Abstract The aims of this study are to consider the experience of flow from a nonlinear dynamics perspective. The processes and temporal nature of intrinsic motivation and flow, would suggest that flow experiences fluctuate over time in a dynamical fashion. Thus it can be argued that the potential for chaos is strong. The sample was composed of 20 employees (both full and part time) recruited from a number of different organizations and work backgrounds. The Experience Sampling Method (ESM) was used for data collection. Once obtained the temporal series, they were subjected to various analyses proper to the complexity theory (Visual Recurrence Analysis and Surrogate Data Analysis). Results showed that in 80% of the cases, flow presented a chaotic dynamic, in that, flow experiences delineated a complex dynamic whose patterns of change were not easy to predict. Implications of the study, its limitations and future research are discussed.

Keywords Flow · Nonlinear dynamics · Work · Experience sampling method · Chaos

1 Introduction

Most researchers in the field of work and organizational psychology (WOP) have tended to adhere to a traditional disease model, and have focused predominantly on issues such as work stress, bullying, burnout, workplace violence, musculoskeletal problems and cardiovascular diseases, among other problems. A complete departure from this traditional disease model, in search for a more positive model, which focuses on human strength, optimal experiences and human flourishing, may open a new and promising field of study.
within WOP, and this is exactly the focus that current research on the construct of flow is seeking: a shift in perspective.

Flow refers to “a particular kind of experience that is so engrossing and enjoyable (that it is) worth doing for its own sake even though it has no consequences outside itself” (Csikszentmihalyi 1990, p. 824). In Csikszentmihalyi’s view, the peak of human happiness is experienced in what he has termed experiences of flow. Moreover, and within a broader sense of thought, flow has been described as the “engine” of psychological selection, this is, flow experiences appear to be the vital link between cultural and biological selection, and thus it has been emphasized the importance to further study flow experiences and to increase their frequency in society (Csikszentmihalyi and Massimini 1985). Given the soundness of the concept of flow and its significance for people’s wellbeing, research on flow experiences has increasingly grown over the past few decades, and the relationship between the conditions of flow and a set of different qualities of this experience has been amply documented (Hektner et al. 2007).

However, little has been studied regarding the dynamical nature of flow over time. Knowledge of how flow experiences fluctuate over time and if there is a specific pattern which characterizes flow experiences may be important for the legitimacy of the flow construct, as well as to emphasize the importance of the time dimension in flow research. Following this line of thought, the principal objective of the present study is to bring in the chaos theory to explore whether the phenomenon of flow predominantly presents a nonlinear dynamic.

Csikszentmihalyi and Figurski (1982) stress that if flow were absent from a person’s life, there would be little purpose for living. It strongly influences an individual’s subjective well-being and increases a person’s happiness, positive affect and life satisfaction (Diener 2000).

Moreover, the flow theory (Csikszentmihalyi 1990, 2000) postulates that the experience of flow is a function of the skills that individuals perceive themselves to have in relation to the activity and the perceived challenges of the activity. Thus, when the skills and challenges are low an individual will tend to experience apathy, which will result in an experience of the lowest quality. When challenges are greater than the skills possessed by an individual, anxiety is likely to be experienced. In contrast to this, when an individual’s skills are greater than those required by the challenges, he/she is likely to experience boredom/relaxation; nevertheless, the quality of experience in the latter condition is considered to be of higher value than when apathy is experienced.

However an optimal situation is thought to be when challenges and skills are high and in equilibrium, such as when the individual experiences flow in consciousness, resulting in an experience of the highest quality (Csikszentmihalyi 1990). Thus according to flow theory, the core elements of flow are related to the skills that an individual believes him/herself to possess in relation to an activity, and the perceived challenges of this activity. It has also been suggested that the experience of flow produces feelings of enjoyment and pleasure which make the experience intrinsically rewarding and, therefore, the person is likely to remember it more fully and also more likely to seek such experiences more often (Csikszentmihalyi 1990). Furthermore, it has been found that the experience of flow can be achieved by anyone engaged in any sort of activity, however, it is suggested that flow experiences are most likely to occur while at work (Csikszentmihalyi and Lefevre 1989).

1.1 Flow at Work

The study of flow at work has been conducted within several arenas. For instance, a number of studies have looked at flow experience in relation to internet usage (Chen et al.
1999), technology workers (Ghani and Deshpande 1994; Webster et al. 1993), music teachers (Bakker 2005), executives (Donner and Csikszentmihalyi 1992), to name a few.

When flow is applied to the context of work, most studies (Ellis et al. 1994) define it as an optimal experience that is the consequence of a situation in which challenges and skills are high and in equilibrium. Some researchers (e.g. Hektner et al. 2007) suggest that a situation like this facilitates the occurrence of a flow-related phenomena, such as positive emotions, enjoyment, interest and absorption. Moreover, Ghani and Deshpande (1994) have emphasized that the three main elements of flow at work are the (a) total immersion in the activity (b) the enjoyment that people experience during such activity and (c) their interest in the activity. These authors go on to argue that there must be an optimum level of challenge relative to an individual’s skill level.

Furthermore, in a study looking at flow experiences in work related activities, Donner and Csikszentmihalyi (1992) found that 80% of the time at work is spent in either high-challenge anxiety, or flow. While the remaining 20% is spent in apathy or boredom. On average, about 44% of time at work is spent in flow, indicating that the workplace is an optimum environment for people to experience flow. Additionally, research has shown that developing a rich and challenging workplace environment that can promote flow experiences, may enhance employee productivity (Csikszentmihalyi 2003). In other words employees who are engaged in complex tasks that challenge them to use their talents and strengths and develop new skills are most likely to find their work enjoyable and intrinsically worthwhile, which, in turn, improves productivity. Csikszentmihalyi (2003, p. 86) argued that “from the view point of the firm such workplace is ideal because it attracts the most able individuals; it is likely to keep them longer, and obtain spontaneous effort from their work.” Following this line of thought, it has been suggested that the key to promoting well-being and engagement in the workplace is the maximization of flow experiences (Novak 1996).

Building on this, we find that studying flow at work is central for increasing people’s well being in the workplace. Even though organizational psychologists have recently become more interested in the concept of flow at work (Bakker 2005; Demerouti 2006) there is still limited knowledge about this phenomenon and more research on the matter is needed.

1.2 Nonlinear Dynamics of Flow

Nowadays research in motivation, also including research on flow, is starting to incorporate the dynamic role of the components within the process of motivation over time, offering a fresh, although more complex, way of understanding the psychological process of motivation (Sansone and Thoman 2008). Yet, researchers are still facing the challenge of figuring out how to integrate time into the outcome-oriented theory and research, which has recently dominated studies in psychology. As Sansone and Thoman (2008) suggest, the outcome-oriented approaches are becoming limited in the sense that they only look at a few points in time. Nevertheless, important patterns of motivation can only be spotted using multiple measuring across time. Therefore, there is a need for researchers to continue developing and introducing theories and methodologies from other disciplines in order to asses the dynamic relationships among variables in the process of motivation (Guastello 2001; Sansone and Thoman 2008; Vallacher and Nowak 1994). This is exactly what the present study is aiming at, to bring in the chaos theory to study the dynamics of what it is known as the purest form of intrinsic motivation: flow.

Building on this line of thought, we believe that the chaos theory can be a good analytical framework to analyze the dynamic of flow. The chaos theory is interested in the
study of the behaviour of multiple systems (physical, biological, psychological, and so on) that show some important properties such as a high nonlinearity, unpredictability or sensitive dependence on initial conditions (Lorenz 1995). To demonstrate this kind of properties, it is necessary to focus on the dynamic of the phenomenon that we are interested in. Moreover, with the analytical and statistical tools that the chaos theory provides us with (Heath 2000) we are able to characterize the dynamic of any system as linear, nonlinear, chaotic, or random.

Furthermore, innovative theoretical approaches such as the chaos theory have started to enrich existing knowledge on organizational behaviour (Navarro et al. 2008), partly as a result of the contemporary quest for enhancing current scholarship in the field through the use of new theoretical approaches and methodologies, and partly as a consequence of the established assumption that most psychosocial processes tend to behave in a regular and stable manner over time, a premise that underpins most investigations within work and organizational psychology (Navarro et al. 2008).

Findings in the field of physiology have shown that regularity in the behaviour of certain organs (i.e. the heart and the brain) can represent the existence of an anomalous organ functioning, whereas nonlinearity is a sign of healthy organ functioning (Goldberger and Rigney 1989; Schuldberg 2007). Although there are clear differences between physiological and psychological processes, this paper intends to evaluate whether an optimal experience such as flow presents a nonlinear behaviour over time, describing a positive psychological state of mind. Moreover, just as psychophysiological comportments, psychological behaviours at work are likely to be anomalous when their dynamics are stable over time and healthy when they present nonlinear dynamics across time.

In this sense, a recent study that has used the chaos theory as a framework to study flow, is the one conducted by Guastello et al. (1999); an interesting part of this research is the methodology they use to study the flow experience of 24 undergraduate students over a period of a week, using the Experience Sampling Method (ESM) which will be explained later in the article. More specifically, participants recorded in a diary the task they were performing, the skills they required to perform such tasks, and the challenges implied by the tasks. The time series obtained were subjected to a series of analysis proper to the chaos theory, which revealed nonlinear dynamic patterns for all cases. More specifically, the dynamics of flow tended to fluctuate over time in a nonlinear fashion, showing important degrees of instability.

In line with Guastello et al. (1999) and taking into account their findings we favour a nonlinear dynamics approach to study flow experiences for several reasons. First, theory and research on flow phenomena have established that optimal experiences such as flow tend to be multicomponent systems, which simultaneously alter patterns of behaviour, subjective experience, physiological activity and thinking (Fredrickson and Joiner 2000).

Second, these multicomponent flow systems are dynamic, this is, they change over time as the components within the flow system mutually influence each other. For example, just as motivation is aided by setting goals, the power of goals increases when there is high motivation to achieve them (Jackson and Csikszentmihalyi 1999). Moreover, when the individual clearly knows what she/he wants and is determined to reach it, the person is lifting both challenges and skills to the flow level, giving rise to feelings of enjoyment and therefore the flow experience, becomes like a magnetic pole that pulls the individual towards it again (Csikszentmihalyi 1990). Nowak and Vallacher (1998) argue that this reciprocal causality and feedback within dynamical systems is best modelled with nonlinear equations because nonlinearity allows interactive and bidirectional relations.
Third, in line with the broaden-and-built theory of positive emotions (Fredrickson 1998) it has been found that optimal states such as experiences that produce high feelings of enjoyment support two concepts within the nonlinear dynamic systems theory: local unpredictability and global stability. Building on Frederickson’s model of positive emotions (Fredrickson 1998), which states that positive states of mind broaden momentary thought-action display, as opposed to negative states of mind which tend to narrow those same displays, people tend to be less predictable in positive states than in negative states. The broaden-and-build model (Fredrickson et al. 2003) proposes that the momentary unpredictability characteristic of positive states of mind tend to enhance resilience over time, which aids people to have more flexibility when facing negative or difficult situations. These connections among positive states of mind, local unpredictability, and global states have been confirmed empirically in several studies (Folkman and Moskowitz 2000; Fredrickson and Branigan 2005; Sutcliffe and Vogus 2003).

Following this line of thought, and as stated earlier, Guastello et al. (1999) research findings attempted to asses the dynamics of flow across time. Based on the core principles of the nonlinear dynamic systems theory, they conducted a study looking at flow as the experience of intrinsic motivation, understood as the result of levels of skills and challenges necessary to conduct a task. Moreover, they measured flow as the cross-product of their skill and challenge levels recorded for each task (actual values), divided by the cross product of the within individual standard deviations for skills and challenge. Results from this study clearly pointed out nonlinear dynamical patterns; mostly chaotic patterns in all cases. More specifically, they found that flow experiences tend to fluctuate over time in a nonlinear fashion showing a great deal of unstable behaviour (Guastello et al. 1999). However, two of the main limitations of this study are as follows: Firstly, that the sample was made of students, therefore it would be interesting to move forward this research and look whether the same results are present in adult working populations; secondly, the authors took measures of flow each time the person changed activities, more specifically if an individual was performing the same activity for 2 h, it was taken for granted that the individual had the same level of skills and challenges over the 2 h period the activity lasted. They then divided this period of time into eight periods of 15 min each, giving the same score to each of the eight periods, taking for granted that the level of skills and challenge would not change over a period of 2 h is not very accurate. Thus, the present study intends to overcome the limitations of this study and take research on nonlinear dynamics of flow further.

In line with Guastello et al. (1999); Navarro et al. (2007) reported equivalent results in a study exploring work motivation, using the ESM in a sample of 20 employees, they looked at three variables: motivation, self-efficacy beliefs and instrumentality perceptions with respect to a specific task. Using common methodological procedures of the complexity theory, they found highly nonlinear dynamics for all of the variables studied, raising questions regarding the basic principles underlying current theories on work motivation, which have commonly studied work motivation as a linear and stable phenomenon.

Likewise, Navarro and Quijano (2003) proposed a complex model for work motivation embracing four variables: motives, self-efficacy beliefs, perceived instrumentality and level of performance. Through simulating the interaction between these four variables in a sample of 271 workers, results suggested that work motivation presents complex behaviours (chaos and instability) when studied from a nonlinear approach.

Taken together, the dynamics of work motivation and flow as shown by other researches (Guastello et al. 1999; Navarro et al. 2007; Navarro and Quijano 2003), it would follow that the experience of flow is most likely to fluctuate over time in a nonlinear dynamic way, depicting a positive state of mind. Moreover, the paradigmatic shift of incorporating the
dynamic role of the flow variables over time, may offer an interesting way of understanding the psychological experience of flow at work.

Within a nutshell, at the core of the present study lies the intention to contribute to the study of positive psychosocial phenomena by conceiving flow as a dynamical process, paying especial consideration to its dynamical characteristics. Moreover, this study intends to unite existing theory on flow with the concepts of the chaos theory, and understand the nature of flow experiences from an innovative perspective. Therefore, this study will address the following hypothesis:

H: The Dynamic of Flow will be Chaotic

In light of the temporal nature of a psychological process such as flow, it would follow that the flow experience or the level of flow is not always the same, and it is not likely to follow a simple pattern of change. If we are able to conceive flow with its temporal dimension a more sophisticated approach to the study of this phenomenon may emerge. Moreover, the base line hypothesis has its roots on previous research (Guastello et al. 1999; Navarro et al. 2007), where the authors have found that the dynamics of flow and motivation in general tend to be chaotic in most of the cases.

2 Method

2.1 Participants

A total of 20 individuals from Mexico and Spain took part in the study. The sample is relatively small due to the difficulty of collecting data with the method used; nevertheless it has been argued that due to the richness of the data, even studies with as few as five or ten participants can produce sufficient data to be used reliably (Hektner et al. 2007). Moreover, experience sampling method samples are usually purposive and they are not typically designed to be representative; rather, they are aimed at understanding the experience of a specific group or groups (Hektner et al. 2007). Therefore, the study sought a heterogeneous sample in terms of sex, age, occupation and origin which allowed us to study flow experiences at work and in leisure activities within a wide range of subject profiles.

Out of the 20 participants, nine were females and 11 were males (mean age 39 years; age range 27 to 62), all of them had undergraduate degrees and two of them had Master degrees. The participants had spent on average 10 years working in their companies (minimum 0.3 years and maximum 43 years), 9 years in their current post (minimum 0.2 and maximum 28), dedicated an average of 7.8 h per day to work (minimum four and maximum 11) and 40 h per week (minimum 20 h and maximum 55). Some of the positions occupied by the participants were as follows: production manager, freelance market research consultant, control manager, administrative manager, project manager, lawyer firm partner, dog trainer, chief executive officer, IT manager, clinical psychologist, sales manager, human resources advisor, barista and Scuba diving instructor.

Participants were reached through personal contacts, either directly by the researcher or via third parties; requirements for inclusion in the study were to have a full/part time employment at the time of the study, and a high commitment to participate in the research. Participants did not receive any financial compensation for taking part in the research.

Moreover, following the ethical principles of psychologists and its code of conduct, some ethical considerations were taken into account. At the beginning of the study each...
participant was given a consent form, where the objectives and procedure of the study were introduced and the confidentiality of the data collected was assured, also the contact details (email address and telephone number) of the researcher were included; participants and researcher signed the consent form. Furthermore, once they finished the study, each of the participants received a personal “face to face” feedback session regarding their levels of flow at work and leisure activities. Each feedback session lasted for approximately 30 min, and consisted in presenting the results of the study to the participants, and inviting them to ask any questions regarding the information they just received.

2.2 Design and Procedure

Due to its solid reputation for studying flow, the Experience Sampling Method (ESM) was used in the present study. The ESM has been widely used within flow research (Hektner et al. 2007) and also in other disciplines such as medicine, nursing and pharmacology (Weber and Beverly 2000; Hektner et al. 2007).

More specifically, the ESM refers to the collection of information about both the context and content of daily life of individuals; this purpose is shared by other methods, however, the advantage of ESM is its ability to capture daily life as it is directly perceived from one moment to the next, giving us the opportunity to examine fluctuations over time (Hektner et al. 2007), thus supporting the main objective of the present study. The method is able to achieve this aim by asking individuals to provide written responses to both open and closed ended questions at several random times during each day of a average week on the life of the participant, whenever a Personal Digital Assistant (PDA) prompts to respond. This method has proved to be very useful for measuring the conditions necessary for flow and the experience of flow per se (Hektner et al. 2007).

The study had a longitudinal design and was conducted using the ESM which allowed recording of the flow experiences from a temporal perspective. All the participants completed the ESM following a standard procedure (Hektner et al. 2007).

To this end, participants were given a PDA that would produce six signals per day at random times (three times during working hours and three times during leisure time); participants were required to answer to six questions at each signal over a period of 21 days including weekends. Beal and Weiss (2003) concluded that periods longer than 21 days presented deterioration in the quality of the data when using the experience sampling method. Therefore, we consider that a period of 21 days to be long enough to capture the dynamics of flow experience without placing excessive burden on the participants, which could lead to the deterioration of the data. The principal aim was to obtain a minimum of 100 recordings per participant for each one of the variables included in the diary. It is important to point out that 100 recordings is the minimum number of registers required to analyse the data using the Visual Recurrence Analyses statistical software and to assure the statistical power of the test (Kononov 2004). In order to achieve this, a flow diary was developed and participants were asked to record the activity they were carrying out at the time being signalled and their levels of challenge, skills, enjoyment, interest and absorption with respect to the activity in question.

After creating the flow diary, this was logged into each PDA using the software Pendragon 4.0† The models of the PDA’s utilized were Palm Zire 21, Palm phone (trio) and Palm Vx. Before conducting the real study a pilot study involving two participants was

† Pendragon 4.0 allows the data from the PDA to be automatically transferred into a database, each time the PDA is synchronized with a computer.
carried out, in order to make sure the instruments were used correctly, and to identify possible difficulties that actual participants could encounter during the study, some of the feedback obtained from this pilot study were: the importance of reminding the participants to make sure the PDA always had its battery fully charged to prevent possible data loss, and also to adjust the volume of the alarm in accordance to the work environment of each individual, among other suggestions.

During the actual study, participants were interviewed in three occasions. The first interview was set during the initial day of the study, where general information needed to identify the sample was gathered (age, sex, educational level, type of work, organization, hours spent at work per day/week), at this instance the participants were also informed on how to use the PDA and how to answer the flow diary, we also discussed with the participants the operating definitions specially of task, challenge and skill and a few examples were given to make sure they understood what was meant by all the terms included in the study. During this first interview each participant was given a consent form, were the study was introduced and the confidentiality of the data collected was assured, also the contact details of the researcher were included, participants and researcher signed the consent form. The second interview was carried out in order to see how the study was going on, this is, the participant was asked to give the researcher some feedback regarding their experience in the study so far. The last interview which took place at the end of the study included several questions regarding the participants’ job, and their own flow experiences while being at work and in leisure activities. Finally, a personal feedback was given after a week of completing the study, once the data was analyzed.

2.3 The Instrument

The flow diary contained six questions covering the six aspects under examination: activity, perceived challenge, skill level, enjoyment, interest and absorption. These variables were included for the following reasons. The variables level of challenge and level of skills were chosen because of their key role as “flow conditions”, this is, when the perceived challenges and skills are in balance and they are high (Csikszentmihalyi 1990, 1997; Stein et al. 1995). The variables of enjoyment, interest and absorption were included because as suggested by the flow theory, these three variables are at the core of the experience of flow (Hunter 2002; Schmidt et al. 2006; Shernoff 2001). From these five variables, two flow measures were created; measure 1 which involved the first two variables: balance of high challenges and skills; and measure 2 that involved the average of the three remaining variables: enjoyment, interest and absorption. Specifically the questions were the following:

1. What activity am I carrying out at this moment?
2. How challenging I find this activity?
3. What is my skill level for performing this activity?
4. How much do I enjoy doing this activity?
5. How interesting is this activity?
6. How quick does time passes while I’m doing this activity?

The first question aimed at focusing the individual’s attention on a specific activity (the one being performed when the PDA sounds), so that the other questions were responded with this activity in mind. The first question was open and the person had to write a brief description of the activity being performed, the information acquired was in the form of text. Some examples of work related activities presented by the participants are: “I am...
having a meeting with my boss”, “I am conducting a family therapy”. As for leisure activities: “I am playing football with my grandchildren”, “I am at home watching a film with my wife”.

For the remaining questions a scale was computed, that consisted on a continuous line blocked off at either end. For questions 2, 4 and 5 which looked at challenge, skills and enjoyment, the scale comprised the labels: “a little” and “a lot” respectively. Similarly, question 3 that assessed interest, contained the labels “very interesting” and “little interesting” As for the question on absorption (question 6) the labels in the scale indicated “time passes very fast” and “time passes very slowly”. For questions 2, 3, 4, 5 and 6 participants were asked to place a mark on the line that appeared in the screen (scale) directly, and the PDA automatically converted the mark into a 0 to 100 scale.

2.4 Analysis

Different information was obtained for each participant from the diary of flow, more specifically: a list of the activities performed; a five time series concerning the variables challenge, skills, enjoyment, interest and absorption; other qualitative information gathered during the three interviews. For each measure of flow a time series was obtained, therefore, two time series per participant were analyzed using the following methods: line graphs, recurrence plots and surrogate data (all three methods will be explained below).

All series were firstly purified to eliminate any possible repeated recordings (where the participant had answered within immediately consecutive time points). It is important to note that all PDA devices were programmed to signal at intervals no smaller than 45 min (in order to allow the participant to get into the flow experience).

Once all the series were purified, they were subjected to descriptive analysis (minimum and maximum values, mean and standard deviation). The standard deviation value and the mean squared successive difference (MSSD) are of particular interest to the study due to the fact that they provide information about the stability and persistence of the process studied. The MSSD statistic was utilized to assess variations in response over time, such as fluctuations in the flow components. We chose to use the MSSD since we were interested in the average variability over time of the flow variables; moreover we were interested in what occurred during the entire course of the series. This statistic was created by Von Neumann et al. (1941), and has been used for many years as a cumulative measure of point-to-point variability in time series over a period of time (Arrieta et al. 2008; Woyshville et al. 1999).

Following Guastello et al.’s (1999) suggestions, the measure 1 of flow for each activity logged by every participant was the cross product of their skill and challenge levels recorded for each activity divided by the cross-product of the within-person standard deviations for skill and challenge. For the second measure 2 of flow was operationalized as the average of the variables enjoyment, interest and absorption. A correlation analysis was also performed among the two measures of flow (measure 1 and measure 2) in order to see the extent to which both measures were related to each other.

Line graphs of both flow measures (measure 1 and measure 2) for each participant were also produced. The information displayed by these graphs enabled us, at first sight, to observe the presence or absence of regular patterns in the dynamics. In addition, they indicate whether the flow dynamics show continuity or the presence of discontinuities.

All series were then studied using statistical methods common to the chaos theory, in order to determine the behaviour and type of dynamic of the variables studied (e.g. linear,
Recurrence is a fundamental characteristic of dynamical systems (Marwan 2007), a property that can be used to characterize the system’s behaviour in phase space. A powerful instrument for its visualization and analysis is called the “recurrence plot”. One of the best programs available for analyzing recurrence plots is the Visual Recurrence Analysis (VRA; Belaire-Franch and Contreras 2002), and therefore it was used in the present study. More specifically the recurrent plot is a rectangular chart consisting of pixels whose colours represent the dimension of data values within a two dimensional formation, and whose coordinates correspond to the locations of the data values in the chart, where both axes correspond to time axes. All recurrence plots have a line of identity easily identifiable as the marked upward diagonal, which is the result of comparing both vectors to themselves which necessarily adds up to zero (Marwan 2007). Once the information of a time series is available, the program VRA recreates a topologically equivalent snapshot of the original system behaviour using the method of time delays; the key parameters in the process are the dimension of the embedding space and the time delay. More specifically, how many state variables should be, and how far apart in time should be the delayed elements of each point in the space (Shelhamer 1998). A common approach for estimating the embedding dimension delay is the false nearest neighbours’ algorithm and for estimating the lag is used the mutual average information’s algorithm. These two algorithms are computed by the VRA program. Once obtained the recurrence plot for a time series, if it is chaotic, the plot will show short line sections parallel to the main diagonal (line of identity), which means that the evolution of states is similar at different times. On the other hand, if the time series is random, then the recurrence plot does not present any structure at all and the process may be uncorrelated random (Marwan 2007). Using the VRA 4.7, forty recurrence plots were obtained showing different patterns respectively.

Following the Visual Recurrence Analysis, we used the TISEAN 3.0.1 program to obtain the series of surrogate data. The use of surrogate data allows us to determine whether the time series present specific chaotic patterns or are merely random. To this end, the original time series are compared to their respective surrogate series, using this method, we are 95% confident when deciding if the series are random, or have a specific nonlinear pattern.

The use of both methods, this is, the recurrence plots and surrogate data, served as a triangulation procedure, in which by using different statistical methods in the study of the same phenomenon, the statistical power is enhanced and, therefore, the reliability of the results is increased (Jick 1979).

3 Results

The number of recordings obtained per participant was equal or above 100 for all participants, and ranged between 100 (participant 1) and 154 (participant 12), the mean number of recordings was 119. Overall the participation level in the study was high and must participants were highly motivated to complete the study as they all found it an innovative area of research and also because they were very interested in the personalized feedback given to all participants at the end of the study. An initial describing approach to the flow series including components of both measures of flow is shown in Table 1.
In this table the average number of records was included, minimum and maximum per variable as well as the mean value and standard deviation. In this case the standard deviation gives us information on the persistence of the variable studied or its stability; as we can see all standard deviations and MSSD values are high, showing unstable behaviours for all variables.

Moreover, in order to see the strength and direction of the relationship between the two measures of flow used in the study, a Pearson correlation analysis for the two measures was performed and there was a significant correlation in a sample of 15 percent of the all data \((r = 0.241, p < 0.01, n = 349)\).

All time series coming from both measures of flow (measure 1 and measure 2) were presented in line graphs, an example of measure 1 and 2 is shown in Fig. 1. This graph was very informative and provided the initial information about the dynamics of the said variables; helping to illustrate the different dynamics of the flow measure. All line graphs revealed fluctuating dynamics; therefore the next step was to find out what patterns (linear or nonlinear) are presented in the dynamics, or whether the dynamics are merely random.

In order to identify the type of dynamics (random, chaos or linear) described by the flow series, once again a graphical tool was used. This time, a more sophisticated program

| Variable          | Number of records | Minimum | Maximum | \(M\) | SD  | MSSD  |
|-------------------|-------------------|---------|---------|-------|-----|-------|
| Challenge         | 119               | 0       | 100     | 43.90 | 28.25| 1054.68 |
| Skill             | 119               | 0       | 100     | 74.13 | 22.85| 2283.76 |
| Flow measure 1    | 119               | 0       | 49.30   | 9.28  | 7.98 | 50.40  |
| Enjoyment         | 119               | 37.71   | 89.06   | 66.57 | 12.05| 948.35 |
| Interest          | 119               | 36.16   | 76.11   | 59.76 | 11.02| 1046.47|
| Absorption        | 119               | 44.67   | 79.81   | 64.25 | 10.97| 827.98 |
| Flow measure 2    | 119               | 0       | 100     | 64.96 | 22.61| 55.24  |

Fig. 1 Measures 1 and 2 from participant number 15
Visual Recurrence Analysis was used; the recurrence plots were produced for flow measure 1 and flow measure 2. These maps, as described before, allow us to detect the dynamical patterns of time series. This is, they show whether the dynamic behaves in a linear, chaotic or random manner. Below there are examples of chaotic and random dynamics found in the present study (see Fig. 2).

Four cases presenting a random dynamic within flow measure 1 were found in the study (participants: 1, 3, 6 and 7) and four cases within flow measure 2 were found (participants: 2, 11, 15 and 18). This pattern was found in participant 16 (for both measures of flow 1 and 2) of the cases in the present study. Nevertheless, the percentages of random and chaotic dynamics for both measures (measure 1 and 2) were the same: 80% of the cases presented a chaotic pattern and 20% of the cases presented a random dynamic.

Finally, and in order to corroborate that the patterns showed in the recurrence graphs were valid, further analyses using the TISEAN 3.0.1 program were performed, in these analyses surrogate data for each of the series were calculated, and then compared to the original series in order to see whether the dynamic was random or had a specific pattern. Thirty-nine surrogate series were created for each of the original series, representing a 95% confidence range. After completing these analyses, 16 cases were confirmed to present a chaotic pattern and four cases were confirmed to present a random dynamic for both measures of flow.

In order to compare the point to point variability of the flow experiences in work and leisure activities, the MSSD measure was computed. Results showed no significant difference in variability between flow at work and leisure activities. However, when comparing the values of flow experiences in work and leisure activities, significant differences were found, more specifically, participants experienced more flow (measure 1) in
work related activities as compared to leisure activities (Table 2). For the measure 2 of flow there were no significant differences when looking at flow in the work context and in leisure activities.

4 Discussion

The study originated a series of new and interesting findings about flow at work and in leisure activities. The diversity of participants, data collected and results are a valuable contribution to this area in generating a series of conclusions and new directions for further research on flow experiences at the workplace and in leisure activities.

All participants were actively engaged in the study, 94.4% of the participants made the 100 recordings which were required to analyze the data (only one participant retired from the study before completing the whole procedure). This was very positive as it is hard to obtain such a high number of recordings from all participants in a study of this nature (Hektner et al. 2007). An important factor that kept participants engaged, was that all of them had certain level of interest on the research topic (flow experiences) thus, they perceived the study as a way to receive feedback on how often they experienced flow over a period of 3 weeks; all of them found the feedback given at the end of the study very interesting and resourceful for their own personal growth. Therefore, it may be important to keep in mind that for ESM research, special attention should be placed on the personalized feedback as a way to keep participants actively engaged in the study.

Furthermore, it is interesting to point out that the five variables assessed in the study (challenge, skills, enjoyment, absorption and interest) presented a high degree of variability. By looking at the standard deviations and MSSD of all variables they show highly unstable behaviours, indicating a fluctuating dynamic, which do not present a stable pattern of behaviour over time, this is to say, the most important antecedents of the flow experience (challenge and skill) and the flow experience (enjoyment, interest and absorption) depict high levels of instability across time. Similarly, when looking at the two flow measures, which resulted from the combination of the two variables challenge and skill and the combination of enjoyment, interest and absorption, we observe a relatively high standard deviation showing a fluctuating dynamic undergoing continuous changes over time.

In addition to that observations, the line graphs clearly show that the variables do not stabilize at any point in time; instead they show continuous fluctuations touching various ranges across the time span. Summing up, line graphs display a crystal-clear feature: flow

| Table 2 | Means of flow at work vs. leisure activities (measure 1 and 2) |
|---------|---------------------------------------------------------------|
|         | Original values                  | Mean | St. deviation | P value |
| Flow measure 1 | Leisure  | 6.27 | 6.18 | <0.001 |
| Work    | 12.56 | 8.15 |
| Flow measure 2 | Leisure | 62.67 | 22.89 | <0.606 |
| Work    | 68.13 | 21.83 |
experiences show constant fluctuations (within different ranges) and do not appear to stabilize over time.

In order to validate this finding, recurrence plots were used showing that the dynamics of flow were chaotic for most participants, more specifically, 80% of the cases in both measures of flow presented a chaotic dynamic, whereas 20% presented random dynamics. This finding is consistent with Guastello et al. (1999) study which found that the dynamics of flow were chaotic for all participants. Moreover, the 80% of the cases which presented a chaotic dynamic in both flow measures after the visual recurrence analysis were also confirmed by the surrogate data analyses.

What the current set of results may be showing us is that the fluctuations in all variables are not noise in the process of flow, but rather are important dynamic patterns that characterize the phenomenon of flow experiences. In other words, the present results may be pointing out that any particularly pattern necessarily happens within a given context, and that may not be the same across contexts (Sansone et al. 1992). Moreover, the context itself may change over time, both from sources outside the person and from actions by the person. The model of self-regulation of motivation process by Sansone and Smith (2000), could be of help when trying to explain the current findings. The model emphasizes intrinsic motivation as a highly unstable phenomenon, this is, that it is in continuous change within a person over time and situations, and its momentary quality makes it highly unstable and difficult to predict the variability within a given person, and even more difficult to predict the variability across individuals (Sansone and Thoman 2008).

More specifically, the model suggests that within the motivation process, there may be a series of avenues through which to enhance interest, and that people may purposefully explore these avenues in order to maintain their motivation performing relatively uninteresting, but possibly important, activities. The authors propose that, in addition to being passively affected by contextual characteristics, people may also actively use the context to make the activity more intrinsically rewarding, and as a result the activity may not be the same one which they began with, this is, their perception of the activity may become more positive and enjoyable. Moreover, if we look at the results from the present study, we find that interest presents the higher point to point variability with an MSSD of 1046.47 (see Table 1) showing that interest is a highly unstable component of the flow experience, and this is consistent with Sansone and Smith’s (2000) model.

Furthermore, the model highlights a phenomenological approach in which an individual’s intrinsic motivation cannot be understood independently of his/her perceptions, cognitions and affect at a particular point in time and in a particular social and physical context (Sansone and Smith 2000). These authors also suggest that intrinsic motivation is created and maintained through an ongoing temporal process, accentuating a dynamical perspective of intrinsic motivation across time. In short, Sansone and Smith’s (2000) model of interest as a self-regulation mechanism of motivation may result very helpful in explaining the high instability of flow experiences over time encountered in the present study.

Furthermore, when looking at the point to point variability in the flow series in work and leisure activities, no differences were found, these results are not definite and it may be interesting to conduct further research using the MSSD measure in larger samples and with a larger number of recordings per participant. Moreover, there were significant differences in terms of flow means (for measure 1) in work related activities vs. leisure activities. We found that the mean of flow experiences was higher for work as compared to leisure when flow is operationalized as a balance of high skill and challenge. This is in line with Csikszentmihalyi and LeFevre (1989) study where they found that flow occurred more often at work than during leisure activities, more specifically, they found that when leisure activities meet the
conditions of flow (i.e. high challenges and high skills) less than 20% of the time, work does so from 47% of the time for blue-collar employees to 64% of the time for managers. Thus, people at work seem to encounter more challenges than in leisure activities, increasing their opportunity for experiencing flow. More specifically, like flow activities, work related activities often have specific goals and objectives, rules and challenges which lead people to become involved in their work, to concentrate and to be absorbed in the situation (Csikszentmihalyi 1990). Whereas, leisure activities are often unstructured and it is usually harder to shape leisure activities into something that can lead to flow experiences.

Nevertheless, how can we explain that people are able to experience flow in work environments, in which the environment places all kinds of daily pressures and stressors on employees? How can employees cope with this changing and pressuring work environments and still experience flow? Antonovsky (1979) proposed the salutogenic theoretical model, where the central resource concept is the sense of coherence (SOC), which refers to a global orientation of the individual towards her/his inner and outer environment, which is proposed to have a direct and positive effect on well-being at work, irrespective of stressors (Feldt 1997). In this global orientation, the individual sees the world as comprehensible, manageable and meaningful. Antonovsky (1987) proposed that a strong SOC, especially a high sense of meaningfulness, which is defined as the extent to which people feel that life makes sense emotionally, and that the exigencies encountered are challenges, worthy of commitment and emotional engagement, makes it possible to perceive a stressful situation as a challenge rather than as a threat (Antonovsky 1993). The sense of meaningfulness is the most central component of SOC and it is the most related to flow experiences, due to its motivational component. A high sense of meaningfulness makes it possible to perceive a stressful situation as a challenge rather than as a threat. In this sense Antonovsky’s SOC may explain why people at work still manage to experience flow, despite of the stress and demands that tend to overrun most work environments nowadays.

Finally, we would like to point out that the correlation analysis between the two measures of flow described that there was a significant relationship between the two measures, which is in line with Mihaly Csikszentmihalyi’s flow theory (1990), where it is suggested that the most important antecedents of flow (balance of high challenge high skill) are likely to lead to the flow experience (enjoyment, interest and absorption), however, further research with larger samples using the ESM may be interesting to validate this theory further.

4.1 Practical Implications of the Study

The results reported here have an important implication for the world of management and human resources. One of the most important goals to achieve in the HR management is to get a highly motivated and committed workforce. As we have stated before, flow represents one kind of intrinsic motivation, more specifically the highest form of intrinsic motivation, in which challenge and skill are both elevated. If we are respectful with the flow model, managers should design jobs in which the level of challenge is high and, consequently, select or train people to guarantee that they also have a high level of skills and sufficient competencies to execute their jobs. To check periodically these two aspects (challenge and skills), having in mind the subjective point of view of the own employees, would be a useful practice. In order to achieve this, the use of questionnaires or diaries would provide the HR management with key information.

Another important point is to consider the importance of self-regulatory processes to manage the flow experiences or the intrinsic motivation of employees. As different motivation theories show us (for example, Deci and Ryan 1985; or Sansone and Smith
2000) in order to promote intrinsic motivation in the workplace, it is important to enable employees with a sense of autonomy and self-direction in their jobs. It is the key to create some conditions that instigate the feeling of control at work. Indeed, to promote intrinsic motivation, it is important that employees feel that they can control the tasks they perform at work. With this feeling, employees can self-manage their own behaviour in order to achieve their work objectives. Summing up, it is very important to provide some contextual conditions that empower employees with self-control rather than trying to externally control their behaviour.

4.2 Limitations of the Study

There are some limitations of the study that we would like to point out. The first limitation is related to the sample size (20 participants). Although, it is important to note that although the sample size was relatively small due to the demands that must longitudinal designs place upon study participants, in this case asking participants to respond to several questions per day over a period of 21 days, it is worthwhile noticing that small samples have been also used in similar studies (Navarro et al. (2007) worked with a sample of 20 participants, and Guastello et al. (1999) used a sample of 24 participants). It would be worthwhile to replicate the study using larger samples.

Secondly, due to the limited number of recordings (minimum 100 recordings per participant) we were unable to explore further the dynamics of flow at work and in leisure activities, this would be of interest in order to shed more light on the apparent paradox, in which people tend to experience more flow while being at work as they encounter more high challenge/high skills situations, however, they tend to express their wish to be doing something else, thus there may be different dynamical patterns when looking at flow at work vs. leisure activities.

Thirdly, one of the initial participants left the study before completing it, this person had an executive position, and expressed that the use of a PDA to collect the data was too disturbing and stressful for the work he was doing, therefore we came to the conclusion that in order to overcome this limitation and to capture the experiences of people in this type of positions an “internet diary” may be an interesting option, in which the diary questions pop-up in the participant’s screen at random times during the course of a day just as with the PDA.

4.3 Future Research

This study opens to future possibilities for analyzing flow; it explores new horizons of sophisticated methodological techniques based on the core elements of the nonlinear dynamics approach, rising new questions and possibilities for conducting research on optimal experiences such as flow. Results from the present study clearly depicts that the experience of flow appears to present a complex dynamic whose patterns of change are not easily predictable. Therefore, this study may be opening a new window to build upon current research and reach further in our understanding of flow from a nonlinear dynamics approach. The challenge ahead is very inspiring and consists in conceiving flow as a nonlinear process, construing flow models with variables having nonlinear relationships among them.

Moreover, further research would be needed using larger samples in order to observe whether the results obtained in the present investigation can be replicated within larger samples, this is to say, to rectify whether flow experiences tend to behave in a nonlinear way, presenting random and chaotic dynamics in most of the cases.
Furthermore, it would be important to study further why these dynamics emerge. A way to achieve this, may be by utilizing qualitative data regarding the characteristics of work and leisure activities proper to each participant, allowing us to relate specific dynamic patterns to qualitative data, such as individual’s target or purpose goals (Sansone and Smith 2000), and type of feedback and autonomy provided by the work or leisure context, among others. This may give us greater understanding about the experience of flow.

Likewise, from a nonlinear dynamics perspective, it may be interesting to look at the dynamic patterns of flow at work and leisure activities in a larger sample with a more extensive set of recordings, and study whether different dynamic patterns exist (random, chaotic) depending on the context where the individual is experiencing flow (work vs. leisure).

Furthermore, by using methodologies that are able to capture the dynamics of intrinsic motivation or flow, researchers will start gaining some grasp of the momentum. Moreover, following Sansone and Smith (2000) model of self-regulation of motivation process, the relationship between intrinsic and extrinsic motivation from a dynamical point of view may be very insightful, this is, instead of looking at intrinsic motivation vs. extrinsic motivation, the inclusion of a temporal component should aid the models of motivation to include coordination dynamics of both intrinsic and extrinsic motivation over time (Kelso 1994; Gottman et al. 2002). The self regulation model of motivation points out that extrinsic motivation (referred to goals and outcomes) is usually required to initiate task engagement, however, intrinsic factors (such as feelings of enjoyment and interest) may become the more proximal motivation once the person has began the task. The model views intrinsic motivation and extrinsic motivation as separate systems but with coupled dynamics across time, this is, they may reciprocally influence each other over time, in ways that can conduce to sustained motivation. A dynamic approach to the study of this model, using as a theoretical framework the chaos theory, may start tracking these potentially dynamic processes.

Finally, from an intervention perspective it may be interesting and worthwhile to analyse why the work context tend to be more conducive to flow experiences than the leisure one; this is important in the sense that the extent to which people experience more flow in both work and leisure contexts, will contribute to their overall well-being as suggested by Bryce and Haworth (2003). Therefore, more research is needed looking at the factors affecting the low prevalence of flow experiences in leisure activities.

Summing up, the present study is among the first investigations to look at flow experiences within a dynamic perspective; it allows us to start uncovering the important dynamics of flow over time and promote it as it occurs in work and leisure contexts, and as it develops over time. The challenge ahead is very inspiring and consists in uniting existing flow theory with the chaos theory. In this way, this study offers a set of results that hopefully will stimulate research on the nonlinear dynamics of flow that might aid in providing further scientific basis to protect and promote human flourishing.

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