What can your body tell about your flow state? Dimensionality and heart rate variability analyses of flow

Abstract

Flow has been widely studied in different disciplines and contexts; but there is a lack of consensus about its dimensionality, measurement and structure. This research presents two studies to better understand the state of flow. On the one hand, the first study tests the dimensionality of flow, through an online survey with a sample of 771 Spanish social commerce users. This study empirically analyzes the state of flow using the statistical software EQS 6, considering that in social commerce the flow state is reached if *enjoyment* during the purchasing process, *concentration* on the action being performed and *temporal distortion* are presented together. On the other hand, the second study, conducted in Japan, presents a pilot experiment focused on studying the experience of flow among individuals within different tasks. The specific objectives of this second study in progress are, firstly, to test how different levels of interactivity affect the state of flow in order to study whether there are some common patterns on heart rate variability when experiencing flow according to the LF/HF (the index of sympathetic activity); and, secondly, to study how the flow state can be experienced or not in various everyday life experiences. The findings will allow companies to know what factors are needed to generate a state that leads users to repeat the experience.

Keywords: *Flow theory, social commerce, heart rate variability, LF/HF*

1. Introduction

Social commerce outstands for its ability to involve customers within the firm, giving them active roles, and optimizing their *social experience* by allowing them to generate and share information (Brodie, Ilic, Juric, & Hollebeek, 2013). Furthermore, the social commerce features enable users to access other users' opinions, as well as to enjoy, to concentrate and to lose track of time when surfing and/or interacting with other users (Zhang, Lu, Gupta, & Zhao, 2014). Hence, companies have to facilitate user participation and socialization because the success of these websites depends on these relationships (Chen & Shen, 2015). One way of achieving these social relationships is to optimize the tools and website design in order to make surfing easier and to bring users to *flow*, keeping them engaged with the website (Chen, Wigand, & Nilan, 2000; Kamis, Stern, & Ladik, 2010; Mahnke & Hess, 2014). *Flow* is an optimal state in which individuals can be so absorbed in and concentrated on the activity that they lose their sense of time and self-consciousness, enjoying every single minute and leading them to repeat the sensation (Csikszentmihalyi, 1975). The interest of flow theory for online commerce is that the state of flow involves an increase in the intentions to purchase, repurchase, and return to the website (Kamis et al., 2010) and, moreover, it enhances loyalty and the intention to spread positive WOM (O'Cass & Carlson, 2010).

This research presents two studies to better understand the state of flow. On the one hand, the first study tests the dimensionality of flow. This research thoroughly reviews the literature about the concept of flow on the field of online marketing and, drawn on the proposal of Kwak, Choi and Lee (2014) and Shin (2006), this study empirically analyzes the dimensionality, measurement and structure of the state of flow, considering that in social commerce the flow state is reached if *enjoyment* during the purchasing process, *concentration* on the action being performed and *temporal distortion* are presented together.

On the other hand, the second study presents a pilot experiment focused on studying the experience of flow among individuals within different tasks. The specific objectives of this second study in progress are, firstly, to test how different levels of interactivity (highly interactive website vs flat website) affect the state of flow in order to study whether there are some common patterns on heart rate variability when experiencing flow according to the LF/HF (the index of sympathetic activity); and, secondly, to study how the flow state can be experienced or not in various everyday life experiences such as when playing videogames or watching a movie (pleasure activity), translating an English text into the mother tongue (stressful activity), and doing nothing (boring activity).

The contribution of this research could help companies to brigde the gap of how to manage social commerce websites accessible worldwide, since a rewarding an optimal experience such as the state of flow can boost the intention to return to the website and purchase, as well as enhance the positive WOM. Likewise, this study can have theoretical contributions regarding online consumer behavior and the state of flow.

2. Study 1

2.1. Flow conceptual discrepancies in online contexts

Flow is a state that can occur anytime and anywhere and is defined as *"the holistic sensation that people feel when they act with total involvement"* (Csikszentmihalyi, 1975). It is reached when the individual is engaged in an activity with "*total implication, concentration and enjoyment, and experiences an intrinsic interest and a temporal distortion"* (Chen et al., 2000). Flow theory has been applied in varied contexts such as work, sport, learning and

online navigation. Within the latter, research in marketing has analyzed topics such as the use of computer-mediated technologies (Hoffman & Novak, 1996), website effectiveness (Sicilia & Ruiz de Maya, 2007), the interactivity of virtual purchases (Huang & Huang, 2014), m-commerce (Zhou & Lu, 2011), students e-interaction (Asakawa & Yana, 2010), online experience (Shim, Forsythe, & Kwon, 2015), online consumer behavior (Richard & Chebat, 2016) and social media (Jiao, Gao, & Yang, 2015), among others. In recent years, there have also been some investigations that analyze the impact of social commerce environments (i.e., Zhang et al., 2014), but they are still scarce. Thus, one of the reasons for the variety and vagueness in the conceptualization of flow is that authors of various disciplines have used it and adapted it to different contexts (Choi, Kim, & Kim, 2007; Hoffman & Novak, 2009).

2.2. The state of flow in social commerce: development of hypotheses

One of the investigations that has been used as a starting point for other studies focused on the online user is that of Shin (2006), which, in the field of online learning, proposes a model where the flow state is measured through concentration, enjoyment, temporal distortion, telepresence and engagement. The scale employed by Shin (2006) to measure the state of flow is also used by Wang and Hsu (2014) in computer-based instruction, but the variable engagement (measured through involvement) in the latter is not significant. Moreover, Lee and Chen (2010), in their investigation about online consumer behavior, consider that the variables that measure flow are enjoyment, concentration, telepresence and temporal distortion, while Zhou and Lu (2011) suggest that the state of flow is composed by only two of these variables –enjoyment and concentration– in m-commerce. Kwak et al. (2014) explain how the state of flow can increase social network usage, defining flow through five constructs (enjoyment, concentration, curiosity, temporal distortion and telepresence). Novak et al. (2000), in an investigation applied to online environments, consider that telepresence and temporal distortion can be measured together because the two concepts, although different, are closely related to not being conscious of one's surroundings when surfing a website.

As a result of the above and the special features of social commerce contexts, we consider that the state of flow is defined by concentration, enjoyment and temporal distortion. On a social commerce website, as its name implies, users relate to others in an environment highly influenced by interactivity, personalization and socialization, which directly affect the state of flow (Zhang et al., 2014). So online social relationships, like those taking place in offline environments, can come from enjoyable experiences, can absorb users –causing a temporal distortion–, and can require users' concentration, for example, the mere fact that they need concentration to share/receive user-generated content, to write referrals, and so on. Thus, we hypothesize the following:

> *H1: The state of flow is a factor composed of three dimensions: concentration, enjoyment and temporal distortion.*

Despite the differences among these three dimensions, we must not forget that they reflect a common concept so, to reach the state of flow, we consider that these three dimensions must be simultaneous and reflective. That is, the dimensions of the state of flow converge toward a single factor as reflective constructs, through a second-order structure, which leads us to hypothesize:

> *H2: The dimensions that compose the state of flow reflect in and converge toward a single factor.*

2.3. Methodology

2.3.1. Data collection

The data used for the analysis were collected in Spain through an online survey. The sample consists of 771 users of social commerce websites, of which 51% are male and 49% female, aged between 16 and 80 years old, similar to the Spanish users' profile according to the annual report of the Telecommunications and Information Society Spanish Watch (ONTSI, 2014). At the beginning of the questionnaire, after an explaination of the concept of social commerce, participants were asked if they had recently purchased on a website with the characteristics of a social commerce platform.

2.3.2. Content validity

To ensure content validity, we carried out a thorough review of the literature that used the measurement factors that we employ in our model, adapting them to the context of social commerce. Concentration was measured with three items from *Flow State Scale* (Jackson & Marsh, 1996) and used by other authors as Huang (2003), Chen (2006) and Lee and Chen (2010). Enjoyment consists of three items, adaptaed from the scale of Koufaris (2002) and used by Kim and Han (2014), Cyr et al. (2007) and Lee and Chen (2010). Temporal distortion was based on the study of Agarwal and Karahanna (2000) and Novak et al. (2000), also used by Lee and Chen (2010) (see Table 1). All the survey variables were measured on a 7-point Likert scale, ranging from "1=*strongly disagree*" to "7=*strongly agree*". Before conducting the online questionnaire, it was checked by various experts. The purpose of this pretest was to ensure that all the questions and texts of the questionnaire were understandable and to assess its length and ease. After the comments and suggestions from the pretest, we made minor changes to improve the reading fluency and comprehensibility of certain issues. The analyses were performed using the statistical softwares SPSS 22 and EQS 6.

Tabla 1. Flow scale on social commerce

	Concentration - Based on Jackson & Marsh (1996).
CON1	My attention was focused entirely on what I was doing.
CON2	I was totally absorbed in what I was doing.
CON3	I had total concentration.
	Enjoyment - Based on Koufaris (2002).
ENJ1	I found my visit interesting.
ENJ2	I found my visit enjoyable.
ENJ3	I found my visit fun.
	Temporal distortion - Based on Agarwal & Karahanna (2000); Novak et al. (2000).
TD1	Time seemed to go by very quickly when I used this social commerce website.
TD2	When I used this social commerce website, I tended to lose track of time.
TD3	I often spend more time on this social commerce website than I had intended.
TD4	I feel I am in a world created by the web I visit.
TD5	Using this web often makes me forget where I am.
TD6	The world generated by the web I visit is more real for me than the "real world".

2.4. Results

2.4.1. Analysis of dimensionality

Since previous studies have already highlighted the multidimensional character of the state of flow, the first step was to identify its dimensions. We began by conducting an exploratory factor analysis of the three factors –concentration, enjoyment and temporal distortion–, using the Principal Axis Factoring method and Varimax rotation (Hair, Anderson, Tatham, &

Black, 1999; Kaiser, 1970; Kaiser, 1974). The Kaiser-Meyer-Olkin value was greater than the threshold of 0.70 (KMO = 0.905) and Barlett's sphericity test was significant. As can be seen in Table 2, the results show that each item loaded onto its factor so we can introduce the three-factor structure that we hypothesized. These three factors explain 80.13% of the total variance. Moreover, Cronbach's alpha ($\alpha = 0.927$) was greater than 0.70 (Nunnally, 1978) and it was not improved if any element was removed.

Table 2. Rotated component matrix

Items	Factor 1 (λ)	Factor 2 (λ)	Factor 3 (λ)
Temporal Distortion 2	.857		
Temporal Distortion 5	.829		
Temporal Distortion 1	.806		
Temporal Distortion 6	.797		
Temporal Distortion 3	.726		
Temporal Distortion 4	.703		
Enjoyment 3		.894	
Enjoyment 2		.811	
Enjoyment 1		.719	
Concentration 3			.782
Concentration 2			.763
Concentration 1			.748

Following the exploratory analysis, that suggested the dimensionality of the flow concept, we tested the normality of the variables through the skewness and kurtosis values, which were greater than 2.52 and 1.96 (Hair, Wiliam, Barry, & Rolph, 2010), and the significance of the Kolmogorov-Smirnov-Lilliefors and Shapiro-Wilk statistics, so the distribution of our data did not fulfil the hypothesis of normality. Because of this, we used the robust maximum-likelihood estimation method (Bentler, 1995). Confirmatory analyses were perfomed with the purpose of analyzing the realiability and validity of the proposed dimensions and to confirm the results obtained. The results show that the three factors fit the data well and the coeficients calculated are all significant (Satorra-Bentler Scaled Chi-Sq = 504.7682, 51 d.f., p-value = 0.001; Bentler-Bonett Normed Fit Index (NFI) = 0.925; Bentler-Bonett Nonnormed Fit Index (NNFI) = 0.912; Comparative Fit Index (CFI) = 0.932; Bollen (IFI) Fit Index = 0.932; Root Mean-Sq. Error of Approximation (RMSEA) = 0.107; ($\chi 2$/d.f)= 9.898). Nevertheless, we must explain that the value of the normed Chi-Squared statistic was greater than the cutoff of 3 (Kline, 2011). The reason for this is that the Chi-Sq test is highly sensible to large sample sizes, not because of internal consistency problems, since all the factorial loadings are significant and greater than 0.50 (Hair et al., 1999), and the goodness of fit indexes are above the recommended values.

We also analyze the reliability and validity of the flow dimensions. All the Cronbach's alpha values are greater than 0.70 (Nunnally, 1978), the composite reliability indexes (CR) (Jöreskog, 1971) exceed the recommended value of 0.70, and the average variance extracted (AVE) shows values higher than 0.50 (Fornell & Larcker, 1981). In addition to studying content validity in Section 4, we carry out convergent and discriminant analyses. Convergent validity was tested to corroborate that the standardized coefficients of all factorial loadings were statistically significant and greater than 0.50 (Hildebrandt, 1984). Discriminant validity was tested with the average variance extracted analysis to compare, in a symmetric matrix, whether the AVE on the diagonal is larger than its corresponding squared correlation coefficients in its rows and columns (Fornell & Larcker, 1981; Hair et al., 1999). Thus, we can conclude that the flow state is composed of three dimensions: concentration, enjoyment and temporal distortion.

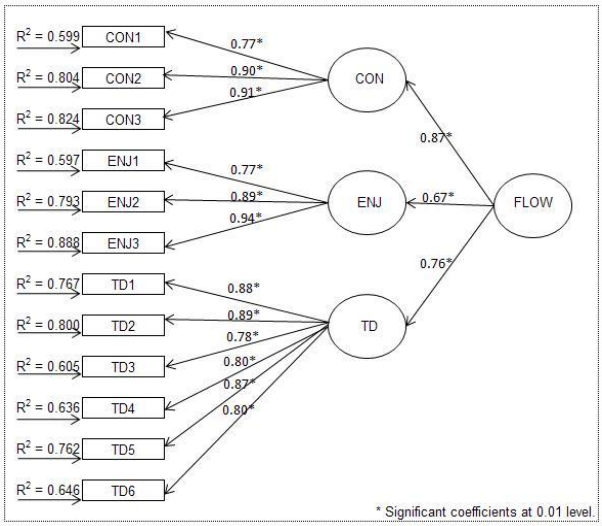
Then, we tested whether the multidimensional model was more appropriate than the unidimensional model. Using the *rival models technique* proposed by Anderson and Gerbing (1988) and Hair et al. (1999), we conducted an analysis that constisted of comparing alternative models. The first alternative established a unidimensional model where all items were gathered in a single factor. The second alternative –based on the three dimensions obtained in the previous analyses– proposed a multidimensional model that contains three factors. As can be seen in Table 3, the comparison between the empirical results confirms that the multidimensional model has better goodness of fit indexes than the unidimensional model. So, the first hypothesis (H1) is supported, confirming that flow is multidimensional and is measured through concentration, enjoyment and temporal distortion.

Table 3. Comparison between unidimensional and multidimensional model

Goodness of fit indexes	Unidimensional model 12 items – 1 factor	Multidimensional model 12 items – 3 factors
Satorra-Bentler Scaled Chi-Sq	1768.078	504.7957
Degrees of freedom	54	51
P	.000	.000
Bentler-Bonett Normed Fit Index (NFI)	.74	.93
Bentler-Bonett Nonnormed Fit Index (NNFI)	.69	.91
Comparative Fit Index (CFI)	.74	.93
Bollen (IFI) Fit Index	.74	.93
Root Mean Sq. Error of App. (RMESA)	.203	.107
Confidence Interval of RMESA	(.195 - .211)	(.099 - .116)

2.4.2. Factorial analysis of the second-order model

Figure 1. Second order model of flow



The next step was to test the convergence of concentration, enjoyment and temporal distortion toward a single factor, *flow*. After reviewing the literature, we proposed a reflective second-order model. Siekpe (2005)'s research analyzes the multidimensionality of the flow concept in computer-mediated environments and examines whether flow should be measured in a formative or in a reflective model, showing better fit for the reflective model of flow. Likewise, authors such as Agarwal and Karahanna (2000) and Reychav and Wu (2015) have studied cognitive absorption –derived from the state of flow– as reflective, since covariance is expected among the indicators that measure it. Moreover, when measuring psychological constructs that show an attitude or behavior, it is better to use reflective indicators because they are the origin of the observed variable and their effects are reflected in this variable. The

Figure 1 shows the results of the analyses. The three factors are significant at the 0.01 level. According to the findings, H2 is supported, so we can confirm that flow as a concept is not directly observable but is measured through three dimensions, namely, concentration, enjoyment and temporal distortion. The confluence of the three factors is what allows users to reach the state of flow.

3. Study 2

3.1. Pilot experiment

The second study is focused on conducting a pilot experiment with the main aim of studying the experience of flow among individuals. The specific objectives of this research are, firstly, to study how different levels of interactivity (highly interactive website vs flat website) affect the state of flow in order to study whether there are some common patterns on heart rate variability when experiencing flow; and, secondly, to study how the flow state can be experienced or not in various everyday life experiences such as when playing videogames (pleasure activity), translating an English text into the mother tongue (stressful activity), and doing nothing (boring activity). The pilot experiment was carried out in Japan and has been accompanied by the following techniques: a short survey in Japanese asking about the users' experience of flow (based on the dimensions of concentration, enjoyment, and temporal distortion) when performance the different activities or tasks; analyses of the Heart Rate Variability (HRV); and recording the screen movement when users were browsing.

3.2. Experimental design and procedure

The purpose of the pilot experiment is trying to analyze whether there are common patterns in the Heart Rate Variability which show the experience of flow so as to try to link these results with the statistical analysis of the survey and the specific moment of the video record of each participant, in order to discover exactly what the participants were doing on the website when experiencing flow. We hope that this psyological technique together with the quantitative methods allow us to explain how the state of flow works and develops. To do that, we will conduct an experiment showing two websites to the participants and asking them to choose a restaurant based on the information from the websites.

To do that, on the first part of the experiment, users had to navigate on two different websites asking them to choose a restaurant based on the information from the websites (one website with five reviews about restaurants in Tokyo and no interaction; and, the other website, "Tabelog", one of the most famous review-based websites in Japan to find a restaurant in Tokyo). In recent years, the search of restaurants on the Internet has dramatically increase due to the existence of recommendation and review based websites, such as "Tabelog", "Gurunavi", "Tripadvisor", etc. We used Tabelog because is the most well-known and used website in Japan to choose or find a restaurant. The website number 1 (Web 1) is designed as an e-commerce platform, completely flat and without any chance of users' interaction (https://www.likealocalguide.com/tokyo/restaurants). The website number 2 (Web 2) is a Tabelog, a famous highly interactive Japanese website for searching restaurants (www.tabelog.com). Hence, the stimulus of the experiment was to search for a restaurant to plan a dinner in Tokyo.

Ten participants took part in the pilot experiment by browsing the two websites during 20 minutes (in the morning and in the afternoon alternatively, to avoid tiredness) and between the two sessions, by doing the other tasks as can be seen in the following Table 4. That is, the task was that participants had to choose/find a restaurant on the website assigned (Web 1 vs.

Web 2), by reading the information, reviews, comments… that they could find on each website. The instructions were the same for both websites:

> ***Introduction to the experiment:*** *Hosei University is carried out a research about online users' experience. This study requires wearing a HRV device (see Picture 1) to measure your heart rate variability when navigating on the website that is opened in your computer and after the following task you must fill in a questionnaire about your experience on this website. The survey is absolutely anonymous and volunteer, so we really appreciate your participation.*
>
> ***Task:*** *Imagine that you are thinking about going out for dinner. On the website, you can find several restaurants and you can read information and comments about them. Please, navigate along the website and read all the information available that you need to make your final decision. Once you have chosen a restaurant, go to the "survey" and complete the questionnaire.*
>
> *Please, be sincere, we completely guarantee anonymity. Thank you very much for your collaboration!*

Table 4. Pilot experiment agenda

Participant	Date/Time	10:15	13:00	14:00	15:00	16:00	Measurements
#1	01/09/2016	Web1	No data	No data	No data	Web 2	HRV, survey, screen record
#2	01/09/2016	Web 2	No data	No data	No data	Web1	HRV, survey, screen record
#3	02/09/2016	Web1	Play	Translate	Do nothing	Web 2	HRV, survey, screen record
#4	02/09/2016	Web 2	Trasnlate	Play	Do nothing	Web1	HRV, survey, screen record,
#5	06/09/2016	Web 2	Play	Trasnlate	Do nothing	Web 1	HRV, survey, screen record,
#6	06/09/2016	Web 1	Trasnlate	Play	Do nothing	Web 2	HRV, survey, screen record
#7	07/09/2016	Web 2	Play	Translate	Do nothing	Web 1	HRV, survey, screen record,
#8	07/09/2016	Web 1	Trasnlate	Play	Do nothing	Web 2	HRV, survey, screen record
#9	08/09/2016	Web 1	Trasnlate	Play	Do nothing	Web 2	HRV, survey, screen record
#10	08/09/2016	Web 2	Play	Trasnlate	Do nothing	Web 1	HRV, survey, screen record

Therefore, the manipulation of the experiment was check through the level of interactivity and the survey asked for the state of flow (concentration, enjoyment and temporal distortion) while developing the task and the intention to return to the website or to do the activity again, and the intention to WOM. According to Wu (2005), the level of interactivity on a website can be manipulating with the presence or absence of interactivity elements. The author highlights six interactive elements: email hot-link, JavaScript-enabled, mouse-over effects, online chat room, searchable pull down menu, product image and dynamic creation of content. Several authors consider interactivity as a multidimensional construct that consists of communication, responsiveness and control (Liu 2003; Liu & Shrum 2002; McMillan & Hwang 2002; Song & Zinkhan 2008; Van Noort, Voorveld & Reijmersdal, 2012). Ratings, recommendations systems and forums allow two-way communication, give active control to users and are thought to enable immediate feedback or synchronicity. Van Noort et al. (2012) manipulate the interactivity of a website, specifically the dimensions of two-way communication and control. High interactivity regarding to two-way communication is manipulated through offering the option to recommend the website to a friend, to register to received updates, etc.; while control is manipulated offering a non-linear website. According

to Song and Zinkhan (2008), communication can be manipulated through some system features such as chat rooms, comment forms, questions and answer, and bulletin boards, among others; while synchronicity refers to response time. Teo et al. (2003) design a one-factorial experiment manipulating three levels of interactivity. For the high interactivity level, the authors highlight the salience of user-user interactivity and the existence of online forum and chats. All in all, checking the Tabelog's interactivity features, we can state that this website (Web 2) fulfills the requirements of a highly interactive page; while Web 1 does not fulfill them and, therefore, can be considered a non-interactive page.

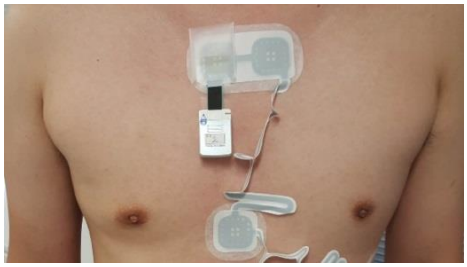
3.3. Preliminary Heart Rate Variability Analyses

Electrocardiogram recordings were made for 10 subjects in different tasks (*Cardy 303 pico+, Suzuken Co., Ltd. Nagoya 461-8701 Japan*). Data were digitized at the sampling rate of 200Hz. *R* wave occurring times TR_n and their intervals $\tau_n (= TR_{n+1} - TR_n)$ were measured offline. The instantaneous heart rate at the mid-point of *R* wave occurring times t_n is defined as the reciprocal of intervals τ_n. Here,

$$t_n = \frac{TR_{n+1} + TR_n}{2}.$$

Now un-evenly spaced sequence of instantaneous heart rate $(t_n, 1/\tau_n)$ is obtained. Then, a spline interpolated function of the sequence is resampled at 4 (Hz) and utilized for the subsequent spectral analysis. The power spectra were estimated for resampled instantaneous heart rate signals and frequency band powers LF (0.04-0.15Hz) and HF (0.15-0.4 Hz) were estimated. It is known that HF and LF/HF are indices of parasympathetic and sympathetic activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

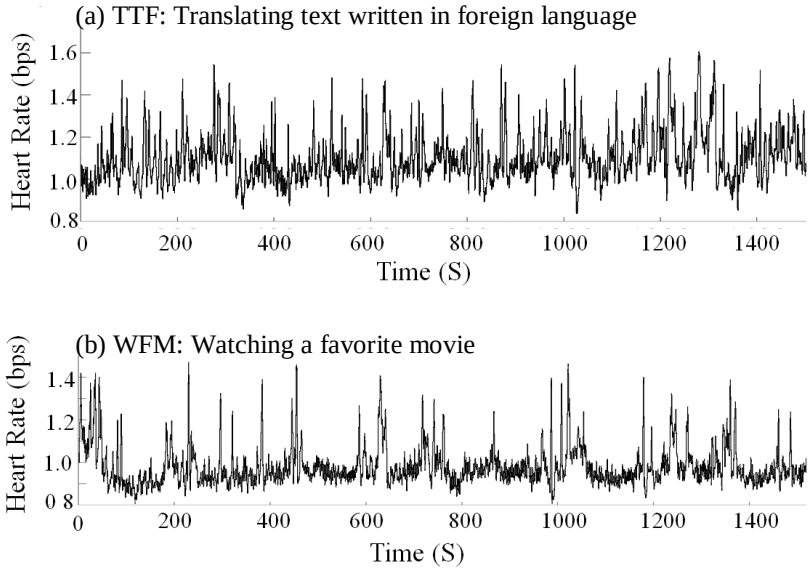
Picture 1. Heart Rate Variability Measuring Device



3.4. Preliminary outlines

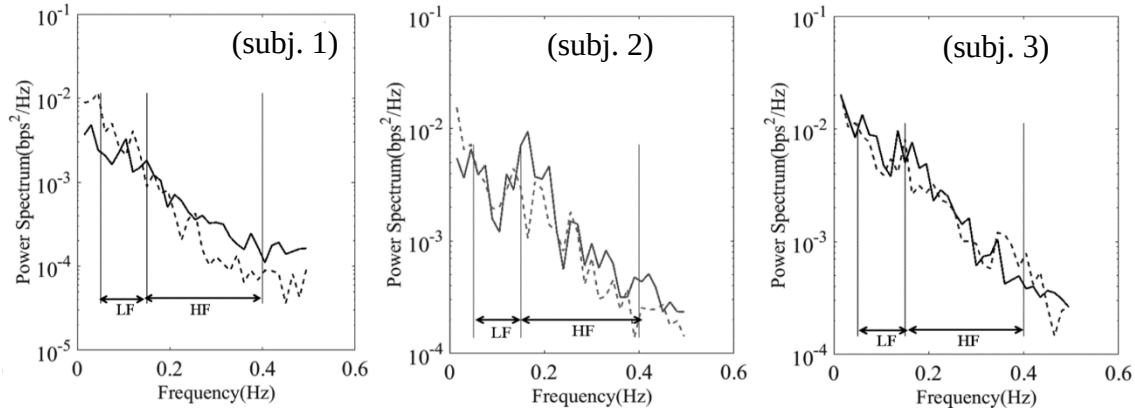
Figure 2 shows the heart rate changes when a subject is either translating text written in unfamiliar foreign language (TTF) or watching his favorite movie (WFM). The both indices HF and LF showed significantly lower values in the task WFM compared to TTF (HF: $3.1\times10^{-4}\ bps^2/Hz$ vs. $6.7\times10^{-4}\ bps^2/Hz$; LF: $3.1\times10^{-4}\ bps^2/Hz$ vs. $5.3\times10^{-4}\ bps^2/Hz$). This indicates that the total autonomic control is less intense for WFM. Eye inspection of the heart rate changes in Figure 2 ratifies this fact by observing smaller fluctuations in WFM. However, it should be noted that the sporadic increases in heart rate have been observed in the TTF task. If the WFM causes flow like state, it could be characterized by a basic steady less variable cardiac activity with sporadic short bursting sympathetic activity. Figure 3 shows three examples of power spectra comparing those for interactive and non-interactive web viewing for 20 minutes.

Figure. 2 Heart rate fluctuations during the two different tasks:



(a) *Watching a favorite movie* (b) *Translating text written in unfamiliar foreign language*

Figure 3. Power spectra comparison between interactive and non-interactive web browsing



(Solid line: Interactive, Dotted line: non-interactive)

Solid lines show power spectra obtained by interactive web browsing whereas dotted lines show those for non-interactive web browsing. It is clearly observed that subject 1 and 2 show prominent differences in indices HF and LF while subject 3 shows no prominent differences in the power spectrum patterns. Estimated indices for 10 subjects are summarized in Table 5. Since the data size is small, no statistically significant differences are found. However, it should be noted that LF/HF tends to be smaller for interactive site browsing suggesting the site viewing is less stressful.

Table 5. Changes in heart rate variability indices

	HF $(\times 10^{-4} bps^2 / Hz)$	LF $(\times 10^{-4} bps^2 / Hz)$	LF/HF
Interactive	3.98 ± 1.67	6.02 ± 2.98	1.55 ± 0.59
Non-Interactive	4.46 ± 3.41	7.21 ± 2.68	2.10 ± 1.15

As seen in this section, there are some cases which showed remarkable differences in heart rate variability depending on the different tasks. However, individual differences are quite large and systematic significant changes are not revealed in this pilot study. Collection of physiological data associated with psychologically reliable flow level annotation could enable to find a quantitative measure for the flow state classification based on the physiological signal measurement.

4. Discussion and conclusions

On the one side, the first study demonstrates that flow is a multidimensional factor composed of concentration, enjoyment and temporal distortion. When users experience the three dimensions, they reach the state of flow or the optimal experience; they not only surf the website, but flow. We first reviewed the literature in which the concept of flow is analyzed in various contexts, to study the variables, dimensions and structure that must be used to measure it. However, we found no consensus about this. Second and focusing on research directly related to social commerce, we theorized a three-dimensional structure that composes a second-order factor to measure flow. After the theoretical proposal, we carried out various statistical analyses where we compared the unidimensional and the multidimensional models through the *rival models technique,* confirming the three-dimensionality of the concept. The next step was to conduct a second-order confirmatory analysis to corroborate that the second-order reflective model fits the data well. Thus, the hypotheses are supported: the state of flow is measured through the dimensions concentration, enjoyment and temporal distortion and can be considered a second-order multidimensional factor. As a result, when users experience flow, they focus their attention on the activity they are performing, enjoying it and losing track of time, which leads them to flow on the website, reaching an optimal experience when surfing. The reason why we test the concept of flow on social commerce website is because experiencing this optimal state will lead users to try to repeat it (Csikszentmihalyi, 1975), with the positive consequences this entails for companies: increasing the intention to purchase (Kim & Han, 2014) and to return to the website (Hausman & Siekpe, 2009), creating satisfaction (Wang & Hsu, 2014), loyalty and positive WOM (O'Cass & Carlson, 2010), among others.

On the other side, the second study, although through a pilot experiment, allow us to open new horizons in the measurement of flow. This research enables academics and practicioners to understand the state of flow through a physiological point of view. Combining the heart rate variability patterns within different activities and the psychological and marketing perspective the understanding of how the state of flow is developed can improve. The preliminary results stems from the heart rate analysis show that the index of sympathetic activity (LF/HF) tends to be smaller for the interactive website, where it is easier to experience flow. These findings encourage academics to carry on the flow research based on physiological techniques.

Therefore, the empirical analyses allow us to shed light on controversial flow issues that were without consensus; studying the flow from a past experience perspective in the study 1 and flow from the current experience point of view with the study 2. We contribute to establish the basis for measuring the state of flow, its structure, factors and measurement instrument, as well as opening a new line of research that combines the physiological analyses with the psychological and marketing analyses. Our study supports the idea of the multidimensionality of the state of flow and establishes the three dimensions that comform it. Likewise, the pilot experiment boosts academic to carry on analyzing common pattern in heart rate variability

when experiencing flow. This research has academic implications for the establishment of guidelines for using flow theory in the specific context of social commerce.

Moreover, these analyses offer companies the chance to know what social commerce cues have to be boosted for users to be able to experience flow. With the tools available on a social commerce website, companies should foster enjoyment and facilitate concentration and temporal distortion. User enjoyment can be affected by socialization and interactions with other users on the company's social networking sites. User concentration can be achieved through the interaction typical of the recommendations and referrals systems because users must concentrate on writing or reading product ratings. User temporal distortion can be encouraged because they can be absorbed by interacting with others and accessing information through the company's virtual community.

Given that people who reach the state of flow affirm that it is a rewarding experience that is worth repeating, users who desire to experience this sensation again, will return to the same website to find it. That will entail benefits for companies because, on the one hand, returning to the website facilitates user repurchase and, on the other, because it can contribute to customers' loyalty and engagement. Nevertheless, in addition to the social interactions and information exchange typical of social commerce websites, the proper functioning of these social commerce platforms is also subject to both website design and usability during the whole purchasing process, from the first impression when entering the website to the post-purchasing service. Therefore, companies that integrate flow theory into their marketing strategies should not forget that surfing and the transaction are as important as the subsequent delivery because, if one of the stages of the purchasing process irritates customers, they may forget that they reached the state of flow and, consequently, the rewarding sensation may vanish. That is, in online purchasing, user surfing time should be considered as important as purchase and post-purchase. Hence, flow and engagement are two concepts that should be studied in unison. Engagement is a sensation of passion, generated slowly and long-lasting (O'Brien & Toms, 2010), which can contribute to solving minor problems that appear during the purchasing process because engaged users are characterized by their loyalty. Thus, the study of the combination of *flow* and *engagement* will be taken into account in future lines of research.

Because social commerce is an interactive environment, the consequences of reaching the state of flow could be related to participation and socialization in this context. Therefore, in future investigations about the state of flow in social commerce, we will analyze the consequences of experiencing flow. Furthermore, given that what users first see when entering a website is its design, this has been considered key in the development of these platforms, since the first few seconds users spend on a webpage may positively or negatively affect their perceptions, emotions, and intentions (Kim, Shaw & Schneider, 2003; Tuch, Bargas-Avila, Opwis, & Wilhelm, 2009; Wang & Emurian, 2005). Hence, website design is a fundamental aspect for both social commerce and flow experience because it can include essential elements that make the purchasing process an optimal experience. For example, website design and usability can make the experience more absorbing, avoiding frustration and anxiety. Furthermore, socialization can lead to users' enjoyment and, social commerce tools, which offer information from various sources, can hold users' attention. Therefore, and given that social commerce is focused on relationships, users will be the starting point in the website design development (Lee & Koubek, 2010). So, another future line of research will be focused on website design as a starting point for experiencing flow.

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