actions measured in the lab are essential properties for competition fencers and they might provide an indication of talent, especially since coaches have indicated that the ability to counter an opponent's attack and the quickness to perform those actions can be regarded as one the most important characteristics in high-level fencing [14]. Although measurement of reaction time and correction time in the lab is cheap and easy to administer, laboratory-conditions significantly differ from a competition setting in which arousal might have influenced our results. During the competition, heart rate and stress will increase while in the lab both factors are most likely less pronounced.

CONCLUSIONS

The current study demonstrated that correction times in humans, which are often measured in laboratory settings, appear to apply for sports situations as well. A quarter of a second is sufficient to correct an on-going movement in which the whole body is involved subtle but effectively when the target unexpectedly changes position. Fast and adequate responding to sudden changes in the game situation is also for other sports an essential characteristic for successful performance.

HIGHLIGHTS

- The capability of elite fencers to correct an on-going attack was evaluated.
- With increasing correction times radial error decreased.
- Correction time influenced the number of adjusted trials.
- A quarter of a second is sufficient to successfully correct on-going actions in 50% of the trials.

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