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Analysis of diachronic relationships in successful and unsuccessful behaviors by world fencing champions using three complementary techniques

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Título: Análisis de las relaciones diacrónicas en los comportamientos de éxito y fracaso de campeones del mundo de esgrima utilizando tres técnicas complementarias.
Resumen: El objetivo de este estudio fue investigar las posibles relaciones diacrónicas en las conductas de éxito y fracaso en campeones del mundo de esgrima desde tres técnicas analíticas complementarias: detección de *T-patterns*, análisis secuencial de retardos y análisis de coordenadas polares. Se utilizó un diseño observacional nomotético, puntual y multidimensional en el registro de 24 asaltos de los seis esgrimistas campeones del mundo de 2014. Se utilizó como instrumento de registro el *software* LINCE. Los resultados revelaron una serie de comportamientos que estaban estadísticamente asociados con la mejora del rendimiento deportivo y también se identificaron acciones que contribuyeron a empeorarlo. Una de las principales conclusiones que pueden extraerse de este estudio es que el uso de estas técnicas complementarias de análisis es perfectamente factible y tiene un gran potencial en el ámbito del deporte. El análisis secuencial en el retardo 0 (co-ocurrencias) y de las configuraciones básicas de los *T-patterns* proporcionan conocimientos tácticos sobre las diferentes acciones de esgrima empleadas. Este análisis se produce en el marco de la interacción entre las técnicas ejecutadas por cada tirador y su rival en cada acción del asalto. El análisis secuencial en los retardos -1 a -5 y +1 a +5, las agrupaciones de *clusters* de los *T-patterns* y el análisis de coordenadas polares contribuyen al análisis de la estrategia de combate. En este caso, se observaron cómo las conductas prospectivas y retrospectivas determinaron la consolidación o modificación de ciertos comportamientos durante cada asalto, con el fin de mejorar la eficacia de las acciones realizadas a lo largo de toda la competición.
Palabras clave: Táctica; análisis secuencial de retardos; coordenadas polares; *T-patterns;* metodología observacional; esgrima.

Abstract: The aim of this study was to investigate diachronic relationships in successful and unsuccessful behaviors by world fencing champions using three complementary techniques: T-pattern analysis, lag sequential analysis, and polar coordinate analysis. We employed a nomothetic, point, multidimensional observational design in which we analyzed 24 bouts fenced by six world fencing champions in 2014. The actions were recorded and coded using LINCE software. The results revealed a series of behaviors that were significantly associated with successful outcomes, and also identified actions that contributed to poorer performance. One key conclusion to be drawn from the study is that the use of these complementary techniques is perfectly feasible and holds great potential in the field of sport. Lag sequential analysis of occurrences at lag 0 (co-occurrences) and analysis of basic T-patterns provided tactical insights into the different fencing actions employed. This analysis is focused on the actions and reactions of each fencer and his rival during each exchange. Insights into combat strategy, by contrast, were provided by lag sequential analysis of occurrences at lags -1 to -5 and lags +1 to +5, analysis of T-pattern clusters, and polar coordinate analysis. In the last case, we observed how prospective and retrospective behaviors, reflected in the modification or extension of certain behaviors during each bout, improved the efficacy of actions performed throughout the competition.
Key words: Tactics; lag sequential analysis; polar coordinates; T-patterns; observational methodology; fencing.

Introduction

Fencing is the only combat sport that has featured at all Olympic Games since the first modern games were held in Athens in 1896. The sport has three variants, épée, foil, and sabre, each with different characteristics and rules, and accordingly, different techniques, strategies, and decision-making processes.

Apart from building on physical and coordination skills (essentially timing and sense of distance), fencing training programs need to address psychological and environmental factors, technical skills specific to the weapon (épée, foil, and saber), and preparation to help fencers analyze complex situations on their feet and take fast, accurate decisions.

The scientific literature on fencing is scarce (Aquili et al., 2013; Roi, & Bianchedi, 2008; Turner et al., 2013), and despite the importance of decision-making in this sport, very few studies have focused on tactical behaviors (Iglesias, Gasset, González-Prado, & Anguera, 2010; Tarragó et al., 2015).

Insights into patterns of behavior exhibited by fencers during a fencing bout could provide information on successful and unsuccessful strategies and tactics for application in training programs. Following on from the work of Tarragó, Iglesias, Lapresa, and Anguera (2016), the aim of this study was to investigate diachronic relationships underlying the tactics employed by male and female épée, foil, and sabre world champions using three complementary analytical techniques commonly used in observational methodology: lag sequential analysis, polar coordinate analysis, and T-pattern analysis.

T-pattern detection

T-patterns are temporal patterns that are not readily visible within sets of complex behaviors. They can be detected using special algorithms developed by Magnusson (1996, 2000, 2005, 2015) in the Theme software package. A T-pattern is essentially a "statistical construction" corresponding to a combination of events that occur in the same order

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and are separated by a time distance that remains invariant relative to the null hypothesis that each event or behavior is independent and randomly distributed over time.

Theme searches for critical intervals [t + d1, t + d2](d2 ≥ d1 ≥ d0) within a dataset corresponding to a period of observation [1, NT], after which A occurs in T, until it finds an occurrence of B that is more likely than would be expected by chance. To do this, it compares the null hypothesis that A and B are independently distributed and that B has a fixed probability of occurrence per unit of time (= NB/T) throughout the observation period (where N is the number of occurrences of B and T is the duration of the observation).

When Theme detects an occurrence of “A” followed by “B” within a critical interval, it generates a simple T-pattern (AB). Occurrences of simple T-patterns become events, which are then treated as initial event-types at the subsequent detection level. Theme repeats this process, level by level (from 1 to n) in search of critical interval relationships featuring T-patterns detected in previous levels. Accordingly, all T-patterns, $Q = X_1 X_2 ... X_m$, can be divided into at least two events within a critical interval. In other words Q_{Left} $[d_1, d_2]$ Q_{Right}; Q_{Left} and Q_{Right} can be part of a more complex T-pattern $X_1 \ldots X_m$ expressed as the terminals of a binary-tree.

Critical interval relationships may be detected between a simple T-pattern (AB) and an event-type K, giving rise to a level-2 T-pattern with three events ((AB)K) or (see Figure 1) between two simple T-patterns (AB) and (CD), giving rise to more complex level-2 T-pattern with four events ((AB)(CD)).

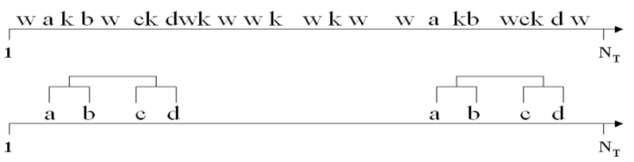

Figure 1. T-pattern detection (Magnusson, 2000, p. 94-95).

The pattern detection algorithms, working level by level, generate increasingly complex T-patterns. These complex patterns are formed by simple, two-event T-patterns detected at the lowest level and subsequent patterns detected at higher levels or containing more events (Pattern Vision Ltd & Noldus Information Technology bv, 2004).

Although Theme was primarily designed to detect temporal patterns, the software also includes a feature for detecting sequential structures based on order of occurrence (Lapresa, Anguera, Alsasua, Arana, & Garzón, 2013; Lapresa, Arana, Anguera, & Garzón, 2013; Magnusson, 1996, 2000).

T-pattern detection has been used in many sports (Jonsson et al., 2010), including, in recent years, fencing (Tarragó et al., 2015; Tarragó et al., 2016) and other combat sports (Camerino, Prieto, Lapresa, Gutiérrez, & Hileno, 2014; Gutiérrez-Santiago, Prieto, Camerino, & Anguera, 2011a, 2011b, 2013; Lapresa, Ibáñez, Arana, Amatria, & Garzón, 2011; Prieto, Gutiérrez-Santiago, Camerino, & Anguera, 2013).

Lag sequential analysis

Lag sequential analysis has its origins in the work of Bakeman (1978), but was subsequently developed by researchers such as Sackett (1987), Bakeman, Adamson, and Strisik (1988), Bakeman (1991), and Quera (1993), with additional contributions from Bakeman and Quera (1995, 2001, 2011). The development of a dedicated software program GSEQ, first released in 1995 (Bakeman & Quera, 1995), has greatly facilitated the analysis of sequential observational data.

Lag sequential analysis has proven to be a powerful tool for analyzing a range of sports, including fencing (Iglesias et al., 2010; Tarragó et al., 2016). The release of the 2011 version of GSEQ, GSEQ5 (Bakeman & Quera, 2011), led to the proliferation of behavioral studies based on lag sequential analysis, as it facilitates the calculation of adjusted residuals between what are known as given and target behaviors and the subsequent interpretation of significant differences between conditional and unconditional probabilities (based on observed and expected frequencies, respectively) in successive steps known as lags.

The computation of adjusted residuals is described in the work of Bakeman and Quera (2011), which included the correction proposed by Allison and Liker (1982). Adjusted residuals can be either positive (i.e., they have an activating effect) or negative (inhibitory effect) and they show the level of statistical association between a given and a target behavior. They are computed prospectively (behaviors that occur after the given behavior) and retrospectively (behaviors that occur before the given behavior), and the analysis also considers co-occurrences (i.e., behaviors that occur at lag 0).

Lag sequential analysis can be applied to any dataset of behaviors or events in which the order of occurrence is recorded; to use Bakeman’s terms (1978), the data may be sequential (type I or III data) or concurrent (type II or IV data) and also event-based (type I or II data) or time-based (type III or IV data). In the second case, both the duration of events and the moment at which they occur are recorded. Sequential analysis can also be used to analyze a single dimension within an observation instrument (type I or type III data) or several dimensions simultaneously (type II or IV data). GSEQ is mainly used to analyze multievent sequential data.

Polar coordinate analysis

Polar coordinate analysis (Sackett, 1980) is used to study the relationship between a given behavior (or focal behavior as it is known in this technique) and one or more conditional behaviors. It requires prior calculation of adjusted residuals using lag sequential analysis (Bakeman, 1978, 1991). This technique is being increasingly used in sports research, particularly since the recent addition to the HOISAN software program of a feature for calculating vector lengths and angles and displaying results in the form of polar coordinate maps (Hernández-Mendo, López-López, Castellano, Morales-Sánchez, & Pastrana, 2012). HOISAN, like GSEQ, includes a feature for calculating adjusted residuals.

The informative potential of polar coordinate analysis has been highlighted by Anguera, Santoyo, and Espinosa (2003) and Espinosa, Anguera, and Santoyo (2004). Essentially, it is a data reduction technique based on the Z_{sum} statistic $\frac{\Sigma z}{\sqrt{n}}$, which was introduced by Cochran (1954) and subsequently developed by Sackett (1980, 1987). It can be applied to series of values that are independent of each other, which is the case of prospective and retrospective adjusted residuals, as these are calculated separately for each lag. Z_{sum} statistics are computed from standardized Z scores obtained from adjusted residuals corresponding to prospective and retrospective lags (Bakeman, 1978, 1991). Prospective and retrospective Z_{sum} statistics are shown on the X and Y axes, respectively. These scores can be positive or negative and are located in one of four quadrants, each with a different significance. They are used to build a vector map showing the relationship between a focal behavior (Gorospe & Anguera, 2000) and one or more behaviors of interest (conditional behaviors).

Once the prospective and retrospective Z_{sum} statistics have been calculated for each focal and conditional behavior, the length and angle of the resulting vectors are calculated:

a) Vector length is the distance between the origin of the Z_{sum} coordinates (0,0) and the point of intersection (Z_{sum} for the focal behavior on the X axis and the conditional behavior on the Y axis). The diagonal representing the length of the vector is obtained by calculating the square root of the square of the prospective Z_{sum} added to square of the retrospective Z_{sum} : $\sqrt{X^2 + Y^2}$. The relationship is considered significant ($p < .05$) when the length exceeds 1.96.

b) The vector angle is the relationship between the focal behavior and the conditional behavior; it is calculated by dividing the retrospective Z_{sum} arcsine by the radius *(ϕ = arcsine of Y/radius)***.** The final value of the angle will depend on the quadrant in which the conditional category is located, which in turn will depend on whether the prospective Z_{sum} (X) and the retrospective Z_{sum} (Y) are positive or negative: quadrant I ($0º < \varphi < 90º$) = φ; quadrant II ($90º < \varphi < 180º$) = 180º – φ; quadrant III ($180º < \varphi < 270º$) = 180º + φ; quadrant IV ($270º < \varphi < 360º$) = 360º - φ.

The relationship between the focal and the conditional behavior (prospective/retrospective activation/inhibition) is depicted by the quadrant in which the behaviors are situated. In brief, quadrant I indicates mutual prospective and retrospective activation (i.e., the two behaviors activate each other in both directions); quadrant II indicates prospective inhibition and retrospective activation (i.e., the focal behavior inhibits the conditional behavior but is also activated by it); quadrant III indicates mutual prospective and retrospective inhibition; and quadrant IV indicates prospective activation and retrospective inhibition.

Tarragó et al. (2016) determined that tactical behavior and efficacy of fencing actions could be analyzed through T-pattern configurations (or clusters) and the sequential analysis of behaviours at lag 0, while strategic behaviors in specific bouts could be analyzed through the diachronic analysis of T-pattern configurations, prospective and retrospective analysis of lags, and polar coordinate analysis.

Method

We undertook an observational methodology study (Anguera, 1979; Anguera, & Hernández-Mendo, 2015; Anguera, & Jonsson, 2003) consisting of active, non-participative observation (Anguera, 1990).

Design

Based on the observational methodology designs described by Anguera et al. (2011), we employed a nomothetic (differential analysis of three fencing variants), point (single competition with different bouts fought by individual fencers considered as a unit), and multidimensional (different possible levels of response for each occurrence) design.

Participants

We analyzed 24 bouts fought in the round of 16, quarterfinals, semifinals, and finals of the 2014 World Fencing Championship. The bouts were all fought by the eventual winners of the championship men’s épée (ME), women’s épée (WE), men's foil (MF), women's foil (WF), men’s sabre (MS), and women’s sabre (WS). One of the MF quarterfinals was replaced by a round of 16 bouts as the necessary video footage was not available.

The study was approved by the Catalan clinical sports research ethics committee (0099S/2912/2010 2607/LA). Because it was an observational study of a publicly broadcast event held in a natural setting, informed consent from the fencers was not required (American Psychological Association, 2002).

Instruments

The observation instrument used for the study was an adaptation of the ESGRIMOBS fencing observation instrument (Tarragó et al., 2015). Table 1 shows the structure and content of the instrument, which included ten broad criteria, each broken down into exhaustive, mutually exclusive categories (51 in total). The categories are described in Tarragó et al. (2016).

Each fencing phrase was considered to be a unit of observation. A fencing phrase, as defined by the International

Fencing Federation (FIE) is "an uninterrupted exchange of blade actions, ending either with a hit or with the fencers breaking off" (FIE, 2014).

Table 1. Observation instrument (adapted from ESGRIMOBS, Tarragó et al., 2015).

Observation instrument

Criteria	Categories system	Code	Criteria	Categories system	Code
Pressure	No pressure	np	5th Action	5th action: champion defensive	vdc
	Champion pressure	pc		5th action: opponent defensive	vdo
	Opponent pressure	po		5th action: champion offensive	voc
Preparation	No preparation	nx		5th action: opponent offensive	voo
	Champion preparation	xc		5th action: champion counteroffensive	vcc
	Opponent preparation	xo		5th action: opponent counteroffensive	vco
	Both preparation	xoc	6th Action	6th action: champion defensive	vidc
1st Action	1st action: champion defensive	idc		6th action: opponent defensive	vido
	1st action: opponent defensive	ido		6th action: champion offensive	vioc
	1st action: champion offensive	ioc		6th action: opponent offensive	vioo
	1st action: opponent offensive	ioo		6th action: champion counteroffensive	vicc
2nd Action	2nd action: champion defensive	iidc		6th action: opponent counteroffensive	vico
	2nd action: opponent defensive	iido	7th Action	7th action: champion defensive	viidc
	2nd action: champion offensive	iioc		7th action: opponent defensive	viido
	2nd action: opponent offensive	iioo		7th action: champion offensive	viioc
	2nd action: champion counteroffensive	iicc		7th action: opponent offensive	viioo
	2nd action: opponent counteroffensive	iico		7th action: champion counteroffensive	viicc
3rd Action	3rd action: champion defensive	iiidc		7th action: opponent counteroffensive	viico
	3rd action: opponent defensive	iiido	Touch	No touch	nt
	3rd action: champion offensive	iiioc		Champion touch	tc
	3rd action: opponent offensive	iiioo		Opponent touch	to
	3rd action: champion counteroffensive	iiicc		Double touch	td
	3rd action: opponent counteroffensive	iiico			
4th Action	4th action: champion defensive	ivdc			
	4th action: opponent defensive	ivdo			
	4th action: champion offensive	ivoc			
	4th action: opponent offensive	ivoo			
	4th action: champion counteroffensive	ivcc			
	4th action: opponent counteroffensive	ivco			

The video footage of the 24 bouts was analyzed and coded in LINCE (v.1.1) (Gabin, Camerino, Anguera, & Castañer, 2012), while the lag sequential analysis, polar coordinate analysis, and T-pattern analysis were performed using GSEQ5, HOISAN, and THEME v.6 Edu, respectively.

Procedure

The coding of the 24 bouts analyzed generated a matrix of 1282 records (ME = 229, WE = 218, MF = 265, WF = 211, MS = 197, WS = 162). Due to the restrictions in Theme concerning the number of codes that constitute an event, we excluded records containing excessively long strings of actions (≥ 5 actions in the same phrase) from the matrix. These corresponded to just 2% of all records.

According to the terminology used in lag sequential analysis, the data were event-based and concurrent (type II). For the T-pattern analysis, considering that we were interested in analyzing the internal sequence of events within phrases (and not their duration or the time distance separating them), we assigned a constant duration (= 1) to each event-type.

The four bouts fought by the six world champions were grouped together to search for behavioral patterns corresponding to each champion using T-pattern and lag sequential analysis.

The following search settings were applied in Theme:

a) Free pattern mode, in which the search for critical intervals is set at the lower starting limit and not at 0 as occurs in the case of fast-patterns. In other words it is set at the shortest distance between two events in a pattern. Accordingly, critical interval events can be separated by a relatively numerous number of behaviors (phrases in our case).
b) Significance level of $p < .005$ (i.e. maximum risk of 0.5% that the critical interval relationships are a result of chance); c) minimum frequency of two occurrences to form a T-pattern; d) reduction of redundancies such that if over 90% of occurrences of a new pattern start and end in a critical interval of patterns that have already been detected, the new pattern is rejected.

For the lag sequential analysis, performed in GSEQ5, based on the criteria of Bakeman and Gottman (1986), we considered the following:

a) significant ($p < .05$) transitions larger than 1.96 represented sequences that occurred more often than would be expected by chance (activating relationship between given and focal behavior);
b) significant ($p < .05$) transitions with a value of 1.96 or smaller represented sequences that occurred less often than would be expected by chance (inhibitory relationship between given and focal behavior).

Finally, in HOISAN, we applied the concept of genuine retrospectivity proposed by Anguera (1997), which is a modification of the original concept described by Sackett (1980) (see Figure 2). Based on the experience of many studies in the social and behavioral sciences (Lapresa et al., 2013), retrospectivity was contemplated from lag -1 to lag -5, as sequential patterns appear to become diluted when more lags are used. The focal behaviors were a hit or touch by the champion or by an opponent, and all the other behaviors in the observation instrument were considered conditional behaviors. Vectors shows the relationship between a focal behavior (touch by champion or opponent), which corresponds to the criterion behavior in lag sequential analysis, and each of the conditional behaviors.

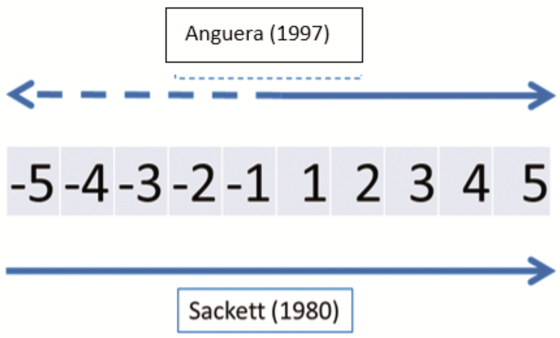

Figure 2. Concept of genuine retrospectivity proposed by Anguera (1997), modifying Sackett's original proposal (1980).

Data quality control

The quality of the data was checked by analyzing the validity and reliability of the observation instrument and datasets (Blanco-Villaseñor & Anguera, 2000). The ESGRI-MOBS observation instrument was built using the theoretical framework of fencing and was reviewed and approved by 17 experts (masters of fencing), thereby guaranteeing its conceptual consistency, robustness, and construct validity. The agreement coefficient for canonical data (agreement among panel of experts) was calculated using an external command (Hayes & Krippendorff, 2007) linked to PASW Statistics for Windows (v.18, SPSS Inc., Chicago, IL). The resulting value of .81 confirmed the reliability of the instrument (Krippendorff, 2004).

The observers ($n = 6$) participated in an instruction and training programme, in which they learned to interpret and apply the observation instrument. The observation criteria were established, and the initial data were coded collectively to achieve consensus between individual observers (Anguera, 1990). Intra- and interobserver reliability was assessed for 45 actions from three bouts for each weapon (épée, foil and sabre). Calculation of kappa statistics in GSEQ5 showed an interobserver agreement value of .77 for foil, .78 for épée, and .64 for sabre and intraobserver values of over .79 for all three weapons.

Results

T-pattern detection

A total of 224 fencing phrases (events) were recorded for ME; there were 49 different types of phrases (event-types in Theme terminology), which corresponds to a mean frequency of 4.57. In WE, there were 203 phrases, of which 118 were different (mean frequency of 1.72). In MS and WS, the respective figures were 197 and 161 phrases, with 49 and 48 distinct phrases (mean frequency of 4.02 and 3.35). Finally, for MF, there were 259 phrases, 76 of which were different (mean frequency of 3.41) and for WF, there were 203 phrases, 68 of which were different (mean frequency of 2.99).

Tables 2 and 3 show the T-patterns detected for the four bouts corresponding to each weapon and also shows the number of occurrences of each pattern, the bouts in which they occur, and the number of phrases interspersed between each phrase that make up the pattern.

Table 2. T-patterns detected in the fencing bouts fought by the three male world champions.

n	T-patterns	Occurrences	Bouts	Interspersed fencing phrases
ME1	((np,xo,ioo,iidcpo, xo,ioo,iicc,iiico,tc) np,nx,ioc,iido)	2	1 3	18-16 18-19
ME2	(np,xo,ioo,iicc,iiido po,xo,ioc,iido,tc)	2	1 3	7 5
ME3	(np,xoc,ioc,iioo,tc np)	2	2 2	/ /
ME4	(po,xo,ioo,iioc,td po,xo,ioo,iioc,td)	3	4 4 4	/ / 1
ME5	(po,xoc,ioo,iicc,to po,xo,ioc,iido,tc)	2	3 4	7 7
MF1	((po,xo,ioc,iico,to po,xo,ioo,iidc,tc) pc,xc,ioc,iido,iiicc)	2	1 1	7-1 6-1
MF2	(po,xo,ioo,iidc,iiido (pc,xc,ioc,iico,to po,xo,ioc,iico,tc))	2	1 1	1-5 1-3
MF3	(pc,xc,ioc,iico,to po,xo,ioc,iico,tc)	3	1 1 3	5 3 3
MF4	(po,xo,ioc,iido np,xoc,ioo,iicc,to)	2	3 4	17 17
MF5	(po,xo,ioc,iido,tc po,xo,ioo,iicc,tc)	3	3 4 4	8 9 10
MF6	(po,xo,ioo,iidc,tc pc,xc,ioc,iido,iiicc)	2	1 1	1 1
MS1	(pc,xoc,ioc,iico,to (np,xoc,ioc,iido (po,xo,ioo,iicc,to np,xoc,ioc,iido)))	2	1 4	4- / -1 6-1-2
MS2	(pc,xoc,ioc,iico,to (np,xoc,ioc,iido po,xo,ioo,iicc,to))	2	1 4	4- / 6-1
MS3	(pc,xoc,ioc,iico,to np,xoc,ioo,iicc,to)	3	1 2 4	14 15 14
MS4	(pc,xoc,ioc,iido,to np,xoc,ioc,iido,to)	2	2 2	4 5

Table 3. T-patterns detected in the fencing bouts fought by the three female world champions.

n	T-patterns	Occurrences	Bouts	Interspersed fencing
WE1	((np,xc,ioc,iico,td po,xo,ioc,iico,to) np,xc,ioc,iico,td)	2	3 3	1 1
WE2	(np,xoc,ioo,iidc (np po,xo,ioc,iico,tc))	2	1 1	19-4 16-4
WE3	(pc,xc,ioo,iidc (po,xo,idc,iico,tc np))	2	1 2	9- / 10- /
WE4	(np,xo,ioc,iico,tc np,nx,ioo,iidc)	2	4 4	2 2
WE5	(pc,xc,ioo,iidc po,xo,idc,iico,tc)	2	1 2	9 10
WE6	(po,nx,ioo,iidc po,xo,ioo,iidc,tc)	2	4 4	1 3
WE7	(po,xo,ioc,iico,to np,xc,ioc,iico,td)	2	3 3	1 1
WF1	((po,xo,ioo,iicc (po,xo,ioo,iidc po,xo,ioo,iicc,to)) pc,xc,ioc,iico,to)	2	1 4	/-6-1 /-4-1
WF2	(pc,xc,ioc,iido,iiicc (pc,xc,ioc,iido,to pc,xc,ioo,iidc,iiico))	2	2 4	7-9 8-10
WF3	(po,xo,ioo,iidc (po,xo,ioo,iicc,to po,xo,ioc,iido,tc))	2	1 4	3-5 3-5
WF4	(np,xc,ioc,iico,tc np,xc,ioc,iico,tc)	2	3 3	8 8
WF5	(pc,xc,ioc,iido,iiicc pc,xc,ioc,iido,to)	2	2 4	7 8
WF6	(pc,xc,ioc,iido,iiidc,ivdo np,xc,ioc,iico,tc)	2	3 4	18 19
WS1	((np,xoc,ioc,iido,tc po,xo,ioo,iidc) pc,xc,ioc,iido,tc)	2	3 3	9-/ 6-/
WS2	(np,xoc,ioc,iido po,xoc,ioo,iidc,tc)	2	1 4	/ /
WS3	(np,xoc,ioc,iido,tc po,xo,ioo,iidc)	4	1 2 3	8 9 9
WS4	(np,xoc,ioo,iidc,tc po,xoc,ioo,iicc,tc)	2	1 3	/ 10
WS5	(po,xo,ioo,iidc pc,xc,ioc,iido,tc)	2	3 3	/ /

Lag sequential analysis

The given behaviors for the lag sequential analysis were "touch by champion" and "touch by opponent". When assessing whether a given action favored the champion or his/her opponent, we did not consider double touches as a given behavior, as these can favor both fencers equally or one in particular if the score is uneven at the time of the strike. Furthermore, a double touch is only possible in épée, preventing comparisons between the different variants. The categories that formed the other criteria in the observation instrument (Table 1) were used as target behaviors.

The results of the lag sequential analysis (Tables 4 and 5) show the level of statistical significance between the given behavior and each of the target behaviors in the prospective lags (+1 to +5), lag 0 (concurrences within phrases), and retrospective lags (-1 to -5).

Table 4. Adjusted residuals for the sequential analysis of the given criterion "touch by champion".

		Women's epee			Men's epee		Women's foil			Men's foil		Women's sabre		Men's sabre
PRESSURE	np	L-3 (-2.30)	L-2 (-2.06)									L-5 (2.69)		L+1 (2.31)
	pc	L+5 (-2.19)								L-5 (1.96)	L+4 (1.99)	L+3 (-2.05)		
	po									L+3 (2.62)		L-5 (-2.71)	L+5 (1.96)	
PREPARATION	nx				L-1 (2.22)		L-2 (-2.10)							
	xc	L+4 (-2.07)					L-1 (2.63)	L+2 (-2.00)				L-2 (-2.11)		L+2 (-2.06)
	xo	L+1 (1.98)					L+2 (2.03)			L+3 (2.36)	L+4 (-2.08)	L-2 (2.22)		L-4 (-2.13)
	xoc	L-1 (2.26)			L0 (2.02)							L+4 (-2.08)		
1st ACTION	idc													
	ido													
	ioc	L+2 (-2.42)			L-3 (-2.18)		L-1 (2.63)	L0 (2.46)	L+5 (-1.99)	L+1 (2.14)	L+3 (-2.02)	L0 (3.76)		L0 (4.82)
	ioo	L+2 (2.12)			L-3 (1.97)		L-1 (-2.63)	L0 (-2.46)	L+5 (1.99)	L+1 (-2.14)	L+3 (2.02)	L0 (-3.76)		L0 (-4.82)
2nd ACTION	iidc	L-3 (2.11)	L+2 (2.04)											
	iido											L+1 (2.19)		L0 (2.42)
	iioc											L+1 (-2.34)		
	iicc	L+4 (-2.19)					L-2 (-2.13)	L0 (-3.09)	l+1 (-2.17)			L0 (-2.29)	L+3 (2.69)	L0 (-4.27)
	iico											L0 (2.30)		L0 (2.75)
3rd ACTION	iiidc	L-4 (2.13)					L-1 (2.33)	L+4 (-2.71)				L-2 (-1.98)		
	iiido									L+1 (-2.85)				
	iiioc											L+5 (2.00)		
	iiioo	L-5 (1.97)										L-4 (-2.45)		
	iiicc									L-4 (2.02)	L+4 (2.05)			
	iiico						L-2 (2.23)							
4th ACTION	ivdo	L-2 (2.18)												
	ivoc						L+5 (2.45)							
	ivcc	L+2 (2.07)	L+5 (-2.31)				L+3 (-3.00)			L+5 (1.98)				
	ivco						L-1 (2.58)							

Significant behaviors ($p < .05$); negative (-) behaviors have an inhibitory effect while positive behaviors have an excitatory (+) effect.

Table 5. Adjusted residuals for the sequential analysis of the given criterion "touch by opponent".

		Women's epee			Men's epee		Women's foil			Men's foil		Women's sabre		Men's sabre
PRESSURE	np	L-3 (2.56)										L-5 (-2.69)		L+1 (-2.31)
	pc	L+1 (1.97)								L-5 (-1.96)	L+4 (-1.99)	L+3 (2.05)		
	po				L-1 (2.20)					L+3 (-2.62)		L-5 (2.71)	L+5 (-1.96)	
PREPARATION	nx						L-2 (2.10)							
	xc	L+4 (1.99)			L-3 (2.62)		L-1 (-2.63)	L+2 (2.00)				L-2 (2.11)		L+2 (2.06)
	xo				L-1 (2.14)		L-1 (3.02)	L+2 (-2.03)		L+3 (-2.36)	L+4 (2.08)	L-2 (2.22)		L-4 (2.13)
	xoc				L-5 (-2.15)	L-3 (-2.11)						L+4 (2.08)		
1st ACTION	ioc	L-3 (2.54)	L0 (-2.59)	L+2 (2.39)			L-1 (-2.63)	L0 (-2.46)	L+5 (1.99)	L+1 (-2.14)	L+3 (2.02)	L0 (-3.76)		L0 (-4.82)
	ioo	L-3 (-2.31)	L+2 (-2.30)				L-1 (2.63)	L0 (2.46)	L+5 (-1.99)	L+1 (2.14)	L+3 (-2.02)	L0 (3.76)		L0 (4.82)
2nd ACTION	iidc	L-3 (-2.44)	L0 (2.24)											
	iido				L-3 (2.46)							L+1 (-2.19)		L0 (-2.42)
	iioc											L+1 (2.34)	L+5 (2.57)	
	iicc				L-2 (2.21)	L+4 (2.00)	L-2 (2.13)	L0 (3.09)	L+1 (2.17)			L0 (2.29)	L+3 (-2.69)	L0 (4.27)
	iico	L+4 (-2.03)										L0 (-2.30)		L0 (-2.75)
3rd ACTION	iiidc				L0 (2.33)		L-1 (-2.33)	L+4 (2.71)				L-2 (1.98)		
	iiido									L+1 (2.85)				
	iiioc				L-3 (2.49)							L+5 (-2.00)		
	iiioo											L-4 (2.45)		
	iiicc									L-4 (-2.02)	L+4 (-2.05)			
	iiico						L-2 (-2.23)							
4th ACTION	ivdc	L+2 (2.07)												
	ivoc						L+5 (-2.45)							
	ivcc	L+5 (2.81)			L-4 (2.45)		L+3 (3.00)			L+5 (-1.98)				
	ivco	L+3 (1.97)					L-1 (-2.58)							

Significant behaviors ($p < .05$); negative (-) behaviors have an inhibitory effect while positive behaviors have an excitatory (+) effect.

Polar coordinate analysis

The polar coordinate maps in Figures 3, 4, and 5 show the relationships between the focal behaviors (touch by champion and touch by opponent) and the conditional behaviors (the rest of the categories in the observation instrument) for the fencers analyzed.

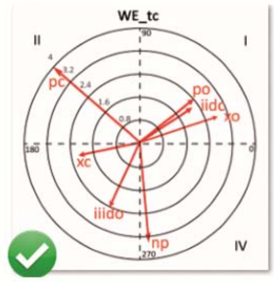

Figure 3a

Figure 3b

Figure 3c

Figure 3d

Figure 3. Results of polar coordinate analysis for épée.

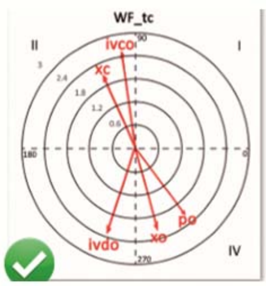

Figure 4a

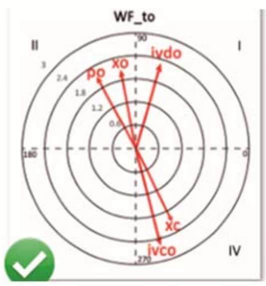

Figure 4b

Figure 4c

Figure 4d

Figure 4. Results of polar coordinate analysis for foil.

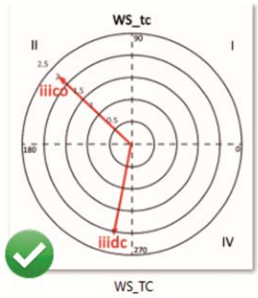

Figure 5a

Figure 5b

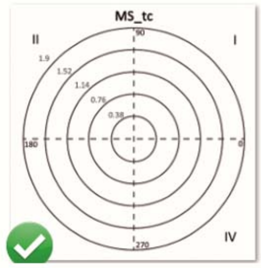

Figure 5c

Figure 5d

Figure 5. Results of polar coordinate analysis for sabre.

Discussion and conclusions

We undertook a detailed analysis of the strategies employed by the six world champions and their opponents at the 2014 World Fencing Championships by studying behaviors according to the tactical system described by the fencing master László Szabó (Szabó, 1977) and the reading of phrases and bouts by fencing referees. These original sources were used to build an ad hoc observation instrument in which sequences of actions were included as they happen, reflecting what actually happens during the refereeing of bouts with conventional weapons (foil and sabre). An original contribution of this study to the tactical analysis of fencing is that we contemplated behaviors intended to place pressure on opponents before the start of each phrase.

We considered that the first action executed could only be offensive or defensive. According to FIE rules (FIE, 2014), a counterattack can be launched only after an attack by an opponent. Unlike Szabó (1977), we included defensive action in the category of initial actions, as we considered that it was a reaction to the use of a feint (without a continuation of the attack) in the preparation stage.

T-patterns

The informative potential of T-pattern detection in the analysis of fencing lies in the fact that this technique can uncover relationships between phrases as well as sequences of actions within the most relevant phrases of a bout. We detected sequences of events using the order parameter (Magnusson, 1996, 2000). To do this, we used a numerical scale that assigns a conventional duration of 1 to each occurrence, allowing us to identify the number of behaviors interspersed between clusters of events forming a T-pattern by studying their internal intervals.

In a previous study by our group (Tarragó et al., 2015), we analyzed T-patterns both separately, in an asymmetric study in which fencers were differentiated by their location on the piste (left vs right), and together, in a symmetric study in which fencer A was the fencer who initiated the action and B was his opponent. The analysis of sequential event patterns loses coherence in a symmetric analysis, as the classification of fencers as A or B changes during bouts. However, a symmetric analysis is of value for identifying which phrases are used most in elite fencing, for example. An asymmetric analysis that analyzes actions bout by bout, however, is more rigorous, as it contemplates exchanges between two fencers in a specific situation (a combat), without other factors that could influence the pure sequence of events that occur within a fencing phrase.

In another more recent study by our group (Tarragó et al., 2016), the combined use of an asymmetric and a multi-bout analysis provided more detailed information on behaviors in elite fencing and their impact on successful and unsuccessful behaviors, defined by the scoring or loss of a touch. We repeated this analysis in the present study, but extended our study to six events (men's and women's individual épée, foil and sabre). Tables 2 and 3 show the T-patterns detected for the four bouts fought by each of the gold medal winners at the 2014 World Championships.

Lag sequential analysis

The results of the lag sequential analysis are interpreted by using the adjusted residuals obtained for each of the given behaviors (touch by champion and touch by opponent) in the different lags studied and analyzing their relationship with each of the target behaviors (categories). The adjusted residuals for lag 0 show the direct impact of actions on the scoring of a touch within the phrase (within-phrase analysis). Each of the prospective and retrospective lags shows whether the target behaviors have an activating or inhibitory effect on the scoring of touches in the four bouts considered as a whole (between-phrase analysis).

Tables 4 and 5 show the results. As can be seen, statistically significant activating (positive) behaviors favor the champions, while statistically significant inhibitory (negative) behaviors favor their opponents (Table 4). The opposite can be seen in Table 5.

Polar coordinate analysis

Polar coordinate analysis condenses a wealth of information relative to the relationship (prospective/retrospective activation/inhibition) between a focal behavior (in this case touch by champion fencer or touch by opponent) and the other categories in the observation instrument (conditional behaviors). In this case, by ignoring lag 0, the focus is on relationships between different phrases. Polar coordinate analysis has been successfully used to analyze strategic behaviors in combat sports (López-López et al., 2015; Tarragó et al., 2016).

Figures 3-5 show the vectors reflecting the relationships between the different actions analyzed and the focal behaviors touch by champion and touch by opponent. Like lag sequential analysis, polar coordinate analysis also identifies behaviors that work to the advantage or disadvantage of the fencers analyzed, i.e., it shows which actions, either prospectively or retrospectively, activate or inhibit the focal behavior.

Figure 3 helps to interpret the tactical behavior of the 2014 world épée champions and their opponents. As shown in Figure 3a and 3b, the WE champion is favored by actions that activate a winning touch by her or that inhibit a winning touch by her opponent, but not by those that inhibit a winning touch by her or activate a winning touch by her opponent. Figure 3a shows how the conditional behaviors in quadrant I (mutual prospective and retrospective activation), pressure from opponent (*po*), preparation by opponent (*xo*), and second defensive actions by champion (*iidc*) activate the landing of a touch by the champion (*tc*). Quadrant II (prospective inhibition and retrospective activation) shows how pressure exerted by the champion (*pc*) inhibits a touch by her opponent (*to*). The opposite is true, however, for behaviors in quadrant III (mutual retrospective and prospective inhibition) and quadrant IV (prospective activation and retrospective inhibition), i.e., these behaviors do not favor the champion. Preparation by champion (*xc*) and third defensive actions by the opponent (*iiido*) inhibit a winning touch by the champion (*tc*), while the absence of pressure (*np*) activates a touch by her opponent (*to*). In Figure 3b, quadrant II shows that the absence of pressure (*np*) and third defensive actions by the champion's opponent (*iiido*) favor the opponent, while quadrant IV shows how pressure exerted by the champion (*pc*) helps her to land a touch. Figures 3c and 3d show the results for the world ME champion. Quadrant I in Figure 3d shows that second counteroffensive by the champion (*iicc*) are not favorable, whereas preparation by both fencers (*xoc*) and third counteroffensive actions by the champion (*iiicc*) are (quadrant IV).

Figure 4 helps to interpret what occurs in the bouts fought by the world WF champion (Figure 4a and 4b) and the world MF champion (Figure 4c and 4d). Quadrant II in Figure 4 shows that the WF champion is favored by her own preparation (*xc*) and fourth counteroffensive actions by opponents but not by fourth defensive actions by opponents (*ivdo*) or by their failure to place pressure on the champion (*po*) or to prepare in advance (*xo*) (quadrants III and IV). What occurs is logical, as foil is a conventional weapon, and allowing one's opponent to take the initiative can be a determining factor in the referee's decision regarding who scores in the case of a double touch. As shown by Figures 4c and 4d, we found no behaviors that activated or inhibited the scoring of a touch by the MF champion or his opponents.

Figure 5 shows the results for the WS (figures 5a and 5b) and MS (figures 5c and 5d) bouts. Quadrant II in Figure 5a shows how the WS champion is favored by third counteroffensive actions by opponents (*iiico*) but not by her own third defensive actions (*iiidc*) (quadrant III). Figure 5b shows the same results, quadrant I shows that she is not favored by his own third defensive actions (*iiidc*) but is by third counteroffensive actions by his opponents (*iiico*) (quadrant IV). Similarly to the case of MF, we found no behaviors that activated or inhibited a scoring touch by the MS champion or his opponents (Figure 5c and 5d).

Complementary use of three analytical techniques

The main objective of this study was to investigate diachronic relationships in successful and unsuccessful behaviors exhibited by world fencing champions using three complementary techniques. For each of the weapons, we have created a table summarizing the results for each technique and showing which behaviors favor the champion or not (Tables 6-8).

In the T-pattern analysis, a behavior was considered favorable when the set of event-types contained the event "touch by champion", and in the lag sequential and polar coordinate analyses, it was considered favorable when it activated a touch by the champion or inhibited a touch by his or her opponent. In the sequential analysis, it should be noted that in the case of opposing significances for the different lags in the same conditional behavior (Tables 4 and 5), lag values of 0 or close to 0 were prioritized.

Table 6. Evaluation of world épée champions from the perspective of three complementary analyses.

T-Patterns	Lags		Polar coordinates	
Favorable behaviors to Women's epee champion				
(np,xoc,ioo,iidc (np po,xo,ioc,iico,tc))	xo	iiidc	pc	xo
(pc,xc,ioo,iidc (po,xo,idc,iico,tc np))	xoc	iiioo	po	iidc
(np,xo,ioc,iico,tc np,nx,ioo,iidc)	ioo	ivdo		
(pc,xc,ioo,iidc po,xo,idc,iico,tc)	iidc	ivcc		
(po,nx,ioo,iidc po,xo,ioo,iidc,tc)				
Unfavorable behaviors to Women's epee champion				
((np,xc,ioc,iico,td po,xo,ioc,iico,to) np,xc,ioc,iico,td)	np	ioc	np	iiido
(po,xo,ioc,iico,to np,xc,ioc,iico,td)	pc	iicc	xc	
	xc			
Favorable behaviors to Men's epee champion				
((np,xo,ioo,iidc po,xo,ioo,iicc,iiico,tc) np,nx,ioc,iido)	nx		xoc	
(np,xo,ioo,iicc,iiido po,xo,ioc,iido,tc)	xoc		iiicc	
(np,xoc,ioc,iioo,tc np)	ioo			
(po,xoc,ioo,iicc,to po,xo,ioc,iido,tc)				
Unfavorable behaviors to Men's epee champion				
(po,xoc,ioo,iicc,to po,xo,ioc,iido,tc)	ioc		iicc	

Table 7. Evaluation of world foil champions from the perspective of three complementary analyses.

T-Patterns	Lags		Polar coordinates	
Favorable behaviors to Women's foil champion				
(po,xo,ioo,iidc (po,xo,ioo,iicc,to po,xo,ioc,iido,tc))	xc	iiico	xc	
(np,xc,ioc,iico,tc np,xc,ioc,iico,tc)	xo	ivoc	ivco	
(pc,xc,ioc,iido,iiidc,ivdo np,xc,ioc,iico,tc)	ioc	ivco		
	iiidc			
Unfavorable behaviors to Women's foil champion				
((po,xo,ioo,iicc (po,xo,ioo,iidc po,xo,ioo,iicc,to)) pc,xc,ioc,iico,to)	nx	iicc	po	ivdo
(pc,xc,ioc,iido,iiicc (pc,xc,ioc,iido,to pc,xc,ioo,iidc,iiico))	ioo	ivcc	xo	
(po,xo,ioo,iidc (po,xo,ioo,iicc,to po,xo,ioc,iido,tc))				
(pc,xc,ioc,iido,iiicc pc,xc,ioc,iido,to)				
Favorable behaviors to Men's foil champion				
((po,xo,ioc,iico,to po,xo,ioo,iidc,tc) pc,xc,ioc,iido,iiicc)	pc	ioc		
(po,xo,ioo,iidc,iiido (pc,xc,ioc,iico,to po,xo,ioc,iico,tc))	po	iiicc		
(pc,xc,ioc,iico,to po,xo,ioc,iico,tc)	xo	ivcc		
(po,xo,ioc,iido,tc po,xo,ioo,iicc,tc)				
(po,xo,ioo,iidc,tc pc,xc,ioc,iido,iiicc)				
Unfavorable behaviors to Men's foil champion				
((po,xo,ioc,iico,to po,xo,ioo,iidc,tc) pc,xc,ioc,iido,iiicc)	ioo	iiido		
(po,xo,ioo,iidc,iiido (pc,xc,ioc,iico,to po,xo,ioc,iico,tc))				
(pc,xc,ioc,iico,to po,xo,ioc,iico,tc)				
(po,xo,ioc,iido np,xoc,ioo,iicc,to)				

Table 8. Evaluation of world sabre champions from the perspective of three complementary analyses.

T-Patterns	Lags		Polar coordinates
Favorable behaviors to Women's sabre champion			
((np,xoc,ioc,iido,tc po,xo,ioo,iidc) pc,xc,ioc,iido,tc)	np	iido	iiico
(np,xoc,ioc,iido po,xoc,ioo,iidc,tc)	xo	iico	
(np,xoc,ioc,iido,tc po,xo,ioo,iidc)	ioc	iiioc	
(np,xoc,ioo,iidc,tc po,xoc,ioo,iicc,tc)			
(po,xo,ioo,iidc pc,xc,ioc,iido,tc)			
Unfavorable behaviors to Women's sabre champion			
	pc	iioc	iiidc
	xc	iicc	
	xoc	iiidc	
	ioo	iiioo	
Favorable behaviors to Men's sabre champion			
	np	iido	
	ioc	iico	
Unfavorable behaviors to Men's sabre champion			
(pc,xoc,ioc,iico,to (np,xoc,ioc,iido (po,xo,ioo,iicc,to np,xoc,ioc,iido)))	xc	ioo	
(pc,xoc,ioc,iico,to (np,xoc,ioc,iido po,xo,ioo,iicc,to))	xo	iicc	
(pc,xoc,ioc,iico,to np,xoc,ioo,iicc,to)			
(pc,xoc,ioc,iido,to np,xoc,ioc,iido,to)			

The summary tables for épée, foil, and sabre, together with the information provided in the results and discussion sections, provide partial yet complementary insights into tactical behaviors of the champions from three perspectives.

Applications for the tactical and strategic analysis of fencing

Analysis of the behaviors of elite fencers in competition situations using three complementary methods provides valuable insights into two distinct aspects of fencing: tactics and strategy.

Tactical decisions can be interpreted by analyzing the relationship between technical actions executed within individual phrases. This information is provided by two of the techniques: lag sequential analysis and T-pattern detection. Sequential analysis of lag 0 shows which techniques used in each phrase (target behaviors) are directly and significantly associated with the scoring of a touch by the eventual world champion or his/opponent (given behaviors). T-pattern analysis, in turn, not only shows isolated unidirectional relationships between the given behaviors and the target behaviors, but also uncovers significant associations between strings of actions and reactions between the two fencers.

Such a methodological approach shows the importance of a particular tactical decision (thanks to the use of lag sequential analysis and polar coordinate analysis) and also links it to a string of other interactions, placing it in context, and helping to identify effective patterns of behavior that could help to guide strategic preparation for competition situations. In sabre, for example (Tables 4 and 5), a second counteroffensive action by an opponent (*iico*) significantly favors the scoring of a touch by the champion (*tc*), but it is not associated with any particular string of actions in the T-pattern analysis (Table 8). The different results for MS in Table 8 show that the first offensive action by the champion (*ioc*) is significant in that it favors his interests, but this is a biased statement, as all the T-patterns detected (n = 4) start with this action, but the ultimate outcome is negative for the champion. The same pattern occurs in all cases; the champion places pressure on his opponent (*pc*), they both prepare (*xoc*), and the champion then takes the initiative in attack (*ioc*), but the opponent scores the touch (*to*) following a counteroffensive action (*iico*). The T-patterns also show that not placing pressure on the champion's opponent makes the opponent less effective. The above is a clear example of how an analysis of behaviors from complementary perspectives can provide interesting information for coaches. An effective action or decision by a champion (*ioc*) can ultimately have a negative effect if he/she is not capable of recognizing the context (pattern) in which the opponent succeeds in turning the situation to his/her advantage (*pc,xoc,ioc,iido,to*).

This complementary analysis also provides insights into behaviors from a strategic perspective. In this case, the relationships correspond to inter-occurrences rather than intra-occurrences (i.e., the behaviors do not occur in the same phrase or dataset). In brief, what happens in a given phrase can affect what happens in earlier or later phrases.

According to Barth (1994), tactics refer to a set of behaviors, actions, and operations that exert an influence on conditions that can be used to one's advantage, while strategy refers to planned actions that involve anticipating what the opponent is going to do and pre-establishing possible decisions to take regarding one action or another.

The three methodologies employed in this study can also provide insights into strategic aspects of the bouts analyzed. Sequential analysis of lags -1 to -5 and lags +1 to +5, for example, shows the impact of different actions at a given moment of a bout on previously scored touches (retrospective), or alternatively shows the impact of touches (activating or inhibitory) on other actions. T-pattern analysis, in turn, allows the detection of significant co-occurrences that are consistent with the internal tactical logic of different phrases and can reveal strategies such as decisions regarding whether to repeat the same pattern or to modify it (permanence vs modification). Finally, polar coordinate analysis establishes diachronic relationships that show how a specific action at a given moment of a bout influences (retrospectively) the effectiveness of a subsequent tactical decision (by activating or inhibiting the focal behavior [touch by champion or opponent]). Polar coordination analysis also shows how the focal behavior influences the permanence (activation) or modification (inhibition) of significantly associated actions (conditional behaviors).

It is not easy to analyze strategic behaviors. For one, the history behind the relationship between two fencers will influence decisions taken in successive phrases. Successful coaches tend to recognize behaviors that should be strengthened or avoided and even advise athletes to combine different actions depending on the moment. The relationships between different actions, however, can be difficult to detect. For example, Figure 3d shows how using a counterattack as a second action by champion (*iicc*) does not favor the champion as his opponent lands the touch (*to*), but despite this, the champion continues to do this throughout the phrase. The same action (*iicc*) is present in three of the four T-patterns detected (Table 6), but in this case, it is associated with different actions that lead to different results. This behavior was not significant in the lag sequential analysis and therefore this strategically interesting behavior would have gone unnoticed had we only performed this analysis.

Finally, the combined analysis using the three techniques also shows some differences between épée, foil, and sabre. Table 6 shows how starting a phrase with an offensive action (*ioc*) does not favor the fencer (in this case the champion) in the men's or women's épée events, whereas it does in foil and sabre (Tables 7 and 8). In both foil and sabre, the behavior (*ioc*) was significant for all events except women's sabre in both the lag sequential and T-pattern analyses. In the two conventional weapons, foil and sabre, by contrast, in the case of a double touch, the touch is awarded to the fencer who takes the initiative in the action. In brief, thus, taking the initiative in the first action (*ioc*) does not favor the champion in épée but it does in foil and sabre. Logically, also, an initial offensive action by an opponent (*ioo*) does not favor the champion.

The above considerations on the use of complementary analytical techniques need to be taken in context. While certain behaviors can be interpreted according to the weapon used, this complementary analysis, focused on behavioral patterns displayed by individual fencers in each of their sports, shows the possibility of analyzing tactical and strategic behaviors by applying analytical techniques inherent to observational methodology.

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