Chapter 1

Introduction

Background of the research

In its early days, fencing was looked upon as the domain of high society, an aristocrat among sports of European origin around the 12th century or earlier. During that period of time, France, Italy, Spain, and Germany had developed their own characteristic fencing techniques. It was one of the four disciplines at the first 1896 Summer Olympics and has been featured at every Olympics since then. In modern competitive fencing, three weapons (foil, épée and sabre) are discriminated by the manner and target area specified by the rules. In foil and épée, the objective is to hit the opponent with a thrust; in sabre, with a cut or thrust. The use of foil and sabre is controlled by agreed-upon rules such as priority rules to determine which fencer's hit will prevail when both fencers have hit. Épée, however, has retained within its sport framework much of the duelling nature of its origin.

Starting with épée in the 1930s, an electrical scoring apparatus was invented to replace the side judges, and its emergence led a so-called fencing revolution in fencing techniques and tactics because it reduced the bias in judging, and permitted more accurate scoring of faster actions, lighter touches, and more touches to the back and flank than were possible with human judges. Take épée fencing for example, a slight force of at least 7.35 newtons (750 grams) fully depressing on the point of blade for 1 ms allowed a hit to be registered by the scoring machine. Since the scoring "touch" required almost no power behind the blow, the essential demands for fencers to survive in the competition focussed more on manipulation of distances between self and the opponent, and preparation of unpredictable timing to the opponent to act, namely, to execute appropriate techniques with refined hand-foot coordination and precision of finger control aiming the target.

Also thanks to the popularity of video camera and the efforts of FIE (International Fencing Federation) to promote fencing throughout the world, techniques and tactics were no longer secrets belong to the few elite. Nowadays, it is not only Europeans reign supreme on the podium places; Asian fencers also have reflected surprising progress and won many shining titles in world championships and Olympics.

Successful techniques and tactics were built on fencer’s ability to sense the subtle differences and changes in rhythm and distance between self and the opponent in split time. How could they match the severe spatio-temporal constraints in such a complex and dynamic situation in which they had to hit the opponent but simultaneously avoid being touched? Fencing coaches are always keen to explore this question due to the kinds of information detected by fencers would influence their subsequent occurring actions instantaneously, and thus their individual techniques and tactics system were constructed accordingly.

The theory of direct perception proposed by the ecological psychologist Gibson (1961) stated that organism would interact with the whole environment consciously and unconsciously by perceiving the information in the environment and acting correspondingly, which could be referenced explicitly in discussion of sports of open skill such as fencing; that is, fencers all the time act with reference to perception of the opponent’s actions. Moreover, what caused their responding actions to occur? Newell’s (1986) triangular constraints model provides an eligible perspective, for it suggested that complex forms of motor behavior could be viewed as products of self-organization arising from interactions between task, environment and organism constraints. For example, in order to put himself out of reach, fencer should be moving backward earlier or faster than usual when confronting with a taller opponent, the difference of movement initiation could be the result of interaction of organism (relatively shorter height) and task (to escape from the opponent) constraints.

Significance of the study

In most researches related to fencing, several specific topics have received much attention, such as effect of target choice on accuracy, reaction time (RT), movement time (MT), total response time (RMT) of the single or combined movement of upper limbs (arm pointing the target) and lower limbs (step, lunge, or combined footwork) by qualitative or quantitative analyses of the electromyographic activity (EMG) of selected muscles under different target choices (Del Rey, 1972; Sanderson, 1983; Williams & Walmsley, 2000); the relationship of muscle strength, power and movement performance (Sapega, Minkoff, Valsamis & Nicholas, 1984; Wang & Shiang, 1997; Cronin, McNair & Marshall, 2003); the relationship of accuracy, RT, RMT, and tournament success by correlative analysis (Singer, 1968; Ketlinski & Pickens, 1973; Klinge & Adian, 1983; Harmenberg, Ceci, Barvestad, Hjerpe & Nyström, 1991); and the relationship of movement kinematics parameters and anticipatory postural adjustment (APA) (Yiou & Do, 2001; Yiou, Schneider & Roussel, 2007; Natta & Nouillot, 2004).

However, in addition to basic demands such as accuracy, short RT or muscle strength, a great deal in fencing depends on being in the right place at the right time, which could be achieved solely via fencer’s refined sense of distance and time relative to the opponent. Fencer's depth perception was influenced by the opponent's moving direction significantly when the task was to perceive self's attack length (lunge length) with a hand-held object (Chen & Liu, 2007); as for perceiving the opponent's lunge length oppositely, opponent's velocity had more crucial effect than height (Chen and Liu, 2008). Yet those were all findings in the conditions requiring one-sided task merely and couldn't provide insight of mutual relationships between fencers in real bout fencing. Under the circumstances when fencers had to perceive and act simultaneously, they needed to observe, get familiar with the opponent's movement length, velocity, and initiation timing extremely quickly and then make best use of it when executing his/her movement tactically. How were those perceptions influenced mutually were of interest and deserved further studies in order to provide the basic understandings of movement kinematics in duel of fencing.

The purpose of study

The purpose of the study was to investigate the mutual relationship of distance, timing and speed between fencers, which were the essential factors in depth perception and time perception; and furthermore, to discuss the footwork pattern applied under different conditions and eventual win-loss outcomes; hopefully to provide another point of view examining the phenomenon of combat sports such as fencing.

Overview of the design of study

Lunge is the most frequently used form of concluding an action such as attack (Szabo, 1977), and its length is about 80 cm for a 175-cm male fencer; along with an extra step forward, the fencer is able to move forward in about 100 cm or more in total. Three different initial distances spacing fencers apart were 90, 100, and 130 cm, respectively. Tasks regarding to attack or defend (not reacting with any hand skills but retreating by footwork only) were designated to fencers in turn. The attack initiator self-triggered the two-step forward movement to reach the opponent, and the opponent, namely, the defender, tried to escape from the attack movement and be ready to begin his attack for reaching the original attack initiator if his escape from the initial attack was successful.

Research questions and hypotheses

There were five parts of research questions:

1. Did initial distance and the role of the dueling pair have an effect on the outcome of the performance?
2. Regular forward step and crossover step were two distinguishable step patterns applied while executing the two-step forward movements. Did the initial distance between the fencers have an effect on which step pattern to use? And, what would be the relation between the performance outcome and the choice of step pattern?

Then, three essential factors related to depth perception and time perception, that is, distance, timing and velocity, aroused the questions as follows:

3. Did the initial distance between fencers have an influence on the relative timing of fencers' movement initiation? And, what would be the relation between the relative initiation timing to the performance outcome?
4. Did the initial distance between fencers have an influence on the spatial error of attack when the attack was not successful? And, what would be the relation between the spatial error and the maximum movement velocity?

5. Did the initial distance between fencers affect the maximum movement velocity of the fencer, time to maximum movement velocity, and relative time of maximum movement velocity between fencers? And how did these parameters relate to the performance outcome?

The research hypotheses corresponding to the research questions were noted as following:

1. The outcome of the performance would be influenced by the initial distance and the role such as attack initiator or defender between dueling fencers.
2. The initial distance between the fencers would have an effect on which step pattern to use. When fencers were standing apart in longer distances, crossover step would be applied more often in order to create longer displacement to touch the opponent successfully.
3. The initial distance between fencers would have an influence on the relative timing of fencers' movement initiation. And, greater relative timing of fencers' movement initiation would bring the advantage for the attacker to touch the opponent.
4. The initial distance between fencers would have an influence on the spatial error of attack when the attack was not successful. And, greater spatial errors would be occurred when the maximal movement was higher.
5. The initial distance between fencers would affect the maximum movement velocity of the fencer, time to maximum movement velocity, and relative time of maximum movement velocity between fencers. The greater maximum movement velocity of the attacker, greater the time to maximum movement velocity; smaller

relative time of maximum movement velocity between fencers would be more likely to result in the success of attack.

Operational definitions

The following terms were utilized and defined for the purpose of this research study:

1. Fencing preparatory standing position (on-guard position) and footwork:

1.1 On-guard position:

In the on-guard position, the body rests naturally and equally on two legs. The trunk is rotated in such a way that the angle between the shoulder axis and the moving upper limb was approximately 130°. Feet are spread about two foot lengths apart, and the legs bent at the knees (by approximately 140°) to the extent that the fencer remains stable and mobile. The arm holding the weapon is bent at elbow at approximately 120°; free arm is relaxed alongside the body.

1.2 Step forward:

The movement starts with the front foot by pointing forward and the sole close to the floor. When the front foot contacts the floor, the rear foot should advance, and then both feet finish moving at approximately the same time with moving an equal distance.

1.3 Step backward:

It starts with the rear foot by moving backward with the front foot pushing to support the movement. Also, it should finish simultaneously and cover an equal distance.

1.4 Crossover step forward:

The crossover variations of forward and backward steps are variations of everyday walking, but done in on-guard position. It starts with the rear foot, which is placed in advance of the front foot, and the step completed by replacing the front foot in its original forward position to take up a normal on-guard position.

1.5 Crossover step backward:

It starts with the front foot, which is placed behind the heel of the rear foot, and the step completed by replacing the rear foot in its usual position to take up a normal on-guard position.

1.6 Lunge:

The lunge is the usual foot movement used to terminate an attack. It starts with the front foot. The toes are lifted and the front swings forward with an extension on the knee. The front heel advances, skimming the floor, as the rear leg pushes with a vigorous extension of the knee.

1.7 Step forward lunge:

It is a compound footwork made up of step forward and lunge.

2. Initial relative distance between participants:

There were three starting conditions spacing participants apart by 90, 100, and 130 cm (near, mid, and far condition), which were the initial relative distance between two participants’ toes while they were facing each other.

3. Movement phase:

The whole sequence of the movement could be divided into two phases, the first one (1st phase) was when the attacker initiated movement and the defender retreated, and the second one (2nd phase) was when the original attack initiator retreated and the original defender attacked after a draw in the first phase.

4. Performance outcome:

For each participant, four performance outcomes are possible in each movement phase depending on the role of the fencer during that trial, namely, to attack or to defend. When designated as the attacker, the outcome of win (W) was determined when the participant touched the opponent, or it would be regarded as a draw (draw A) when he did not touch the opponent. When designated as the defender, the outcome of loss (L) or draw (draw D) would be determined depending on whether the participant was touched by the opponent or not.

5. Success rate:

A success in a trial is defined as either the attack initiator or the original defender touched the opponent on the return attack. Success rate was computed as the percentage of success trials measured for a situation over the corresponding total trial measured in that situation (number of success trial / number of total trial × 100%).

6. Rate of using crossover step:

Rate of using crossover step was computed as the percentage of trials when crossover step forward was applied for a situation over the corresponding total trials in that situation (number of trial of crossover step applied / number of total trial × 100%).

7. Relative timing of movement initiation:

The defender was asked to trigger the retreat movement after the attacker initiated the movement. As a consequence, the relative timing (RelTiming) of participants' movement initiation was the timing difference between their movement initiations derived from the timing of the defender's movement initiation minus that of the attacker's.

8. Spatial error of attack distance:

An attack error was identified when attack initiator did not reach the defender within two forward movements in the 1st phase, which could be divided into two conditions based on the performance outcomes of the 2nd phase, that is, draw- and loss-outcome to the attack initiator. The spatial error of attack distance was derived from computing the relative distances between the attacker's index finger and his target, namely, the defender's neck.

9. Maximum movement velocity:

Maximum movement velocity was the maximum of the velocity (MaxV) of the participants during each movement phases.

10. Time to maximum movement velocity:

Time to maximum movement velocity (T to MaxV) was computed as the percentage of time to maximum movement velocity over the total time of the corresponding phase (time to maximum movement velocity / total time of the corresponding phase × 100%).

11. Relative maximum movement velocity:

Relative maximum movement velocity (Rel MaxV) between participants was the difference of maximum movement velocity (MaxV) between participants derived from maximum movement velocity of the defender minus that of the attacker.

12. Relative time of maximum movement velocity:

Relative time of maximum movement velocity (RelT of MaxV) was the time difference between participants' maximum movement velocity (MaxV) derived from the time of the defender's maximum movement velocity minus that of the attacker's.

Chapter 2

Review of literature

The perspective of direct perception vs. traditional information-processing theory

The study of perception is the study of an animal knowing its environment, while theory of perception can be divided into two main categories, direct and indirect perception. Direct perception, proposed by ecologist James Gibson (1979), is a contrast perspective of traditional cognitive psychology, namely, the indirect perception. The main philosophical difference between these two categories is that do we necessarily need the internally represented systems to help us understand the world. Gibson's radical proposition was that we do not. He acclaimed that perceiving is a process in an animal-environment system, and perception is, quite simply, the detection of information, with no need of derivative intervention of memories or representations from cognitive processing system additionally, that was why the perspective was labelled direct.

Regards to information of the environment, Gibson proposed that "*information is structure that specifies an environment to an animal; it is carried by higher-order patterns of stimulation, neither points of light nor collections of such points (images), but, rather, complex structures often given over time, namely, invariants. And these patterns, or invariants, are information about the world*" (Michaels & Carello, 1981, p9). Conversely, the traditional information-processing perspective assumed that senses are provided with an impoverished description in the world, and stimuli must be processed otherwise they are meaningless. Put it easier, for the indirect view, perceptual richness is a result of processing carried out by the perceiver; as for the direct approach, the stimulation specifies the environment and no elaboration is needed (Michaels & Carello, 1981).

Furthermore, the notion such as perception of the accumulating discrete time-slices (instantaneous retinal snapshot of the external surrounding) was discarded in ecological perspective; on the contrary, it was noted that visual information is provided by the transforming optic array, namely, the occurring events of a period of time. For example, the static picture of a fencer standing in the on-guard position can be the instant before he/she starts a bout of fencing or after he/she recovers from a lunge movement, we need the next picture to determinate what happened to the fencer in the on-guard position, meaning that the single time-slide reveals insufficient and ambiguous information to the perceiver. However, if observing the fencer over a period of time, the on-guard position may exhibit how well he/she keeps his/her centre of mass in balance when he/she moves back and forth. The information gained from the events over time includes the messages of both time and space adequately, then, can specify what happened to the fencer clearly. In sum, perception is of events, an ongoing activity of knowing the environment, not of objects isolated in time or space illustrated in Figure A (Michaels & Carello, 1981).

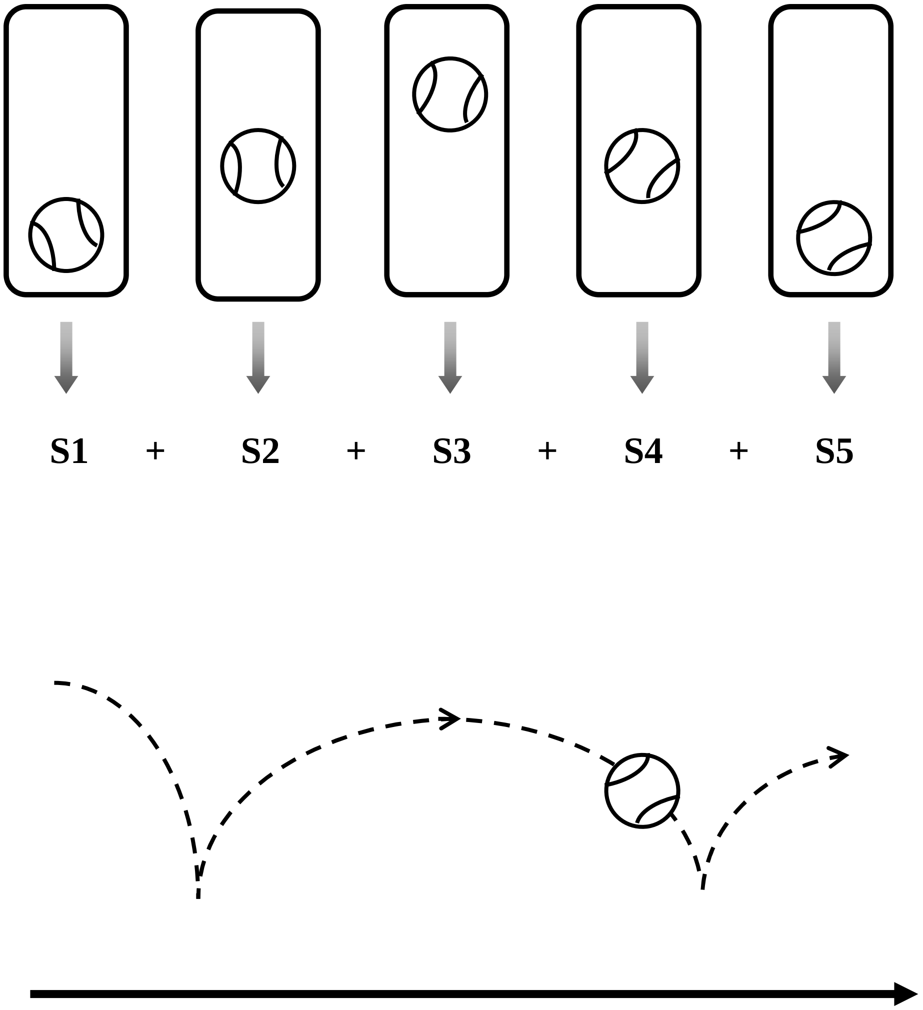

Figure A. The traditional (the upper panel) and ecological (the lower panel) approaches to events and stimuli (Michaels & Carello, 1981).

Another most-discussed distinction between these two perspectives is the relationship between the animal and the environment. In traditional psychology, an animal and its environment are thought of as logically independent; that is, the environment is animal-neutral; a perceiver is active in constructing his senses (Neisser, 1967), indicating that he is an active creator or elaborator of his perceptual experiences via information-processing in the brain. Such animal-environment dualism may limit the research findings because it lacks relevance to the biological organisms (Edelman, 1987) and neglects the goal-directed behaviour constrained by the environment (Newell, 1986). In the ecological approach, the animal knowing its environment is focused instead; therefore, physical laws constructing the relationship between the perceiver and the environment, and biological constraints of the perceiver become extremely important because they heavily influence the perception and action (Turvey & Shaw, 1979). "*A perceiver here is active in that he actively explores (look, feel, sniff, taste, and listen to) the contents of his environments, and is treated as a purposeful obtainer of the information, but not a passive recipient of information*" (Michaels & Carello, 1981, p15).

Two important characteristics of information.

In the direct perception camp, invariants and affordances are the key concepts. "*Invariants are the higher order properties from the surrounding energy flows which remain constantly available for pick-up, despite transformations associated with the perceiver and the environment*"(Williams, Davids & Williams, 1999, p193). That is, the higher order invariants are left unchanged despite of changes; they remain available to provide meaning, information. The concept of invariants relates to laws of physics in perceptual constancy, and can be quantified or described mathematically (Michaels & Carello, 1981). A melody is a simple example of an invariant pattern in time; in whatever key and tempo a song is played, a perceiver can always recognize it because the invariants of the song, a set of ratios and times and fundamental frequencies, remain constant.

Since information invariants reveal constant messages to perceivers, why perceivers differentiate in perceiving them? The concept of affordances can elaborate this difference explicitly.

"*The affordances of the environment are what it offers animals, what it provides or furnishes, either for good or ill*" (Gibson, 1979, p27). Let us adopt the evolutionary perspective to clarify the meaning of affordances. The information such as predators, food, or habitat sensitively detected by an animal via its attuned perceptual system helps the species survive in the stream of evolution (Michaels & Carello, 1981). Similarly, a perceiver detects the particular information by a properly attuned perceptual system for his actions; that is, affordances are the invitations to act, and they belong to the perceiver exclusively according to his perceptual outcome. Chen and Liu (2007) found that taller fencers performed longer lunge, which increasing the estimates of their imaginary reachability to the opponent.

Perception and action are coupling together tightly; perception is the act of directly picking up the transformational structural invariants in the environment in order to achieve a specific task (Gibson, 1979), and affordances for action are unique for each individual due to the personal characteristics interact with the perceptual system attuned to the invariants strongly. Therefore, the mutually interactive, or constraining, relationship between perception and action, or affordances and invariants cannot be neglected or separated.

In the present study, we applied the perspective of direct perception as the fundamental theoretical framework, whereas more interests were drawn in the space-time events of open-skilled combat sports such as fencing, and in the mutually constraining relationship between the perceiver and his environment (the fencer and his opponent).

Constraints model of Newell

Following Gibson's ecological perspective, Newell (1986) also proposed a constraints-led view to re-examine the development of coordination and action of children, which was traditionally couched in terms of maturation (Bower, 1974). In contrast of the early work of Gesell's (1929) charting, describing the chronological milestones in the emergence of infants' coordination behaviours, Kugler, Kelso, and Turvey (1980) argued that coordination emerges not from prescriptions for action but can be treated as a consequence of the constraints imposed on action. That is, "*constraints eliminate certain configurations of response dynamics, with the resulting pattern of coordination as reflection of self-organising optimality of the biological system, rather than specifications from some perspective symbolic knowledge structure*" (Newell, 1986, p342). As illustrated in Figure B, three categories of constraints, organismic constraints, environmental constraints, and task constraints, interact to determine organism's optimal pattern of coordination and control for his activity (Newell, 1986).

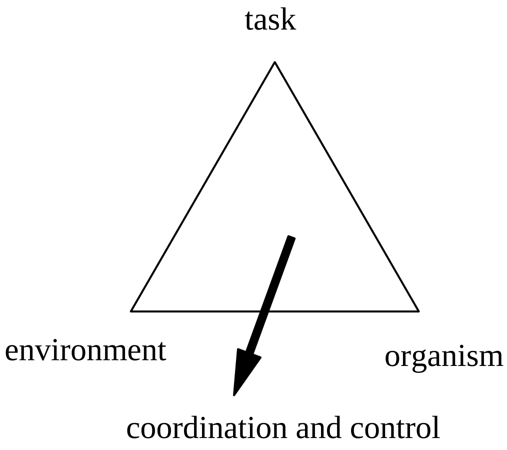

Figure B. A schematic diagram of the categories of constraints that specify the optimal pattern of coordination and control (Newell, 1986).

Organisimic constraints can be divided into two categories, relatively time independent constraints and relatively time dependent constraints. The former are typically viewed as structural constraints such as height and weight of the organism; whereas the latter are interpreted as functional constraints such as the development of synaptic connections (Newell, 1986). Rochat (1985) compared the reachability for self and for others between 3- to 5-year-old children and adults, and found that adults were more accurate and less overestimated in judging others' reachability, which could be referred as a result of organisimic constraints of children who lacked experiences in estimating distances in comparison of adults.

Environmental constraints are generally recognized as those constraints that are external to the organism and relatively time independent, such as gravity, natural ambient temperature, natural light and other environmental features (Newell, 1986). Environmental constraints reflect the ambient conditions for the task; task constraints, on the other hand, focus on the goal of the activity and the specific constraints imposed, which relate to goal of the task, rules specifying or constraining response dynamics, and implements or machine specifying or constraining response dynamics (Newell, 1986). For example, Chen and Liu (2007) suggested that fencers performed longer lunge lengths than tennis players and students who had no extended experience in fencing or racket sports even they are quite similar in height, because fencers were much more familiar with the lunge task that requires more strength and flexibility of hamstring muscles which are relatively less trained for the compared groups.

Sensory receptors

More than one hundred years ago, Sir Charles Sherrington (1906) proposed the two primary distributions of the receptor-organs, and each constitutes a field fundamentally different from each other. The deep field is called proprioceptive field, and the surface field can be subdivided into intero-ceptive field and extero-ceptive field.

"*The organism, like the word surrounding it, is a field of ceaseless change, where internal energy is continually being liberated, whence chemical, thermal, mechanical, and electrical effects appear. It is a microcosm in which force are at work as in the microcosm around. In its depth lie receptor-organs adapted consonantly with the changes going on in the microcosm itself, particularly in its muscles and their accessory apparatus (tendons, joints, walls of blood vessels, and the like)*" (Sherrington, 1906, p316).

In proprioceptive field, stimuli are events in the microcosm itself, and proprioceptive recepors furnish information concerning the movements and positions of the body; therefore, the proprioceptors play an extremely important role in body movement, not to mention its significance in sports.

The intero-ceptive surface is usually alimentary in function; interoceptor refers to sensory nerve receptors for stimuli that originate inside the body, situating within the walls of the respiratory and gastrointestinal tracts or in other viscera.

The extero-ceptive surface, on the contrary, lies fully open to the influences of the outer environment, and exteroceptors indicate the sensory nerve end receptors that respond to external stimuli; located in the skin, eyes, ears, nose, and so on. In sports, vision, one of the exteroceptions, is not less important than any other reception because it provides most information from the external environment, and it also holds similar function as proprioception does, that’s why Lee (1978) defined it as extero-proprioception.

Visual perception

Fencing is an open-skilled combat sport, so that fencers extremely depend on their visual system to provide them the information produced by the opponent for their action. How does visual perception work?

From Gibson's (1979) theory of direct perception to the study of visual perception and action in sports, "*optical variables are the properties of the light reflected in a lawfully structured way from important surfaces and objects and which are available for pick-up by all perceivers equipped with a visual system*" (Williams, Davids, & Williams, 1999, p196). When a performer moves, a specific transformational optic flow is created, reflecting on the retina from surfaces and objects near and far; this optic changes on the retina allows the performer to understand the changes of the external environment, such as the direction of motion of the observing object, the distance between the performer and the observing object and so on, and thus supports the performer's actions.

Depth perception

Humans are very adept at judging the relative distances of objectives; in sports, refined depth perception is one of the essential factors of expert athletes, and fencing is no exception.

A common misconception regarding depth perception is that the use of both eyes (binocular vision) is necessary. Actually, if one eye is covered, however, strong sense of depth persists. Monocular depth cues are perceived just as strongly when viewed with one eye as when viewed with both eyes; it includes pictorial depth cues, motion parallax, and accommodation (Schwartz, 1990). Pictorial depth cues are those cues that can be presented in a two-dimensional representation, such as a photograph or a painting, including size, linear perspective, texture, interposition, clarity, and lighting and shadow. Motion parallax is a kinetic monocular depth produced by the relative motion of two or more objects. And accommodation refers to the increment of dioptric power of the lens, which allows near objects to be clearly focused on the retina.

As for viewing objects binocularly, stereopsis is the process leading to the sensation of depth from the two slightly different projections of the world onto the retinas of the two eyes. The differences in the two retinal images are called binocular disparity. The differences arise from the eyes' different positions in the head. When viewing objects at various distances, the eyes converge and diverge. The degree of convergence potentially provides information regarding the distance of objects.

Visual illusions are erroneous perceptions, and they are commonly occurred when pictorial cues are used to judge the size of unfamiliar objects such as size illusion (Shepard, 1990), Müller-Lyer illusion (Müller-Lyer, 1889), and so on.

Therefore, the importance of transformations of the optic flow over time must be drawn again, neither monocular nor binocular static information can possibly help the perceiver understand what and when will happen. It is the transformational invariants specify how far away the observing object is, and also the shapes or sizes of the object (Michaels & Carello, 1981).

Speed and accuracy

“Speed and accuracy” is always the goal of athletes in many sports, but the tradeoff relationship can never be disregarded. Psychologist Woodworth (1899) is often credited being the founder of research on this tradeoff relationship; he demonstrated the tradeoffs by the task of drawing the line of different lengths, or according to different frequency given by the metronome. The results showed that when the movement speed increased, the movement accuracy decreased correspondingly. Fitts (1954) used a logarithmic equation to demonstrate the tradeoffs in rapid, aimed movement (reciprocal tapping, disk transfer, and pin transfer). After his study, it had been challenged by many studies via manipulating all possible environmental and task constraints of the movement. However, it can stand the test of time, and thus have been used widely to design of user interfaces and evaluation of alternative task methods in Graphical User Interface (GUI).

As Fitts’ Law was applied to sports, there are still some limitations. For example, if the task of the movement requires the use of hand-held implement such as fencing blade and racket or ball, the properties of the implement and movement trajectory of the ball should be concerned. Moreover, the target position (horizontal or vertical relative to the performer) and the position of arm stretching in fencing or the ball-release cannot be neglected. Furthermore, “timing accuracy” was not discussed in Fitts’ study, but it’s rather important in sports. Take baseball for example, the timing of batting the ball will strongly affect the timing of the ball contact. Similarly, skilled fencers can match the severe spatio-temporal constraints by judging the right time and right place to initiate their necessary movements corresponding to the opponent, which is the high performance of “timing accuracy” combined to the refined depth perception; therefore, it would be explored in this study.

Related research

Reachability.

Reaching is one of the earliest naturally occurring behaviours of humans which we can infer sensitivity to information for spatial layout. Gibson’s (1979) theory of affordances calls for the inseparability of perception and action, defined the affordances of an object or situation as the activities that it offers or affords an organism with the capabilities of certain actions. From this perspective, the possibilities for action are determined by the fit between the environmental situation and the characteristics of the organism; therefore, many studies have explored the early developmental capacities of infants for this action. Infants started to reach systematically and successfully at around four months (Clifton et al., 1993); five-month-olds can perceive the distance at which an object is either within or beyond their reach (Rochat & Goubet, 1993; Yonas & Hartman, 1993); six-month-olds with different levels of postural abilities (i.e. non-sitter, near-sitter, and sitter infants) revealed reachability calibrated in relation to the degree of their ability of postural control (Rochat, Goubet & Senders, 1999).

On the other hand, reachability in different situations was also demonstrated in many studies. In general, the tendency to overestimate the reachability was found, and two possible explanations were proposed. The first possibility was based on the postural stability, assuming that if the body’s centre of mass were not safely supported, overestimation would then reflect a risky setting of the system (Carello et al., 1989; Robinovitch, 1998). The other competing account for the reachability estimation bias was the engagement of whole body (Rochat & Wrage, 1997; Robinovitch, 1998). It was explained that reachability judgements reflect the engagement of the whole body in a mentally simulated reach that includes all degrees of freedom that are normally available to solve the task even the experimental instruction was to immobilize the whole body.

As for comparison of reachability estimation for self and others, Rochat (1995) found that both children (3- to 5-year-old) and adults underestimated for others in a horizontal presentation of the object but generally overestimated for self in the same condition, and judgements of reachability for self were body-scaled; Chen and Liu (2008) found the tendency of overestimation in either estimating for self or for the opponent, and the bias was more obvious for estimating for the opponent due to the different task constraints; that is, to attack (to estimate self's lunge length) required more accuracy compared with the task of escape from the opponent's lunge (to estimate the opponent's lunge length).

Research related to fencing.

Do and Yiou (1999) examined whether maximum velocity of the touché fencing movement is affected by the anticipatory postural adjustments (APA) preceding a voluntary lunge. The results showed that performance of touché was increasingly affected during the development of the APA of the lunge; more precisely, the APA in the lunge movement had a negative effect on performance of the touché. When the touché was initiated prior to the onset of the APA of the lunge, the maximal foil velocity remained similar to that of an isolated touché; and if the initiation was during the APA of the lunge, the maximal foil velocity was lower than that of an isolated touché. Moreover, Yiou and Do (2000) investigated the effect of intensive practice for speed performance of the touché and the touché plus lunge movement between elite and novice fencers. It was reported that significant difference was found only in the touché plus lunge condition, and similarly in this condition, the velocity of the centre of mass at the time of peak velocity of the touché was statistically higher in the elite fencers. In 2007, Yiou, Schneider, and Roussel further explored whether rapid stepping is influenced by the coordination of an arm pointing task. The results showed that coordinating arm pointing with stepping increased initial propulsive forces for stepping initiation, and enabled to reach the maximal velocity earlier. To summarize the above studies, we could learn that the movement velocity of special arm-leg coordination in fencing such as touché and lunge could be affected by the initiation timing of arm aiming, APA, and the familiarity of the movement. With regards to combat sports like fencing, faster velocity of self seems fundamental or necessary but not the only key for successful performance. How to make the maximal velocity of self a threat to the opponent is quite another story, because the relationship between the duelling is much more complex than the absolute, voluntary movement triggered by oneself.

Similarly, many studies related to accuracy, reaction time (RT), movement time (MT), total response time (RMT), strength, power, and flexibility (Del Rey, 1972; Sanderson, 1983; Singer, 1968; Ketlinski & Pickens, 1973; Klinge & Adrian, 1983; Harmenberg, Ceci, Barvestad, Hjerpe & NystrÖm, 1991; Sapega, Minkoff, Valsamis & Nicholas, 1984; Wang & Shiang, 1997; Williams & Walmsley, 2000; Cronin, McNair & Marshall, 2003) demonstrated the findings of basic demands in fencing from one-sided but not mutually constraining condition for their experimental manipulations. Those were not built on the dynamic condition where the external environment should also have influence on the performer relatively.

Studies which have investigated the relation of speed and accuracy to tournament success revealed conflicting results. Singer (1968) used a correlative analysis of the relationship of reaction time, total reaction time, and accuracy to tournament success in the study of fencing lunge, and no significant relationship was found. Similarly, in Ketlinski and Pickens’s study (1973), low correlation revealed. On the contrary, Klinger and Adrian (1983) found that although the lunge speed differentiated from 1.5 to 4 meters/sec among twenty fencers, the more skilled fencers generally achieved the higher speed. Harmenberg, Ceci, Barvestad, Hjerpe and Nyström (1991) compared the reaction time of world class fencers and beginners on three different fencing movements; they found only the most complicated movement could differentiate between fencers with different skill levels, and the reaction time of the most complicated movement correlated significantly with competition success. The source of the conflicting results came from the participants recruited in the research; that is, fencers who were seriously practicing and competing and those who were just introduced the required fencing-related task demonstrated the inconsistent results due to their familiarity with the required task.

An interesting study of sabre fencers' footwork pattern (Natta & Nouillot, 2004) investigated the posturo-dynamic organization of the attacker in different conditions of initial distances between fighters. Participants were asked to attack in three initial distances conditions (MR: step forward plus come back, MF: step forward plus lunge, MM: two step forwards plus lunge), and the first step was analyzed via distance between feet, front leg angle, vertical angle of sabre and trunk, peak velocity of toes of front and rear foot, and so on. Peak velocity, trunk and front leg angles showed significant differences among conditions due to the different following movements.

Chen and Liu (2007) compared the depth perception with a hand-held implement (a 110-cm fencing blade and a 180-cm wooden stick) and lunge among fencers, tennis players, and students who have no extended experiences in fencing or racket sports. Three different arm positions while holding a fencing blade and two different postures without holding a blade when approaching or moving away from participants were manipulated as the target to the perceived distance. Participants had to perceive the distances under each condition in a standing, hands-free position, and then their actual movement length was measured for comparison. All groups could distinguish the length difference between the 2 hand-held objects but both were overestimated. The smallest ratio of absolute errors was found in the fencers. Different target conditions did not affect participants' judgments of the relative accuracy of the perceived length. All participants perceived longer distances when the target was approaching than moving away.

Following the study of self-perception, how fencers respond to opponents of different heights and different approaching velocities, namely, their depth perception for others' movement length, was also investigated (Chen & Liu, 2008). The results showed that all the perceived distances were overestimated; the approaching velocity of the opponent had crucial influence on fencers' depth perception, and there was a significant correlation between the approaching velocity of the opponent and the absolute errors of the perceived distance. In sum, these two studies had separately clarified the possible factors to affect fencer's depth perception in two opposite role-conditions of a combat, that is, to attack and to defend (to step back). And due to the different role-conditions, different degrees of accuracy in depth perception (though all overestimation) were demonstrated. It was not surprising that attack condition revealed less-overestimated depth perception, whereas in the defense condition more overestimations were observed due to the safety concern, meaning the fencers initiated the step back earlier than they actually had to, and this early initiation contributed to more overestimations.

Chapter 3

Method

Participants

The study was carried out with six male national class fencers (5 right-handed, 1 left-handed, mean age 22.2 ± 1.9 years, mean height 174.4 ± 4.0 cm, mean weight 70.0 ± 3.7 kg) including 3 saber fencers, 1 foil fencer, and 2 epeeists. All participants signed the consent form prior to participating in the experiment. No disabilities or injuries were reported during the experimental period.

Task

Two fencers (**A** and **B**) stood facing each other in on-guard positions at instructed distances. Following the Go signal, fencer **A** self-triggered the attack in an attempt to touch fencer **B**’s chest with index finger with the compound footwork made up of two simple forward steps, namely, the combination of forward step, crossover step and lunge. **B**’s first task was to escape from **A**’s attack, he could execute his retreat by any possible backward footwork combination without limits of number of steps, then initiating his attack immediately after a successful escape. The rebound attack from B was also limited in two forward steps to touch **A**.

The trial ended when a successful attack was made or A successfully escaped from B’s rebound attack. The fencer who made a successful attack was regarded as winner in that trial; it was a draw when no one was touched. Participants were encouraged to win as many trials as possible.

Apparatuses

A high-speed video camera (PULNIX Model JAI-TM 6740GE) was used to record trials; it was remained in a fixed position, focusing on center of participants' movement area (10 m long × 2 m wide), without panning to follow the participants' movement. The distance from the lens to the subjects was approximately 8.5 m. Two sets of bright spotlights were shone on participants' movement area to enhance the lighting condition for video recording (See Figure C).

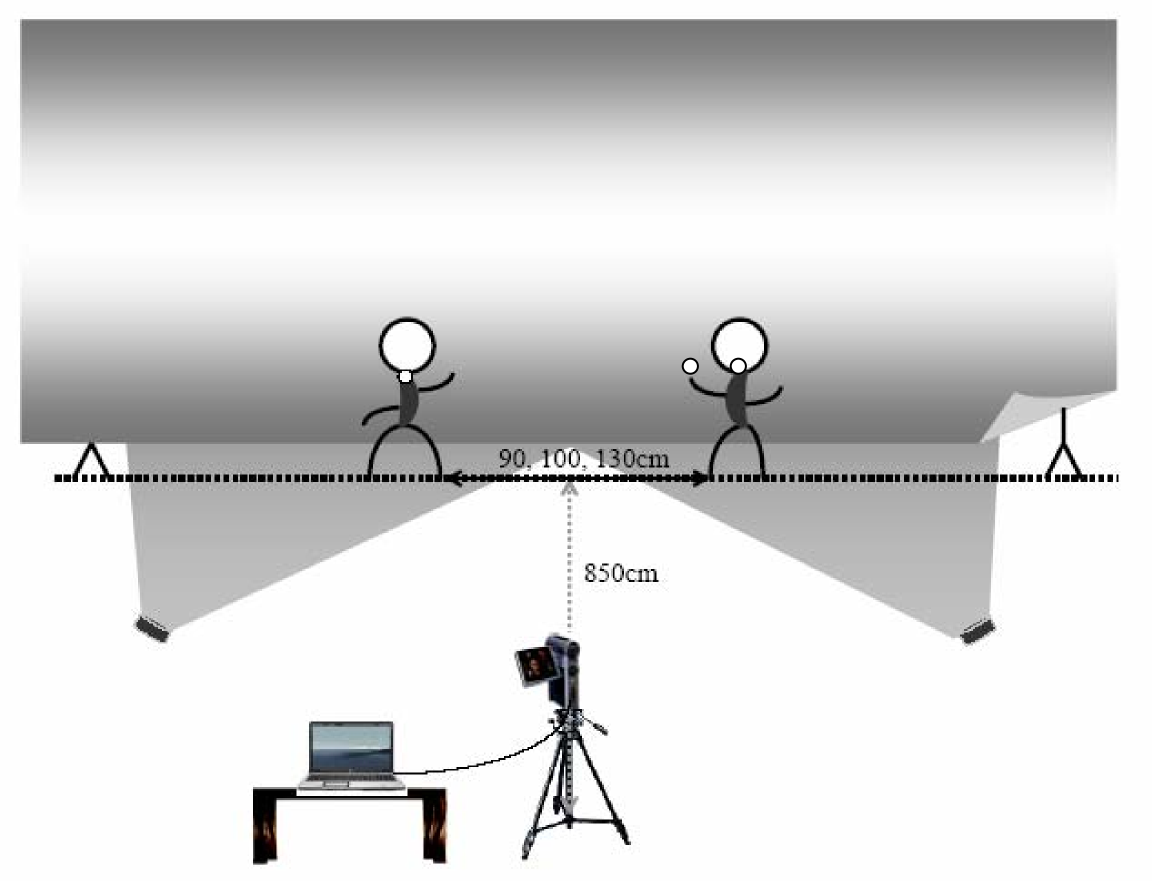

Figure C. The display of experimental apparatuses.

Procedure

All participants wore dark T-shirts, shorts, and white fencing shoes during the recording sessions. The white adhesive tape of 2.5 cm wide was used as the reflective markers on the fencers' neck and the index finger of dominant hand. In order to indicate three different initial distances, 90, 100, and 130 cm, respectively, between two participants, three sets of markers were placed on the floor. The calibration procedure was conducted with a 2 m × 2 m calibration frame placed in the center of the recording area before each data collection session.

Six participants paired with one another twice in a round robin format, once as attack initiator and once as defender, yielding a total of thirty match-ups between them. In every match-up, there were three starting conditions spacing them apart by 90, 100, and 130 cm. For each match-up/condition, ten trials were performed. So it made a total of 900 trials (30 match-ups × 3 starting conditions × 10 trials). The entire sequence was randomized. A trial lasted less than 5 sec, participants had a 10 s rest between trials and 10 min break every 30 trials to avoid the effects of fatigue. Win, lose, or draw outcomes were judged by a division A (national level) referee on site. Trials were recorded at 200 fps and video images were stored on a computer for later offline analyses.

Data reduction

Three points were digitized for analyses in a trial: the anterior part of the neck of both participants and the index finger of the attacker. Neck point was used because it was always visible during the trial and its displacement tended to correspond to the trunk movement. Therefore the neck point was used to approximate the chest position as the target.

The data acquisition was triggered prior to the Go signal, which allowed the post-hoc determination of the onset of the participants' movement from the initial posture. Video images recorded by high-speed video camera in StreamPix 4.70 were output to Kwon 3D 3.01 motion digitizing system to derive the x-axis (horizontal) position. To reduce noise of raw data, the position time-series were filtered with a fourth-order Butterworth Low-Pass filter with a cutoff frequency of 6 Hz. Subsequent data derivation algorithms were written with Mathematica 6.0 for the following analyses.

Index finger point of the attacker was tracked during first phase, and neck points of both participants were tracked for both phases. In the first phase, the movement onset was defined at the first frame in which the displacement between 3 frames (15 ms) of the attacker's neck point continued to increase for thirty frames (150 ms); end-point was determined when his neck point position reached the maximum. As for the second phase, the last frame of the first phase was used as the starting frame, and the end-point was also determined at the frame when the position of the original defender's neck point reached to the maximum.

In order to compare the win-loss outcome differences in different distance conditions and different match role (attacker or defender), success rate was calculated by dividing the winning trials by the total trials of the condition/role. The relative frequency of the occurrence of the crossover step was computed by dividing the number of trials adopting crossover step by the total trials of the condition/outcome (win or draw) for the first phase. Relative timing of participants' movement initiation (RelTiming) was derived from calculating the relative timing between two participants' movement onset timing in both phases, respectively. The error of attack was identified when the attack initiator did not touch the defender successfully in the first phase, and the spatial error of attack distance was derived from computing the distance between the attacker's index finger and the defender's neck at the end-frame of the first phase. Maximum neck velocity of the participants (MaxV), time to the maximum (TtoMaxV), and relative time of maximum movement velocity (RelT of MaxV) were derived in both phases. The TtoMaxV was normalized to the duration of the corresponding phase; the RelT of MaxV was derived from the time of the defender's maximum movement velocity minus that of the attacker's in both phases similarly.

Statistical analyses

The success rate was compared in a two way (3 distance × 2 attack or defender situation) repeated measure analysis of variance (ANOVA); the applied rate of crossover step and the spatial error of attack distance was analyzed in the two-way (3 distance × 2 outcome) repeated measure ANOVA. The relative timing of participants' movement initiation (RelTiming), the maximum velocity of the fencer (MaxV), the time to maximum velocity (T to MaxV), and the relative time of maximum movement velocity between fencers (RelT of MaxV) were analyzed in three-way (2 phase × 4 outcome × 3 distance, and 2 phase × 2 kind of outcome × 3 distance or 2 phase × 2 kind of role × 3 distance) repeated measure ANOVA. SPSS 15.0 was used for statistical analyses, the significance level for all tests was set at $p< .05$, and post-hoc analysis of simple main effects was based on Bonferroni.

Chapter 4

Results

Results were presented in five parts corresponding to the research questions, including win-loss outcomes, rate of using crossover step, relative timing of fencers' movement initiation, spatial errors of attack distance, and maximum movement velocity, time to maximum movement velocity, and relative time of fencer's maximum movement velocity.

All trials were available for win-loss analysis. Trials, when the defender anticipated to retreat earlier than the attack initiator moved, and then recovered to on-guard position later than the attack initiator moved, were discarded from the other analyses (4% of all trials).

Win-loss analysis

Illustrated in Figure 1, the 2 (Attack initiator vs. Original defender situation) × 3 (distance) repeated measure ANOVA showed no significant main effect of Attack initiator vs. Original defender situation, $F(1,5)=1.28$, $p=.31$, but a significant main effect of distance, $F(2,10)=12.92$, $p<.05$, with near condition revealing statistically greater success rate than far condition, $p<.05$; and a significant interaction, $F(2,10)=8.57$, $p<.05$. Post-hoc analyses of simple main effects indicated that the significant interaction rested on the fact that attack initiator demonstrated a significant decrease trend for success rate from near to far conditions, $F(2,10)=17.46$, $p<.05$, whereas no such trend was found for the Original defender situation, $F(2,10)=.13$, $p=.88$.

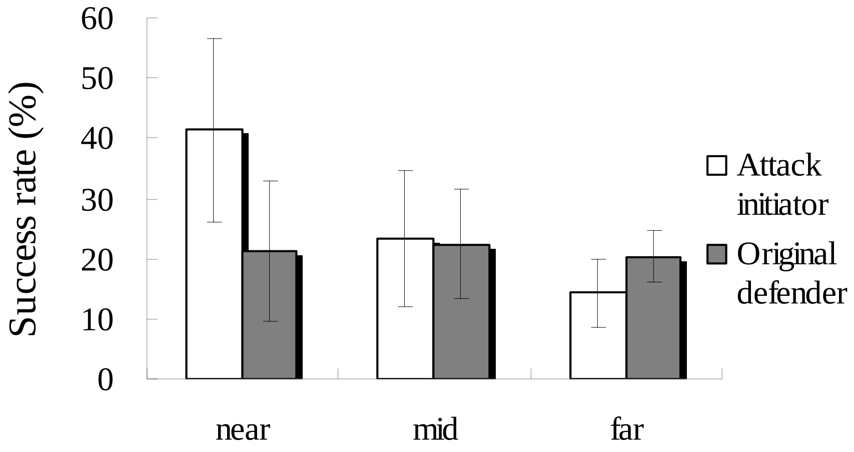

Figure 1. Average success rate for the situations when the participant was designated as attack initiator or defender in three conditions of initial relative distance between participants (near, mid and far).

Rate of using crossover step

Shown in Figure 2, the 2 (Win vs. Draw outcome) × 3 (distance) repeated measure ANOVA demonstrated that there was a significant main effect of outcome, F(1,5)=14.94, *p*<.05, with win-outcome revealing greater rate; and a main effect of distance, F(2,10)=10.34, *p*<.05, with far condition showing greater rate significantly than near condition, *p*<.05; and a significant interaction, F(2,10)=8.76, *p*<.05. The post-hoc analyses of simple main effects showed that there was no statistical distinction among the three conditions of initial relative distance in draw-outcome, *p*=.46, whereas in win-outcomes, far condition demonstrating greater rate significantly than mid and near conditions, *p*<.05.

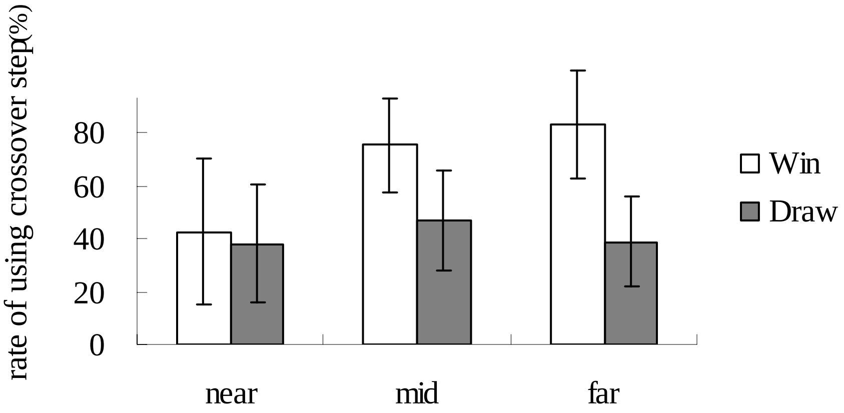

Figure 2. Average rate of using crossover step for win- and draw-outcomes in three conditions of initial relative distance between participants (near, mid and far).

Relative timing of movement initiation (RelTiming)

Shown in Figure 3.1, the 2 (phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA demonstrated a significant main effect of phase, F(1,5)=288.92, $p<.05$, with the 1st phase revealing greater RelTiming than the 2nd phase; a main effect of outcome, F(3,15)=21.89, $p<.05$, with loss- and win-outcome presenting greater RelTiming than the two draw-outcomes, *p*s<.05; and a main effect of distance, F(2,10)=22.38, $p<.05$, with far condition showing greater RelTiming than mid and near conditions, *ps*<.05. Furthermore, there was a significant phase-by-outcome interaction, F(3,15)=11.57, $p<.05$; post-hoc analyses of simple main effects showed significant differences for each phase and each outcome situation, *p*s<.05 (See Figure 3.2). Similarly, there was a phase-by-distance interaction, F (2,10)=4.42, $p<.05$; post-hoc analyses of simple main effects likewise indicated the significant difference, for each phase and each distance, *p*s<.05 (See Figure 3.3). Finally, neither outcome-by-distance interaction effect, F(6,30)=1.00, $p=.44$, nor three-way interaction effect, F(6,30)=.25, $p=.96$, were found significant.

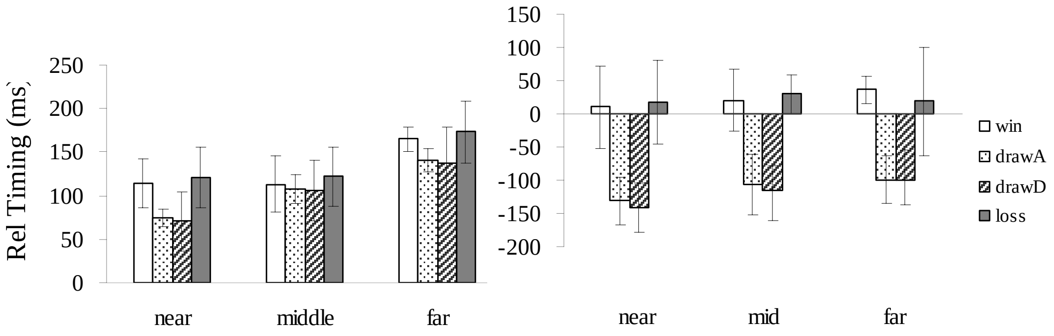

Figure 3.1. Average relative timing of movement initiation for four performance outcomes in the 1st phase (left panel) and in the 2nd phase (right panel) in three conditions of initial relative distance between participants (near, mid and far).

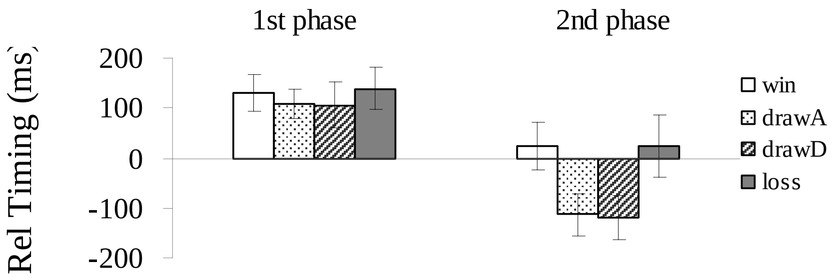

Figure 3.2. Average relative timing of movement initiation for four performance outcomes in the 1st and 2nd phase.

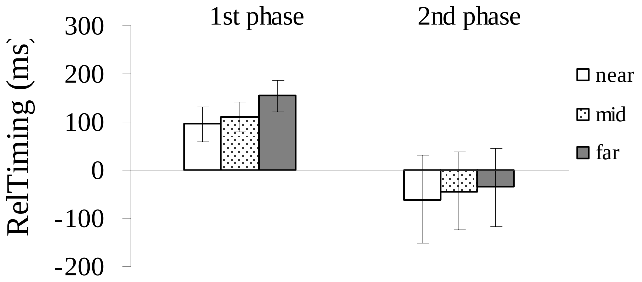

Figure 3.3. Average relative timing of movement initiation for three conditions of initial relative distance (near, mid and far) in the 1st and the 2nd phase.

From the above results, the four outcomes data seemed to be able to be grouped into win/loss and draw groups. Therefore, the averaged data of win/loss and draws were again analysed in a 2 (phase) × 2 (outcome) × 3 (distance) repeated measure ANOVA in order to explore the differences resulted from different outcomes (See Figure 3.4). Likewise, it demonstrated significant differences in different phase conditions, F(1,15)=288.81, p<.05, outcomes, F(1,5)=134.45, p< .05, and distances conditions, F(2,10)=22.36, p< .05. Furthermore, there was a phase-by-outcome interaction, F(1,5)=64.92, p< .05 (See Figure 3.5), which was caused by the fact that significant difference was found for the two kinds of outcome in both phases, ps<.05, and each kind of outcome showed significant difference from the 1st phase to the 2nd phase, ps<.05. Similarly, a phase-by-distance interaction was also revealed as that from the previous analysis of 2 (phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA. One more time, the outcome-by-distance interaction effect, F(2,10)=2.40, p=.14, and the three-way interaction effect, F(2,10)=1.07, p=.38, were not found significant.

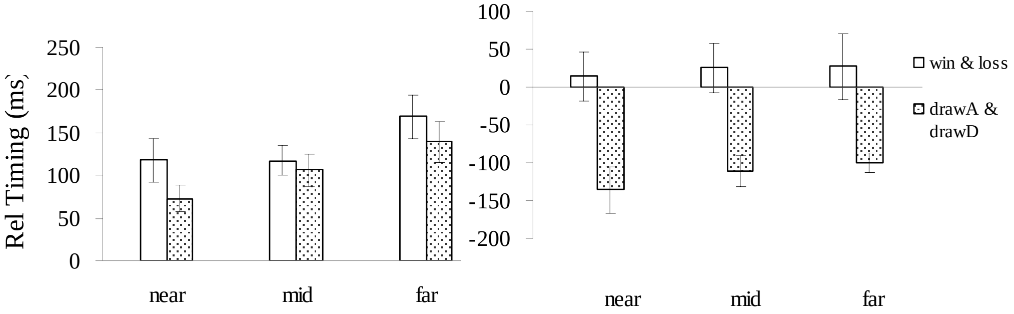

Figure 3.4. Average relative timing of movement initiation for two kinds of performance outcomes in the 1st phase (left panel) and in the 2nd phase (right panel) in three conditions of initial relative distance between participants (near, mid and far).

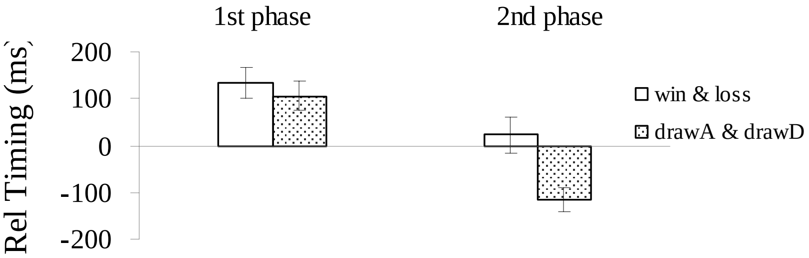

Figure 3.5. Average relative timing of movement initiation for two kinds of performances in the 1st and the 2nd phase.

Spatial error of attack distance

As shown in the Figure 4.1, the 2 (Draw vs. Loss outcome) × 3 (distance) repeated measure ANOVA revealed there was a significant main effect of outcome, F(1,5)=18.40, *p*<.05, with draw-outcome demonstrating greater errors than loss-outcome, *p*<.05; a main effect of distance, F(2,10)=8.70, *p*<.05, with far condition revealing greater errors significantly than near condition, *p*<.05; but the interaction was not significant, F(2,10)=3.56, *p*=.07.

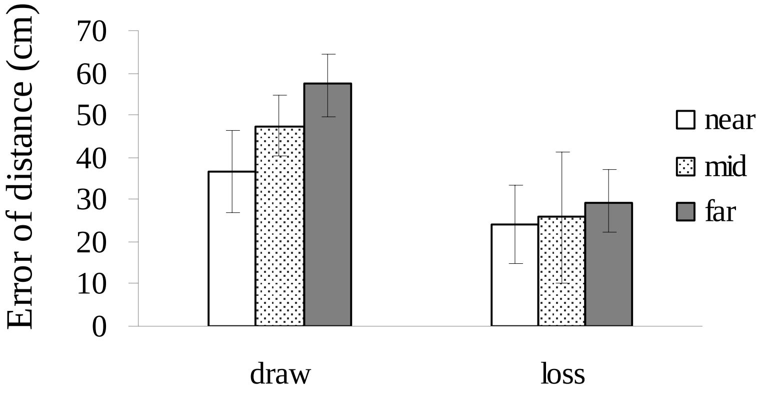

Figure 4.1. Average error of attack distance for three conditions of initial relative distance (near, mid and far) when attack initiator did not touch the opponent in the 1st phase (which could be divided into two conditions based on the performance outcomes of the 2nd phase, draw- and loss-outcome, to the attack initiator).

In order to understand the relationship between speed and accuracy, the correlation of maximum movement velocity and the spatial errors was analysed. As illustrated in Figure 4.2, there was a significant negative correlation, r=-.85, *p*<.05, indicating greater movement velocity resulted in smaller errors of attack distance.

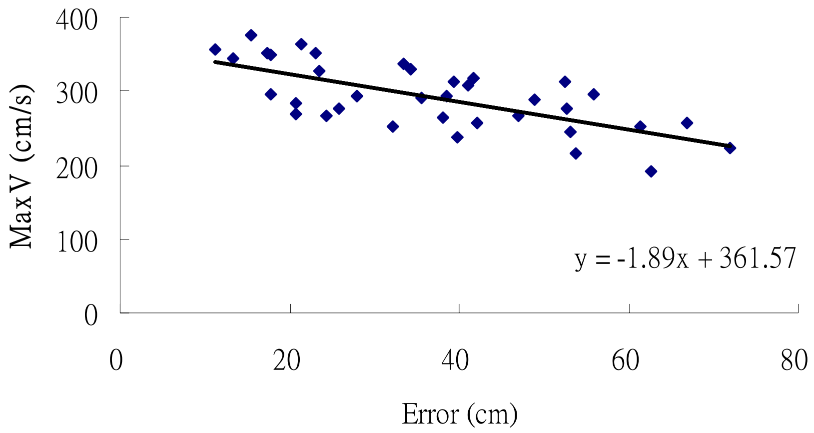

Figure 4.2. The correlation between attacker’s maximum movement velocity and his errors of attack distance.

Analyses of velocity

Maximum movement velocity (MaxV).

The 2 (phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA revealed that there was a significant main effect of phase, F(1,5)=13.97, *p*<.05, indicating MaxV in the 1st phase was significantly larger than that in the 2nd phase; a main effect of outcome, F(3,15)=21.75, *p*<.05, suggesting that MaxV for win- and drawA-outcomes were significantly larger than that for drawD-outcomes, *ps*<.05; a main effect of distance, F(2,10)=6.64, *p*<.05, demonstrating that MaxV for near condition was statistically larger than that for far condition, *p*<.05 (See Figure 5.1). Moreover, there were a significant phase-by-outcome interaction, F(3,15)=10.62, *p*<.05, causing by the fact that the significant effect was only found in the win- and loss-outcomes, *p*s<.05, but not in the two draw-outcomes, *p*=.75; *p*=.95 (See Figure 5.2); and a significant phase-by-distance interaction, F(2,10)=7.37, *p*<.05, which was due to the fact that there was a decrease trend for the 1st phase, *p*<.05, but not for the 2nd phase, *p*=.22 (See Figure 5.3). The outcome-by-distance interaction effect, F(6,30)=1.89, *p*=.12, and the three-way interaction effect, F(6,30)=1.22, *p*=.33, were not found significant, F(6,30)=1.22, *p*=.33.

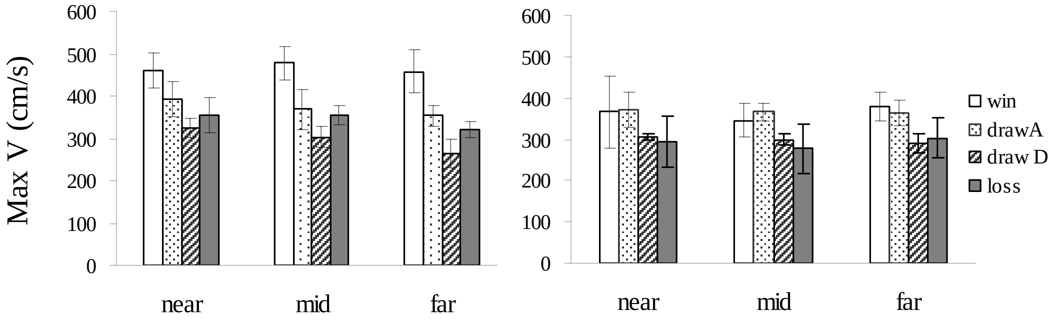

Figure 5.1. Average maximum movement velocity for four performance outcomes for the 1st phase (left panel) and the 2nd phase (right panel) in different conditions of initial relative distance between participants (near, mid and far).

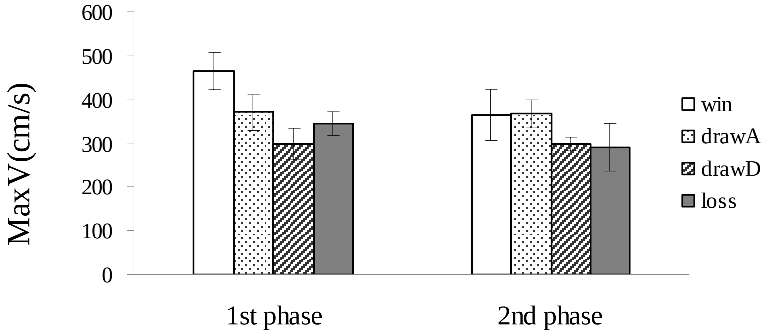

Figure 5.2. Average maximum movement velocity for four performance outcomes in the 1st phase and in the 2nd phase.

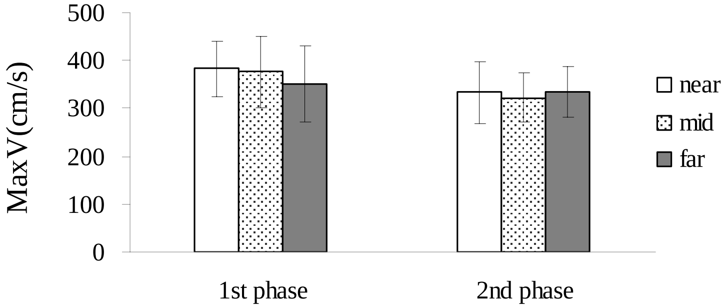

Figure 5.3. Average maximum movement velocity for three different conditions of initial relative distance (near, mid and far) in the 1st phase and in the 2nd phase.

Once again, the results seemed to suggest that the MaxV was influenced by the role of the performers; therefore, the data were analysed again in a 2 (phase) × 2 (Attacker vs. Defender role) × 3 (distance) repeated measure ANOVA. All main effects were significant, including phase, F(1,5)=13.97, $p< .05$; with the 1st phase revealing the greater MaxV than the 2nd phase; Attacker vs. Defender role, F(1,5)=25.58, $p<.05$, indicating that Attacker role showing greater MaxV than the Defender role; and distance, F(2,10)=6.64, $p<.05$, with far condition demonstrating significant smaller MaxV than near condition, $p< .05$ (See Figure 5.4). Similarly as illustrated in Figure 5.3, there was also a significant phase-by-distance interaction found, F(2,10)=7.37, *p*<.05, as that from the previous analysis of 2 (phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA. Once again, the outcome-by-distance interaction effect, F(2,10)=1.31, *p*=.31, and the three-way interaction effect, F(2,10)=.47, *p*=.64, were not found significant.

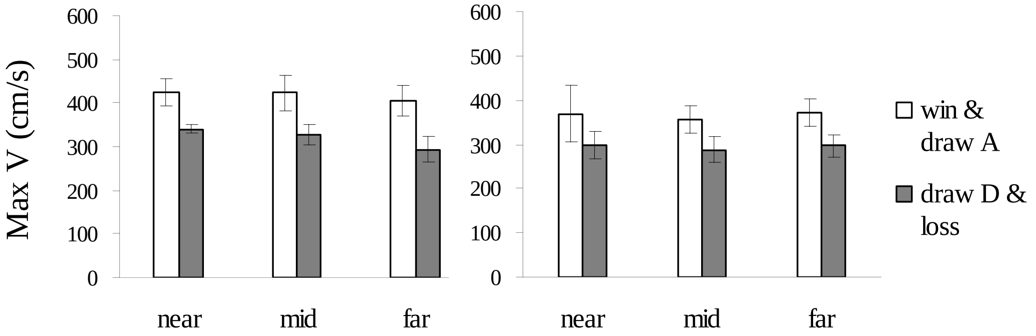

Figure 5.4. Average maximum movement velocity for two kinds of performance outcome for the 1st phase (left panel) and the 2nd phase (right panel) in different conditions of initial relative distance between participants (near, mid and far).

Time to maximum movement velocity (TtoMaxV).

Shown in Figure 5.5, the 2(phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA revealed a significant main effect of outcome, F(3,15)=7.65, *p*<.05, indicating the TtoMaxVs for the win-outcomes were larger than that of the drawD-outcomes, *p*<.05; but not a significant main effect of phase, F(1, 5)=2.51, *p*=.17, and distance, F(2, 10)=2.94, *p*=.10. Moreover, a phase-by-outcome interaction effect, F(3,15)=26.43, *p*<.05, was also demonstrated, which was due to the differential phase effect for the four outcomes, *p*s<.05 (See Figure 5.6). Phase-by-distance interaction effect, F(2,10)=1.88, *p*=.20, outcome-by-distance interaction effect, F(6,30)=.71, *p*=.64, and the three-way interaction effect were not significant, F(6,30)=.84, *p*=.55.

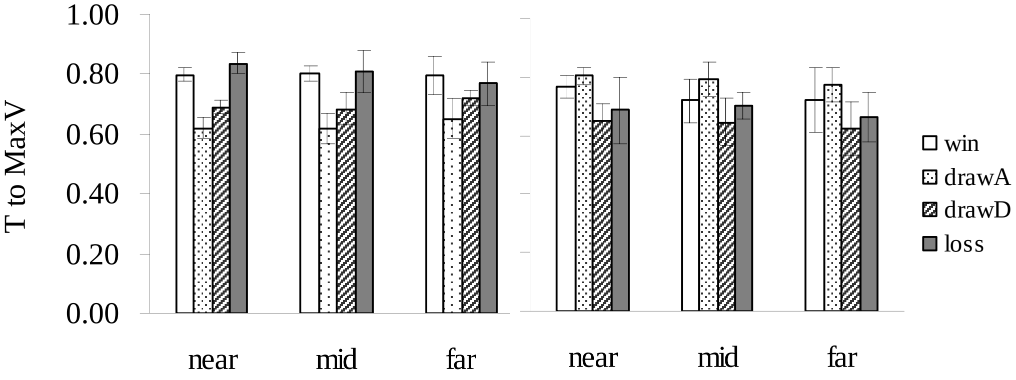

Figure 5.5. Average time to maximum movement velocity for four performance outcome situations for the 1st phase (left panel) and the 2nd phase (right panel) in different conditions of initial relative distance between participants (near, mid and far).

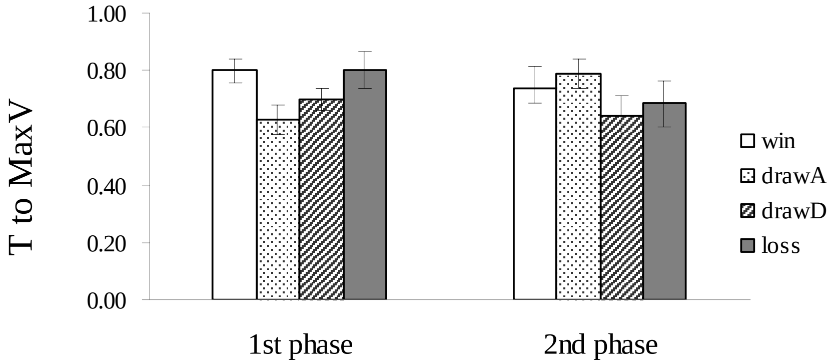

Figure 5.6. Average time to maximum movement velocity for four performance outcomes in the 1st phase and in the 2nd phase.

One more time, it seemed that data for win/loss- and draw-outcome situations could be grouped to be analyzed in the 2 (phase) × 2 (outcome) × 3 (distance) repeated measure ANOVA. The results also demonstrated a significant main effect of outcome, F(1,5)=13.21, *p*<.05, with the win/loss-outcomes revealing greater TtoMaxV; but not a significant main effect of phase, F(1,5)=2.39, *p*=.18, and distance, F(2,10)=2.96, *p*=.10. Similarly, the phase-by-outcome interaction was significant, F(1,5)=55.66, *p*<.05, based on the fact that no significant difference between the two kinds of outcome was found in the 2nd phase, *p*=.81 (See Figure 5.7). As for the phase-by-distance interaction effect, F(2,10)=1.71, *p*=.23, outcome-by-distance interaction effect, F(2,10)=.88, *p*=.44, and the three-way interaction effect, F(2,10)=1.01, *p*=.40, they were not found significant.

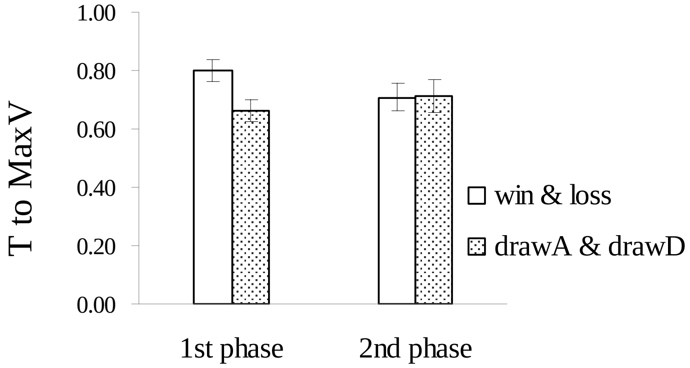

Figure 5.7. Average time to maximum movement velocity for two kinds of performance outcomes in the 1st phase and in the 2nd phase.

Relative maximum movement velocity (Rel MaxV).

Shown in Figure 5.8, the 2(phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA revealed that there was a significant main effect of phase, F(1,5)=15.03, *p*<.05, with the 1st phase demonstrating smaller Rel MaxV; a main effect of outcome, F(3,15)=5.76, *p*<.05; and a main effect of distance, F(2,10)=11.77, *p*<.05, indicating that Rel MaxV for far condition was smaller than that for near condition, *p*<.05. Neither phase-by-outcome, F(3,15)=2.08, *p*=.15, phase-by-distance, F(2,10)=2.94, *p*=.10, outcome-by-distance, F(6,30)=.25, *p*=.95, nor three-way interaction, F(6,30)=.69, *p*=.66, were found significant..

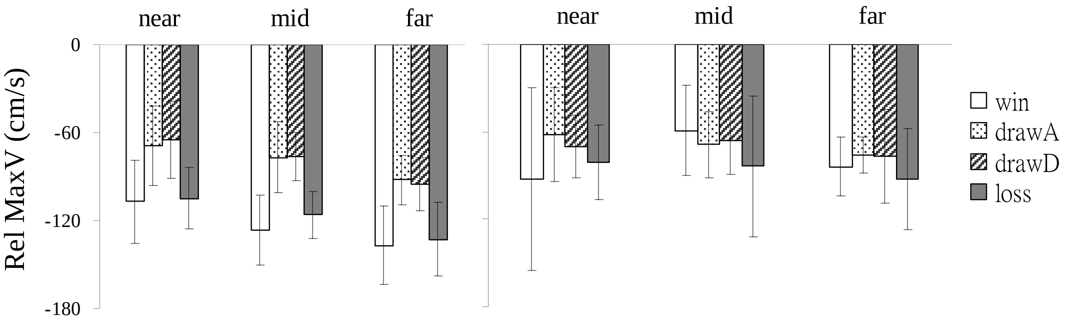

Figure 5.8. Average relative maximum movement velocity for four performance outcomes for the 1st phase (left panel) and 2nd phase (right panel) in different conditions of initial relative distance between participants (near, mid and far).

The win- and loss-outcome situations revealed similar trend no matter in the 1st phase or in the 2nd phase, and this trend seemed to hold for the two draw-outcome situations as well. Therefore, a 2 (phase) × 2 (outcome) × 3 (distance) repeated measure ANOVA was again used, and it demonstrated the significant differences in different phases, F(1,5)=15.03, *p*<.05, in different outcomes, F(1,5)=30.97, *p*<.05, with win- and loss-outcomes revealing smaller Rel MaxV than the draw-outcomes; and in different distances, F(2,10)=11.77, *p*<.05. The phase-by-outcome interaction

F(1,5)=17.71, *p*<.05 was found significant (See Figure 5.9); from examinations of post-hoc analyses of the simple main effects, the significant interaction was due that significant difference between 2 kinds of outcome was found only for the 1st phase, *p*<.05, but not for the 2nd phase, *p*=.10 (See Figure 5.10). Similarly, the phase-by-distance interaction effect, F(2,10)=2.94, *p*=.10, outcome-by-distance interaction effect, F(2,10)=.15, *p*=.87, and the three-way interaction effect, F(2,10)=.76, *p*=.49, were not found significant.

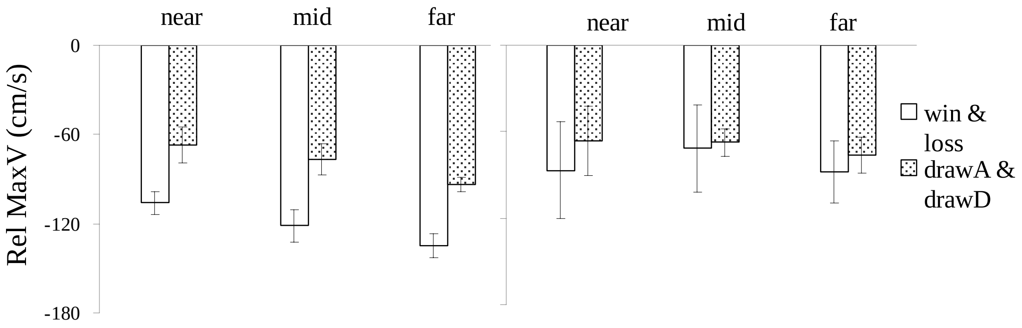

Figure 5.9. Average relative maximum movement velocity for two kinds of performance outcomes for the 1st phase (left panel) and 2nd phase (right panel) in different conditions of initial relative distance participants (near, mid and far).

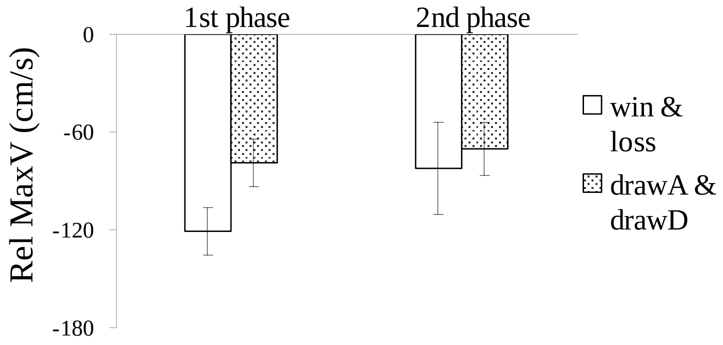

Figure 5.10. Average relative maximum movement velocity for two kinds of performance outcomes in the 1st and the 2nd phase.

Relative time of maximum movement velocity (RelT of MaxV).

Illustrated in Figure 5.11, the 2(phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA showed a significant main effect of phase, F(1,5)=147.54, $p<.05$, with the 1st phase revealing larger RelT of MaxV; but not a significant main effect of outcome, F(3,15)=.88, $p=.48$, and distance, F(2,10)=.53, $p=.61$. Furthermore, there was a significant phase-by-outcome interaction, F(3,15)=4.51, $p<.05$; from post-hoc analyses of simple main effects, it was the differential trend for four outcomes between two phases that caused the significant interaction, *p*s<.05 (See Figure 5.12). Once again, no significant phase-by-distance interaction effect, F(2,10)=.37, $p=.70$, outcome-by-distance interaction effect, F(6,30)=.10, $p=.99$, and the three-way interaction, F(6,30)=.36, $p=.90$, were found.

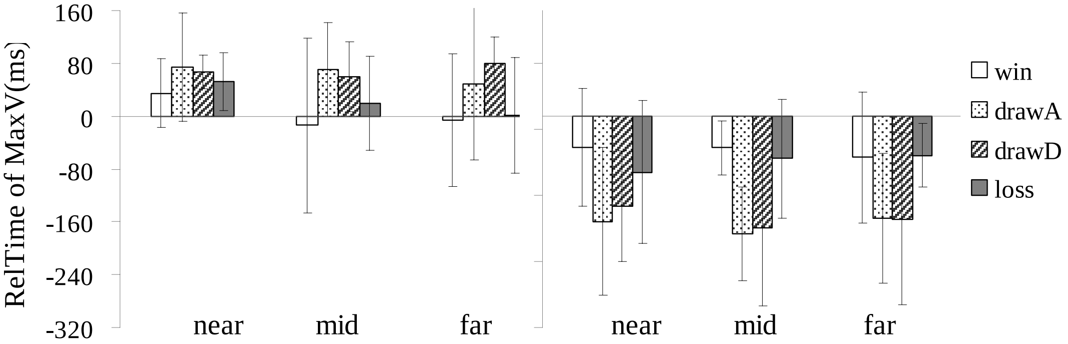

Figure 5.11. Average relative time of maximum movement velocity for four performance outcomes for the 1st phase (left panel) and the 2nd phase (right panel) in different conditions of initial relative distance between participants (near, mid and far).

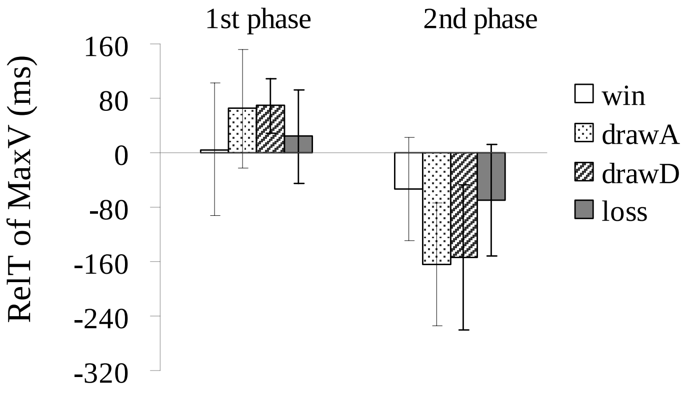

Figure 5.12. Average relative time of maximum movement velocity for four performance outcomes in the 1st and the 2nd phase.

Similarly, the four outcomes data could be able to be grouped into win-loss and draw groups; therefore, the averaged data of win-loss and draws were again analysed in a 2 (phase) × 2 (outcome) × 3 (distance) repeated measure ANOVA in order to investigate the differences resulted from different outcomes (See Figure 5.13). Likewise, it demonstrated significant differences only in different phase conditions, F(1,5)=147.54, *p*<.05, but not in different outcome conditions, F(1,5)=5.38, *p*=.07; and in different distance conditions, F(2,10)=.53, *p*=.61. Furthermore, a phase-by-outcome interaction, F(1,5)=64.72, *p*<.05, was demonstrated (See Figure5.14), which was caused by the differential phase effect for outcomes, *p*s<.05. As the 2 (phase) × 4 (outcome) × 3 (distance) repeated measure ANOVA, no significant phase-by-distance, F(2,10)=.37, *p*=.70, outcome-by-distance, F(2,10)=.19, *p*=.83, and three-way interaction effect were found, F(2,10)=.70, *p*=.52.

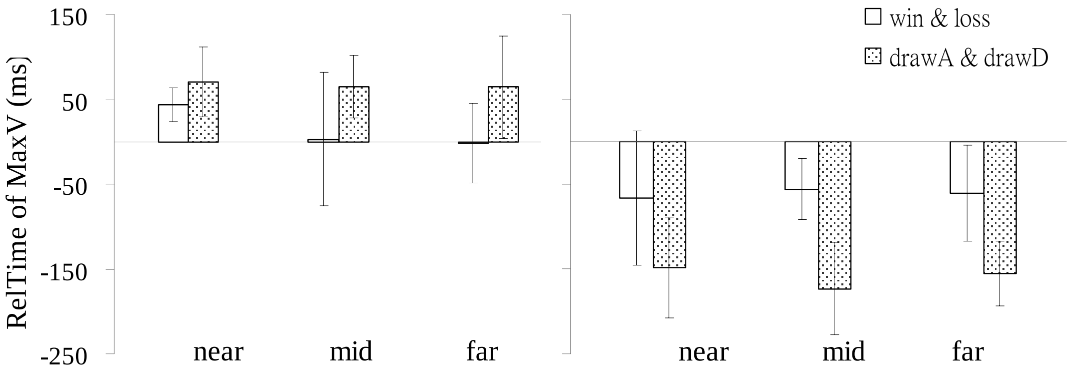

Figure 5.13. Average relative time of maximum movement velocity for two kinds of performance outcomes for the 1st phase (left panel) and 2nd phase (right panel) in different conditions of initial relative distance participants (near, mid and far).

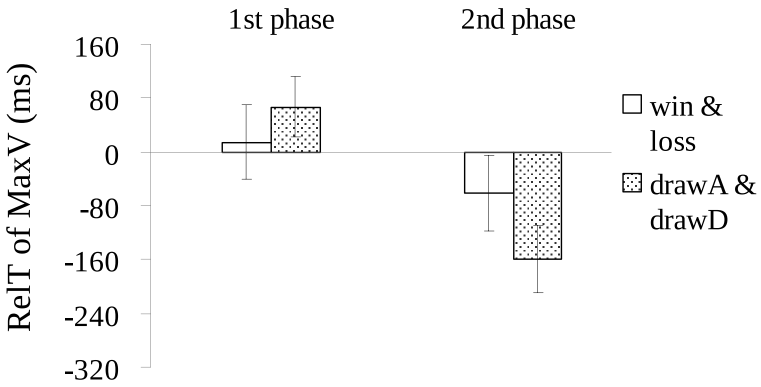

Figure 5.14. Average relative time of maximum movement velocity for two kinds of performance outcomes in the 1st and the 2nd phase.

Chapter 5

Discussion

According to the research questions and results, the discussion that followed was also organized in five sections.

Influence of initial distance between fencers and role of duelling pair on win-loss outcomes

The first question of this study was to examine the effect of initial distance between fencers and role (Attack initiator vs. Original defender) of duelling pair on performance outcome. To examine the source of the significant role-by-distance interaction, it was found that the fencer designated as the defender revealed quite stable success rate averaged about 21.3% no matter in which distance conditions (21.3%, 23.3%, and 20.3% for near, mid and far conditions), whereas the attack initiator demonstrated a decrease trend from near to mid and far conditions (from 41.3% to 23.3% and 14.3%). These differential results may suggest that the 2nd phase of the duel was not influenced by the initial distance anymore. In the far condition, the attack initiator even showed a lower success rate than the defender did. From the success rate results alone, it seems to suggest that it was rather dangerous to initiate the attack in far distance, however, if combining the spatial error results, it is possible that the attackers might have strategically planed a draw in the far condition to better prepare for the rebound retreat later.

Influence of initial distance between fencers on the rate of using crossover step and relation between performance outcomes to the choice of step pattern

Fencers had two choices to apply the step pattern (regular forward step and crossover step) when executing the two-step forward movements to touch the opponent, the second question of the study was to examine the influence of initial distance between fencers on the rate of using crossover step, and the relation between performance outcomes and the choice of step pattern. The significant outcome-by-distance interaction rested on the facts that fencers demonstrated an increase trend from near to far conditions for the win-outcomes, but revealed a rather stable trend among three different distance conditions for the draw-outcomes. More in detail, rates of using crossover step in the mid and far condition for win-outcomes even reached to 75.2% and 83.3%, meaning the crossover step was used in most trials in those two conditions when the fencer touched the opponent successfully. The result provided the evidence that fencers could perceive the different distance between self and the opponent, and thus their action, applying the crossover step, occurred accordingly. Also, it indicated that different initial distance between fencers constrained the step pattern of fencers for fulfilling the task to touch the opponent, which conformed to Newell's (1986) suggestion that coordination and action emerge from the interaction of task, organismic, and environment constraints.

To sum up, the result indicated the great advantage of using crossover step for attack when the opponent is more far away and suggested the variety of the step pattern was necessary during fencing movement; to put it simply, to apply the step pattern flexibly could create more chances to come closer to the opponent.

Influence of initial distance between fencers on the relative timing (RelTiming) of fencers' movement initiation, and relation between RelTIming to the performance outcomes

In this study, the defender was asked to trigger the retreat movement after the attacker initiated the movement, and the relative timing between fencers' movement initiation (RelTiming) was taken as of the difference between the defender's movement initiation time and that of the attacker's. The positive RelTiming indicated that the defender moved later than the attacker.

In this part, the influence of the initial distance between fencers was examined; also, the RelTiming for different trial phases and performance outcomes were compared. There was a significant effect of initial distance between fencers, showing that the RelTiming was greater in the far condition than in the mid and near conditions (59.0 ms, 34.5 ms, and 17.2 ms, respectively), which meant that fencer could initiate his retreat movement later in the far condition than in the mid and near conditions perhaps because farther distance might compensate for later initiation.

Furthermore, RelTiming in the 1st phase (120.5 ms) was greater than in the 2nd phase (-46.5 ms), and the negative RelTiming in the 2nd phase meant that the defender initiated his movement earlier than the attacker, because defender was not limited to move after attacker initiated his movement in the first phase. As for RelTiming for different outcomes which could be categorized into two kinds (win/loss vs. drawA/drawD), the values were larger in win/loss-outcomes than in draw-outcomes (78.5 ms vs. -4.75 ms), meaning that defender initiated his retreat movement much earlier so that made a draw outcome; and the timing difference, only about 80 ms, determined whether the defender was touched or not. That is, the defender’s earlier movement initiation helped him escape from the attack in time. Interestingly, even though the RelTimings for all outcomes were different, they were all smaller than 100 ms, which inferred that defenders had anticipated the attacker’s movement initiation, but did not move until they really observed the attacker’s movement initiation.

In sum, the RelTimings were similarly constrained by the initial distance between fencers; the different RelTimings of fencers’ actions for different initial distances were tightly related to what they perceived, namely, the approaching opponent. Whether the defender was touched or not was determined by the extremely small timing difference about only 80 ms. Also, from the results, in general, that defender had anticipated before he actually observed the movement initiation of the attacker.

Influence of initial distance between fencers on the spatial error of attack and relation between spatial errors to the maximum movement velocity of the fencer

In this part, the effect of initial distance between fencers on the spatial error of attack was investigated under the circumstances when the attack was not successful in the 1st phase, and it could be further divided into two conditions based on the 2nd phase performance outcome of the trial, namely, the draw- and loss-outcome to the attack initiator.

The effect of initial distance between fencers was found significant revealing greater errors for the far condition than the near condition (43.3 cm vs. 30.3 cm). And, errors for the draw-outcomes were significantly larger than that for the loss-outcomes (47.2 cm vs. 26.3 cm). However, 47.2 cm was too large to be regarded as the error of attack but could be taken as the outcome of "strategy"; that is to say, the attacker did not intend to fulfil the attack movement to touch the opponent, but merely to execute the two-step forward movements without violating the task demands and then retreated quickly for not being touched by the rebound attack from the original defender. Since the focus was put on "step back fast to escape the rebound attack", it was reasonable that the attacker did not come close to the defender, thus the large spatial errors were occurred. On the other hand, the errors for the loss-outcomes among the three conditions of initial relative distance were much smaller and quite similar (24.1cm, 25.8 cm, and 29.0cm from near to far conditions), which indicated that if the attacker came rather close to the defender but did not touch him successfully, he ran a higher risk of being touched by the rebound attack from the original defender. Moreover, the errors for loss-outcomes, about 26.3 cm, were nearly the length of one step, which could be the suggestion for the fencers to concern about one step more for their attack distance, or they would better to keep their attack deception more than one step far away to avoid the rebound attack from the opponent.

As for the relation between speed and accuracy, that is, the correlation of fencer's maximum movement velocity (MaxV) and the performance outcomes; generally, higher MaxV would bring the fencer closer to the opponent and thus made a successful touch to the opponent, and even under the circumstances when the fencer did not touch the opponent, it were smaller errors that occurred if the MaxV of the fencer was high.

In sum, fencers who achieved the higher MaxV would make the successful touch to the opponent; and it was the effect of strategy that resulting in the different spatial errors of attack distance, and the eventually draw- or loss-outcomes of performance.

Influence of initial distance between fencers on velocity-related parameters and relation between these parameters to performance outcomes

Maximum movement velocity (MaxV) of the fencers and time to maximum movement velocity (TtoMaxV).

The statistical results of the maximum movement velocity indicated that the 2 phases had very different profiles. In the 1st phase, the initial distance had a significant effect in that fencers achieved higher MaxV in the near condition than in the far condition (382.86 cm/s vs. 349.73 cm/s). Further examine the interaction between outcome and distance in the 1st phase, the low maximum velocity in the far condition seemed to be more salient from the defenders part, that is, the retreat movement become slower due to the increase of the distance between the fencers. As for the attackers side, the winning outcome always maintain high velocity but in the draw situation, the maximum velocity of the attackers decreased along the increasing distances. It is possible that the increased distance provided the attackers with a strategic plan not to touch but to prepare for the rebound retreat, therefore the velocity was reduced from the near condition.

For the 2nd phase, there was no distance effect on the maximum velocity because the original distance manipulation had been washed out after the 1st attack. However, due to the different movement directions for attackers and the defenders, that is, approaching forward for attackers and retreat backward for the defenders, the maximum velocity showed a difference between the roles of the fencers. No difference was observed between the “touch” and “no-touch” indicating the maximum velocity of the fencers may not be a critical factor in deciding the outcome of the duel.

The results were also in agreement with Chen and Liu’s (2008) previous study, which examined the distance errors of fencers’ estimation of the opponent’s attack distance, namely, the length of the opponent’s lunge, and found that larger errors, meaning too early initiation of retreat movement, occurred when the opponent’s was moving toward the fencer faster. Similarly, in this study, the defender initiated his actions later when the attacker was standing farther away because more time was needed for the attacker to generate longer displacement.

Relative maximum movement velocity (Rel MaxV) and relative time of maximum movement velocity (RelT of MaxV).

To be noted, relative maximum movement velocity (Rel MaxV) was derived from MaxV of the defender minus that of the attacker; therefore, the negative Rel MaxV indicated that the defender has lower MaxV, and vice versa. Similarly, the relative time of maximum movement velocity (RelT of MaxV) of the fencers was also derived from the time of the defender’s MaxV minus that of the attacker’s.

From the results of Rel MaxV, there was significant difference in different phases, with the 1st phase revealing the larger difference between the duel (-99.99 cm/s vs. -76.14 cm/s), and in different distance conditions, with far condition demonstrating larger difference than the near condition (-98.35 cm/s vs. -81.52 cm/s). The distance and phase effect may be confounded because the 2nd phase started when the 1st phase ended with a draw and from the results of the spatial error, the distance between the fencers would be close to, if not smaller than, the near distance of the 1st phase (90cm). Therefore it was very much likely that the short distance between the fencers in the 2nd phase indirectly caused the phase effect found in the analysis. In terms of the outcome, if we group the win/loss and drawA/drawD results to look at the distinction between the “touch” vs. “no-touch”, it seemed to suggest that larger difference in the RelMaxV tend to result in the ”touch” outcome.

The results of RelT of MaxV From the 1st phase were in the opposite trend to the results of RelTiming of fencer’s movement initiation for the outcome effect. Further examining the velocity profile of individual trials revealed that the shorter time difference between the defender and the attacker might have come from an incomplete 2-step retreat of the defender, therefore the peak velocity of the defender was picked from the first retreating step. The result of RelT to MaxV of the 2nd phase, however, was in the similar trend of the RelTiming of movement initiation, suggesting that the time difference of the peak velocity occurrence was a direct consequence of the time difference of the movement initiation.

Chapter 6

Conclusions

Based on the results of the data and the discussions of related issues, it should be noted that duels at different phases had very different profiles because the original distance manipulation had been washed out after the initial attack, and the conclusions were as followed:

When a fencer is confronting with his opponent, “the relative distance between them” determines the question of “to fight or to flight”. Put it simpler, when the fencer is moving quite closely to the opponent, “to fight” aggressively is suggested rather than “to flight”. Moreover, if to attack, the fencer should keep accelerating as long as possible in order to achieve the highest forward velocity, and to apply the crossover step flexibly in order to shorten the relative distance. As for the defender, only under the circumstances when he initiated his step back early enough could he escape from the attack in time.

Generally, the distance between the fencers had larger influence to the defenders than the attackers. The data suggested that the defenders tended to initiate the retreat movement later and slower when farther away from the attackers. Therefore if the attacker at the far distance condition take an aggressive, high velocity forward movement when the defender retreat late and slow, there is still a chance of “touché”. When a “miss” occurred, the defender needs to initiate the rebound attack as soon as possible in order to make a successful attack. Because the distance between the fencers at the rebound attack situation was usually less than 90 cm which is the shortest distance manipulated in this study, the consequence of the duel almost solely depend on the difference of the movement initiation time due to the constant movement patterns of the approach and retreat of the elite athletes (e.g., Hubbard & Seng, 1954; Bootsma & Van Wierigen, 1990).

For the 1st phase of the duel, although the distance effect seemed to influence the outcome, the analyses results suggested that the deciding factor of “touché” resided in the attackers’ maximum velocity. Unlike in the 2nd phase where the movement initiation time was more critical, when there was at least 90 cm between the fencers, the relative maximum velocity plays a more important role in determining the result.

Although the reported study manipulated 3 initial distances between the fencers, with the possible rebound attack after the “miss’ of the initial attacks where the distance between the fencers became shorter than 90 cm, another “distance” effect seemed to fall on the “90cm” boundary. In the 1st phase of the duel, distances between the fencers were always longer than 90 cm, the most critical factor for making a successful attack is the relative maximum velocity of the fencers; if the 1st phase ended with a “miss”, the distance between fencers at the 2nd phase was usually shorter than the 90 cm boundary, then the quick initiation of the rebound attack became the key element in winning the duel.

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Appendix

參與實驗同意書

本研究題目為：「刺不到？！退不開？！擊劍攻退間之運動學分析」，主要目的在探討不同情境下攻退間距離知覺的差異。由於資料分析的需要，請您據實填寫基本資料。本實驗參與者需以前進長刺腳步接觸對手、逃避對手之前進長刺攻擊並予以回擊，請依實驗者的指示進行，以利資料蒐集。

您在參與過程中所提供的所有資料在未經您的同意前不會告知非本研究相關人員；在發表、出版本研究時亦不會以可辨識參與者的方式呈現。研究者有保障參與者之安全與義務，並回答參與者不影響實驗結果之問題。您在實驗過程中如有不適或改變意願，可隨時退出本實驗，但請務必事先通知實驗者。本實驗所有過程將於台灣師範大學分部體育館進行，請您於實驗期間在實驗者的指示下全力配合，並盡自己最大努力來完成試作任務。

感謝您的參與及合作！

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中華民國 97 年　月　日

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