Abstract

The aims of this study are to consider the experience of flow from a nonlinear dynamics perspective. The dynamic history of motivation, coupled with the temporal nature of the flow experience, 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. Limitations of the study and future research are discussed.

Key words: Flow, nonlinear dynamics, work, experience sampling method, chaos.

PsycINFO Classification: 3600, 3650, 3660

1. INTRODUCTION

Researchers in work and organizational psychology (WOP) have tended to adhere to a traditional disease model, and have focused predominantly on problems like work stress, bullying, burnout, workplace violence, musculoskeletal problems and cardiovascular diseases among other problems. A complete departure from this traditional disease model, in a 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 what the current research focus 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 study further flow experiences and to increase their frequency in society (Csikszentmihalyi and Massimini, 1985). Given the soundness of the concept of flow and its importance 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 the experience has been amply documented (Hektner, Schmidt and Csikszentmihalyi, 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 construct and to demonstrate the importance of incorporating the time dimension in flow research. Following this line of thought, the principal objective of the present study is to explore whether the phenomenon of flow predominantly presents a nonlinear dynamic.

2. Flow at work

Csikszentmihalyi and Figurski (1982) stresses that if flow were absent from a person's life, there would be little purpose for living. It strongly influences an individual subjective well-being (Diener, 2000) and increases a person's happiness, positive affect and life satisfaction. Moreover, flow theory (Csikszentmihalyi, 1990, 2000) postulates that the experience of flow is a function of the skills that an individual perceives 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, resulting 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 quality than when apathy is experienced.

However an optimal situation is thought to be when challenges and skills are high and in equilibrium, such that the individual tends to experience 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 makes the experience

intrinsically rewarding and the person is likely to remember it more fully and will 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 activity, however, it is suggested that flow experiences are most likely to occur while at work (Csikszentmihalyi and Lefevre, 1989).

The study of flow at work has been conducted within several arenas. For example a number of studies have looked at flow experience in relation to internet usage (Chen, Wigand and Nilan, 1999), technology workers (Ghani and Deshpande, 1994; Webster, Trevino and Ryan, 1993), music teachers (Bakker, 2005), to name a few.

When flow is applied to the context of work, most studies (Ellis, Voelkl and Morris, 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, Schmidt and Csikszentmihalyi, 2007) suggest that a situation like this facilitates the happening of flow-related phenomena, like positive emotions, enjoyment, interest and absorption. Moreover, Ghani and Deshpande (1994) have emphasized that the two main elements of flow at work are the (a) total immersion in the activity and (b) the enjoyment that people experience during such activity. These authors go on to argue that there is an optimum level of challenge relative to an individual's skill level.

Furthermore, 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 must 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* (Nojak, 1996). Therefore, studying flow at work has been shown to be important for both managers and employees. Even though organizational psychologists have 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.

3. Measuring flow using the Experience Sampling Method

A method that has been widely used within flow research is the Experience Sampling Method (ESM; Hektner, Schmidt and Csikszentmihalyi, 2006) and also in other disciplines such as medicine, nursing and pharmacology (Weber and Beverly, 2000; Hektner, Schmidt and Csikszentmihalyi, 2006). Due to its importance for studying flow the ESM was used in the present study.

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, Schmidt and Csikszentmihalyi, 2007). The method is able to achieve this by asking individuals to provide written responses to both open and closed ended questions at several random points during each day of a normal week, whenever a 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, Schmidt and Csikszentmihalyi, 2007). The method is also very useful to study the dynamics of flow over time, thus supporting the main objective of the present study.

A recent study that has taken an innovative approach to study flow and has utilized the ESM, is the one conducted by Guastello, Johnson and Rieke (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. Participants recorded in a diary the task they were performing, the skills they required to perform such task and the challenge implied by the task. 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 tend to fluctuate over time in a nonlinear fashion, showing important degrees of instability.

4. Nonlinear Dynamics of Flow

In line with Guastello, Johnson and Rieke (1999) and taking into account their findings we favor a nonlinear dynamics approach to 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, 2002). 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, 1999). Nowak and Vallacher (1998) argue that this reciprocal causality and feedback within dynamical systems is best modeled 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 go in line with two concepts within the nonlinear dynamic systems theory: local unpredictability and global stability. Building on Fredrickson´s model of positive emotions (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) propones 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, Johnson and Rieke (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 challenge necessitated 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 skill 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, Johnson and Rieke 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 Guastello, Johnson and Rieke (1999) research and look whether the same results are present in adult working populations. Secondly Guastello, Johnson and Rieke (1999) took measures of flow each time the person changed activities, more specifically if an individual was performing the same activity for 2 hours, it was taken for granted that the individual had the same level of skills and challenges over the two hour period the activity lasted, they then divided this period of time into 8 periods of 15 minutes each period, giving the same score to each of the 8 periods, nevertheless to take for granted that the level of skills and challenges would not change over a period of two hours is not very realistic. Thus, the present study intends to overcome the limitations of this study and take research on nonlinear dynamics of flow one step further.

In line with Guastello, Johnson and Rieke (1999), Navarro, Arrieta and Ballen (2007) reported equivalent results in a study concerned with work motivation, using the ESM in a sample of twenty 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 commonly conceive 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, nonlinearity and stability) when studied from a nonlinear approach.

Taken together, the dynamical history of work motivation and the temporal nature of flow as shown by Guastello, Johnson and Rieke (1999), it would follow that the experience of flow is most likely to fluctuate over time in a nonlinear dynamic way. By looking at flow experiences from a nonlinear dynamics perspective, the approaches for studying such phenomenon may start to widen and will shed some light to determine whether or not temporality is a core aspect for understanding the experience of flow at work and in leisure activities.

This is in line with the case made by several authors within Social Psychology about the importance of time and its neglect in social psychology research (McGrath and Tschan, 2004). These authors strongly believe that the shortfall to include time as an important factor in psychological research may lead to important questions regarding the validity of the theoretical formulations generated; they suggest there is an urgent call for the incorporation of the time dimension in psychological research. Likewise, George and Jones (2000), argue that the temporal factor is an essential feature of research within organizational psychology, and it makes no sense to neglect it, treat it implicitly, or in an insufficient manner. They suggest that the consideration of time in theory development may not only result in better theoretical models but may also enhance our understanding of sound research questions and debates in the field.

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 nonlinear dynamics approach and understand the nature of flow experiences from an innovative perspective. The study will address the following hypothesis:

1. *The dynamic of flow will be chaotic in more than 70 % of the cases.*

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.

5. METHOD

Participants

A total of 20 people took part in the study. Although the sample is relatively small due to the difficulty of collecting the data with the design used, the study sought a heterogeneous sample in terms of sex, age, occupation and home town, which allowed studying flow experiences at work and in leisure activities within a wide range of subject profiles.

Out of the 20 participants, 9 were females and 11 were males (mean age 39 years; age range 27 to 62), all of them had university degrees and two of them had Master degrees. The participants had spent on average 10 years 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 hours per day to work (minimum 4 and maximum 11) and 40 hours per week (minimum 20 hours and maximum 55). The positions occupied by the 19 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, selling manager, HR advisor, Coffee Bartender 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 high commitment to participate in the study. Participants did not receive any reward for taking part in the research. However, they received a personal feedback about their levels of flow during work and leisure activities at the end of the study.

Design and Procedure

The study had a longitudinal design and was conducted using the ESM which allowed recording the flow experience from a temporal perspective. All the participants completed the ESM following the standard procedure (Hektner, Schmidt and Csikszentmihalyi, 2006). Participants were given a Personal Digital Assistant (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. At the beginning of the study all participants were introduced on how to use the PDA and the principal objectives of the study.

The principal aim was to obtain a minimum of 100 recordings per participant for each one of the variables included in the diary. 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 signaled and their levels of challenge, skills, enjoyment, interest and absorption with respect to the activity in question. 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). 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, Shernof, and Csikszentmihalyi, 2005; Shernoff, 2001). From these five

variables, two flow measures were created; measure 1 which involved the first two variables: balance of high challenge and skills; and measure 2 that involved the average of the three remaining variables: enjoyment, interest and absorption.

After creating the flow diary, this was logged into each PDA using the software Pendragon 4.0. The models of the PDA´s utilized where Palm Zire 21, Palm phone (trio) and Palm Vx. Before conducting the real study a pilot study involving two participants was carried out, this was to make sure the instrument was used correctly and to identify possible difficulties that real participants could encounter during the actual study, some of the feedback obtained from this pilot study was the importance of reminding the participants to make sure the PDA was always full charged to prevent possible data loss as a result of uncharged batteries, to adjust the volume of the alarm in accordance to the work environment of each individual, etc.

During the actual study, participants were interviewed in three occasions. The first interview was set during the first day of the study, were general information needed to identify the sample (age, sex, educational level, type of work, organization, hour spent at work per day/week) the participants were also informed on how to use de 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 was realized 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.

The instrument

The flow diary contained six questions covering the six aspects under examination: activity, perceived challenge, skill level, 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 within a specific activity 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. 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", for the question on absorption the labels in the scale indicated "time passes very fast" and "time passes very slowly". Finally, 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.

Analysis

Different information was obtained for each participant from the diary of flow. More specifically, a list of the activities performed, five time series concerning the variables challenge, skills, enjoyment, interest, absorption and 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´s were programmed to signal at intervals no smaller than 45 minutes (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 or (MSSD) which is a point to point variability measure, more specifically it is a cumulative measure of point to point variability in time series (Von Neumann et al., 1941), are of particular interest to the study due to the fact that they provide information about the stability and persistence of the process studied. Following Guestello, Johnson and Rieke (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 of flow (measure 2), flow was operationalized as a continuum based on 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 complexity theory, in order to determine the behaviour and type of dynamic of the variables studied (e.g. linear, nonlinear, chaotic or random) these analyses were performed using the following programs: Visual Recurrence Analysis (VRA 4.7) and TISEAN 3.0.1.

Recurrence is a fundamental characteristic of dynamical systems (Marwan et al, 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 was used in the present study. More specifically the recurrent plot is a rectangular chart consisting of pixels whose colors 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 that necessarily adds up to zero (Marwan et al, 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 (the embedding dimension M) and the time delay L. 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, 2007). A common approach for estimating both the embedding dimension and time delay is the false nearest neighbors' algorithm, which is computed automatically 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 et al, 2007). Using the VRA 4.7, nineteen recurrence plots were obtained showing different patterns respectively.

Following the VRA 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.

6. RESULTS

The number of recordings obtained per participant was 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 they were also highly 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.

*****Insert Table 1 here****

In this Table we have included the average number of records, 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 instable 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 between the two measures in a sample of 15% of the all data ($r = 0.241$, $p < .01$, $N = 349$).

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 Figure 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.

****Insert Figure 1 here ****

In order to identify the type of dynamics (random, chaos or linear) described by the flow series, again a graphical tool was used. This time, a more sophisticated program (Visual Recurrence Analysis) was used; the recurrence plots were produced for flow measure 1 and flow measure 2. These maps as described before, allow detecting the dynamical patterns of time series. This is they show whether the dynamic behaves in a linear, chaotic or random manner. Bellow there are examples of chaotic and random dynamics found in the present study (see Figure 2).

**** Insert here Figure 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. 39 surrogate series were created for each of the original series, representing a 99% confidence range. After completing these analyses, 16 cases were confirmed to present a chaotic pattern and 4 cases were confirmed to present a random dynamic for both measures of flow 1 and 2,

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 frequency of flow experiences in work and leisure activities, significant differences were found, more specifically, participants experienced more flow 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 flow in leisure activities.

**** Insert Table 2 here ****

7. DISCUSSION

The study originated a series of new and interesting findings about flow at work and leisure activities. The diversity of participants, data collected and results are a valuable contribution to this area in generating a series of interesting conclusions and new directions for further research on flow experiences in the workplace and 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, Schmidt and Csikszentmihalti, 2006). 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 three 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 of all variables they show highly unstable behaviours, indicating a fluctuating dynamics, 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, the two flow measures, which resulted from the combination of the two variables challenge and skills 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 of 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 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, Johnson and Rieke (1999) study which found that the dynamics of flow were chaotic for all participants. Moreover, it was interesting to see that although 80 % of the cases presented a chaotic dynamic in both flow measures. These results are also confirmed by the surrogate data analyses.

Moreover, 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 were they found that flow occurred more often at work than during leisure activities, this finding is worth discussing due to the fact that the extent to which people experience more flow in work and leisure activities will contribute to their overall well-being as suggested by Bryce and Haworth (2003). Therefore, more research is needed looking at the factors affecting flow in leisure activities in order to promote flow in both domains work and leisure.

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

Finally 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 further the theory.

Limitations of the study

A limitation of the study is the sample size (20 participants). However 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, Arrieta and Ballén, 2007 worked with a sample of 20 participants and Guastello, Johnson and Rieke, 1999 used a sample of 24 participants). Moreover the study had a

heterogeneous cohort of participants and this allowed us to draw a number of noteworthy conclusions. Nevertheless, it would be worthwhile to replicate the study using larger samples.

Moreover, 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 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.

Furthermore, one of the initial participants left the study before completing it, this person had a high job position, and expressed that the use of a PDA to collect the data was too disturbing and stressing 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 a with the PDA.

Future Research

More than giving solid answers, 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 see 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 short term and long term goals and autonomy within the workplace and leisure activities among others. This may give us greater understanding about flow research.

Summing up, this is one of the first studies to look at flow from a nonlinear approach; the challenge ahead is very inspiring and consists in uniting existing flow theory with the chaos theory. This study offers a set of results that hopefully will stimulate research on the nonlinear dynamics of flow that might provide a scientific basis to protect and promote human flourishing.

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Table 1.

Descriptive statistics from the time series.

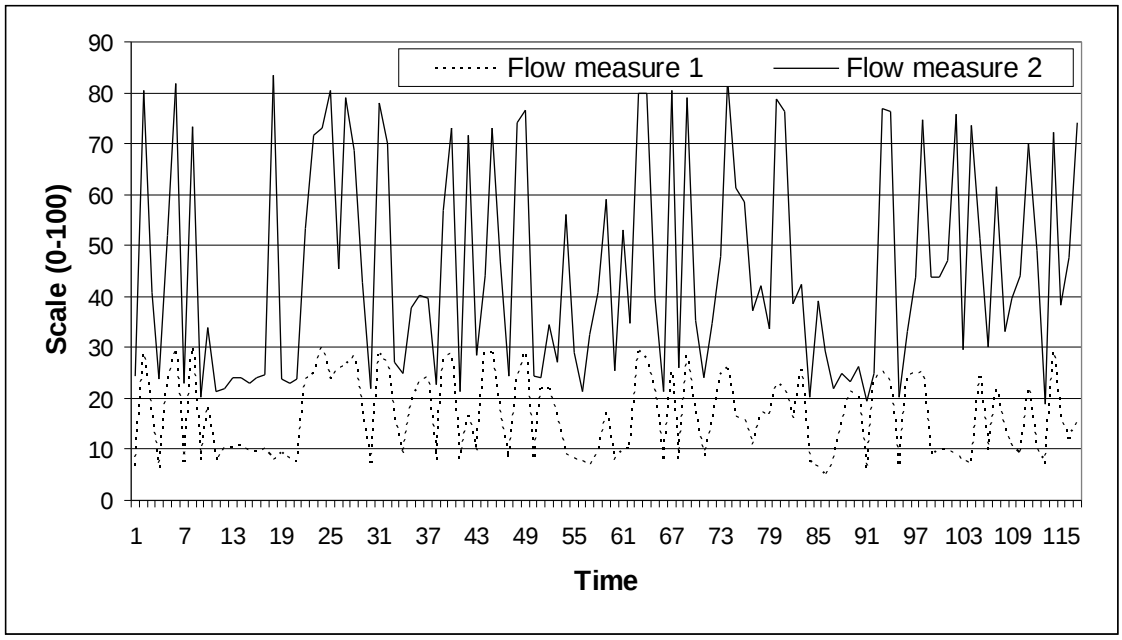
Variable	Number of records	Minimum	Maximum	*M*	*SD*	*MSSD*
Challenge	119	0	100	43.90	28.25	1054.68
Skill	119	0	100	74.13	22.85	2283.76
Flow measure 1	119	0	49.30	9.28	7.98	50.40
Enjoyment	119	37.71	89.06	66.57	12.05	948.35
Interest	119	36.16	76.11	59.76	11.02	1046.47
Absorption	119	44.67	79.81	64.25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

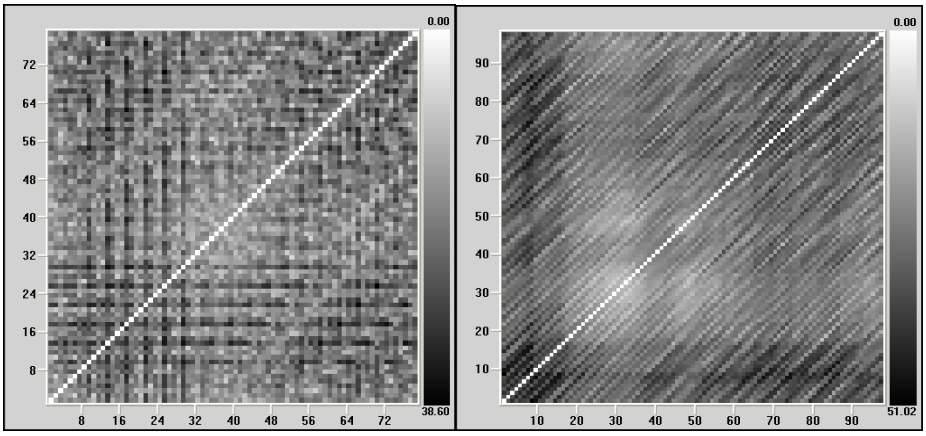
Table 2.

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	<.001
	Work	12.56	8.15	<.001
Flow measure 2	**Leisure**	62.67	22.89	<.606
	Work	68.13	21.83	<.606

Figure 1. Measures 1 and 2 from participant number 15





Left: Random dynamic (Participant 1) Right: Chaotic dynamic (Participant 18)

Figure. 2. Differences in gray color represent the concentration of points in different areas of the dynamic; this is to say the spaces that are more visited by the dynamic. Looking at the first graph we find that there is a heterogeneous pattern across the whole space, this is to say that all the points have the same probability to be visited by the system, this type of dynamic is called random dynamic. Random dynamic can be understood as unpredictable behaviour, in which the variables present a strong fluctuation in the process, and therefore the process may be an uncorrelated random or in some occasions anti-correlated process (Marwan et al, 2007). The second graph presents a complex pattern where the dynamic appears to be concentrated in some areas more frequently than in other areas. This pattern would be located in an intermediate zone of complex behaviour referred as chaos.