Careers, Chaos, and Complexity

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Introduction

While the field of activity of career research was until quite recently almost exclusively limited to careers within organizations (e.g. Becker & Strauss, 1956; Glaser, 1968; Schein, 1978; Super, 1957), a different type of careers is now apparently gaining more and more theoretical as well as practical relevance. It is marked by numerous transitions between jobs, organizations, or fields of professional activity, and the fact that it is almost solely up to the individual actor to take care of his or her career, with little or no external support. All this results in a less stable, less predictable career path labeled for instance as "boundaryless career" (Arthur et al., 1999), "protean career" (Hall, 1996), "post-corporate career" (Peiperl & Baruch, 1997), or "chronic flexibility" (Mayrhofer et al., 2000). Based on these concepts, many authors claim that careers have become increasingly complex in recent years, an assumption that we will term the "complexity hypothesis in career research".

Empirical support for the complexity hypothesis has hitherto been mostly based on case studies and interviews (e.g. Arthur et al., 1999), but we want to propose another way of investigating the complexity hypothesis in career research, by applying quantitative methods that stem from research domains that can be subsumed under the label of "chaos research". Although these methods have their origin in the sciences of nature, they have already been applied successfully to the social sciences (for an overview, Tschacher et al., 1992), and chaos theory has also had its first appearances in career research (e.g. Bird et al., 2002; Gunz et al., 2002a; Lichtenstein et al., 2002; Drodge, 2002; Gunz et al., 2002b; Chakrabarti et al., 2002; Parker et al., 2002). Despite the difficulties that come with this approach, using these methods should prove fruitful, especially for analyzing careers as a *dynamic process*. In the present paper, methods from chaos research are applied to a set of empirical data on actual career paths, in an attempt to investigate whether careers have indeed become more complex over the last few decades, as the complexity hypothesis in career research postulates. More specific, the article deals with three questions:

1. Have careers indeed become more complex during the last decades? Aside from the evidence provided by the sources mentioned above, we will examine this question within a mathematically formalized definition of complexity.
2. Should careers be perceived as a complex yet deterministic system or a random process? Although both chaotic systems and random processes are complex, chaotic systems are deterministic. The difference is an important one, considering the limited value of theories and research attempts that aim at discovering and explaining the dynamics of a *random* process.
3. Are the methods used here appropriate for the analysis of career paths?

Coupling and Configuration

Based on Bourdieu's capital, habitus and field concept (e.g. Bourdieu, 1986), Mayrhofer et al. (2000) suggested four different fields of careers resulting from an interplay of two dimensions: coupling and configuration between actors. The *coupling dimension* focuses on the closeness of relationships and the degree of mutual influence between the focal actor and the other actor(s) in the field (e.g. Orton & Weick, 1990; Staehle, 1991; Weick, 1976). Tight coupling means that the actors are closely intertwined in their decisions, whereas in situations marked by loose coupling, the decisions of one actor have very little consequences for the decisions of another. The *configuration dimension* focuses on changes over time in the configuration of relationships between the focal actor and other relevant actors. A stable configuration implies that neither the social environment nor the tasks of the focal actor change rapidly and frequently, while the opposite applies to an unstable configuration. Combining the extremes of these dimensions results in four ideal types of careers that were labeled "Company World", "Free-Floating Professionalism", "Self-Employment", and "Chronic Flexibility" (see figures 1 and 2).

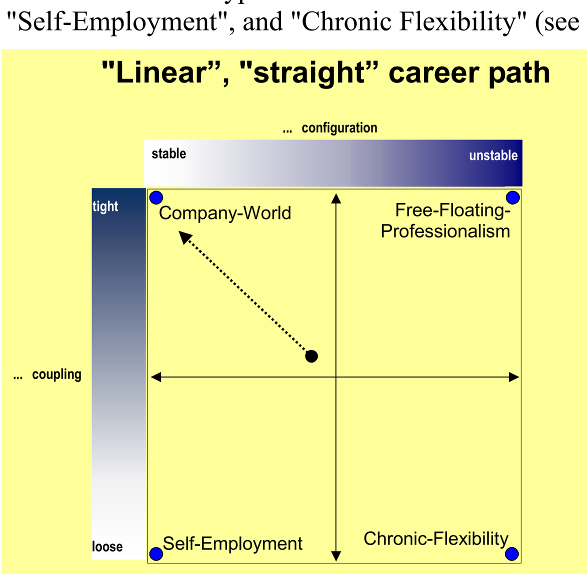

Figure 1

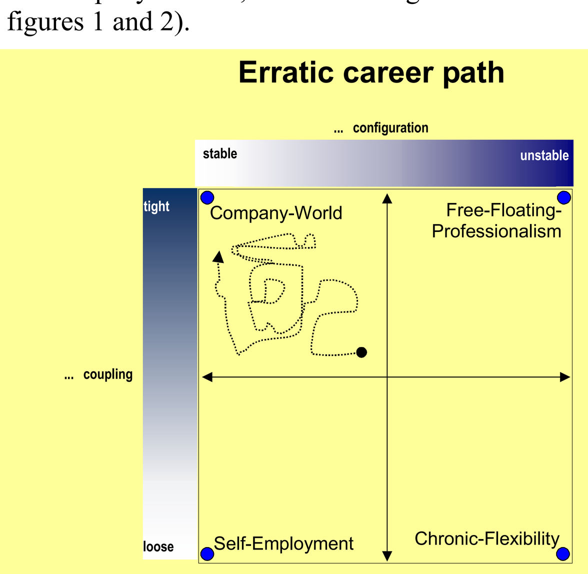

Figure 2

Many authors in career research claim that a tendency towards careers that are marked by more loosely coupled and unstable relationships between actors could be observed in recent years (for an overview, see Mayrhofer et al., 2000), which already represents one concept of increased career complexity. The perspective taken here, however, is a different one: we shall focus on complexity as a criterion regarding the *movement* of a person along the two dimensions. Therefore, complexity could also be found in a career that is limited to the "Company World" career field, defined by tight coupling and a stable configuration (see figure 1 for a straight and non-complex career path, and figure 2 for a highly complex one). So, instead of adopting a "static" perspective in order to examine whether careers have indeed become more complex, the article will deal with this question from a *dynamic* standpoint. Before we turn to the analyses of complexity, their empirical basis shall briefly be introduced in the following section.

The Vienna Career Panel Project

Started in 2000 and supported by the Austrian Science Fund (FWF), the Vienna Career Panel Project (ViCaPP) attempts to explore the professional careers of business school graduates in Austria. In summer 2002, two cohorts of former graduates of the Vienna University of Economics and Business Administration (WU Wien), who finished their studies around 1970 and 1990 respectively, were asked to participate in a survey about their professional development. Based on a curriculum-vitae-like list of professional activities for each person, their professional development was charted for each year since their graduation along several variables.

Operationalizing Coupling and Configuration

One central element of the theoretical framework introduced by Mayrhofer et al. (2000) to describe careers are the two dimensions of coupling and configuration (see above). Although the survey collected information on a much broader set of variables, the following analyses will focus on these two dimensions. Three likert scales referring to coupling and two scales referring to configuration were included in the interview questionnaire. Coupling was operationalized by the mean of the following three items:

- Security and calculability of career-related prospects (very secure vs. very precarious)
- Subjection of career-related prospects to specific external actors and/or constraints (very dependent vs. completely independent)
- How easily another adequate job could be found should the need arise (very easily vs. not at all)

Configuration was represented by the mean of the following two items:

- Stability of work content (very stable vs. ever-changing)
- Stability of professional relations (very stable vs. ever-changing)

For the 90s cohort, data on coupling and configuration were available for a period of 13 years. In order to make results comparable, the first 13 working years are also chosen for the 70s cohort. Additionally the last 13 career years of the 70s cohort were also entered into the analyses, allowing us to compare the career paths of the two cohorts in identical calendar years.

Sample Description

The results presented here are based on 215 former graduates, of which 95 belong to the 70s cohort and 120 to the 90s cohort. The structural differences between the two cohorts are not very pronounced. The most conspicuous differences are due to an underrepresentation of women in the 70s cohort (14% female) compared to the 90s cohort (42% female). This is mostly due to the fact that there were fewer women who commenced and finished their studies at the WU Wien in the 70s.

Mean age was 37.1 years (± 2.0) for the women and 37.9 years (± 3.8) for the men in the 90s cohort, and 55.6 years (± 2.1) for the women and 57.4 years (± 3.2) for the men in the 70s cohort. If one examines the first 13 career years, the proportion of self-employed persons vs. salaried employees hardly differs between the two cohorts. After this brief introduction of our sample, the next section deals with the methods employed to analyze the dynamics of the sample's movements along the two dimensions of coupling and configuration.

Dynamic Definitions of Complexity

One standard method to determine the complexity of a sequence of events or symbols is Shannon's definition of the information content given by equation 1 (Shannon, 1948):

Equation 1: $$I_s = -\sum_{i=1}^{N} P(s_i)\log_2 P(s_i).$$

The information content of a person's career movements could therefore be determined by putting a grid over the career path in question and recording the boxes the person is located in during his or her career. Figure 3 shows the above-mentioned linear career path with such a grid. Assuming a uniform movement and a recording of 16 sampling points, the resulting sequence of "visited boxes" would look somewhat like the following (a "box" may appear more than once as the person stays in it during several years):

$$9 \to 9 \to 9 \to 9 \to 8 \to 8 \to 5 \to 5 \to 5 \to 5 \to 5 \to 5 \to 4 \to 4 \to 1 \to 1$$

The information content of this sequence of events can now quite easily be calculated according to equation 1 and amounts to 2.35 bit. Despite being one of the most widely used complexity measurements, Shannon's definition of the information content has some serious shortcomings, in particular it ignores the order of the values within the sequence, yielding the same result for the following sequence which would however imply a much more complex career path:

$$9 \to 1 \to 9 \to 5 \to 9 \to 5 \to 8 \to 5 \to 8 \to 5 \to 9 \to 4 \to 5 \to 5 \to 4 \to 1$$

One solution proposed for this problem is based on work in the field of algorithmic information theory (Chaitin, 1974; Kolmogorov, 1965; Zvonkin & Levin, 1970), which determines the information content of a sequence of values by the information content necessary to completely describe the sequence. The square root of two, for example, is a number with infinitely many decimals that produce an extremely complex sequence of digits. Nonetheless it can be calculated using a quite simple algorithm. Sequences that show patterns of ordered complexity can normally be put down to simpler algorithms, but in the case of a random sequence, the necessary algorithm is just as complex as the sequence itself (Hubermann & Hogg, 1986). One of the easiest ways to calculate measurements of algorithmic entropy is to use a data compression algorithm (similar to file compression used on computers). While it is not possible to compress random data very much, it is possible to distinguish random time series from ordered ones. We used a compression algorithm called *Grammar Complexity* (Ebling & Jiménez-Montano, 1980; Rapp et al., 1991) that basically "looks for" recurring patterns in the data and replaces them with shorter wildcards.

This algorithm achieves maximum compression with completely ordered data sets (such as our "straight" career path shown in figure 3 below), whereas a randomly shuffled data set leads to a markedly worse compression. We assume that our sample's careers are more complex than a completely linear career path but not random either, so the algorithmic entropy of a person's actual career path should be higher than that of its most ordered variant but lower compared to the same sequence shuffled randomly. Furthermore, if the assumption that careers have become more complex over the last decades holds true, the algorithmic entropy of careers that have begun more than 30 years ago should be lower than the algorithmic entropy of careers that have begun about 20 years later.

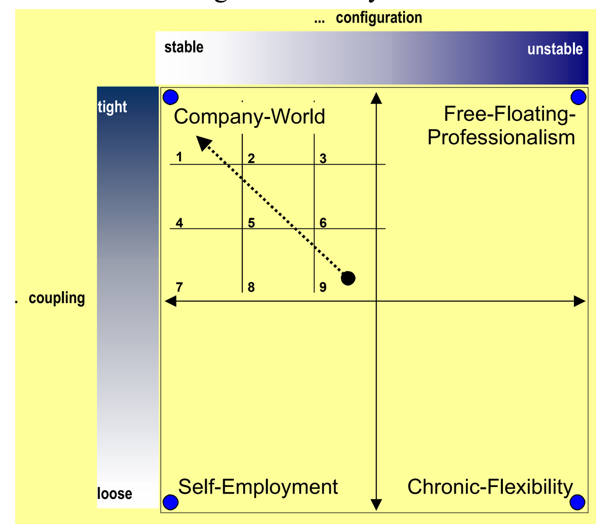

Figure 3

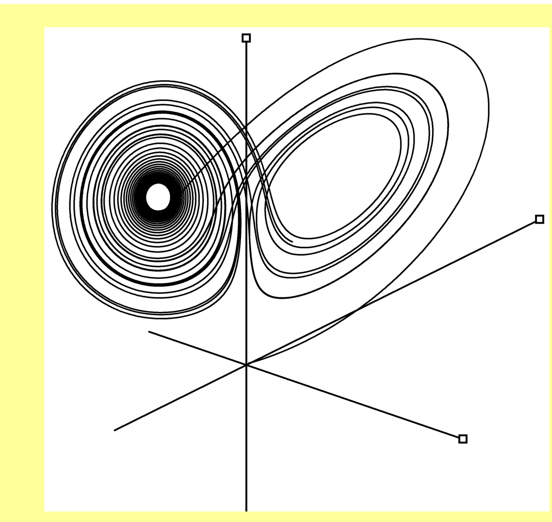

Figure 4

Algorithmic entropy requires just a nominal sequence of values. However, this may result in a loss of information for sample data that feature a higher level of measurement. The theories of non-linear dynamic systems offer several methods that allow to examine the complexity of an interval scaled sequence. The best-known term within the theories of non-linear dynamic systems, which has also become quite common in popular science, is probably the concept of chaos. Chaos (in the sense of non-linear dynamics) denotes extremely complex processes that can only be forecast for a very limited period of time ("butterfly effect"; e.g. Lorenz, 1963), but that are not random either. An important feature of chaotic motion is their fractal structure (Mandelbrot, 1987) that can be visualized in a phase space portrait. The term "phase space" stands for a coordinate system where the variables that affect the system form the coordinate axes. The career paths shown in figures 1 and 2 are examples of simple phase space representations. The changes in coupling and configuration are not depicted as time series but plotted along the two axes. The development over time can only be represented by following the trajectory. Figure 4 shows the phase space of the (chaotic) weather system, first described by Lorenz (1963). The structure of the chaotic motion shows a highly ordered but complex geometrical form, known as a fractal. If it can be shown that a phase space structure based on empirical data is a fractal, this would suggest that the underlying system is a chaotic one. This conclusion is not a compelling one, as Pincus (1991) aptly remarked. Nevertheless, a successful determination of the fractal dimension of a dynamic process allows to draw the following conclusions:

a) The higher the fractal dimension of a dynamic process, the higher its complexity.
b) if the fractal dimension of a dynamic process derived from empirical data can be determined, the process in question is not a random process.
c) The fractal dimension rounded up to the next integer number specifies the minimum number of independent but interacting factors the system needs to generate its dynamics.

Several authors in career research have recently claimed that careers can be viewed as chaotic processes (see above). If the dynamics of careers are influenced by more than three variables and if the relationship between these variables is not a linear one (either a premise for chaotic systems; cf. Schiepek & Strunk, 1994), career paths could indeed be chaotic processes. In that case, however, the factors that influence careers would indeed have to form a system, and careers ought not to be determined by random influencing factors. If phase space representations of career paths turn out to have a fractal structure, this would at least imply that these career paths are not completely determined by random factors. Furthermore, the fractal structure of careers that have begun more than 30 years ago should be less complex than that of careers that have begun 20 years later. Several methods have been proposed to determine the fractal dimension of a time series. The most common one, which is also used here, is the *Correlation Dimension* D2 (Grassberger & Procaccia, 1983b, 1983a).

All these methods theoretically require an infinitely long time series to reliably determine the fractal dimension. Even though about 1.000 sampling points are generally regarded as a small yet sufficient number for attractors of a low fractal dimension (Tsonis, 1992), this is still far beyond the 13 sampling points provided by the 90s cohort (one per year since graduation). Therefore, the determination of the fractal dimension of the data was executed via a somewhat unorthodox procedure: the time series of all persons in each cohort are put together. This results in two quasi-time series with 1.235 sampling points for the 70s cohort, and 1.560 sampling points for the 90s cohort. For both cohorts, the first 13 years of their career are taken. In order for such a procedure to be methodically sound, the dynamics of career paths must not differ too much between the individual cases. However, this cannot be examined at the outset, therefore 100 different variants of the time series for each of the two cohorts were generated and calculated separately. Additionally, in case the individual time series really do differ very much from each other, the generated "overall" time series should be identified as a random process, therefore showing no fractal structure.

Results on Algorithmic Entropy

The results of the calculations of algorithmic entropy suggest that the career paths are indeed more complex for the 90s cohort than for the 70s cohort. However, these results should be accepted with caution, as the test power of the method is rather poor due to the extremely short sequences of merely 13 values.

Two indicators were calculated for each person in order to analyze the algorithmic entropy. The first one is the quotient of the Grammar Complexity value of the original time series divided by the Grammar Complexity value of the same time series sorted in ascending order. The higher the quotient, the more complex the observed sequence. The mean quotient values for the two cohorts are presented in figure 5. It is apparent that the values scarcely exceed the theoretical minimum of 1, which is largely due to the limited sensitivity of this method for short symbol sequences. Despite all these limitations, the 90s cohort has higher complexity values on all five scales, both when compared to the first and last 13 working years of the 70s cohort. The differences in complexity for the first 13 career years of both cohorts are all statistically significant, except for stability of work content.

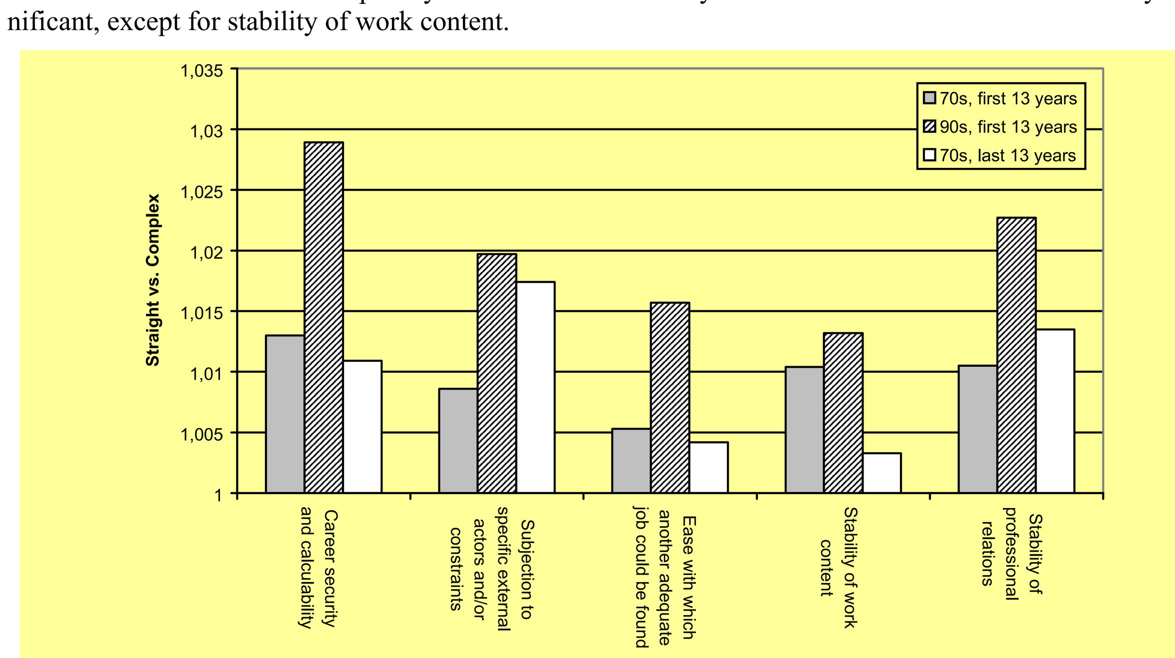

Figure 5

Both aspects just mentioned – the limited sensitivity of the method employed for short time series as well as the nevertheless higher complexity values for the 90s cohort – are also reflected in the results for the second indicator, based on the test of surrogate sequences, where the Grammar Complexity value for the original sequence is compared to a distribution of Grammar Complexity values for 200 randomized surrogate sequences (consisting of the same elements). Figure 6 shows the mean of the z-transformed Grammar Complexity values for both cohorts. The higher the value, the more ordered the underlying sequence, compared to a random sequence. Additionally, z-values larger than 1.96 indicate that the observed sequence is significantly more ordered than a random sequence. It is apparent that the results for both cohorts fall short of this value.

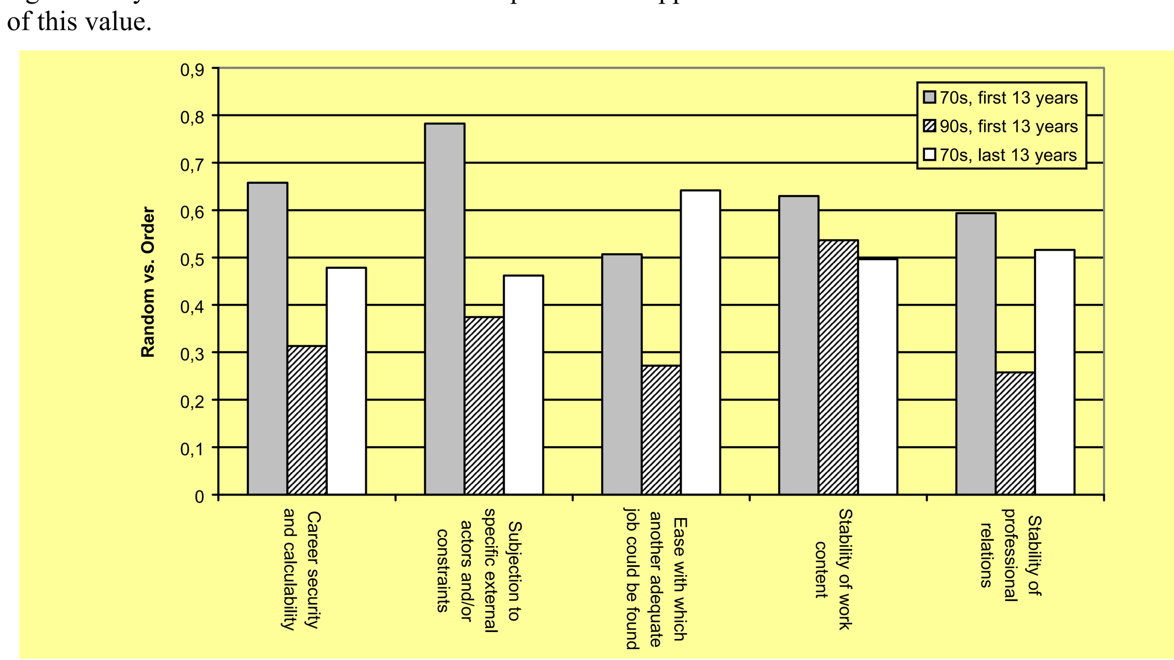

Figure 6

While the first indicator suggests that the observed career paths are at least a bit more complex than their "most ordered" variant, the second indicator implies that the complexity found in these career paths does not clearly distinguish them from a random process. Although both indicators are basically in accordance with the "complexity hypothesis in career research", the results are not very satisfying. With only 13 sampling points, it is almost impossible to clearly differentiate the original sequence from random and/or complete order (cf. Rapp et al., 1991), even when comparing the ordered sequences to the random surrogates. It can therefore not be clearly decided on the basis of these results whether the observed career paths do indeed follow a pattern of ordered complexity, determined rather by a complex yet deterministic system than by random biographic events. On the other hand, the observed differences between the two cohorts regarding the complexity of their career paths do indeed support our predictions.

Results on Correlation Dimension (D2)

Contrary to Grammar Complexity, correlation dimension (D2) makes use of the additional information provided by interval scaled data, compared to nominal symbol sequences. However, it has stricter standards concerning the required length of the time series, so the individual time series were added up here to form a quasi-time series of sufficient length. In order to examine whether the specific complexity found for this resulting time series is actually due to the dynamics of the process and not to the order in which the time series were added up, 100 (differently assembled) quasi-time series were examined for each cohort. One crucial feature of this method is the distinction between a random process, which can be clearly identified by the absence of a saturation of the D2 value for growing embedding dimensions. Figure 7 shows the two-dimensional embedding for a randomly chosen variant of each of the three time series. As usual in social sciences but also in medicine (e.g. Schiepek et al., 1997), no clearly structured attractors could be identified, as opposed to mathematically generated time series.

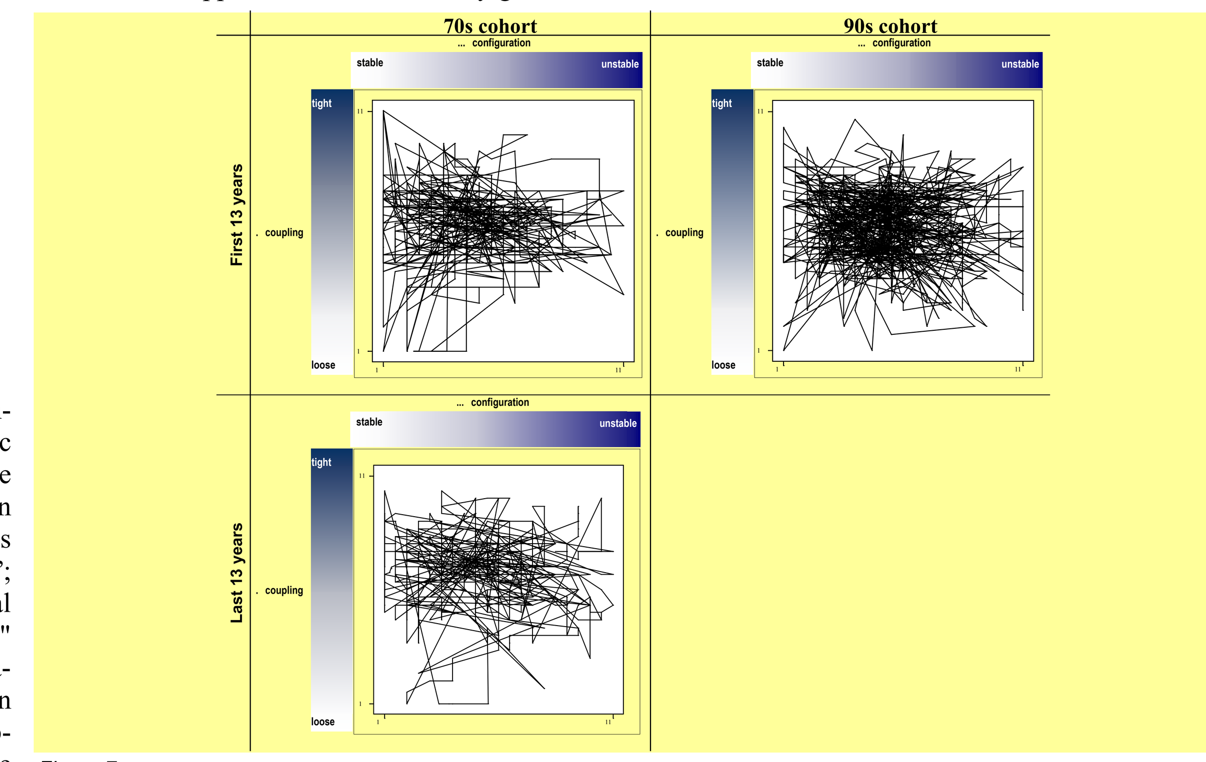

Figure 7

A simple order structure cannot be identified with the naked eye, nevertheless the phase space embedding for the 90s cohort appears more complex than that for the 70s. This may (partly) be due to the fact that the quasi-time series for the 90s cohort contained more sampling points than for the 70s cohort (1.560 vs. 1.235 points). Examining the results for the 70s cohort only, it is also apparent that the representation for the last 13 years looks less complex than for the first 13 years, with the number of points being equal for these two quasi-time series.

The calculations of the respective D2 correlation dimensions confirm this impression. The results of the calculations clearly suggest that the career paths represented by the quasi-time series are not random processes. Rather, the results imply that career paths are complex, dynamic structures that can be put down to deterministic processes. Furthermore, there are only marginal differences between the results for the 100 different calculations which rarely exceed the error margin.

Correlation dimension (D2) of the three quasi-time series

period	70s cohort Mean D2	70s cohort standard deviation	70s cohort N	90s cohort mean	90s cohort standard deviation	90s cohort N	T-Test (1-tailed)
First 13 years	3.4004	0.2923	94	4.4611	0.3906	88	**
Last 13 years	3.1070	0.2360	100	*last 13 years 70s vs. first 13 years 90s*			**

* p < 0.05
** p < 0.01

Table 1

The fractal dimension for the 90s cohort is higher by about one dimension than that of the 70s cohort (see table 1). Consequently, while at least four interacting variables of a deterministic system are necessary to describe the career paths of the 70s cohort, the respective number for the 90s cohort is five. In addition, it is apparent that the system formed by the last 13 working years of the 70s cohort is less complex than the system formed by their first 13 years.

Discussion

As outlined in the introduction, the present article dealt with three questions. First, it should examine whether careers have indeed become more complex over the last years ("complexity hypothesis in career research") via a mathematically formalized concept of complexity stemming from chaos theory. The second question was whether the results obtained would support the concept of careers as complex yet deterministic systems or rather the concept of careers as a random process. The third question aimed at investigating whether the methods applied here are appropriate for career research.

Complexity Hypothesis

Given that the available data hardly met the standards normally required for the application of chaos research methods, the results are surprisingly clear and significant. Both methods employed suggest that the career paths of persons who started their professional career in the 90s are more complex than for persons who graduated around 1970, and the results were even more conspicuous for the more complex and demanding method of correlation dimension than for Grammar Complexity, although the latter seemed more appropriate for the given data at the outset. Nevertheless, there are a few limitations to our study that should be taken into account: the data used here stem from questionnaire-based interviews where the interviewees were asked to assess their whole careers retrospectively. This task may be more difficult for a person with more than 30 years of professional experience than for someone who started his or her professional career around 12 years ago. The difference in observed complexity may therefore partly be a consequence of the "mellowing" effect of time on career recollections. On the other hand, the last 13 career years of the 70s cohort (which are just as "recent" as the working years experienced hitherto by the 90s cohort), show an even lower degree of complexity than the first 13 years, which in turn could be due to a reduction of career complexity in later career stages. In order to better understand and explore these issues, the Vienna Career Panel Project attempts to establish a panel of business graduates that will be asked to participate in a survey of their professional development in fixed intervals.

Complex or Random?

The methods for identifying a deterministic system and distinguishing it from a random process are still slightly embryonic. Only rather simple processes with limited complexity can already be identified as deterministic systems. The attempt to reveal these career paths as complex yet deterministic systems via Grammar Complexity did not yield a successful result, which is probably due to the very limited testing power of this method. The fact that a saturation of the D2 was attained for almost all variants of all three quasi-time series suggests that the observed career paths are based on a rather simple system, despite all complexity. In any case, the results obtained say nothing about the complexity of individual career paths.

Appropriateness of these Methods for Career Research

The approaches introduced here are just a small fraction of the methods, tools and algorithms currently used and discussed in chaos research. We believe that a more widespread use of methods stemming from chaos research faces two main obstacles. First, the data collected within career research will rarely meet the standards required to successfully apply methods of chaos research. For example, a demonstration that the observed career paths are chaotic processes in a mathematical sense (via the calculation of Lyapunov exponents which are a proof for the butterfly effect) cannot be done with the available data. Second, the methods employed here are far less widely-used than "standard" statistical procedures, which is also reflected in a lack of computer software that can perform this sort of calculations.

Despite all these shortcomings, we think that this article represents a successful application of methods from chaos research to career-related questions. Furthermore, we believe that the merit of this paper and the concepts and methods contained therein lies less in the results as such, but rather in the fact of having introduced a theory that is able to describe and quantify career dynamics in a precise and methodically sound way.

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