Personality and Social Psyhology

Effect of marital satisfaction on self-regulation efforts in couples: Value of heart rate variability measurements

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This study explored self-regulatory efforts during the viewing of couple interactions and their association with relationship satisfaction. High-frequency heart rate variability (HF-HRV) was measured for each participant during a video recall of a recent couple interaction to quantify the self-regulatory processes governed by parasympathetic activity. Among 30 couples, HF-HRV was measured continuously during three specific periods to explore its change over time using a video-recall procedure: (1) resting state; (2) viewing of couple interactions (expressing daily life situations and conflictual interactions); and (3) recovery. Results of multilevel models revealed a u-shaped pattern of HF-HRV responses for men and women across the three periods with a nadir at the midway through the process. This pattern of physiological change (vagal suppression) reflects a flexible response to a stressful situation. Nevertheless, the pattern of physiological responses varied according to the level of relationship satisfaction. Men who were more satisfied in their couple relationship presented greater vagal suppression than dissatisfied men. In contrast, no significant HF-HRV changes were found in women over the different periods of the video-recall procedure and no moderating effect of relationship satisfaction. We discuss the different patterns of physiological responses observed both for men and women in terms of interindividual variability according to the level of their relationship satisfaction. The present study highlights the important role of relationship satisfaction in regulatory processes.

Key words: Couple interaction, couples, psychophysiology, relationship satisfaction, self-regulatory efforts.

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INTRODUCTION

The couple relationship is one of the most important close relationships in life. Dissatisfaction with couple relationship appears to be deleterious for both physical and psychological health (Kiecolt-Glaser & Wilson, 2017). Partners must manage a wide range of emotions, particularly in marital interactions with their loved ones. Such contexts require flexible self-regulatory efforts in response to an emotional context to ensure the optimal functioning of intimate relationships (Tani, Pascuzzi & Raffagnino, 2015). In this line, there is growing interest in identifying biological markers associated with social interaction skills (Porges, 2007; Shahrestani, Stewart, Quintana, Hickie & Guastella, 2015) and with the ability to regulate stress in a social environment (Heinrichs & Gaab, 2007). The adjustment of autonomic activity in dyadic interactions or in challenging social contexts has been termed autonomic flexibility (Appelhans & Luecken, 2006; Friedman & Thayer, 1998; Geisler, Kubiak, Siewert & Weber, 2013). Autonomic flexibility corresponds to adaptive modifications in arousal, respiration or heart rate related to parasympathetic nervous system regulation and to increase in vagal tone (Kok & Fredrickson, 2010). Thus, effective social interaction may reflect both increased activity of the vagus nerve, leading to flexible and responsive behavioral and sensorial systems, and effective stress regulation in stressful social contexts, as indicated by a reduced adreno-cortical response (Shahrestani *et al.*, 2015). Both the polyvagal model (Porges, 2007) and the neurovisceral integration model (Thayer & Lane, 2009) underlined the role of the vagus nerve in social interaction, considering heart rate variability (HRV) as a reliable measure to assess vagus nerve outflow and characterize physiological resources to assist goal-directed behavior (Thayer & Lane, 2009). In particular, the high frequency (HF) band of the cardiac signal in the frequency domain is classically used as it is influenced almost exclusively by parasympathetic activity (Laborde, Mosley & Thayer, 2017; Lane, Mcrae, Reinman, Chen, Ahern & Thayer, 2009; Quintana, Guastella, Outhred, Hickie & Kemp, 2012).

Although there is a growing body of research supporting the hypothesis that changes in cardiac activity reflected by phasic HRV correspond to self-regulatory effort (e.g., Berna Ott & Nandrino, 2014; Butler, Wilhelm & Gross, 2006; Gaebler Daniels, Lamke, Fydrich & Walter, 2013; Park, Vasey, Van Bavel & Thayer, 2014; Segerstrom & Nes, 2007), one of the main questions is whether the latter is associated with a classic vagal suppression response or rather with an increase in heart rate variability (For a review see Balzarotti, Biassoni, Colombo & Ciceri, 2017; Park & Thayer, 2014). In fact, the self-regulatory efforts observed with vagal suppression or vagal enhancement may depend on the context in which HRV phase changes occur (Park & Thayer, 2014; Park *et al.*, 2014). Vagal suppression has been interpreted as an autonomous response to stress, reflecting the withdrawal of cardiac vagal control and the activation of defensive systems to cope with a stressor (Park *et al.*, 2014; Thayer, Friedman & Borkovec, 1996). For example, when video clips that trigger stress are presented, such as the representation of conflict (Beauchaine, Gatzke-Kopp & Mead, 2007; El-Sheikh &

Erath., 2011) or engaging in worry and fear or anger imagery (Lyonfields, Borkovec & Thayer, 1995; Thayer *et al.*, 1996), a phasic HRV suppression is observed. By contrast, the increase in phasic HRV has been interpreted as self-regulatory effort associated with engagement in emotional regulation processes (e.g., using emotional self-regulatory methods such as suppression or reappraisal or performing a task that requires self-regulatory effort; Butler *et al.*, 2006; Segerstrom & Nes, 2007). For example, HRV increased when participants were forced to select only carrots as the foods they were going to eat, which required more self-regulatory effort than when they were asked to eat only cookies, which required less self-regulatory effort. In addition, there was greater phasic improvement in HRV when participants exposed to an emotional film were asked to regulate their emotions by suppressing emotions or reassessing them (Butler *et al.*, 2006). Those who adjusted their emotions showed a higher HRV than those who did not adjust them (Butler *et al.*, 2006). In addition, when participants are asked to discuss a major life event with a supportive friend, a higher HRV is observed than when they discuss one with an ambivalent friend (Holt-Lunstad, Birmingham & Light, 2008). Furthermore, Lane, Weidenbacher, Smith, Fort, Thayer, and Allen, (2013) showed in a neuroimaging study that phasic HRV improvement was associated with greater activation in the anterior cingulate cortex associated with emotional regulation processes.

In studies on dyadic interactions, previous studies investigating conflictual interactions by means of a psychophysiological approach found that partners showed significant cardiovascular reactivity during conflictual interactions, indicating high emotional arousal during conflictual interactions (Smith, Uchino, MacKenzie, Hicks, Campo & Reblin, 2013). The recent review conducted by Shahrestani, Stewart, Quintana, Hickie and Guastella (2015) found that negative dyadic social interactions are associated with a reduced HRV, with an effect size indicative of a small-to-medium effect. This strong emotional reactivity involved in conflictual interactions highlights how important it is for couples to have a flexible self-regulatory capacity to deal with this highly emotional or stressful context. In addition, to our knowledge, only one study (Smith, Cribbet, Nealey-Moore, Uchino, Williams, Mackenzie & Thayer, 2011) has explored the association between changes in vagal activity and marital satisfaction by analyzing both tonic and phasic HF-HRV responses. Higher tonic HF-HRV (i.e., overall self-regulatory capacity measured at rest) was associated with greater marital quality. Moreover, the authors found a decrease in HF-HRV followed by an increase in HF-HRV during the conflictual interaction task in women. This pattern of HF-HRV changes across different periods reflects the exertion of women's self-regulatory efforts during a negative task. However, they did not explore phasic HRV changes until the recovery period (i.e., after the stressful situation when recovering from stress), and this result was found only in women. Hence, to date, little is known about how HF-HRV regulation is associated with relationship satisfaction when couples face stressful events by combining both tonic and phasic indices including recovery after a stressful induction such as couple interactions. In the current study, we investigated individuals' subjective understanding of their emotional experience (affective and cognitive) associated with their own couple interactions in terms of both daily life and conflictual discussions. We hypothesized when partners watched their couple interaction, the emotional experience felt would activate their internal working model related to their interpersonal experiences and guide their interpretation of the interactions within close relationships, as postulated by the attachment theory (e.g., Feeney, Noller & Roberts, 2000). A video-recall procedure was used to capture both partners' self-regulatory efforts associated with their own emotional experience during the pre-recorded viewing of their couple interaction (Welsh & Dickson, 2005). While direct observation of couple interactions provides precise information about emotion regulation in response to the interactional process, physiological measures recorded during viewing offer further insight into partners' subjective understanding of their couple interaction. As demonstrated by Gottman and Levenson (1985) and Welsh and Dickson (2005), the video-recall procedure is a useful method to quantify self-regulatory efforts of individuals using objective indices in response to their emotional experience during the viewing of their couple interaction in terms of both daily life and conflictual discussions.

The present study aimed to expand on previous research in the field of couple relationships by examining the association between partners' self-regulatory efforts in a situation of couple interaction and the level of their relationship satisfaction. We were also interested in gender differences in physiological responses throughout the procedure. We hypothesized that HF-HRV would decline during the viewing, followed by an increase in HF-HRV during the recovery period that would reflecting the exertion of self-regulatory efforts (Hypothesis 1). Second, we predicted that partners would present a vagal suppression or enhancement caused by viewing their couple interactions according to their relationship satisfaction perceived (Hypothesis 2).

MATERIALS AND METHODS

Participants

The initial sample consisted of 40 married or cohabiting heterosexual couples. From the initial sample, physiological data from 10 couples were unusable because of the poor signal reception of the participants. The final sample consisted of 30 couples. The couples were between 18 and 57 years old, with an average age of $M = 25.87$ ($SD = 7.47$) years for men, and $M = 24.87$ ($SD = 8.67$) for women. The average length of the relationship was $M = 4.70$ years ($SD = 5.48$, range = 1–29). The sample was predominantly Caucasian (95%), with a senior high school degree (48%; 45% with a bachelor or more degree; 2% with a junior high school degree; 5% of missing values) and childless (90%).

Procedure

Couples were recruited via social networks or posters displayed in different locations (e.g., university, professional networks). Couples that were interested in participating contacted the experimenter by telephone to fix an appointment for the experiment. In the laboratory session, the study was explained to them. After giving their written informed consent, a psychologist researcher conducted a clinical interview with them to create a climate of confidence, as well as to understand the history of their relationship. Then, partners completed a questionnaire independently of one another. Afterwards, they participated in two couple discussions, each lasting at least 10 minutes. The first was about a daily life topic (i.e., a conversation that did not involve a disagreement between partners and no negative emotions), while the second discussion was about a conflictual topic. The researcher left the room during the conversations and the conversations were videotaped. After each discussion, the researcher joined the couple to talk with them about their feelings.

Subsequently, a video-recall session took place in which each partner individually viewed the original videotaped couple interactions. The video-recall session consisted of four periods: (1) a 3-minute rest; (2) viewing of the daily life interaction; (3) viewing of the conflictual interaction; and (4) a 3-minute recovery. During all periods, HF-HRV was recorded continuously. During the experiment, participants were instructed to limit their movements and not to talk in order to reduce movement artifacts. Between viewing the daily life interaction and the conflictual interaction, the participants took as long a break as they needed. The present study was approved by the local ethics committee.

Measures

Relationship satisfaction. Relationship satisfaction was assessed by the French version of the Dyadic Adjustment Scale (DAS; Antoine, Christophe & Nandrino, 2008). The scale contains two dimensions measuring: (1) the degree of agreement (10 items); and (2) the quality of interaction (6 items), based on a six-point Likert scale. Some examples of items for the degree of agreement dimension are the degree to which partners' agree on: *Sex relations*, *Aims, goals, and things they believe important*, *Making major decisions*, *Leisure time interests and activities*; and for the quality of interaction: *How often do you confide in your mate?*, *How often do you and your mate "get on each other's nerves"?*, *How often do you have a stimulating exchange of ideas?*, *How often do you laugh together?*. In the present study we used the sum of all items in order to calculate the overall score. The DAS-16 presented an acceptable internal consistency with a Cronbach's alpha = 0.82.

HF-HRV measures. During the video-recall session, we recorded the electrocardiogram (ECG) signal via two pre-gelled electrodes placed in a Lead II configuration connected to a BIOPAC amplifier (MP36; AcqKnowledge® 4.2 Software). We did not measure the respiration rate because it does not affect HRV in resting state recordings (Denver, Reed & Porges, 2007). The signal was digitized at a 24-bit resolution and 1000-Hz sample rate. The R-R intervals of the QRS complex from the ECG signals were inspected offline and band-pass filtered at 0.5 and 35 Hz with a notch filter set at 50 Hz using a commercial software package (MATLAB R2009b, The MathWorks Inc., Natick, MA). ECG signals were band-pass filtered at 0.5 and 35 Hz with a notch filter set at 50 Hz in acquisition software. Using the BIOPAC algorithm, the R-R intervals were calculated and then corrected by visual examination. HRV quantification was performed in the frequency domain (Tarvainen, Ranta-Aho & Karjalainen, 2002) using HRV guidelines (Berntson, Thomas Bigger, Eckberg, Grossman, Kaufmann, Malik & Molen, 1997; Malik, Bigger, Camm, Kleiger, Malliani, Moss & Schwartz, 1996), and the Kubios software user's guide (Tarvainen & Niskanen, 2012). R-R intervals were first extracted with a smoothness-prior method (Tarvainen *et al.*, 2002) to remove the very low frequency component (<0.04 Hz). Then, as we were specifically interested in parasympathetic activity, a power spectral density analysis was performed using a nonparametric method (Fast-Fourier transformation) with a high frequency (HF) band set at 0.15–0.4 Hz. We used normalization of HF (HFnu) as an index of modulation of the parasympathetic branch of the autonomic nervous system (ANS) as it influences the sinoatrial node of the heart (Burr, 2007). The normalized (or normalized unit) spectral indices are computed as HFnu = HF/(LF + HF).

To explore the pattern of HRV changes across the four periods, 14 HF-HRV measures were extracted: (1) one during the rest period, corresponding to the tonic HF-HRV (resting HF-HRV); (2) six equally long measures during viewing of daily life; (3) six equally long measures during viewing of conflictual interaction (stressful event HF-HRV); and (4) one during the recovery period (recovery HF-HRV). The measures captured during viewing and the recovery period in comparison with the baseline quantified the phasic HF-HRV, that is, the reactivity to a stressful event followed by the exertion of self-regulatory efforts in response to it.

Statistical analyses

In our first hypothesis, we were interested in whether and how partners' HF-HRV changed across the three periods. In the second, we tested whether changes in partners' HF-HRV are moderated by relationship satisfaction. Gender differences were also tested for both hypotheses. Our dataset consisted of 30 (couples) × 2 (persons) × 14 (time measurement) = 840 data points. To consider the nested and dyadic structure of our data, we used a multilevel model for dyadic data that included the three hierarchical levels of our data (i.e., HF-HRV values nested within persons nested within couples) as two levels. Level 1 represents variability within person repeated measures of HF-HRV for both men and women, and Level 2 represents variability between couples (Bolger & Laurenceau, 2013). We used the lme4 package for multilevel modeling (Bates, Mächler, Bolker & Walker, 2015) in R (R Core Team, 2016) and the lmerTest function in order to estimate p-values with Satterthwaite's degrees of freedom method. To ensure the interpretation of our statistical analysis, the time variable was centered such that Time = 0 represented the beginning of the procedure (i.e., resting measurement time of HF-HRV). Our predictor relationship satisfaction was grand-mean centered separately for men and women by subtracting the mean of relationship satisfaction across all men (and women) from each man's (and woman's) individual score (Bolger & Laurenceau, 2013). First, we built a multilevel model to examine the linear and quadratic effects of time on the HF-HRV values for men and women. In a second model, we included the effects of relationship satisfaction and the cross-level interaction of time × relationship satisfaction for both the linear and quadratic time effects. We included random intercepts and random slopes for linear time. For quadratic time, our sample size did not allow us statistically to include random slopes in order to run the models properly.

RESULTS

Descriptive statistics

Means and standard deviations of all study variables are presented in Table 1. Men and women did not differ significantly in their relationship satisfaction ($t(58) = -0.30$, $p = 0.767$) and resting HF-HRV ($t(57) = -1.87$, $p = 0.066$). However, women reported higher daily life interaction HF-HRV ($t(58) = -3.18$, $p < 0.01$), conflictual interaction HF-HRV ($t(58) = -3.58$, $p < 0.01$), and recovery HF-HRV ($t(58) = -2.38$, $p < 0.05$) than men.

For each group, we built two sub-groups of approximately the same size on the basis of their grand-mean centered score of relationship satisfaction and tested whether high and low relationship satisfaction sub-groups were different. For men and women, the sub-groups differed significantly (men: $U = 43.00$; $p = .005$; women, $U = .00$; $p = .000$).

Multilevel model of HF-HRV changes predicted by relationship satisfaction

The results of our models are summarized in Table 2. Our first hypothesis predicted that resting HF-HRV in men and women would decrease during viewing, followed by an increase until the recovery period. This u-shaped pattern would reflect the exertion of self-regulatory efforts in response to a stress aroused by viewing. We tested this prediction by estimating the linear and quadratic effects of time on HF-HRV changes. For men, results of

Table 1. *Descriptive statistics of all study variables*

	Men		Women		
	M	*SD*	*M*	*SD*	*t*-test
Resting HF-HRV [n.u.]	0.32	0.14	0.39	0.15	−1.87
Daily life interaction HF-HRV [n.u.]	0.27	0.12	0.37	0.14	−3.18**
Conflict interaction HF-HRV [n.u.]	0.25	0.11	0.36	0.14	−3.58**
Recovery HF-HRV [n.u.]	0.29	0.13	0.39	0.18	−2.38*
Relationship satisfaction	75.83	9.18	76.57	9.90	−0.30

Notes: HF-HRV = high-frequency heart rate variability. Resting HF-HRV correspond to the HF-HRV measured during the initial baseline; daily life interaction HF-HRV corresponds to the mean of HF-HRV measured during the viewing of the daily life interaction videotaped; conflict interaction HF-HRV corresponds to the mean of HF-HRV measured during the viewing of the conflict interaction videotaped; recovery HF-HRV correspond to the HF-HRV measured after the emotional event.
*$p < 0.05$.
**$p < 0.01$ (two-tailed).

this model showed a significant main effect of the linear time trend ($b = 0.486$, $SE = 0.017$, $p < 0.001$) and a significant main effect of the quadratic time trend ($b = 0.0002$, $SE = 0.015$, $p < 0.01$). For women, the linear and the quadratic time were also significant (linear time trend: $b = -0.002$, $SE = 0.016$, $p < 0.05$; quadratic time trend: $b = 0.001$, $SE = 0.016$, $p < 0.05$). Gender differences were not significant either in the main effect of the linear time trend ($\chi^2(1) = 3.11$, $p = 0.078$) or in the quadratic time trend ($\chi^2(1) = 0.56$, $p = 0.453$).

The graphs presented in Fig. 1 illustrate the estimated HF-HRV changes over time for both men and women. On the left, it may be seen that HF-HRV values in men declined after the resting period until the middle of the stressful event period, followed by a gradual increase in the second half of the stressful event period up to the recovery period. This u-shaped pattern indicates that viewing of the interaction aroused emotional reactivity in men, followed by the exertion of ER efforts until the recovery period. Women showed a similar pattern although the quadratic effect seemed to be less intense, albeit significant.

In our second hypothesis, we postulated that relationship satisfaction would moderate HF-HRV changes over time. For men, results showed a significant cross-level interaction of the linear time trend × relationship satisfaction ($b = 0.0001$, $SE = 0.003$, $p < 0.05$) and a significant cross-level interaction of the quadratic time trend × relationship satisfaction ($b = 0.00002$, $SE = 0.003$, $p < 0.01$). For women, effects of the cross-level interaction of the linear time trend × relationship satisfaction ($b = 0.001$, $SE = 0.004$, $p = 0.917$) and the quadratic time trend × relationship satisfaction ($b = 0.007$, $SE = 0.005$, $p = 0.936$) were not significant. Gender differences in the cross-level interaction linear time trend × relationship satisfaction ($\chi^2(1) = 2.98$, $p = 0.084$) and in the cross-level interaction quadratic time trend × relationship satisfaction ($\chi^2(1) = 3.80$, $p = 0.051$) were marginally significant.

The graphs on the left of Fig 2 show that men with a higher relationship satisfaction had a stronger decrease in HF-HRV after the resting period, followed by a progressive increase in HF-HRV

Table 2. *Parameter estimates of the multilevel model predicting men and women's HF-HRV across time*

	Model 1		Model 2	
Fixed effects	Estimate (*SE*)	*p*[a]	Estimate (*SE*)	*p*[a]
Intercept				
Men	0.32 (0.18)	<0.001	0.32 (0.21)	<0.001
Women	0.25 (0.14)	<0.001	0.25 (0.14)	<0.001
Linear time trend				
Men	0.486 (0.017)	<0.001	0.446 (0.017)	<0.001
Women	−0.002 (0.016)	0.038	−0.002 (0.016)	0.038
Quadratic time trend				
Men	0.0002 (0.015)	0.003	0.0001 (0.01)	<0.001
Women	0.001 (0.016)	0.046	0.001 (0.01)	0.045
Relationship satisfaction				
Men			−0.016 (0.072)	0.109
Women			0.626 (0.051)	0.667
Linear time trend × Relationship satisfaction				
Men			0.0001 (0.003)	0.027
Women			0.001 (0.004)	0.917
Quadratic time trend × Relationship satisfaction				
Men			0.00002 (0.003)	0.008
Women			0.007 (0.005)	0.936
Random effects	*SD*		*SD*	
Intercept				
Men	0.116		0.104	
Women	0.133		0.135	
Linear time trend				
Men	0.004		0.004	
Women	0.007		0.007	

Notes: [a]All *p*-values are two-tailed.

in the second half of the stressful event period until the recovery period. In contrast, men with lower relationship satisfaction presented a different pattern of HF-HRV responses, indicating a continuous decline over time. These results indicate a greater reactivity to viewing of the couple interaction followed by a better recovery in highly satisfied men than in those less satisfied. Women's HF-HRV values did not depend on their level of relationship satisfaction, so HF-HRV changes across the three periods were similar patterns in both highly satisfied women and in those less satisfied.

DISCUSSION

The present study aimed to examine the self-regulatory efforts of partners during the viewing of their couple interactions (both daily and conflictual discussions) and investigated whether relationship satisfaction moderates these patterns of self-regulatory efforts in both women and men.

Both men's and women's HF-HRV decreased during the viewing of their couple interaction when compared with HF-HRV measured at rest, followed by an increase in their HF-HRV midway through the process until the recovery period. This decrease in HF-HRV is thought to indicate parasympathetic withdrawal, a pattern that reflects an adaptive response to stressful or challenging situations (Park & Thayer, 2014; Shahrestani *et al.*, 2015). In men, viewing seemed to generate stress, so they attempted to manage it until the recovery period. In women, HF-HRV changes across the three periods were also significant.

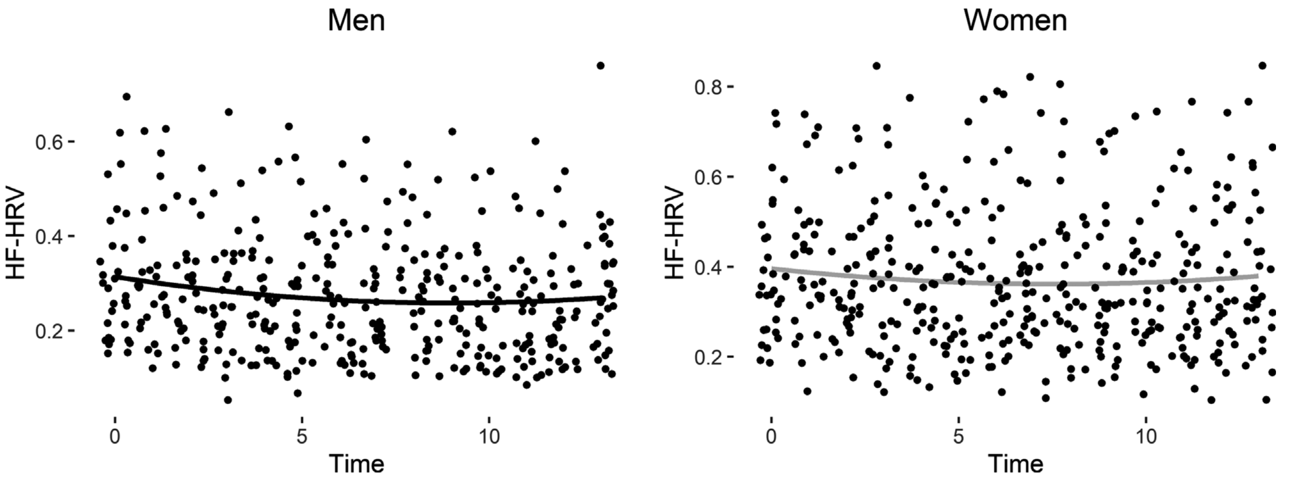

Fig. 1. Plot of raw data of HF-HRV across time for men (left side) and women (right side). The lines represent the quadratic time trends. HF-HRV = high-frequency heart rate variability. Time 0 = resting period, Time 1 to 6 = viewing of the daily life interaction, Time 7 to 12 = viewing of the conflict interaction videotaped, Time 13 = recovery period.

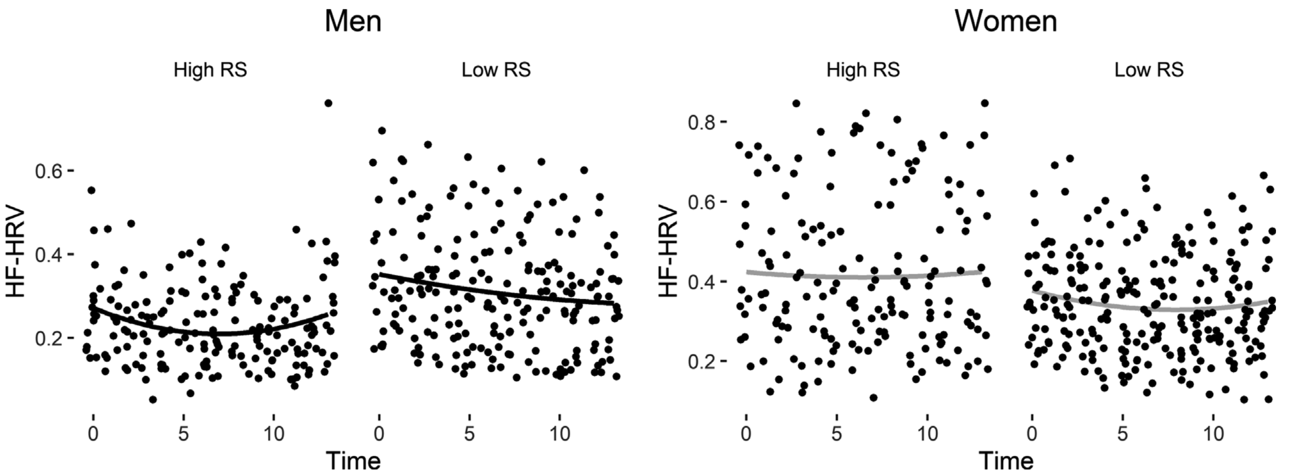

Fig. 2. Quadratic time trends of HF-HRV are presented for men (left) and women (right) depending on their relationship satisfaction (low RS = relationship satisfaction lower than the median; high RS = relationship satisfaction higher than the median). The lines represent the time trends within the subgroups. HF-HRV = high-frequency heart rate variability. Time 0 = resting period, Time 1 to 6 = viewing of the daily life interaction, Time 7 to 12 = conflict interaction videotaped, Time 13 = recovery period.

These findings are partially consistent with those of Smith *et al.* (2011), who found that negative marital interactions momentarily reduce women's self-regulatory capacity, but not that of men. In contrast, the men in our study appeared to be more affected by viewing their couple interaction than the women, who showed slight HF-HRV changes over time. The paradigm used in this study consisted of "re-living" the experience of partners' couple interactions. Watching and hearing oneself interact with one's partner seemed to generate more self-awareness in men than in women. Men may be more attentive to behaviors and emotional reactions, or to the way in which they interact with their loved one.

Regarding our main hypothesis, men's relationship satisfaction was significantly associated with their HF-HRV changes during the procedure. This seems to indicate that men demonstrate specific patterns of self-regulatory efforts to manage their stress according to the level of their relationship satisfaction. Men who reported a higher level of relationship satisfaction showed a significant decrease in their HF-HRV, indicating a high level of stress aroused by viewing their couple interaction. This decrease was followed by the exertion of self-regulatory efforts until the recovery period (i.e., u-shaped pattern of HF-HRV responses across the three periods), suggesting that men who are highly satisfied in their relationship are very efficient in making self-regulatory efforts. In contrast, dissatisfied men presented a continuous decrease in their HF-HRV during viewing and in the recovery period, which indicates that they found it more difficult to regulate their stress. Hence, men's relationship satisfaction seems to be an important factor in explaining their flexibility in their attempts to regulate their stress. Indeed, satisfied men seemed to be emotionally more responsive to their couple interactions (regardless of the topic of discussion).

In women, however, we found no significant moderating effect of relationship satisfaction on the time trend of HF-HRV. These results contrast with previous studies showing that the regulatory capacity of women is more strongly related with relationship satisfaction than that of men. For example, Bloch, Haase, and Levenson (2014) showed in their cross-sectional associations that a greater down-regulation of women's negative behaviors, both at the experiential and the behavioral level, was positively associated with women's relationship satisfaction. They also found that both women's and men's down-regulation (particularly at the behavioral level) were associated with an increase in women's relationship satisfaction in the long term. Additionally, many studies suggest that women play a more important role in regulating emotions within a couple relationship than men (for a review see Gottman & Notarius, 2000). Thus, according to previous studies, women's relationship satisfaction is associated with women's own regulatory capacity and with that of their husband. Hence, one explanation for the difference between the current results and previous ones might be that because of the low sample size, we did not consider partner effects, that is, associations between partner A's self-regulatory efforts when faced with a stressful situation and the relationship satisfaction of partner B. Furthermore, we assumed that the women were already more aware of the quality of the interaction according to their own perception of relationship satisfaction before watching the video and therefore needed to make fewer self-regulatory efforts to manage the stress during the recall period, as they would be less emotionally involved in viewing the interaction.

Regarding the variability of physiological responses of men and women over time (see Fig. 2), two patterns can be distinguished according to the quality of their couple relationship. In men with a high level of relationship satisfaction, HF-HRV varied less than in those with a low level. Thus, in the former, viewing their couple interactions might create a high emotional load or even a stressful situation that they have to regulate emotionally. This response was reflected in their marked vagal suppression. By contrast, the latter showed more heterogeneous physiological response patterns during the task. This greater variability could be explained by two distinct response patterns. Poorly satisfied men might feel particularly threatened and emotionally stressed by viewing their relationship, as reflected by a marked vagal suppression. Their HF-HRV increased over time in response to the emotional situation, suggesting that they have to make a greater self-regulatory effort when observing their couple interaction (Balzarotti *et al.*, 2017; Park & Thayer, 2014).

We also observed different patterns of physiological responses in women according to their relationship satisfaction. Unlike men, women reporting higher satisfaction presented more heterogeneous responses, corresponding to both vagal suppression and vagal increase responses, as observed in the group of men with a low level of satisfaction. Thus, when highly satisfied women viewed their interactions, it gave rise to self-regulatory effort (vagal enhancement) in some and to more direct adjustment to stress (vagal suppression) in others. In contrast, in women reporting low relationship satisfaction, their pattern of physiological responses appeared more homogeneous and to correspond to vagal suppression, indicating a response to the stressful situation. Moreover, this subgroup seemed to present greater difficulty in regulating their stress than the men since they found it more difficult to recover after the task.

By studying interindividual variability, we observed specific patterns of physiological responses according to the level of relationship satisfaction and partner's gender. The social psychophysiological theory of gender differences in couples proposes that men and women experience emotional arousal differently (Gottman & Levenson, 1988). Women are considered to feel more comfortable in emotional interactions (including interactions with negative emotions) and less likely to make self-regulatory efforts at the physiological level. In contrast, men are thought to be more physiologically aroused by prolonged negative emotions and to experience this arousal as aversive. In this perspective, our results suggest that men's emotional sensitivity is better regulated when they report higher relationship satisfaction. Thus, their physiological sensitivity to emotions, especially negative ones, might partly explain why we found specific patterns of HF-HRV in both satisfied and less satisfied men, compared to women who presented similar patterns. In fact, men engaged in a satisfying relationship might be more able to regulate their emotional state when faced with a stressful situation. We posit that the environment of security that men feel in a relationship might play a greater role for them than it does for women in regulating the physiological arousal associated with their subjective understanding.

Strengths, limitations and future perspectives

In the present study, we examined the association between the flexibility of self-regulatory efforts in response to partners' subjective understanding of their couple interactions and the level of their relationship satisfaction. Using a video-recall procedure, we explored self-regulatory efforts at the physiological level to investigate the emotional regulatory process in response to men's and women's subjective understanding of their couple interactions. Thus, the findings shed further light on the emotional processes involved in couple interactions. The task proposed in this study, that is, the partners' physiological responses during the viewing of their couple interactions, coupled with a self-report questionnaire of their relationship satisfaction, offers an interesting integrative understanding of men's and women's perception of the quality of their couple relationship and emotional regulatory processes. Furthermore, the study highlights the importance of modeling both intra- and interindividual variability to further understand the underlying processes. Regarding the differences in the patterns of physiological responses according to relationship satisfaction and gender, it would be interesting to replicate this research with a larger sample. This would provide greater insight into these differences in response to this paradigm among men with poor satisfaction and women who are highly satisfied, for example.

The study has some limitations. First, the sample is quite small and consists mainly of young couples, thus limiting the generalizability of the findings. Indeed, young couples are in a process of constructing their relationship so the pattern of results might be different in couples who have been in a long-term relationship. Furthermore, larger and more diverse samples should be studied with regard to age, relationship duration, and couple distress. The present study is also cross-sectional so longitudinal studies are required to explore how partners' emotional responses to their subjective understanding are associated with their relationship satisfaction in the long term. Finally, to have a thorough perspective regarding the role of relationship satisfaction in self-regulatory mechanisms among couples, it would be interesting to combine quantification of behavioral patterns of emotion regulation during the interaction with physiological processes measured during the viewing of couple interactions.

In conclusion, men's physiological self-regulatory efforts in response to the stressful situation generated by their subjective understanding experienced during the viewing of their couple interaction with their partner appeared to be more flexible and efficient when they were satisfied with their couple relationship. The positive association between physiological self-regulatory efforts and relationship satisfaction demonstrates how spouses, especially men, regulate emotions in their relationship. Combined with previous research in this field, this study could have important implications for couple therapists, helping them to further understand gender differences in the regulatory processes involved in couple interactions.

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