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Un enfoque plural del análisis secuencial desde perspectivas complementarias: estudio de caso de la esgrima desde un diseño de métodos mixtos

A Plural approach to sequence analysis using complementary perspectives: A case study of fencing behaviors from a mixed methods perspective

Uma abordagem plural da análise sequencial a partir de perspectivas complementares: estudo de caso do comportamento na esgrima com um delineamento de métodos mistos

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RESUMEN

El objetivo de este estudio es destacar diferentes perspectivas de la secuencialidad, cada una de las cuales implica técnicas analíticas distintas, desde una perspectiva de métodos mixtos. Los estudios de métodos mixtos han sido definidos por varios autores como aquellos que integran elementos cualitativos y cuantitativos. Por un lado, desde un enfoque "clásico" y utilizando un conjunto de datos simulados, examinamos los méritos de calcular la distancia entre secuencias como medida de su similitud o disimilitud. Por otro lado, exploramos tres enfoques del análisis secuencial—análisis secuencial de retardos, análisis de coordenadas polares y detección de *T-patterns*—con el objetivo de analizar el grado de convergencia de sus resultados. Tras una discusión de estas técnicas, presentamos un estudio de caso empírico en el ámbito de las ciencias del deporte. En este estudio, analizamos una competición de esgrima en las etapas finales de un campeonato mundial como un caso particular de observación sistemática. Considerando el fuerte componente metodológico de este trabajo, nos centramos en el primer nivel de la diacronía—el análisis intrasesional—aunque nuestro objetivo es ampliar los análisis para incluir la diacronía intersesional. Mediante un instrumento observacional específico, creamos un conjunto de datos que, tras los controles necesarios de calidad, fue analizado utilizando las tres técnicas mencionadas. Los resultados fueron luego combinados y analizados en términos de similitudes y diferencias. Finalmente, a partir de los resultados de este estudio de caso, proponemos un procedimiento para aprovechar el potencial y las garantías que ofrece el análisis secuencial a fin de integrar casos individuales con estructuras y secuencias similares en la construcción de un sólido estudio de caso múltiple.

Palabras clave: Análisis secuencial de retardos, análisis de coordenadas polares, detección de *T-patterns*, estudio de caso múltiple.

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ABSTRACT

The aim of this study is to highlight different perspectives of sequentiality, each involving different analytical techniques, and from a mixed methods perspective. Mixed methods studies have been defined by several authors as studies aiming to integrate qualitative and quantitative elements. On the one hand, from a "classic" approach and using a set of simulated data, we examine the merits of calculating the distance between sequences as a measure of their similarity or dissimilarity. On the other hand, we explore three approaches to sequence analysis—lag sequential analysis, polar coordinate analysis, and T-pattern detection—with the aim of analyzing the degree to which their results converge. Following a discussion of these techniques, we present an empirical case study from the field of sport sciences. In this study, we analyze a fencing competition in the final stages of a World Fencing Championship as a particular case of systematic observation. Considering the strong methodological component of this study, we focus on the first step of diachrony—intrasessional analysis—although our goal is to extend our analyses to include intersessional diachrony. Using a specific observational instrument, we created a dataset reflecting the sequences of events that, following the necessary data quality controls, was analyzed using lag sequential analysis, polar coordinate analysis, and T-pattern detection. The results were then combined and analyzed for similarities and dissimilarities. Finally, drawing from the results of this case study, we propose a procedure for harnessing the potential and guarantees offered by sequence analysis to bring together individual cases with similar structures and sequences to build a robust multiple-case study.

Keywords: Sequence similarity, lag sequential analysis, polar coordinate analysis, detection of T-patterns, multiple case.

RESUMO

O objetivo deste estudo é destacar diferentes perspetivas da sequencialidade, cada uma envolvendo técnicas analíticas distintas, a partir de uma perspetiva de métodos mistos. Os estudos de métodos mistos têm sido definidos por vários autores como aqueles que integram elementos qualitativos e quantitativos. Por um lado, a partir de uma abordagem "clássica" e utilizando um conjunto de dados simulados, examinamos os méritos do cálculo da distância entre sequências como medida da sua similaridade ou dissimilaridade. Por outro lado, exploramos três abordagens da análise sequencial—análise sequencial de retardos, análise de coordenadas polares e deteção de T-padrões—com o objetivo de analisar o grau de convergência dos seus resultados. Após a discussão destas técnicas, apresentamos um estudo de caso empírico no domínio das ciências do desporto. Neste estudo, analisamos uma competição de esgrima nas fases finais de um campeonato mundial como um caso particular de observação sistemática. Considerando o forte componente metodológico deste trabalho, centramo-nos no primeiro nível da diacronia—análise intra-sessão—ainda que o nosso objetivo seja alargar a análise à diacronia inter-sessão. Utilizando um instrumento observacional específico, criámos um conjunto de dados que, após os controlos necessários de qualidade, foi analisado recorrendo às três técnicas referidas. Os resultados foram depois combinados e analisados quanto às suas semelhanças e diferenças. Finalmente, com base nos resultados deste estudo de caso, propomos um procedimento para aproveitar o potencial e as garantias oferecidas pela análise sequencial, de modo a reunir casos individuais com estruturas e sequências semelhantes, construindo assim um estudo de caso múltiplo robusto.

Palavras chave: Similaridade de sequências, análise sequencial de retardos, análise de coordenadas polares, detecção de *T-patterns*, estudo de caso múltiplo.

El presente trabajo, como demuestra su enjundia y rigor metodológico, ha sido desarrollado por M. Teresa Anguera como autora primera. Los coautores hemos tenido el privilegio de colaborar con ella en su realización y nos hemos permitido cerrar el trabajo. Este monográfico homenaje a su persona y legado nos parece el mejor destino posible para su publicación.

Muchas gracias, por todo, querida M. Teresa; tu sonrisa y ejemplo nos acompañará siempre.

Un enfoque plural del análisis secuencial desde perspectivas complementarias

This work, as evidenced by its depth and methodological rigor, was developed by M. Teresa Anguera as first author. We, the co-authors, had the privilege of collaborating with her in its preparation and have taken the liberty of completing it. We believe this monographic tribute to her life and legacy is the most fitting place for its publication.

Thank you for everything, dear M. Teresa; your smile and example will always be with us.

INTRODUCTION

Although observation and other sources of data have been given some attention in the mixed methods research literature, few researchers have applied systematic observational research methods (Anguera et al., 2017). Systematic observation is a scientific procedure for analyzing perceivable behaviors that occur spontaneously in a usual setting (Anguera, 2003; Bakeman & Gottman, 1997; Quera, 2018). In recent years, however, there has been a surge in the number of empirical studies involving the application of mixed methods research designs rooted in systematic observation in the field of sport and physical activity (Anguera et al., 2023; Camerino et al., 2012; Preciado et al., 2021; Sáiz-Manzanares et al., 2022). For this reason, we also believe that it is time to reconsider studies that apply systematic observation through a mixed methods design in certain sports, and sequence analysis is an suitable analysis technique, used in fencing (Iglesias & Anguera, 2012; José et al., 2017; Tarragó et al., 2017) and other sports. The plural approach includes other convergent analytical techniques, which implies a richer perspective that enlarges the broad field of study, but always with the common goal of detecting the deep structure. Sequence analysis is a key part of life course research in which sequences of events are analyzed through a "lens" that can zoom in to a more immediate situation (e.g., a video recording of a series of episodes that form a life event) or zoom out to provide just a general overview. The combined results provide an increasingly clear picture of reality.

In this study, we provide an overview of classic and more recent approaches to sequence analysis, and through a case study of behaviors in fencing, we analyze the extent to which the use of three sequence analysis techniques applied to the same dataset can provide complementary insights. Drawing from our case study, we then propose a method for overcoming the limitations of single-case studies by using a methodological framework designed to build a multiple-case study with guarantees of both uniqueness and homogeneity.

First, from what we term a "classic" perspective, we outline the merits of measuring distances between sequences as a means of analyzing their similarities and dissimilarities between these sequences. This approach offers a compelling way of analyzing associations between sequences from highly heterogeneous cases, which may involve different participants, contexts, and so on. Using a set of simulated data, we illustrate how distances between sequences are calculated.

Next, we examine three approaches to sequence analysis—lag sequential analysis, polar coordinate analysis, and T-pattern detection—with the aim of analyzing the degree to which their results converge.

We then present an empirical case study of a sporting event that we propose as a particular "life event." In this study, we observed the behaviors of two fencers during the final stages of a World Fencing Championship and created a dataset reflecting the sequences of events which, following the necessary data quality controls, were analyzed using lag sequential analysis, polar coordinate analysis, and T-pattern detection. The results were then combined and analyzed for similarities and dissimilarities. Finally, drawing from the results of our case study, we propose, as a methodological desideratum, a procedure for harnessing the potential and guarantees offered by sequence analysis to bring together individual cases with similar structures and sequences to build a robust multiple-case study.

METHOD

Sequence analysis: at the crossroads of different perspectives

The classic perspective: distance between sequences

Sequence analysis is the statistical study of successions of states and events over time (Gauthier et al., 2014). Over the past 40 years, it has become a highly productive branch of knowledge that takes the life course as its referent, with little regard for contextual factors, at least in terms of key issues.

The life course framework offers an enormous range of opportunities to study events at different substantive levels, at varying levels of detail along the continuum from the molecular to the molar, and on different time scales (e.g., from the split-second movements of a fencer during a competition to the eruptions of a volcano, which may be centuries apart). In all cases, however, sequence analysis seeks to identify a trajectory or structure—a backbone, as it were—that emerges as a straight or branching line that can have any number of links in the chain, based on data collected using standard and non-standard instruments. This structure reveals a matrix of relationships, presuming these exist, between duly coded events. In addition, this approach allows a diachronic perspective (prospective or retrospective) and, when necessary, can also be used to provide a synchronic account.

Sequence analysis has not been exempt from controversy and debate among researchers from different methodological backgrounds—for example, Bakeman (1978), Blossfeld and Rohwer (1995), Magnusson (1996), Billari (2001), Quera (2018), and Liao et al. (2022)—although it is widely accepted that sequence analysis techniques are robust.

Any facet of reality in the social sciences can be studied as a narrative, in the figurative sense of the term used by Abbott (2001). Most facets are described formally (Levy et al., 2005) using the following concepts: a) *trajectory:* stability and change over time (George, 1993), which may or may not be long-term and which allows the study of intersessional and/or intrasessional diachronies; b) *stage* or *state*: a period of relative structural or functional stability, and hence persistence of patterns detected; c) *event*: something that happens at a given time and in a given place and can be perceived objectively; series of events—in our case, the behaviors of fencers—form the building blocks for creating non-standard observation instruments; and d) *transition*: a shift between two stages or states manifested by short patterns or no patterns at all and reflecting the randomness of behavior during transition.
These narratives, which are understood as structured patterns (Gauthier et al., 2014), may be affected by endogenous and exogenous factors that act as noise in the system. We refer to these in Section 4, corresponding to Moving beyond single-case studies, in relation to the possibilities of moving beyond single cases to build a multiple-case study. As Gauthier et al. (2014, p.4) stated, “this unity of narratives forms the basis for generalisation”.

From a broad classic perspective, different approaches have been proposed for studying sequences obtained at different points of time.

One such approach is the event history model (Blossfeld et al., 1989), in which an event is considered to be a transition between two states. An event history is thus a sequence of consecutive events, all related to a given trajectory that includes a record of when these events occur. Event history data have also been applied to survival analysis (Yamaguchi, 1991), as they permit the evaluation of the impact of a series of unforeseen events that may occur at a given time.

A subsequent development was a surge in the analysis of event histories using the approach proposed by Abbott (1990, 1992), along with Abbott and Forrest (1986) and Abbott and Hrycak (1990), who, instead of studying particular episodes within an event history or the determinants of specific transitions, focused on classifying “whole” event histories with the aim of identifying similar histories that could be grouped together. We wonder if a similar —or even more ambitious —approach (see Section 4) could be applied to individual case studies, which would be linked more by explanatory variables than by particular transitions.

We agree with Dijkstra and Taris (1995, p.215) that the two event history approaches described above "complement each other well". Perhaps the greatest challenge lies in classifying similar sequences, as the exponential number of possible "trajectories" would result in an excessively laborious procedure. To address this problem, Dijkstra and Taris (1995) recommended creating a series of dummy variables that would each indicate whether a particular individual belonged to a specific state at a particular point in time. In our fencing case, for example, we could look at whether a given fencer was winning, drawing, or losing at a given moment.

One essential difference between the two approaches is related to the order of occurrence. Like Abbott and colleagues, we consider this to be essential. Abbott and Hrycak (1990) made very important contributions in this respect. In addition to reviewing the literature on sequence analysis in different disciplines, including conversation analysis (McClure, 1983; Vuchinich, 1984)—which, figuratively speaking, allows us to draw certain parallels with phrases in fencing (sequences of uninterrupted movements)—the authors described an optimal matching algorithm that was a considerable improvement over existing procedures for comparing trajectories and could be applied to any situation in which a sequential list of events exists.

Optimal matching (Abbott & Hrycak, 1990) uses a dynamic programming technique developed from sequence alignment methods applied in molecular biology. Sequences must consist of strings of well-defined elements that may or may not be repeated and the algorithm calculates interval level measures of resemblance between sequences. These interval-level measures, or distances, treated as sequences of data, are also used to group algorithms, which in turn generate information about typical sequence patterns (Sankoff & Kruskal, 1983). Recent reviews reaffirm the foundational role of optimal matching in social sequence analysis while highlighting its continued relevance in contemporary methodological developments (Liao et al., 2022).

In this section, we use a set of simulated data to show how optimal matching works. Let us consider the following sequences and calculate the distance between them to determine their level of resemblance.

Table 1

Six sequences showing events occurring at successive time points (category system = {A B C D E F G H I}).

Sequence	Successive Equidistant Time Points							
	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
Sequence #1	A	A	B	C	D	E	F	
Sequence #2	A	B	C	D	E	F	G	H
Sequence #3	A	A	D	E	G	H	G	G
Sequence #4	D	E	F	G	G	G	G	G
Sequence #5	A	B	C	D	E			
Sequence #6	A	B	C	D	E	F		

The optimal matching algorithm measures the distance between sequences in terms of the insertions, deletions, and substitutions needed to transform one sequence into another. Sequence #1, for example, can be transformed into sequence #2 by deleting A at the beginning and inserting G and H at the end. Likewise, sequence #2 can be transformed into sequence #5, by deleting A at the beginning and F at the end, and sequence #1 can be transformed into sequence #6 by simply deleting A at the beginning. Thus, based on the number of actions required, sequence #1 is closer to sequence #6 than to sequence #5 but it is closer to sequence #5 than to sequence #2. This measure of similarity is known as Levenshtein distance (Sankoff & Kruskal, 1983, p.18).

The minimum number of actions required to transform the sequences are shown in Table 2.

Table 2

Minimum Number of Actions Required to Transform Sequences.

Sequence	#1	#2	#3	#4	#5
#2	3				
#3	6	5			
#4	8	7	5		
#5	2	3	6	8	
#6	1	2	6	8	1

There are multiple ways to transform one sequence into another, but the important figure is the *minimum* number of actions required for a given transformation (Abbott & Hrycak, 1990).

For example, two strategies can be used to transform sequence #2 into sequence #3. We will call these Alpha and Beta (Tables 3 and 4). They comprise six and five actions. As five is fewer than six, this is the minimum number shown in Table 2.

Table 3

Transformation of Sequence #2 into Sequence #3 (Alpha Strategy). Six Actions Are Required.

Sequence #2		A	B	C	D	E	F	G	H		
Sequence #3	A	A			D	E		G	H	G	G

Table 4

Transformation of Sequence #2 into Sequence #3 (Beta Strategy). Five Actions Are Required.

Sequence #2	A	B	C	D	E	F	G	H		
Sequence #3	A	A		D	E		G	H	G	G

Optimal matching, however, involves an additional layer of complexity. The main issue is that the number of actions required for a particular transformation is influenced by the length of the sequence. To address this, Abbott and Hrycak (1990) suggested standardizing by dividing the minimum number of transformations—what they called the "transformation distance"—by the length of the longer sequence (see Table 5 for results). This is one of several standardization options; others, such as using average length or aligned positions, may be chosen depending on research aims (Studer & Ritschard, 2016).

Table 5

Measures of Distance Between Sequences.

Sequence	#1	#2	#3	#4	#5
#2	0.375				
#3	0.750	0.625			
#4	1.000	0.875	0.625		
#5	0.286	0.375	0.750	1.000	
#6	0.142	0.250	0.750	1.000	0.166

The table shows that sequences #1 and #6 are the closest to each other, followed by sequences #5 and #6. The most dissimilar sequences—i.e., those separated by the greatest distance—are sequences #1 and #4, sequences #4 and #5, and sequences #4 and #6.

This optimal matching procedure proposed by Abbott and Hrycak (1990), offers many possibilities for situations that require comparisons of sequences.

New developments in sequence analysis: a complementary analysis using three techniques

Methodologically, sequences are analyzed from a plural perspective. This is important not only for conceptual expansion and enrichment but also because it drives methodological developments and increases the number of potential applications.

In the next section, we describe three novel sequence analysis techniques. They are considered novel not because they are "new" (they were all developed some time ago), but because their potential has been optimized through subsequent work and because more powerful software capable of performing the necessary calculations has been developed.

Lag sequential analysis

Lag sequential analysis, proposed by Bakeman (1978) and subsequently extended by Bakeman and Gottman (1997), Bakeman and Quera (2011), and Quera (2018), has proven to be highly effective in diverse fields (García-Fariña et al., 2018; Lapresa et al., 2013b, 2018; Roustan et al., 2013; Santoyo & Mendoza, 2018), and is extremely useful for analyzing datasets compiled from direct and/or indirect observation that contain sequences of behaviors coded using an *ad hoc* observation instrument. Lag sequential analysis is used to detect communication patterns and investigate associations between categories by calculating of observed and expected probabilities. This method is applicable to datasets of behaviors that occur in a certain order; the data can be type I or type II data (where the parameter of interest is sequence) or type III or type IV data (where the parameter of interest is duration). Lag 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. The first step in this analysis is to define our criterion behaviors (the starting point of any possible patterns detected) and to apply the time lags defined for the study. Observed probabilities are calculated for each of the lags using the binomial test; this test produces adjusted residuals (Allison & Liker, 1982), which show the strength of association between significantly associated categories (i.e., between criterion behaviors and the conditional behaviors with which they are associated). In our case, the level of significance was set at $p<.05$. Adjusted residuals were calculated to determine the strength of association between behaviors. Lag sequential analysis was performed in both the prospective and retrospective modes to investigate sequences of behaviors that occurred before and after the criterion behavior. Adjusted residuals are prospective when the lags are analyzed in a forward direction from the criterion behavior (lags +1, +2, etc.) and retrospective when they are analyzed in a backward direction (lags -1, -2, etc.). Adjusted residual values greater than 1.96 or less than -1.96 are considered statistically significant. Drawing on findings from prior studies in the behavioral and social sciences (Lapresa et al., 2013b), we decided to use ten lags (from lag -5 to lag -1 and lag +1 to lag +5), as patterns tend to become diluted when more lags are included.

Polar coordinate analysis

Polar coordinate analysis is an elaborate data reduction technique that provides a vectorial representation of the complex network of interrelations between categories that make up the different dimensions of the observation instrument. The structure of polar coordinate analysis complements prospective and retrospective sequential analysis (Bakeman, 1978). The retrospective, or "backward" perspective, which incorporates what Anguera (1997) referred to as the concept of "genuine retrospectivity", reveals significant associations between the focal behavior and behaviors that occur *before* this behavior (i.e., negative lags). In our study, this retrospective analysis produced a "mirror-like" image of associations between observation units that occur before the focal behavior; the sequence followed is last, second-to-last, third-to-last, etc. In other words, patterns obtained through retrospective sequential analysis reveal patterns formed by categories that lead up to the occurrence of the behavior of interest.

Polar coordinate analysis provides interpretable data through the application of an extremely powerful data reduction technique involving the calculation of the Z_{sum} statistic $Z_{sum} = \frac{\sum Z}{\sqrt{n}}$, described by Cochran (1954) and later proposed by Sackett (1980). Prospective and retrospective Z_{sum} scores can have a positive or negative sign. Each conditional behavior is represented by a vector, which, in turn, is located in one of four quadrants (I, II, III, or IV) depending on the positive or negative sign of the prospective and retrospective Z_{sum} scores. These quadrants indicate whether the focal and conditional behaviors activate or inhibit each other.

Polar coordinate analysis has been used extensively in several fields (Alcover et al., 2019; Arias-Pujol & Anguera, 2017; Escolano et al., 2019; Pérez-Tejera et al., 2018; Portell et al., 2019; Rodríguez-Medina et al., 2018), and also in diverse sports (Aragón et al., 2016; Castañer et al., 2016; Font et al., 2022; Maneiro & Amatria, 2018; Maneiro et al., 2019; Menescardi et al., 2019; Morillo et al., 2017; Nunes et al., 2022; Tarragó et al., 2017).

Detection of T-patterns

The assumption underlying the T-pattern detection method is that complex human behaviors have a temporal structure that cannot be fully detected through traditional observational methods or mere quantitative statistical logic (Magnusson, 1996, 2000, 2018). By detecting T-patterns, or "temporal patterns", this method can detect structural analogies across very different levels of organization and enable an important shift from quantitative to structural analysis.

T-patterns detection studies have been conducted in very different scientific domains and also in the field of sport (Aragón et al., 2016; Borrie et al., 2002; Castañer et al., 2017; Chaverri et al., 2010; Gutiérrez-Santiago et al., 2013; Lapresa et al., 2013a, 2013c; Soriano et al., 2024; Tarragó et al., 2015; Zurloni et al., 2014). Since observational records of human behavior have a temporal and sequential structure, an analytical tool that can describe this structure can only enhance the understanding of the target behavior(s). In fencing, for example, T-pattern analysis can reveal the hidden yet stable structures that underlie the interactions that determine what occurs in a competition. The discovery of hidden T-patterns could help fencing coaches to better predict the behaviors of both competitors in a fencing bout thanks to an integrated system that allows for an increased depth of analysis.

For the T-pattern analysis in this study, we used the software program THEME v. 6 Edu, and assigned a constant duration (=1) to each event-type (Lapresa et al., 2013a), as the focus of our analysis was not on the duration of each phrase or the distance between phrases (which is very similar), but rather their internal sequentiality.

The calculations for the methods employed in this study were performed using the following freely available software programs: GSEQ5 for lag sequential analysis (Bakeman & Quera, 2011; Quera, 2018); HOISAN v.1.6.3. for lag sequential and polar coordinate analysis (Hernández-Mendo et al., 2012); THEME v.6 Edu for T-Pattern detection (Magnusson, 1996, 2000, 2018); and R v.3.5.3, using the *irr* and *boot* packages.

Case study

To illustrate the possibilities offered by the sequence analysis techniques discussed in the previous section, we undertook a case study of fencing behaviors using lag sequential analysis, polar coordinate analysis, and T-pattern detection and analyzed the complementary insights that these techniques can provide into the same "reality." Before describing this study, we would like to make two comments.

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First, from a methodological perspective, our aim is to break through the "ceiling" imposed by the separate use of each of the techniques. We believe that the perspectives offered by each technique in isolation are complementary as they all share a common element: a sequential dataset (Bakeman, 1978). The feasibility of such an approach has been demonstrated on several occasions over the past 10 years (Anguera, 2007, 2017; Lapresa et al., 2013b; Santoyo et al., 2017; Tarragó et al., 2016, 2017), and we must continue to push forward.

Second, if we are to examine a real-life situation through any lens, clearly we must do so at a distance that is consistent with the specific objectives of the analyses. Life events occur at the convergence of the infinite factors that influence our everyday lives (Portell et al., 2015). In this study, we analyze a fencing competition in the final stages of a World Fencing Championship as a particular life event within the broader life course of the athletes observed. Considering the strong methodological component of this study, which seeks to lay the foundations for subsequent developments, we focus on the first step of diachrony—intrasessional analysis—although our goal is to extend our analyses to include intersessional diachrony over time.

Below is a description of the case study, which is called *A Complementary Study of Elite Fencing Tactics Using Lag Sequential, Polar Coordinate, and T-Pattern Analyses.*

The aim of the study was to perform a diachronic analysis, using lag sequential analysis, polar coordinate analysis, and T-pattern detection, of behaviors in fencing, a sport in which the exchange of actions between two fencers is determined by a series of decisional processes (Iglesias et al., 2010; Tarragó et al., 2015).

The continuous interchange of actions and reactions during a fencing bout, the aim of which is to gain a touch, is known as a fencing phrase and can be analyzed sequentially from two perspectives. In the first case, the objective is to determine what happens within each phrase, i.e., to identify actions and reactions triggered by the techniques employed by the two fencers; each phrase is characterized by an internal logic that determines the tactics used and in which the different actions executed influence the result (i.e., gain or loss of a touch). In the second case, the objective is to determine how these phrases evolve throughout the bout, i.e., to analyze the diachronic relationships underlying the tactics employed (succession of actions over time), as this can shed light on strategic and tactical decisions that lead fencers to use or modify a certain behavior (technical action), giving rise to the repetition or diversification of sequences of actions, or phrases, during the bout.

We employed an observational methodology design, as the actions to be studied were perceivable, regular (i.e., performed repeatedly by professional fencers), and took place in a setting that lends itself particularly well to observation. Observational methodology is also an ideal technique for analyzing whether behaviors that occur throughout episodes or periods of time have an internal sequential structure (Abbott, 1990, 1995; Abbott & Hrycak, 1990; Abbott & Tsay, 2000).

This internal structure can be analyzed using different methods, each with its own principles, processes, and analytical methods. In our case, we chose lag sequential analysis, polar coordinate analysis, and T-pattern detection.

The ultimate aim of this empirical study was to analyze the confluence of results from three complementary methods to identify direct relationships between different tactical actions and their efficacy (in terms of score), and to shed light on successful strategies that could help fencers make better decisions during competitions.

Procedure

We employed a nomothetic, point, multidimensional observational study design (Anguera et al., 2011). In order to satisfy the aims of the study, a convenience sample was carried out. We analyzed four bouts, from the direct elimination (DE16) round to the final, of the épée fencer who won the silver medal and was consistently observed on the right-hand side of the piste during the Men's Individual World Fencing Championships in Kazan, Russia (2014).

The data were recorded using LINCE v.1.4 (Gabin et al., 2012) and LINCE PLUS (Soto et al., 2022), and a total of 187 fencing phrases were recorded using the type II data modality. The images were obtained from broadcasts made available by the *Fédération Internationale d'Escrime* (FIE).

The study formed part of a larger fencing project approved by the clinical research ethics committee of the Catalan Public Sports Authority (2005) and was conducted in accordance with the principles of the Declaration of Helsinki. In line with the ethical requirements specified in the American Psychological Association guidelines (2002) and the Belmont Report (1978), informed consent was not required because the research was an observational study conducted in a natural setting using publicly broadcast, publicly available images.

The observation instrument ESGRIMOBS described by Tarragó et al. (2015) was adapted for the purpose of the study (Table 6). The resulting instrument consisted of six criteria or dimensions, which gave rise to 21 categories. Given the complexity of analyzing fencing tactics, we based our analysis on observation units drawn from concepts described in fencing rules published by the Fédération Internationale d'Escrime (2014). Each observational unit was formed by a fencing phrase, the aim of which is to gain a touch, and each phrase was analyzed by applying the different criteria that formed the observation instrument.

Data quality was ensured by analyzing the validity of the observation instrument and the reliability of the observation process (Blanco-Villaseñor & Anguera, 2000). The ESGRIMOBS observation instrument had been validated in a previous study (Tarragó et al., 2015). Reliability was assessed with the participation of two observers, who received specific training to accurately interpret and apply the ESGRIMOBS instrument. Observation criteria were jointly established, and initial data were coded collaboratively to reach consensus (Anguera, 1990). Intra- and interobserver reliability was assessed using 45 actions from three épée bouts. Kappa statistics calculated with GSEQ5 showed an interobserver agreement of 0.78 and intraobserver values above 0.79.

RESULTS

Given the primary aim of this study—to analyze diachronic relationships underlying the tactics employed by one of the world's top fencers using three complementary techniques—we developed a summary table (Table 7) that highlights both "favorable" and "unfavorable" tactical sequences identified by each technique. In the T-pattern analysis, a behavior was considered favorable when the set of event-types contained the event "touch", and in the lag sequential and polar coordinate analyses, it was considered favorable when it activated a touch for the fencer or inhibited a touch by his rival. It should be noted that in the case of antagonistic significances for the different lags in the sequential analysis, lag values or 0 or close to 0 were prioritized.

The combined application of these complementary techniques was first introduced by Tarragó et al. (2016). Our proposal supports the value of interpreting observational records in sports such as fencing through the complementarity of these three techniques, providing the coaches with a new approach to the analysis of the strategies and tactics employed by the fencers analyzed.

The summary table (Table 7) and the analyses described partially in the results section provide detailed insight into the tactics used by the fencer (on the right) in relation to his rivals (on the left) in each bout, as each of the techniques provides a distinct yet complementary interpretation. Each dataset corresponds to a phrase, which may be viewed as a "co-occurrence" of behaviors, but actually exhibits internal or intra-phrase sequentiality (left-to-right sequentiality based on transcription order). In other words, our analysis shows how behaviors influence other behaviors within each phrase. This relationship links tactical behaviors with specific technical executions, analyzed by sequential analysis at lag 0 and T-pattern analysis.

The strategic analysis also considers between-phrase relationships —that is, relationships between each phrase (datasets arranged vertically from top to bottom). This approach reveals how co-occurrences or events (phrases) influence one another through T-patterns, as illustrated by dendrograms linking two or more phrases with statistically significant associations. Additionally, it captures how specific behaviors (actions) influence preceding or subsequent behaviors using lag sequential analysis (lags -1 to -5 and +1 to +5) and polar coordinate analysis.

Table 6

Adaptation of the observation instrument ESGRIMOBS (Tarragó et al., 2015).

Criteria	Codes	Categories
Pressure	PD	Right pressure
	PI	Left pressure
	NP	No pressure
Preparation	XD	Right preparation
	XI	Left preparation
First action	OD	First action: right offensive
	OI	First action: left offensive
Second action	DOD	Second action: right offensive
	DOI	Second action: left offensive
	DCD	Second action: right counteroffensive
	DCI	Second action: left counteroffensive
	DDD	Second action: right defensive
	DDI	Second action: left defensive
Third action	TOD	Third action: right offensive
	TOI	Third action: left offensive
	TCD	Third action: right counteroffensive
	TCI	Third action: left counteroffensive
	TDD	Third action: right defensive
	TDI	Third action: left defensive
Touch	TI	Left touch
	TD	Right touch

Note: Pressure refers to a series of forward movements to shorten the distance with the opponent, forcing them to retreat or take action. “Right pressure” is when the pressure is applied by the fencer on the right side of the image. Preparation is the movement made with the intention of generating a reaction in the opponent or of gaining an advantage in a subsequent action of one's own. “Left preparation” is when the preparation is applied by the fencer on the left side of the image.

Table 7

Complementary evaluation of tactical sequences for the silver medalist fencer (observed on the right side of the piste) in the Men’s Individual Épée World Championship, 2014.

T-Patterns	Lags		Polar Coordinate
Behaviors that favor the fencer on the right			
	DCI	DOI	NP
((PD,XD,OI,DDD PD,OD,DDI)(PD,XD,OD,DDI (PD,XD,OI,DCD,TD PD,OD,DDI)))	DDI	TOD	OI
(PD,OD,DDI (PD,XD,OI,DDD (PD,XD,OI,DCD,TD PD,OD,DDI)))	TCI	TOI	DCD
(PD,XD,OD,DCI,TD PD,OD,DDI)			DOD
(PD,XD,OD,DCI,TD PD,XD,OD,DDI)			DDI
Behaviors that do **not favor** the fencer on the right			
(PI,XI,OD,DCI,TDD (NP,XD,OD,DDI (PD,XI,OD,DDI PD,XD,OD,DCI,TI)))	PI	NP	PI
(PD,OD,DDI (PD,OD,DDI,TCD,TI PD,XD,OD,DDI))	XI	OI	PD
(PD,XD,OD,DDI,TCD,TID PI,XI,OI,DCD,TI)	DDI	DDD	TOD
(PD,OD,DDI PD,OD,DDI,TCD,TI)	DOD		

DISCUSSION

Moving beyond single-case studies

While a single-case study can provide a rich and nuanced account of a life event or phenomenon (Siggelkow, 2007), multiple-case studies (Yin, 2014) offer a more robust foundation for the theory building, allowing a distinction to be drawn between idiosyncratic events and events that can be consistently replicated. In addition, multiple cases allow for a level of abstraction that enhances the robustness of findings (Anguera, 2018).

As stated by Hilliard (1993, p.375), "The issue of homogeneity is not as simple and straightforward as it might first appear. A single-case approach would exert great caution in assuming that a group is truly homogeneous until this has been clearly shown, which would involve considerable understanding of the phenomenon of interest at the single-case level. Once a phenomenon is sufficiently well understood at the single-case level, intelligent aggregation may be possible." Consequently, a multiple-case study typically begins as a single-case study, and additional cases are incorporated only after demonstrating that they are truly homogeneous.

Single cases are by nature individual and aim to capture unique characteristics. They contain a core element and several concentric circumferences that vary in their reach. They are studied intensively, preferably using a systematic approach, drawing on information from various sources. It is important to note here a key methodological consideration. The initial uniqueness that characterizes a single case may be progressively complemented through the addition of cases that hold sufficient similarities to the original case, within a methodological procedure that advances towards a multiple-case study comprising homogeneous cases. *Ad hoc* inclusion criteria can be established, based on the presence of essential characteristics or a minimum threshold of similarity. A multiple-case study can be considered genuinely multiple when it is shown that its constituent cases share a common structure or contain similar sequences.

The term "multiple-case study" was first used by Stake in 2006, although his seminal work on case study research, from 1995, used the term "collective case study," which is essentially what Herriott and Firestone (1983) referred to as "multisite qualitative research." Stake may be credited with coining the expression "multiple-case study," although he did not outline a procedure for conducting such studies. This remains a key methodological desideratum.

In the 2014 edition of his book *Case Study Research: Design and Methods* (the first edition of which was published in 1984), Yin refers to multiple-case studies as case studies that contain multiple cases. This concept serves to highlight the importance of clearly defining aspects related to the selection and aggregation of cases and the establishment of limits and solutions for filling gaps in the methodological procedure.

The questions formulated by researchers building a multiple-case study first and foremost relate to the profile or the characteristics of the successive cases—referred to by some authors, such as Gerring (2004), as "units"—and the degree with which they share characteristics with the matrix case, with varying levels of ambiguity or blurriness. The second issue concerns the number of cases to be included. Several authors, adopting different approaches, have proposed a number that will guarantee representativeness (Gerring, 2004; Sandelowski, 1996).

The crux of the matter, however, is to provide sufficient guarantees that a multiple-case study is truly multiple, as its name implies. Sandelowski (1996, p.527) very rightly states: "*The search for common and uncommon themes and patterns across cases is premature*, and likely to yield superficial results lacking in subtlety and credibility, without initial efforts toward understanding the ensemble features in each case, or how these features or variables are configured to create a whole. Indeed, a primary reason for choosing a qualitative method to study a phenomenon is to grab the nuances and contradictions of real life experiences, which will likely make the findings from any subsequent move to a variable oriented treatment of these data more valid because it better reflects these subtleties" (our emphasis).

Indeed, the search for patterns is perfectly feasible, as is the exploration for relationships between sequences.

The question, however, is how we can demonstrate that a multiple-case study has a common structure or that the individual cases that make up the study have similar sequences.

Whatever the case, what is needed is a system that reveals the hidden structure of the data. Of course, "'real' research does not happen in such a linear way. Its chronological order is more of a cyclical process of interrelated steps that happen in parallel and repeatedly, often overlapping with, and influencing each other" (Diefenbach, 2009, p. 876).

The central concern of a multiple-case study is to create a solid foundation to support the gradual and inductive process of adding single cases. In our opinion, it is not sufficient to simply apply rules based on specific homogeneity criteria to determine whether a case can be included or not. Considering that a single case can contain a large amount and density of information, it would be superficial not to introduce more demanding methodological requirements.

The first consideration is that the information in such cases may come from various sources. For both the matrix and subsequent cases, it is important to submit the raw data to an initial process that enables joint analysis in a subsequent stage.

Stage 1: Systematic organization of data

The first step is to organize all available information, from its various sources, into a format that yields one or more code matrices.

Stage 2: Analysis of data to identify a structure in the single case and in groups of multiple cases

The main challenge in multiple-case studies lies in identifying a common structure and detecting shared patterns. In other words, we need to know whether the hidden patterns underlying the structure of the matrix case are maintained as new cases are added. As Posner et al. (2007, p.24) stated, "we need to understand both common processes and individual differences".

The idea of investigating the internal structure of the datasets corresponding to each case added to a multiple-case study is novel one, as is our proposal to use a combination of sequence analysis techniques to search for patterns.

After investigating multiple situations over the last three decades, situations for which only systematic diachronic records with different levels of "granularity" (Schegloff, 2000) were available, we have accumulated more than enough evidence to demonstrate that the complementary use of trend analysis, lag sequential analysis, polar coordinate analysis, and T-pattern detection provides the necessary information, with methodological robustness, to confirm that a multiple-case study is, in fact, what its name implies (Anguera, 2017, 2018).

PRACTICAL APPLICATIONS

The use of sequence analysis in the study of life events deserves constructive criticism to highlight both its strengths and weaknesses within mixed methods research.

On the negative side, the range of sequence analysis approaches used to date is extremely diverse. One might reasonably conclude that this field of knowledge is in its infancy, populated by researchers who tend to work alone and do not cite each other, but this situation can be partially explained by the fact that the researchers using these techniques represent a variety of disciplines.

Several positive aspects also deserve mention. The approach we propose encompasses a wide range of methodologies that have led to important advances, and further breakthroughs are expected in the near future. We highlight the feasibility of using multiple complementary sequence analysis techniques, as well as the methodological benefits of constructing multiple-case studies by applying these techniques to individual cases.

ETHICAL CONSIDERATIONS

The study formed part of a larger fencing project approved by the clinical research ethics committee of the Catalan Public Sports Authority (2005) and was conducted in accordance with the principles of the Declaration of Helsinki. The study was also carried out in compliance with the Ethical Standards in Sport and Exercise Science Research (Harriss et al., 2019). In line with the ethical requirements specified in the American Psychological Association guidelines (2002) and the Belmont Report (1978), informed consent was not required because the research was an observational study conducted in a natural setting using publicly broadcast, publicly available images.

DECLARATION OF CONFLICTING INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

AUTHORS’ CONTRIBUTIONS

All authors contributed to this manuscript. M. Teresa Anguera passed away on 19 January 2025.

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REFERENCES

1. Abbott, A. (1990). A primer on sequence methods. *Organization Science*, *1*(4), 373–392. https://doi.org/10.1287/orsc.1.4.373
2. Abbott, A. (1992). From causes to events: Notes on narrative positivism. *Sociological Methods & Research*, *20*(4), 428–455. https://doi.org/10.1177/0049124192020004002
3. Abbott, A. (1995). Sequence analysis. *Annual Review of Sociology*, *21*, 93–113. https://doi.org/10.1146/annurev.so.21.080195.000521
4. Abbott, A. (2001). *Time matters: On theory and method.* University of Chicago Press.
5. Abbott, A., & Forrest, J. (1986). Optimal matching methods for historical sequences. *The Journal of Interdisciplinary History*, *15*(1), 471–494. https://doi.org/10.2307/204500
6. Abbott, A., & Hrycak, A. (1990). Measuring resemblance in sequence data: An optimal matching analysis of musicians' careers. *American Journal of Sociology*, *96*(1), 144–185. https://doi.org/10.1086/229526
7. Abbott, A., & Tsay, A. (2000). Sequence analysis and optimal matching methods in sociology. *Sociological Methods & Research*, *29*(1), 3–33. https://doi.org/10.1177/0049124100029001001

8. Alcover, C., Mairena, M. A., Mezzatesta, M., Elías, N., Díez, M., Balañá, G., González, M., Rodríguez-Medina, J., Anguera, M. T., & Arias-Pujol, E. (2019). Mixed methods approach to describe social interaction during a group intervention for adolescents with Autism Spectrum Disorders. *Frontiers in Psychology*, *10*, Article 1158. https://doi.org/10.3389/fpsyg.2019.01158
9. Allison, P. D., & Liker, J. K. (1982). Analyzing sequential categorical data on dyadic interaction: A comment on Gottman. *Psychological Bulletin*, *91*(2), 393–403. https://doi.org/10.1037/0033-2909.91.2.393
10. American Psychological Association. (2002). Ethical principles of psychologists and code of conduct. *American Psychologist*, *57*(12), 1060–1073. https://doi.org/10.1037/0003-066X.57.12.1060
11. Anguera, M. T. (1990). Metodología observacional. In J. Arnau, M. T. Anguera, & J. Gómez (Eds.), *Metodología de la investigación en Ciencias del Comportamiento* (pp. 125–236). Secretariado de Publicaciones de la Universidad de Murcia.
12. Anguera, M. T. (1997). From prospective patterns in behavior to joint analysis with a retrospective perspective. In *Colloque sur invitation «Méthodologie d'analyse des interactions sociales»*. Université de la Sorbonne.
13. Anguera, M. T. (2003). Observational methods (General). In R. Fernández-Ballesteros (Ed.), *Encyclopedia of psychological assessment* (Vol. 2, pp. 632–637). Sage.
14. Anguera, M. T. (2007). Análisis de la temporalidad en registros observacionales de situaciones deportivas: ¿Dos caras de una misma realidad? [Analysis of temporality in observational datasets from sporting situations: Two sides of the same coin?]. In A. Borges & P. Prieto (Eds.), *Psicología y Ciencias Afines en los albores del siglo XXI. Homenaje al Profesor Sánchez Bruno* (pp. 25–40). Grupo Editorial Universitario.
15. Anguera, M. T. (2017). Transiciones interactivas a lo largo de un proceso de desarrollo: Complementariedad de análisis [Interactive transitions throughout a development process: A complementary analysis approach]. In C. Santoyo (Coord.), *Mecanismos básicos de toma de decisiones: Perspectivas desde las ciencias del comportamiento y del desarrollo* (pp. 179–213). CONACYT 178383/UNAM.
16. Anguera, M. T. (2018). Avances sostenidos en pos de la indagación de regularidades en el comportamiento humano: Del caso único al caso múltiple [Sustained progress in investigating patterns in human behavior: From the single to the multiple case]. In Academia de Psicología de España (Ed.), *Psicología para un mundo sostenible* (Vol. II, pp. 31–50). Editorial Pirámide.
17. Anguera, M. T., Blanco-Villaseñor, A., Hernández-Mendo, A., & Losada, J. L. (2011). Diseños observacionales: ajuste y aplicación en psicología del deporte. *Cuadernos de Psicología del Deporte*, *11*(2), 63–76.
18. Anguera, M. T., Camerino, O., Castañer, M., Sánchez-Algarra, P., & Onwuegbuzie, A. J. (2017). The specificity of observational studies in physical activity and sports sciences: Moving forward in mixed methods research and proposals for achieving quantitative and qualitative symmetry. *Frontiers in Psychology*, *8*, Article 2196. https://doi.org/10.3389/fpsyg.2017.02196
19. Anguera, M. T., Jonsson, G. K., Escolano-Pérez, E., Sánchez-Lopez, C. R., Losada, J. L., & Portell, M. (2023). T-pattern detection in the scientific literature of this century: A systematic review. *Frontiers in Psychology*, *14*, 1085980. https://doi.org/10.3389/fpsyg.2023.1085980
20. Aragón, S., Lapresa, D., Arana, X., Anguera, M. T., & Garzón, B. (2016). Tactical behaviour of winning athletes in major championship 1500-m and 5000-m track finals. *European Journal of Sport Science*, *16*(3), 279–286. https://doi.org/10.1080/17461391.2015.1009494
21. Arias-Pujol, E., & Anguera, M. T. (2017). Observation of interactions in adolescent group therapy: A mixed methods study. *Frontiers in Psychology*, *8*, Article 1188. https://doi.org/10.3389/fpsyg.2017.01188
22. Bakeman, R. (1978). Untangling streams of behavior: Sequential analysis of observation data. In G. P. Sackett (Ed.), *Observing behavior* (Vol. 2, pp. 63–78). University Park Press.

23. Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis* (2nd ed.). Cambridge University Press.

24. Bakeman, R., & Quera, V. (2011). *Sequential analysis and observational methods for the behavioral sciences*. Cambridge University Press. https://doi.org/10.1017/CBO9780511984324

25. Billari, F. C. (2001). Sequence analysis in demographic research. *Canadian Studies in Population*, *28*(2), 439–458. https://doi.org/10.25336/P6G30C

26. Blanco-Villaseñor, A., & Anguera, M. T. (2000). Evaluación de la calidad en el registro del comportamiento: Aplicación a deportes de equipo. In E. Oñate, F. García-Sicilia, & L. Ramallo (Eds.), *Métodos numéricos en ciencias sociales* (pp. 30–48). Centro Internacional de Métodos Numéricos en Ingeniería (CIMNE).

27. Blossfeld, H.-P., Hamerle, A., & Mayer, K. U. (1989). *Event history analysis: Statistical theory and application in the social sciences*. Lawrence Erlbaum.

28. Blossfeld, H.-P., & Rohwer, G. (1995). *Techniques of event history modeling: New approaches to causal analysis*. Lawrence Erlbaum Associates.

29. Borrie, A., Jonsson, G. K., & Magnusson, M. S. (2002). Temporal pattern analysis and its applicability in sport: An explanation and preliminary data. *Journal of Sports Sciences*, *20*(10), 845–852. https://doi.org/10.1080/026404102320675675

30. Camerino, O., Castañer, M., & Anguera, M. T. (Eds.). (2012). *Mixed methods research in the movement sciences: Case studies in sport, physical education and dance*. Routledge.

31. Castañer, M., Barreira, D., Camerino, O., Anguera, M. T., Canton, A., & Hileno, R. (2016). Goal scoring in soccer: A polar coordinate analysis of motor skills used by Lionel Messi. *Frontiers in Psychology*, *7*, Article 806. https://doi.org/10.3389/fpsyg.2016.00806

32. Castañer, M., Barreira, D., Camerino, O., Anguera, M. T., Fernandes, T., & Hileno, R. (2017). Mastery in goal scoring, T-pattern detection and polar coordinate analysis of motor skills used by Lionel Messi and Cristiano Ronaldo. *Frontiers in Psychology*, *8*, Article 741. https://doi.org/10.3389/fpsyg.2017.00741

33. Chaverri, J., Camerino, O., Anguera, M. T., Blanco-Villaseñor, Á., & Losada, J. L. (2010). Interaction contexts in soccer: Detection of T-patterns. *Gymnasium: Revista de Educação Física, Desporto e Saúde*, *2*(1), 69–92.

34. Cochran, W. G. (1954). Some methods for strengthening the common χ^2 test. *Biometrics*, *10*, 417–451. https://doi.org/10.2307/3001616

35. Comité de Ética de Investigaciones Clínicas de la Administración Deportiva de Cataluña. (2005). *Orden PRE/99/2005* (DOGC 4347 de 21/3/2005). http://portaldogc.gencat.cat/utilsEADOP/PDF/4347/417073.pdf

36. Diefenbach, T. (2009). Are case studies more than sophisticated storytelling? Methodological problems of qualitative empirical research mainly based on semi-structured interviews. *Quality & Quantity*, *43*, 875–894. https://doi.org/10.1007/s11135-008-9164-0

37. Dijkstra, W., & Taris, T. (1995). Measuring the agreement between sequences. *Sociological Methods & Research*, *24*(2), 214–231. https://doi.org/10.1177/0049124195024002004

38. Escolano-Pérez, E., Herrero-Nivela, M. L., & Anguera, M. T. (2019). Preschool metacognitive skill assessment in order to promote educational sensitive response from mixed-methods approach: Complementarity of data analysis. *Frontiers in Psychology*, *10*, Article 1298. https://doi.org/10.3389/fpsyg.2019.01298

39. Fédération Internationale d'Escrime. (2014). *Rules and regulations*. http://www.fie.ch/Fencing/Rules.aspx

40. Font, R., Daza, G., Irurtia, A., Tremps, V., Cadens, M., Mesas, J. A., & Iglesias, X. (2022). Analysis of the variables influencing success in elite handball with polar coordinates. *Sustainability*, *14*(23), 15542. https://doi.org/10.3390/su142315542

41. Gabin, B., Camerino, O., Anguera, M. T., & Castañer, M. (2012). Lince: Multiplatform sport analysis software. *Procedia - Social and Behavioral Sciences*, *46*, 4692–4694. https://doi.org/10.1016/j.sbspro.2012.06.320
42. García-Fariña, A., Jiménez Jiménez, F., & Anguera, M. T. (2018). Observation of physical education teachers' communication: Detecting patterns in verbal behavior. *Frontiers in Psychology*, *9*, Article 334. https://doi.org/10.3389/fpsyg.2018.00334
43. Gauthier, J.A., Bühlmann, F., & Blanchard, P. (2014). Introduction: Sequence analysis in 2014. In P. Blanchard, F. Bühlmann, & J.-A. Gauthier (Eds.), *Advances in sequence analysis: Theory, method, applications* (pp. 1–17). Springer. https://doi.org/10.1007/978-3-319-04969-4_1
44. George, L. K. (1993). Sociological perspectives on life transitions. *Annual Review of Sociology*, *19*(1), 353–373. https://doi.org/10.1146/annurev.so.19.080193.002033
45. Gerring, J. (2004). What is a case study and what is it good for? *American Political Science Review*, *98*(2), 341–354. https://doi.org/10.1017/S0003055404001182
46. Gutiérrez-Santiago, A., Prieto, I., Camerino, O., & Anguera, M. T. (2013). Sequences of errors in the judo throw Morote Seoi Nage and their relationship to the learning process. *Journal of Sports Engineering and Technology*, *227*(1), 57–63. https://doi.org/10.1177/1754337111431916
47. Harriss, D. J., MacSween, A., & Atkinson, G. (2019). Ethical standards in sport and exercise science research: 2020 update. *International journal of sports medicine, 40*(13), 813-817. https://doi.org/10.1055/a-1015-3123
48. Hernández-Mendo, A., López-López, J. A., Castellano, J., Morales-Sánchez, V., & Pastrana, J. L. (2012). Hoisan 1.2: Programa informático para uso en metodología observacional. *Cuadernos de Psicología del Deporte, 12*(1), 55–78. https://doi.org/10.4321/S1578-84232012000100006
49. Herriott, R. E., & Firestone, W. A. (1983). Multisite qualitative policy research: Optimizing description and generalizability. *Educational Researcher*, *12*(2), 14–19. https://doi.org/10.3102/0013189X012002014
50. Hilliard, R. B. (1993). Single-case methodology in psychotherapy process and outcome research. *Journal of Consulting and Clinical Psychology*, *61*, 373–380. https://doi.org/10.1037/0022-006X.61.3.373
51. Iglesias, X., & Anguera, M. T. (2012). The influence of environmental factors in the context of elite fencing. In O. Camerino, M. Castañer, & M. T. Anguera (Eds.), *Mixed methods research in the movement sciences: Cases in sport, physical education and dance* (pp. 83–93). Routledge.
52. Iglesias, X., Gasset, A., González, C., & Anguera, M. T. (2010). Interacción competitiva y presión ambiental en deportes de combate: Aplicación de la metodología observacional. *Revista Iberoamericana de Psicología del Ejercicio y el Deporte*, *5*(2), 267–282.
53. José, J., Leitão, J., Iglesias, X., Anguera, M. T., & Campaniço, J. (2017). Observational instrument for fencing: Tactical actions characterization. *Motricidade*, *13*(1), 209.
54. Lapresa, D., Alsasua, R., Arana, J., & Garzón, B. (2013a). Comparative analysis of T-patterns using real time data and simulated data by assignment of conventional durations: The construction of efficacy in children's basketball. *International Journal of Performance Analysis in Sport*, *13*(2), 321–339. https://doi.org/10.1080/24748668.2013.11868651
55. Lapresa, D., Álvarez, L., Arana, J., Garzón, B., & Caballero, V. (2013c). Observational analysis of the offensive sequences that ended in a shot by the winning team of the 2010 UEFA Futsal Championship. *Journal of Sports Sciences*, *31*(5), 1731–1739. https://doi.org/10.1080/02640414.2013.803584
56. Lapresa, D., Arana, J., Anguera, M. T., & Garzón, B. (2013b). Comparative analysis of the sequentiality using SDIS-GSEQ and THEME: A concrete example in soccer. *Journal of Sports Sciences*, *31*(5), 1687–1695. https://doi.org/10.1080/02640414.2013.796061

57. Lapresa, D., Del Río, A., Arana, J., Amatria, M., & Anguera, M. T. (2018). Use of effective play-space by U12 FC Barcelona players: An observational study combining lag sequential analysis and T-pattern detection. *International Journal of Performance Analysis in Sport*, *18*(2), 293–309. https://doi.org/10.1080/24748668.2018.1475195
58. Levy, R., Ghisletta, P., Le Goff, J. M., Spini, D., & Widmer, E. (Eds.). (2005). *Towards an interdisciplinary perspective on the life course* (Vol. 10). Elsevier. https://doi.org/10.1016/S1040-2608(05)10016-1
59. Liao, T. F., Bolano, D., Brzinsky-Fay, C., Cornwell, B., Fasang, A. E., Helske, S., Piccarreta, R., Raab, M., Ritschard, G., Struffolino, E., & Studer, M. (2022). Sequence analysis: Its past, present, and future. *Social Science Research*, *107*, 102772. https://doi.org/10.1016/j.ssresearch.2022.102772
60. Magnusson, M. S. (1996). Hidden real-time patterns in intra- and inter-individual behavior: Description and detection. *European Journal of Psychological Assessment*, *12*(2), 112–123. https://doi.org/10.1027/1015-5759.12.2.112
61. Magnusson, M. S. (2000). Discovering hidden time patterns in behavior: T-patterns and their detection. *Behavior Research Methods, Instruments, & Computers*, *32*(1), 93–110. https://doi.org/10.3758/BF03200792
62. Magnusson, M. S. (2018). Temporal patterns in interactions. In E. Brauner, M. Boos, & M. Kolbe (Eds.), *The Cambridge handbook of group interaction analysis* (pp. 323–353). Cambridge University Press. https://doi.org/10.1017/9781316286302.017
63. Maneiro, R., & Amatria, M. (2018). Polar coordinate analysis of relationships with teammates, areas of the pitch, and dynamic play in soccer: A study of Xabi Alonso. *Frontiers in Psychology*, *9*, Article 389. https://doi.org/10.3389/fpsyg.2018.00389
64. Maneiro, R., Amatria, M., & Anguera, M. T. (2019). Dynamics of Xavi Hernández's game: A vectorial study through polar coordinate analysis. *Journal of Sports Engineering and Technology*, *233*(2), 143–155. https://doi.org/10.1177/1754337119830472
65. McClure, E. (1983). Sociocultural variables in children's sequencing of stories. *Discourse Processes*, *6*(2), 131–143. https://doi.org/10.1080/01638538309544559
66. Menescardi, C., Falco, C., Estevan, I., Ros, C., Morales-Sánchez, V., & Hernández-Mendo, A. (2019). Is it possible to predict an athlete's behavior? The use of polar coordinates to identify key patterns in taekwondo. *Frontiers in Psychology*, *10*, Article 1232. https://doi.org/10.3389/fpsyg.2019.01232
67. Morillo, J. P., Reigal, R. E., Hernández-Mendo, A., Montaña, A., & Morales-Sánchez, V. (2017). Decision-making by handball referees: Design of an ad hoc observation instrument and polar coordinate analysis. *Frontiers in Psychology*, *8*, Article 1842. https://doi.org/10.3389/fpsyg.2017.01842
68. Nunes, H., Iglesias, X., Del Giacco, L., & Anguera, M. T. (2022). The pick-and-roll in basketball from deep interviews of elite coaches: A mixed method approach from polar coordinate analysis. *Frontiers in Psychology*, *13*, 801100. https://doi.org/10.3389/fpsyg.2022.801100
69. Pérez-Tejera, F., Valera, S., & Anguera, M. T. (2018). Using systematic observation and polar coordinates analysis to assess gender-based differences in park use in Barcelona. *Frontiers in Psychology*, *9*, Article 2299. https://doi.org/10.3389/fpsyg.2018.02299
70. Portell, M., Anguera, M. T., Hernández-Mendo, A., & Jonsson, G. K. (2015). Quantifying biopsychosocial aspects in everyday contexts: An integrative methodological approach from the behavioral sciences. *Psychology Research and Behavior Management*, *8*, 153–160. https://doi.org/10.2147/PRBM.S82417
71. Portell, M., Sene-Mir, A. M., Anguera, M. T., Jonsson, G. K., & Losada, J. L. (2019). Support system for the assessment and intervention during the manual material handling training at the workplace: Contributions from the systematic observation. *Frontiers in Psychology*, *10*, Article 1247. https://doi.org/10.3389/fpsyg.2019.01247

72. Posner, M. I., Rothbart, M. K., & Sheese, B. E. (2007). Attention genes. *Developmental Science*, *10*(1), 24–29. https://doi.org/10.1111/j.1467-7687.2007.00559.x
73. Preciado, M., Anguera, M. T., Olarte, M., & Lapresa, D. (2021). Revisión sistemática en fútbol sala desde los mixed methods. *Revista de Psicología del Deporte*, *30*, 75–96.
74. Quera, V. (2018). Analysis of interaction sequences. In E. Brauner, M. Boos, & M. Kolbe (Eds.), *The Cambridge handbook of group interaction analysis* (pp. 295–322). Cambridge University Press. https://doi.org/10.1017/9781316286302.016
75. Rodríguez-Medina, J., Rodríguez-Navarro, H., Arias, V., Arias, B., & Anguera, M. T. (2018). Non-reciprocal friendships in a school-age boy with autism: The ties that build? *Journal of Autism and Developmental Disorders*, *48*(9), 2980–2994. https://doi.org/10.1007/s10803-018-3575-0
76. Roustan, M., Izquierdo, C., & Anguera, M. T. (2013). Sequential analysis of an interactive peer support group. *Psicothema, 25*(3), 396–401. https://doi.org/10.7334/psicothema2012.93
77. Sackett, G. P. (1980). Lag sequential analysis as a data reduction technique in social interaction research. In D. B. Sawin, R. C. Hawkins, L. O. Walker, & J. H. Penticuff (Eds.), *Exceptional infant: Psychosocial risks in infant-environment transactions* (Vol. 4, pp. 300–340). Brunner/Mazel.
78. Sáiz-Manzanares, M. C., Alonso-Martínez, L., & Marticorena-Sánchez, R. (2022). A systematic review of the use of T-Patterns and T-String analysis (TPA) with THEME: Analysis using mixed methods and data mining techniques. *Frontiers in Psychology*, *13*, 943907. https://doi.org/10.3389/fpsyg.2022.943907
79. Sandelowski, M. (1996). One is the liveliest number: The case orientation of qualitative research. *Research in Nursing & Health*, *19*, 525–529. https://doi.org/10.1002/(SICI)1098-240X(199612)19:6<525::AID-NUR8>3.0.CO;2-Q
80. Sankoff, D., & Kruskal, J. B. (1983). *Time warps, string edits, and macromolecules*. Addison-Wesley.
81. Santoyo, C., Jonsson, G. K., Anguera, M. T., & López-López, J. A. (2017). Observational analysis of the organization of on-task behavior in the classroom using complementary data analyses. *Anales de Psicología*, *33*(3), 497–514. https://doi.org/10.6018/analesps.33.3.271061
82. Santoyo, C. V., & Mendoza, B. G. (2018). Behavioral patterns of children involved in bullying episodes. *Frontiers in Psychology*, *9*, Article 456. https://doi.org/10.3389/fpsyg.2018.00456
83. Schegloff, E. (2000). On granularity. *Annual Review of Sociology*, *26*, 715–720. https://doi.org/10.1146/annurev.soc.26.1.715
84. Siggelkow, N. (2007). Persuasion with case studies. *Academy of Management Journal*, *50*, 20–24. https://doi.org/10.5465/amj.2007.24160882
85. Soriano, D., Tarragó, R., Lapresa, D., Callan, M., & Iglesias, X. (2024). Observation system for the technical-tactical analysis of judo by the Rio 2016 Olympic champions. *PLoS One*, *19*(5), e0303689. https://doi.org/10.1371/journal.pone.0303689
86. Soto, A., Camerino, O., Iglesias, X., Anguera, M. T., & Castañer, M. (2022). LINCE PLUS software for systematic observational studies in sports and health. *Behavior Research Methods, 54*(3), 1263–1271. https://doi.org/10.3758/s13428-021-01642-1
87. Stake, R. E. (1995). *The art of case study research*. Sage.
88. Stake, R. E. (2006). *Multiple case study analysis*. Guilford Press.
89. Studer, M., & Ritschard, G. (2016). What matters in differences between life trajectories: A comparative review of sequence dissimilarity measures. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, *179*(2), 481–511. https://doi.org/10.1111/rssa.12125

90. Tarragó, R., Iglesias, X., Lapresa, D., & Anguera, M. T. (2016). Complementariedad entre las relaciones diacrónicas de los T-patterns y los patrones de conducta en acciones de esgrima de espada masculina de élite. *Cuadernos de Psicología del Deporte*, *16*(1), 113–128.
91. Tarragó, R., Iglesias, X., Lapresa, D., Anguera, M. T., Ruiz-Sanchís, L., & Arana, J. (2017). Analysis of diachronic relationships in successful and unsuccessful behaviors by world fencing champions using three complementary techniques. *Anales de Psicología*, *33*(3), 471–485. https://doi.org/10.6018/analesps.33.3.271041
92. Tarragó, R., Iglesias, X., Michavila, J. J., Chaverri, D., Ruiz-Sanchís, L., & Anguera, M. T. (2015). Análisis de patrones en asaltos de espada de alto nivel. *Cuadernos de Psicología del Deporte*, *15*(1), 149–158. https://doi.org/10.4321/S1578-84232015000100015
93. Vuchinich, S. (1984). Sequencing and social structure in family conflict. *Social Psychology Quarterly*, *47*, 217–234. https://doi.org/10.2307/3033819
94. Yamaguchi, K. (1991). *Event history analysis*. Sage.
95. Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Sage.
96. Zurloni, V., Cavalera, C., Diana, B., Elia, M., & Jonsson, G. K. (2014). Detecting regularities in soccer dynamics: A T-pattern approach. *Revista de Psicología del Deporte*, *23*(1), 157–164.