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How to cite

STUDER, Matthias, GAUTHIER, Jacques-Antoine, LE GOFF, Jean Marie Alian F. Combining Event History and Sequence Analysis to Study Vulnerability over the Life Course. In: Withstanding Vulnerability throughout Adult Life. Spini, D., Widmer, E (Ed.). Singapore : Springer Nature Singapore, 2023. p. 375–389. doi: 10.1007/978-981-19-4567-0_23

This publication URL: https://archive-ouverte.unige.ch/unige:174227

Publication DOI: 10.1007/978-981-19-4567-0_23

CHAPTER 23

Combining Event History and Sequence Analysis to Study Vulnerability over the Life Course

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Introduction

Spini and Widmer (2022) identify three consecutive stages when studying vulnerability processes from a life-course perspective: before, during and after exposure to stressors and critical events. When considering the situation preceding the occurrence of stressors, research often focuses on the likelihood of their occurrence and on the available resources and reserves

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D. Spini, E. Widmer (eds.), *Withstanding Vulnerability throughout Adult Life*, https://doi.org/10.1007/978-981-19-4567-0_23

that might prevent them from occurring (Cullati et al., 2018). At this stage, vulnerable people are those considered ‘at risk’.

In the second and third stages (during and after the onset of a stressor), research generally focuses on how people cope with the stressor and then on how they recover from it. Vulnerable people are those who experience difficulties either coping with or recovering from these situations. The amount of reserves accumulated before the occurrence of the stressor is considered a central explanatory factor of the vulnerability process.

These three stages are, however, not independent from one another. ‘At-risk’ individuals are often those with fewer resources or reserves to deal with stressors and therefore are also less likely to cope with or recover from them (Spini & Widmer, 2022). This dynamic view of vulnerability requires not only a longitudinal perspective, but also a precise understanding of the interdependencies linking the different stages of the process. These interdependencies call for designing and developing specific methods that can adequately meet these needs.

In this paper, we review two methodological developments aiming to tackle this issue by combining two frameworks that are often presented as opposed to each other: event history and sequence analyses. First, we present Sequence History Analysis (SHA, Rossignon et al., 2018), which focuses on the relationship between the unfolding of a trajectory and the occurrence of a subsequent disruptive event (e.g., stressor). Within SHA, Sequence Analysis (SA) is used to capture the pattern of the life trajectory preceding the onset of the stressor, whereas Event History Analysis (EHA) allows the assessment of the instantaneous risk of the occurrence of this event.

Second, we consider the Competing Trajectory Analysis (CTA; Studer, Liefbroer, & Mooyaart, 2018) and the Sequence Analysis Multistate Model (SAMM; Studer, Struffolino, & Fasang, 2018). Both methods aim to simultaneously study the occurrence of a disruptive event through EHA and the recovery trajectory following the event, using SA to summarise it. By jointly analysing the risk of the event and identifying the pattern of the following trajectory, this approach links these two stages of the vulnerability process.

This chapter is organised as follows. We start by introducing the EHA and SA methodological frameworks before presenting SHA and CTA/SAMM. We then highlight their added value for the study of vulnerability over the life course before concluding on how they might be combined in future studies.

Short Methods Presentation

As noted by Billari (2005), SA and EHA were developed in two different research cultures and for different purposes (see Piccarreta & Studer, 2019 for a review). Rooted in exploratory data analysis, SA, often called optimal matching, aims to provide a holistic view of processes described as a sequence, i.e., a succession of states (Abbott, 1995). SA is based on the computation of distances between sequences of states (see Studer & Ritschard, 2016 for a review), which allows the comparison of sequences without making any assumptions about their underlying generating process.

Most often, these distances are used to create a typology of trajectories through cluster analysis (see, for instance, Studer, 2013). This method aims to identify recurrent patterns in the sequences or, in other words, typical successions of states through which the trajectories unfold. Individual sequences are often distinguished from one another by a multitude of small, sometimes meaningless, differences. The construction of a typology of sequences is designed to ignore such small differences, to identify types of trajectories that are homogeneous and distinct from one another. The types are then interpreted as describing the main processes or trajectories. The main strength of SA is, therefore, its ability to describe and summarise trajectories using only a few types.

In contrast, EHA is rooted in the statistical modelling approach. This stochastic framework gathers several methods for modelling the duration between two events, such as starting and stopping a period of employment, or similarly, the hazard of experiencing the second event once the first has occurred. One of the main advantages of EHA is that it handles (right- or left-)censored observations and thus allows for the inclusion of individuals whose trajectories are not fully observed. Furthermore, several methods within the EHA framework allow the estimation of the influence of possibly time-varying explanatory factors on the occurrence of a given event (e.g., Allison, 2014). In the social sciences, EHA has been primarily used to analyse the occurrence of normative and nonnormative events of the life course (e.g., marriage and birth but also divorce and health issues).

Many extensions of the EHA framework are of interest from a life-course perspective. Among others, multistate models represent an interesting attempt to study trajectories described as a succession of states (Therneau & Grambsch, 2000). Multistate models aim to analyse state sequences by focusing on the hazard of observing transitions between states and the time spent in each state. More precisely, these models measure the chance to end a spell in a given state, considering each possible 'destination' state as a competing event. In a vulnerability framework, the main strength of EHA is therefore its ability to describe the factors associated with the occurrence of disruptive events or transitions.

Estimating the Effect of a Past Trajectory on an Upcoming Event: Resources and Reserves Produced by Life Histories

The life course paradigm insists on the need to situate the study of any event within its unfolding trajectory. This necessity also applies to the study of disruptive events, as the past trajectory can often be considered a reserve, i.e., a process by which some resources accumulate (or not) over the life course. These reserves can then be mobilised either to avoid the occurrence of a stressor event or to prevent its damaging consequences (Cullati et al., 2018).

The study by Madero-Cabib et al. (2016) on retirement timing is an illustration of how a past trajectory can be interpreted as a reserve. This study used the joint family and occupational trajectory to capture how the patterns of accumulation of economic resources in the institutionalised pension system may protect against poverty after retirement, thereby helping explain its timing. These authors showed that in Switzerland, men tend to leave the labour market before the legal retirement age more often than women. One reason for this is that women are more likely to experience a discontinuous occupational career, with spells of part-time work or out of the labour market that are associated with family events. Consequently, women do not accumulate as much economic reserve in their pension fund as men, a large majority of whom are continuously full-time employed.

Aeby et al. (2019) offered another example of how reserves are linked with past trajectories in the family domain. They found that previous family and occupational trajectories are linked with the subsequent accumulated social capital in personal networks, which is known to be an efficient buffer of adverse conditions. They showed that nuclear family trajectories are more frequently associated with denser personal networks, which are known to be supportive and protective. In contrast, trajectories diverging from the normative family model (childlessness, separation or stepfamilies) are associated with smaller personal networks, providing more autonomy but less protection (Widmer, 2016).

From a methodological point of view, the estimation of the link between a past trajectory and a subsequent (disruptive) event is generally estimated with one of the two following strategies. First, an EHA model might include indicators of a past trajectory, such as the time previously spent in education, to estimate its effect on the risk of experiencing the considered event. However, the chosen indicators might offer too crude an estimation of the effect of a past trajectory and fail to identify its key dimensions. Second, some studies have used SA to analyse the trajectories up to a given point and then used EHA to estimate the risk of experiencing the event starting at that point. For instance, Madero-Cabib et al. (2016) used SA to summarise individuals' past occupational trajectories until age 58 and then EHA for older ages. However, this strategy also has a considerable limitation. The subtrajectory occurring between age 58 and the event under consideration is not included in the model, as the past trajectory type is only built using information up to age 58.

To overcome these limitations, Rossignon et al. (2018) proposed the "Sequence History Analysis (SHA)," which aims to estimate the effect of the past trajectory on an upcoming event by combining SA and EHA. This procedure relies on SA to identify the type of past trajectory as a time-varying covariate and uses discrete-time EHA models to estimate its relationship with the upcoming event under consideration.

The procedure operates in three steps. First, it employs a discrete-time representation of the data, also known as a person-period file (Allison, 2014). In this format, one observation is generated for each individual i at each time point t. Let us illustrate how this procedure works with a small example taken from the study by Rossignon (2017) on the link between residence permit trajectory and obtaining a first job in Switzerland. The left-hand side table of Fig. 23.2 provides an example of such data for individual 1, who obtained his first job at age 19. He held a temporary permit until age 15, a permanent residence permit between ages 16 and 17, and then received Swiss nationality at age 18.

In the second step of the procedure, the *past* trajectory at each time point is coded as the sequence of states from the beginning ($t = 1$ in our example) until the *previous* position $t - 1$. In Fig. 23.1, this corresponds to the column 'trajectory until $t - 1$' of the person-period table. For instance, our illustrative individual had the following past trajectory when he was 16 years old: 'T/15', meaning that he had previously spent 15 years

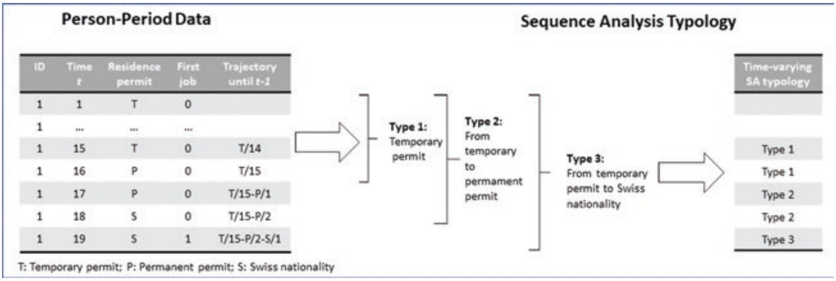

Fig. 23.1 Illustration of the sequence history analysis procedure

holding a temporary permit. Logically, this past trajectory changes as he grows older. At age 18, it is 'T/15-P/2-S/1', which corresponds to having a temporary permit for 15 years, then a permanent permit for two years, and then Swiss citizenship for one year.

In the third step, a typology of the past trajectory is created with SA.[1] As a result, a new covariate coding the type of past trajectory is now available for subsequent analysis. Since we have several observations for each individual that are clustered separately, the same individual can switch from one type of past trajectory to another over time. In other words, the unfolding of the individual's past trajectory is incrementally associated with a time-varying type of trajectory at each time t. Let us assume that the clustering of the previous residence permit trajectories of our example identified three types: 'Temporary permit' (type 1), 'Transition from temporary to permanent permit' (type 2) and 'Transition from temporary permit to Swiss nationality' (type 3). The result is shown on the right-hand side of Fig. 23.2. At age 15, the individual has the 'past trajectory type 1' (temporary permit), and at age 17, he has type 2, as his trajectory unfolds over time.

In the last step, the relationship between the past trajectory and the subsequent event is estimated with a discrete-time model, which includes the past trajectory type as a covariate. In this step, other covariates can be included as well (for detailed output, see Rossignon, 2017).

Using this methodology, Rossignon (2017) found that the residence permit trajectory can be considered a reserve because it is directly linked

[1] The past trajectories are of varying lengths but fully observed at each time point, i.e., there are no missing or censored data. For this reason, SA can be applied.

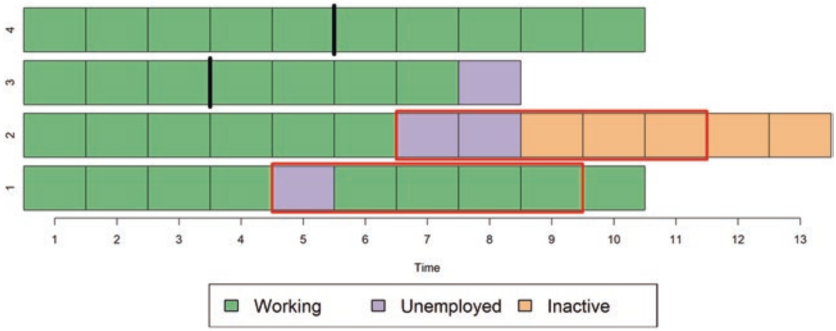

Fig. 23.2 Illustration of the competing trajectory analysis procedure applied to job loss

not only to legal rights, such as the possibility to vote, but also to job opportunities. Six types of permit trajectories were identified and used as covariates in an EHA that modelled the likelihood of obtaining a first job according to its position within the Swiss social stratification (using a competing risk model). The results showed that the risk of obtaining a high position is lower for those who experienced a 'Temporary to permanent' type of trajectory, an observation that would not have been made with the standard EHA approach. Rossignon et al. (2018) empirically applied this method to study the relationship between past childhood coresidence patterns and the likelihood of leaving the parental home. Leaving home is a key step in understanding the transition to adulthood, as it is often a prerequisite for cohabitation, marriage and parenthood (Mulder, 2009). The results showed that 'history matters', as the occurrence, timing and order of events exert a statistically significant influence on the departure from the parental home. Even when controlling for the effect of simple indicators of the past trajectory, such as parental divorce or having a sibling, the effect of the past trajectory was significant and highlighted, for instance, the importance of siblings' departure from the parental home.

This first attempt to estimate the relationship between a past trajectory and an upcoming event using SHA may be extended by considering more than one past trajectory. For instance, when studying academic careers from a gender perspective, one may want to record both the history of previous peer-reviewed publications and past family trajectories to predict the attainment of a professor position.

The SHA approach aims to study the period *before* the occurrence of a stressor and how the unfolding of the trajectory, and often the associated accumulation of reserves, might affect its occurrence. However, the vulnerability framework also stresses the importance of understanding what happens *after* the stressor, as some individuals might be more affected by it than others. This understanding is precisely the aim of the methods presented in the next section.

The Simultaneous Study of Risk and Recovery Trajectories

The Competing Trajectory Analysis (CTA) (Studer, Liefbroer, & Mooyaart, 2018) and the Sequence Analysis Multistate Model (SAMM) procedure (Studer, Struffolino, & Fasang, 2018) allow the simultaneous study of an event's occurrence and the trajectory following it. This is of special interest when the focus is not only on the event's occurrence but also its consequences over time.

Within the social sciences literature, the notion of 'vulnerability' over the life course is related to the occurrence of disruptive life events and their consequences. Such an event can be normative and socially anticipated (e.g., childbirth) or unexpected and most often negative (e.g., divorce). These events are considered stressors (Pearlin, 2010), as they are potentially associated with systemic disorder (e.g., in this case, within the work-family balance).

One may consider two intertwined definitions of vulnerability (Spini & Widmer, 2022). For some authors, 'vulnerable' people are those who are at greater risk of facing stressors (e.g., being poor, young, female, a foreigner). However, vulnerability further refers to the (in)ability of people to cope with disruptive events (Spini et al., 2017). From this perspective, the focus is thus on how people recover (or not) from the stressor, which can be described by the trajectory following the event. While some people might be barely affected by an event, others might face significant functional and/or structural changes. From a sociological perspective, the availability of resources and reserves (economic, cultural, social) explains much of this ability to deal with and to recover from disruptive events.

What does this perspective mean in methodological terms? On the one hand, as EHA aims at estimating the risk of occurrence of an event over time, it allows the analysis of exposure to a disruptive event. On the other hand, SA can adequately capture how individuals recover from stressors by considering the timing, duration and order of situations taking place after their occurrence. However, exposure and recovery from disruptive events are most likely not independent from each other. Resources and reserves might help prevent the occurrence of disruptive events and help the individual cope with them if they occur (Spini & Widmer, 2022). Similarly, individuals expecting to experience only small consequences from a given event might not mobilise their resources or reserves to prevent it. This assessment calls for the joint analysis of these two elements of exposure and coping. The aim of the CTA approach, which simultaneously studies the occurrence of an event and the trajectory following it, satisfies this call.

More practically, the CTA approach operates in three steps. In the first step, the focus is on the recovery pattern from instantaneous stressor onset, i.e., on the trajectories following the event under investigation, only for those having experienced the event of interest. More formally, let t be the time of the event, and let ℓ be the predefined time span of interest for studying the consequence of the event. We centre on the subsequences between positions t and $t + 1$. Figure 23.2 illustrates this process through a small example focusing on the trajectory following a job loss and distinguishing among three states: working, unemployed and inactive.

For instance, if we set $\ell = 5$ time units, we extract the subsequence highlighted in red ('Unemployed/1—Working/4') from the first trajectory. In the second trajectory, we consider the subsequence 'Unemployed/2—Inactive/3' ranging from positions 7 to 11.

In this step, only fully observed subsequences of length ℓ are considered. As a result, no subsequences are extracted from trajectories in which the event 'losing a job' did not occur, as exemplified in the fourth trajectory of Fig. 23.2. The same applies to sequences that have not been observed for ℓ time units after this event (e.g., third trajectory in Fig. 23.2). In both cases, the recovery trajectory cannot be fully observed. However, these trajectories will be included in the third step of the analysis (EHA) as censored observations.

These subsequences are then clustered with SA to identify typical trajectories following the event under study. This step reduces the usually large number of distinct subsequences into a few types that describe the typical medium-term consequence of this event. Let us assume that two types, 'back to work' and 'leaving the workforce', were identified for our illustrative application. The subsequence extracted from sequence 1 would be clustered in the 'back to work' type, whereas that of sequence 2 would be clustered in the 'leaving the workforce' type. These types would describe the typical expected trajectory following the event of losing a job.

The third step of the analysis is to simultaneously study the event's occurrence and the trajectory following it. The risks of following any of these typical subsequences after the event are mutually exclusive, as a subsequence cannot be simultaneously clustered into two different types. We therefore estimate the risk of starting one of these typical subsequences by using a competing risk model, which allows us to study jointly the timing of the commencement of the transition and the type of process that follows. In our example, we consider that the type associated with the subsequence 'Unemployed/1—Working/4' occurs after 4 years (i.e., the time spent before the event). In a vulnerability framework, we therefore associate the study of the exposure to a (potentially stressful) event and the recovery trajectory that follows this event.

In the EHA procedure, censored trajectories can be included. However, the censoring time needs to be adjusted because a complete subsequence can only be observed if the event occurs ℓ time units before the end of the trajectory. This limit, therefore, becomes our censoring time. More formally, let L be the length of the full sequence; then, the censoring time is L-ℓ. This new censoring time is illustrated in Fig. 23.2 with a vertical bar.

The Sequence Analysis Multistate Model (SAMM; Studer, Struffolino, & Fasang, 2018) procedure extends CTA by considering *any* transition or event (e.g., marriage, childbirth, divorce) observed in the trajectories. As in CTA, the procedure consists of three steps. First, the subsequences over a given time span ℓ following any transition in the trajectories are extracted. Then, these subsequences are clustered through SA to identify typical subsequences of medium-term changes. In the final step, the effect of covariates on the chances of initiating each kind of subsequence is estimated using a multilevel multistate model. This new procedure allows studying the time spent in each state as well as the patterns of medium-term changes occurring in trajectories.

Aside from the simultaneous study of the risk and the following recovery or coping trajectory, the combination of EHA and SA offers several advantages over the traditional use of SA alone. First, the use of EHA allows the inclusion of censored observations in the analysis, which is often not possible in traditional SA. Second, the combination of EHA and SA allows the inclusion of time-varying (micro- and macro-level) covariates. In traditional SA, only covariates measured at the beginning of the trajectory can be included to avoid explaining the first part of the trajectory by something that happened later (also called anticipative analysis, see Hoem & Kreyenfeld, 2006). The handling of time-varying covariates is of special interest when studying vulnerability over the life course, as evolving resources or reserve accumulation can be considered. Third, the combination allows for a more precise study of the timing of the events (or transitions in SAMM) than traditional SA does. Indeed, in traditional SA, the distinction between those experiencing the event earlier or later is only possible by creating an additional type of trajectory. In some applications, this might be too crude an approximation to describe all the timing variations of the process. For instance, Studer, Liefbroer, and Mooyaart (2018) used CTA to estimate the relationship between transition into adulthood patterns and youth unemployment. They found that the start of the transition into adulthood is generally postponed and that fast demographic paths to fatherhood become less frequent in hard economic times. Finally, focusing on subsequences instead of full trajectories often reduces the complexity of the analysis, which often leads to considerably higher clustering quality in the SA step.

To date, several scholars have applied either the SAMM or the CTA approach. Studer, Liefbroer, and Mooyaart (2018) and Mooyaart (2019) used CTA to study the transition to adulthood in Europe. Studer, Struffolino, and Fasang (2018) relied on SAMM to study the effect of German reunification on the employment trajectories of women in East and West Germany. Among others, SAMM was able to capture the increase in the chances of following patterns of short-term employment in East Germany after the reunification, an effect of the reunification that had not been captured by a traditional multistate model. Struffolino and Van Winkle (2019) applied SAMM to study pathways out of the working poor status in the US. Among others, their results highlighted that these pathways are more frequently temporary for people with a disadvantaged background.

Software

These approaches combining EHA and SA can be implemented in any software providing both methods, such as R or Stata. Indeed, these approaches only require reformatting the data and sequentially applying each method.

In R (R Core Team, 2021), the TraMineRextras R package (Ritschard et al., 2021) provides functions to make these operations easier. More specifically, the function seqsha helps format the data for the SHA

(Sequence History Analysis) approach. The function seqcta is designed to apply the CTA (Competing Trajectory Approach) and seqsamm the SAMM (Sequence Analysis Multistate Model) procedure. The associated help pages (accessible in R by using ?seqsamm, for instance) further propose a step-by-step example of performing each of the approaches.

Conclusion

We presented two approaches combining EHA and SA to study vulnerability over the life course. SHA aims to shed light on the relationship between an unfolding trajectory and a subsequent event. When studying vulnerability, SHA might capture the role of resources and reserve accumulation during the past trajectory on the risk of experiencing disruptive events. It is therefore centred on the period *before* the occurrence of a stressor event (Spini & Widmer, 2022). For instance, in Rossignon's (2017) study on professional integration of children of migrants, SHA showed that the history of residence permit explains more than the current permit status alone.

In contrast, CTA and SAMM aim to simultaneously study the occurrence of an event and the following trajectory, which can shed light on how people cope with and recover from potentially disruptive events. Furthermore, CTA and SAMM can be used to understand the relationship between exposure to stressors and their potential negative consequences over a medium-term period. From a vulnerability perspective, CTA and SAMM are centred on the description of the period *after* stressor exposure.

Although a combination has not yet been attempted, the two approaches can be combined to understand how the unfolding of a trajectory affects both the risk of a disruptive event and the trajectory following it. We think that such a combined approach would prove very useful to understand the temporal interdependencies and the dynamics of vulnerability from a life-course perspective.

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