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When head is tempered by heart: Heart rate variability modulates perception of other-blame reducing anger

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Abstract This study examined the relationship between heart rate variability (HRV), as an index of individual differences in emotion regulation, and perception of other-blame, as a mechanism of anger induction. The physiological responses were recorded while subjects read a story from a computer screen. The story narrated a negative event in self-referred way -dismissal from a job as the result of a colleague's action- under conditions of intentionality versus non-intentionality. Cognitive and emotional variables were assessed by questionnaire immediately after the physiological test. The resulting structural model supports the conclusion that HRV exerts its regulatory influence directly on perception of other-blame rather than on emotion. In situations of intentionality, individuals with higher HRV make less extreme evaluation of the offender's blame, versus those with lower HRV, thus leading to a reduction in anger reaction. These results suggest that HRV is a direct index of cognitive rather than emotional regulation.

Keywords Heart rate variability · Anger · Emotion · Other-blame · Structural models

Introduction

Appraisal theories of emotion conceive of emotion as the distillation of an individual's perception of personally relevant environmental interactions. In contrast to the classic assumption that prototypical situations serve as antecedents of different emotions, these theories assume that, before feeling an emotion, people must in some way evaluate the significance for their personal well-being of events in the environment (Ellsworth and Smith 1985; Frijda 1986; Lazarus 1991; Lazarus and Smith 1988; Roseman 1984; Scherer 1988). This process of personal evaluation is known as *appraisal*. Hence, for an emotion to occur, events must be appraised as having implications for personal benefit or harm.

Although there is some disagreement between these theories with respect to the proposed appraisal dimensions, there is also agreement on the dimensions for some emotions. Thus, anger has a well-documented relationship with cognitions and has been the focus of considerable attention in the scientific literature on both attribution (McGraw 1987; Weiner 1986; Weiner et al. 1982) and appraisal (Roseman 1991; Smith et al. 1993; Smith and Lazarus 1993). In a comparative study designed to detect the best predictors of anger, Roseman et al. (1996) concluded that the greatest anger is produced by a negative outcome caused by another person when a positive outcome is deserved.

The appraisal theory underlying the present study was developed by Lazarus and Smith (1988; Smith and Lazarus 1993). An interesting aspect of this theory is that it includes a global evaluation of the situation closest to the emotion as a second level alongside the components proposed by most authors to constitute the first appraisal of the situation. This first level, known as the "molecular" level, comprises primary appraisals of motivational relevance (the event's meaning for the subject) and motivational congruence (the event's consistency or inconsistency with the person's goal) and an additional appraisal of

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accountability, which determines who or what is the agent of the event's positive or negative outcome. The second level, called the "molar" level, is defined by the authors as the core relational theme. It provides individuals with the specific global adaptive significance of the event for them. Lazarus and Smith considered the meanings of the core relational theme to be emergent, in the sense that they are "greater than the sum of the appraisal components that imply them, and have properties and adaptational implications that cannot be easily derived from considering just the appraisal components taken individually" (Smith and Lazarus 1993, p. 260). An emotion like anger was defined by an event motivationally relevant and incongruent with the person's goal, produced by other accountability. But the global meaning is given by the core relational theme, which for anger is other-blame.

Two studies carried out by León and Hernández (1998) and Smith et al. (1993) confirmed the hypothesis that the best predictor of the level of anger felt toward the perceived offender is the evaluation of other-blame. The results of both studies support the idea that "the apparent efficiency of the core relation theme is considerably greater than that of the appraisal components" (Smith et al. 1993, p. 296). Therefore, for the present study, "blaming an offense on someone" was the cognition selected to predict anger.

Nevertheless, the other-blame/anger relationship, though strong, may not be simple. A given behavior can be interpreted as an offense by some individuals but barely noticed by others. Individual particularities may be acting on the relation between the two variables. In fact, substantial evidence links several dimensions of personality, e.g., hardiness, locus of control, self-efficacy, helplessness, affectivity, extraversion, and neuroticism, to appraisals made in specific situations (Elliott et al. 1994; Gallagher 1990; Rhodewalt and Agustsdottir 1984; Vitaliano et al. 1987).

Individual differences in the other-blame/anger relationship may also be influenced by physiological variables. As Witvliet (2001) pointed out, some people may have a highly reactive sympathetic nervous system but a slow-to-respond parasympathetic nervous system. This may make them more likely to experience hurt and anger when memories of offenses are aroused. These types of individual differences may well be powerful effectors on people's beliefs, attributions, or appraisals that affect emotions such as anger. To explore this issue, we designed a study that examined the role of a physiological index of individual differences, i.e., heart rate variability (HRV), on the blame-anger relationship.

In recent years, HRV has proven to be a reliable index of individual differences in autonomic and emotional regulation. HRV characterizes and differentiates heart rate time series (Thayer and Siegle 2002). Part of this variability is due to changes in respiration. Functionally, the HRV associated with respiratory changes (respiratory HRV) is vagally mediated (i.e., regulated by parasympathetic influence on the heart) and is therefore considered to reflect antagonism of sympathoexcitatory influences (Uijtdehage and Thayer 2000). High respiratory HRV has been positively associated with good psychological and physiological functioning. Some results summarized by Thayer and Brosschot (2005) show that individuals with low respiratory HRV reacted to neutral, harmless stimuli as if they were aversive and threatening. In contrast, individuals with high HRV were better able to match their response to situational demands and therefore respond more appropriately to the energy requirements of the situation (Ruiz-Padial et al. 2003). In another study, high levels of vagally mediated HRV were associated with larger orienting responses but faster habituation to non-threat stimuli, whereas low HRV was associated with a failure to habituate to non-threat stimuli (Thayer and Lane 2000).

The relevance of vagal control on the heart, as indexed by the respiratory HRV, is the central theme of the Polyvagal Theory proposed by Porges (1995, 2007). This theory assumes that beat-to-beat heart rate changes reflect neurovisceral processes that mediate the expression of health or disease and are an integral component of a Social Engagement System that facilitates positive interactions with people and objects. This system promotes flexible adaptation to shifting environmental demands, an important ability in social interactions. When a threat is identified, activation of the defensive behavioral system may imply the mobilization of the organism for "fight or flight" responses. However, fully aggressive or escape responses are rarely appropriate in contemporary social contexts, when more flexible responses are required. Individuals with greater cardiac vagal control would be better prepared to respond efficiently in these situations.

The brain structures involved in this neurovisceral integration are presumably connections from the prefrontal cortex to the amygdala, and from the amygdala via other subcortical structures to the sympathetic and parasympathetic innervations of the heart (Thayer and Siegle 2002). The prefrontal cortex is the neural structure most involved in the regulation of adapted social behavior (Damasio 1996; Oschner and Gross 2005; Raine et al. 1997). The relationship between prefrontal cortex activity and respiratory HRV has been suggested by various researchers. Thus, Lane et al. (2001) found decreases in the activation of medial prefrontal areas associated with concomitant decreases in HRV and increases in emotional arousal. This finding supports the proposal of a general inhibitory role for the medial prefrontal cortex on subcortical structures that control negative emotions and HRV via the vagus (Ter

Horst 1999). The role of the prefrontal cortex in vagally-mediated HRV and autonomic regulation has also been demonstrated in recent neurobiological studies. Functionally, prefrontal circuits regulate autonomic reactions via projections to the amygdala and other limbic regions and from there to nuclei directly controlling parasympathetic innervations of the heart (nucleus ambiguus). Lane et al. (2001) performed neuroimaging and pharmacological blockade studies and reported an association between medial prefrontal activity and HRV. They correlated a spectrally derived index of vagally-mediated HRV (High Frequency HRV) with cerebral blood flow (rCBF) measured by positron emission tomography (PET) and found emotional arousal to be associated with a decrease in HRV and concomitant decreases in brain activation in the medial prefrontal cortex. High HRV can therefore be seen as an index of prefrontal regulation of emotion, enhancing the cognitive appraisal of environmental demands in an adaptive manner.

In sum, whereas the relationship between attributions or appraisals and anger has been widely investigated, no published study has considered the influence of HRV on these two variables together. Hence, the aim of the present study was to examine the protective influence of HRV on anger induced by perception of other-blame. In addition, because some psychological variables, e.g., self-efficacy and emotion regulation, have been shown to have a greater modulatory effect on stress responses under moderate to high levels of stress (Fabes and Eisenberg 1997; Rutter 1990), we introduced two levels of interpersonal implication in the other-blame situation in order to increase the intensity of the emotional reaction. This was done through manipulation of the intentionality of the action (intentional versus non-intentional). Intentionality, as conceived by Weiner (1986), is a property of action that allows the intensity level of the eliciting situation to be manipulated. Hence, two levels of stress (high and low) were introduced according to the intentionality of the action, allowing us to test the hypothesis that HRV has a beneficial effect on anger under conditions of high stress (intentionality). It was expected that only under an explicit other-blame intentionality condition, individuals with higher HRV would show a more rational interpretation of the situation, moderating their perception of blame and consequently reducing their feeling of anger.

To test our predictions, we selected causal analysis models based on structural equations (Bollen 1989). This type of analysis permits a clearer estimate of the overall fit among variables, allowing us to determine whether the expected relationship between higher HRV and lesser informed anger involves a direct pathway or, as hypothesized, a cognitive evaluative pathway via perception of “other-blame”.

Method

Participants

Participants were 84 students (69 females) from the University of Granada who volunteered to take part in the study. They were informed that the research was about impressions that people form concerning certain life events and that physiological measures would be taken during a single session in the laboratory. Participants were all healthy volunteers without visual or auditory deficits. They received academic credits for participation.

Procedure

Participants attended a single 60-min laboratory session in a sound-attenuated room. They were seated in an armchair in front of a computer monitor and given a brief description of the study before signing their informed consent. They were told that they would relax for a few minutes and then read a story, which would take around 4 min, presented automatically paragraph-by-paragraph on the screen while their physiological responses were recorded. After instructions had been received and the electrodes attached, participants were left alone in the room. A baseline 5-min resting period preceded the presentation of the story. Once the experimental phase was over, physiological sensors were removed and participants completed the appraisal-emotion questionnaire.

Design

The independent variable of the study, the Eliciting Situation, was manipulated in a between-group design with two levels. Participants were randomly assigned to one of two groups: *intentional* eliciting situation versus *non-intentional* eliciting situation. HRV acted as an antecedent variable. Two dependent variables were measured: the core relational theme, other-blame, and the emotion, anger.

Material

The scenario paradigm (Betancourt 1990; León and Hernández 1998; Smith et al. 1993; Roseman 1991) was used as eliciting situation. Participants had to read a story and feel personally involved in it as if they were the protagonists. The story, previously used in the study of León and Hernández (1998), was narrated paragraph-by-paragraph on a computer monitor. The story was constructed in such a way as to be emotionally meaningful and also to involve a negative consequence for the protagonist, i.e., being dismissed from his/her part-time job. This was done to ensure that it would be perceived as motivationally relevant and incongruent. The first part of the story told how the main character (the participant) is called to the phone during a group working meeting with his/her boss and told he/she has been selected for another part-time job that is very important for him/her. On returning to the meeting, he/she passes a note with the news to his/her colleague Jose, who is sitting next to him/her. He/she asks him to read the note when nobody is looking and then destroy it. Once the colleague has read the note, and without any indication of how, it reaches the boss' hands. Then, a series of negative workplace repercussions are narrated in order to further reinforce the motivational incongruence of the events. The manipulation of intentionality was introduced in the last part of the story, according to the reasons and circumstances leading to the note being read by the boss. For one half of the participants (non-intentional condition), the locus of the events was placed in a very limited way on the friend (Jose): "Jose opens the note discreetly and is about to read it when his boss looks his way and grabs the note thinking that it was addressed to him. The boss got to read the note before Jose could do anything to prevent it". For the other half of the participants (intentional condition), the locus and causal controllability lie firmly with the friend (Jose), since his action is deemed to be deliberate: "Jose reads it at once and then hands it on to his boss, commenting that you have something to tell him because you appear to have found work with another company".

Psychophysiological measures

The VPM 11 software program (Cook 1997), installed in a Pentium 2 computer, controlled the sequence of stimuli presentations and the acquisition and analysis of physiological data, both of which were accomplished using the Advantech-PCL812PG A/D (12 bits) converter and input–output data card. A Grass polygraph (Model Rps 7c 8b) was used to record the electrocardiogram (EKG) using a 7P4 preamplifier. Three Ag–AgCl electrodes filled with electrode paste were placed as follows: one electrode on the right arm, one on the left leg, and ground on the right leg. R–R intervals (time between R waves of each beat from the heart) were measured in milliseconds and transformed into beat-to-beat heart rate (HR) using the VPM program.

Time and frequency domain analyses were performed on the HR data recorded during a 5-min baseline period, and the complete HR signal was carefully edited using visual checks and manual corrections of individual R–R intervals. Time domain measures are the simplest to perform and are recommended for the analysis of long-term recordings, whereas frequency domain measures provide results in stationary short-term recordings that are easier to interpret in terms of physiological regulations. Time domain analysis provided estimates of mean HR and HRV (variation index). Frequency domain analyses provided estimates of HRV (power spectral density), using spectral analyses and an autoregressive algorithm following Task Force guidelines (1996). Power spectral density (PSD) provides data on the distribution of power (variance) as a function of frequency. In the present study, the PSD of the signal was obtained by fast Fourier transform (FFT) using Analysis Software 1.1 for Windows developed by The Biomedical Signal Analysis Group (Tarvainen et al. 2002). Vagal activity is the major contributor to the high frequency component (HF) of the spectrum. The HF (HF: 0.15–0.4 Hz) power associated with respiratory-modulated parasympathetic outflow was used to index HRV. The variation index and HF power were satisfactorily correlated in the present study ($r = 0.80$, $p < 0.001$).

Cognitive-emotional measures

The questionnaire applied was an adaptation of a previously used instrument (León and Hernández 1998; Smith et al. 1993). It contains one set of questions related to cognitive variables and another related to emotional variables. The first set addresses the cognitive latent variable, measuring the "the core relational theme" for anger, other-blame, with three items. The second set addresses the emotional variables of the protagonists. The emotion relevant to the present study was anger. Some other cognitive (appraisals and attributions) and emotional (guilt, sadness, and shame) variables were used as fillers. Subjects had to record their degree of agreement with the proposed item on a 9-point scale from "absolutely not" to "absolutely yes". In both sets, the questions were presented in two counterbalanced orders. Table 1 shows the questions used to measure other-blame and anger together with their indexes of internal consistency.

Table 1 Indicators questions for latent variables and the internal consistency (alpha coefficient) corresponding to each one

Variable	Indicator questions	Alpha
Other-blame	Do you think that Jose is culprit of the bad situation in which you are after the facts?	0.93
	To what extent do you think that you were cheated or wronged by Jose?	
	Do you think that you have been treated very thoughtlessly by Jose?	
Anger	To what extent, while reading the story, did you experience the following emotions about Jose (a, anger; b, annoyance; c, resentment)?	0.95

Data analysis

Prior to the structural model analysis, exploratory analyses were carried out to observe the behavior of the variables in a less complex model. Two between-group *t*-tests were performed for each intentionality group, one for each dependent variable (other blame and anger). Because a search of the literature revealed no data on this relationship, and we wished to maximize the possibility of finding any difference, we formed two "extreme" groups of subjects with lowest and highest HRV values. Thus, high and low HRV quartile groups acted as the two levels of the independent variables in these analyses, and four *t*-tests were carried out. In a second step, we proceeded with the causal modeling analysis, using the whole sample of participants, in order to test the overall relations fit. This step implied testing whether the expected relationship between higher HRV and lesser informed anger involves a direct pathway or, as hypothesized, a cognitive evaluative pathway through perception of other-blame. We also wished to test the role of the intentionality of the eliciting situation in this set of paths. The EQS 5.7 program was used for structural equation modeling (Bentler and Wu 2005). This process consisted of performing covariance structure analyses in different stages. In the first stage, measurement models were calculated for the two latent variables (other-blame and anger). This analysis estimates the loads of the observable variables in the latent structure. In subsequent stages, structural models were adjusted in accordance with the previous results in order to establish whether the postulated model adequately generated the sample variance–covariance matrix. As this process is data-dependent, a detailed description of the procedure is given in the "Results" section. The same analyses were repeated for the HRV time and frequency indexes.

Results

Initial analyses

The *t*-test results revealed significant differences in other-blame between the high and low HRV participants, but only for the intentional group. In the intentional group, participants with high HRV attributed significantly less other-blame than did those with low HRV ($t(18) = 2.19$, $p < 0.05$). No significant differences in the anger measure were found between the high and low HRV groups ($t(18) = 1.16$, ns, for the intentional group; $t(18) = 0.41$, ns, for anger; and $t(18) = 0.66$, ns, for blame in the non-intentional group). Means and standard deviations are given in Table 2.

Table 2 Mean rating and standard deviation of latent variables for each eliciting situation and HRV level

Dep. variables	Eliciting situation							
	Non intentionality[a]				Intentionality[a]			
	HRV				HRV			
	Low-HRV		High HRV		Low-HRV		High HRV	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Other-blame	2.93	1.55	3.20	1.73	8.15	0.65	6.92	1.59
Anger	4.36	2.21	4.73	1.64	8.15	0.65	7.64	1.19

[a] $N = 22$; Range of scores for dependent variables: 1–9

Structural model tests

The estimated loads of the observable variables in the latent structure were all significant ($p < 0.01$). This confirmed that the measured latent variables (other-blame and anger) were reasonably valid and were, therefore, retained for the subsequent analysis ($\chi^2(8) = 6.75$, ns, NFI = 0.98, NNFI = 1, CFI = 1, RMSEA = 0.01). During the second stage, and considering the *t*-test results, a multisample analysis was applied with the two levels of the manipulated variable (intentional and non-intentional) treated as different groups and tested simultaneously. The initial restrictions considered that the estimated covariance parameters of the two groups were equal. Then, a covariance and mean structure model was estimated to determine significant differences between the groups in the studied factors. This more complex model was estimated by considering the covariance model structure parameters and the intercept of all observable variables as free parameters as long as they were the same for both groups. Mean factor values were calculated by freely estimating the mean of one group (non-intentional group) and fixing the mean of the other group at zero (intentional group). These restrictions enabled the model to establish the intentional group as a reference group. Thus, the estimated mean value for the non-intentional group measures the relative difference with respect to the other group, and this difference can be tested by contrasting it against a null hypothesis that predicts no differences by means of a z test. If the relative difference between the groups divided by its robust standard error is greater than 1.96, the difference between groups is considered significant. Figure 1 shows the results of this analysis. The first path represents the influence of HRV, taken as a continuous variable, on the evaluation of other-blame, whereas the second path represents the influence of other-blame on the emotional factor (anger). The two HRV indexes (in the time and frequency domain) yielded similar factorial and structural loads and similar fit values. As can be seen, the set of factorial loads in the

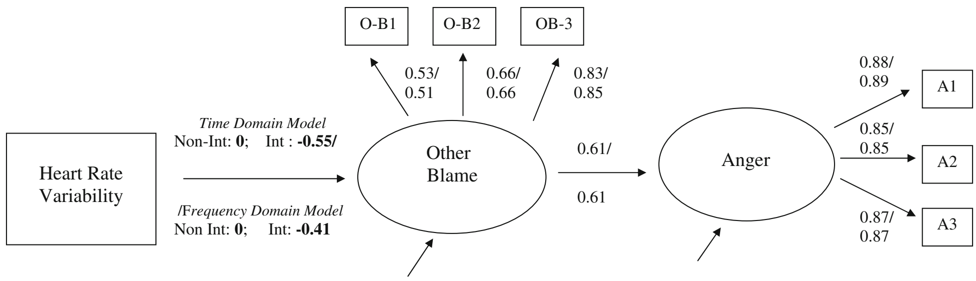

Fig. 1 Structural models representing anger as a function of other-blame, HRV and the eliciting situation. *Ovals* indicate latent constructs, *rectangles* indicate manifest variables. Values are standardized coefficients; all coefficients are significant at $p < 0.05$. *Note*: Data *before the slash* correspond to the time domain HRV model (TD) and *after the slash* to the frequency domain HRV model (FD). O-B1 to O-B3 are the observable indicators corresponding to the latent variable "other-blame", and A1 to A3 correspond to the latent variable "anger". Only the gamma parameter, showing the effect from HRV to the other-blame factor, both in time and frequency domain models, differed between the non-intentional eliciting situation and the intentional eliciting situation

cognitive (other-blame) and emotional (anger) factors were all significant and different from zero but were the same for both groups and similar for both HRV indexes.

Regarding the structural loads, the beta parameter indicating the effect of the other-blame factor on anger was significant and similar for the intentional and non-intentional groups ($\beta = 0.61$, $z = 4.19$, $p < 0.001$ for the HRV time domain index; $\beta = 0.61$, $z = 4.\ 24$, $p < 0.001$ for the HRV frequency domain index). The only difference between groups was in the load of the path from the HRV to the other-blame factor. When the constraint of equality was removed and different values were permitted for each group on this path, a standardized value of 0 was obtained for the non-intentional group compared with a $\beta = -0.55$ ($z = -3.39$, $p < 0.001$) (in the time domain index) and $\beta = -0.43$ ($z = -3.54$, $p < 0.001$) (in the frequency domain index) for the intentional group. This result indicates that, in an explicit intentional situation, participants with higher HRV evaluated the protagonist as being less to blame in comparison to those with lower HRV.

Regarding the value of the estimated mean for anger in the non-intentional group with respect to the fixed zero-value in the intentional group, no significant difference was obtained (*difference* = 0.06; $z = 0.06$, ns) for the HRV time domain index ($z = 0.23$, ns); for HRV frequency domain index. However, the mean value of the other-blame factor was significantly lower in the non-intentional group than in the intentional group (*difference* = −6.23; $z = -8.77$, $p < 0.001$).

The structural analysis showed a good fit, as reflected by the lack of significance ($\chi^2(36) = 35.87$, ns). In this type of model, the absence of significance must be understood as evidence of the goodness-of-fit between the proposed model and the real data. Conversely, the presence of significance would mean that the two data matrices were significantly different and that the proposed structural model was therefore not supported by the data. Moreover, the magnitudes of the other fit indexes, the so-called incremental indexes, were satisfactory (NFI = .85, NNFI = 0.98, CFI = 0.98 and RMSEA = 0.05). The first three indexes are considered to estimate the distance between the statistical value of the fitted model and that of the null model; their closeness to 1 indicates that they are highly satisfactory. As regards the RMSEA index, Hu and Bentler (1999) stated that acceptable models must produce RMSEA values lower than or equal to 0.07.

Hence, on the basis of these data, a reasonably satisfactory prediction can be obtained. Examination of the paths in the model leads to the conclusion that, although perception of other-blame continues to influence the emotion in the same way, this variable is differentially influenced by the HRV according to the intentionality of the eliciting situation. In situations of intentionality, subjects with high HRV make less extreme evaluations of the blame of the protagonist than do those with lower HRV.

Discussion

Our results indicate that, in situations of high intentionality, HRV affects the perception of other-blame, which in turn affects emotion. No direct path was found between HRV and emotion. Specifically, HRV acted by influencing subjects' evaluation of perceived other-blame. Perception of other-blame then acted by influencing subjects' feeling of anger.

The core relational theme of other-blame has previously been linked with anger (Smith et al. 1993; León and Hernández 1998), but the present study suggests a more complex relationship. As predicted, higher HRV acted as a factor that tempered the evaluation of other-blame, which in turn reduced anger. This effect of HRV was only evident under the experimental condition of intentionality, suggesting that the beneficial effect of HRV is greater under conditions of higher tension or stress.

The finding that the protective function of HRV was only evident under the intentionality condition is consistent with previous reports relating vulnerability and protection factors to situational stress (Fabes and Eisenberg 1997; Rutter 1990). HRV showed a protective function when there was a high level of intentionality by the offender. It was only under this condition that individuals with higher HRV showed a more rational interpretation of the situation. In contrast, individuals with lower HRV failed to make a cool appraisal of the situation, enhancing their perception of blame and consequently increasing their feeling of anger.

The present results are also consistent with recent theories of vagal control and emotional regulation (Porges 1995, 2007; Thayer and Lane 2000). According to Porges' Polyvagal Theory, "increased vagal action on the heart reduces cardiac output and creates a physiological state that promotes the calm behavioral profile necessary to sustain interactions with people and objects". Efficient vagal regulation, as indexed by high HRV in the respiratory frequency band, appears to facilitate coping with stress and to be related to positive engagement strategies (Porges 2007; Bazhenova et al. 2001). The Neurovisceral Integration Theory proposed by Thayer and Lane assumes a similar role for HRV, stating that "individuals with high HRV would be more able to best match their response to situational demands and thus respond most appropriately to the situation" (Thayer and Brosschot 2005). They argue that the neural networks that regulate autonomic balance are closely related and partially overlap with networks that regulate goal-directed behavior and adaptability.

In our study, HRV did not influence emotion directly but rather by the regulation of cognitions that are at the origin of a more appropriate emotional response. This result helps to clarify the status of cognitions in relation to emotion regulation. Several models postulate that cognitive control of emotion occurs via prefrontal modulation of subcortical structures that directly control emotional expression and goal-directed behavior (Spyer 1989; Mastermam and Cummings 1997; Damasio 1998; Thayer and Lane 2000; Phan et al. 2002; Oschner and Gross 2005). Although the data are still limited and it is difficult to draw firm conclusions on specific control systems, the prefrontal cortex (PFC), orbitofrontal cortex (OFC), and anterior cingulate cortex (ACC) appear to be specifically involved in the modulation of emotional appraisal systems, "activated either (i) by high-level expectations concerning beliefs about, and interpretations of, stimuli, or (ii) by learning to associate new emotional responses with stimuli" (Oschner and Gross 2005, p. 245). Activity in the medial prefrontal cortex (MPFC) has been shown to correlate with externally generated and recalled emotions, suggesting its role in cognitive aspects of emotional processing (e.g., attention to emotion, appraisal/identification of emotion) (Phan et al. 2002). The ACC, which is closely interconnected with the MPFC, is also known to be involved in the cognitive regulation of emotion. Both structures are considered to serve as top-down modulators of intense emotional responses via connections with subcortical limbic structures, e.g., the amygdala (Phan et al. 2002). A similar relationship has been reported between the prefrontal cortex and HRV (Lane et al. 2001).

Our findings have theoretical and practical implications for other research areas related to anger regulation. One of these areas is psychopathology. Several studies have reported associations between poor vagal regulation (low HRV and low vagal suppression) and behavioral problems (Bazhenova et al. 2001; El Sheikh and Whitson 2006; El Sheikh 2001; Porges 1995; DeGangi et al. 1991). In general, low HRV and low vagal suppression have been associated with increased psychopathology and social problems in children and adolescents. In contrast, high HRV and high vagal suppression have been found to be protective against the development of behavioral problems. It would be interesting to test whether these positive effects of HRV, which appear to support a direct effect on behavior and emotion, are also accompanied by cognitive changes, as in the present study. In our case, however, no direct effect of HRV on emotion was found. HRV acted as a regulatory tool that modulated cognitions, helping people to be more tolerant or understanding in other-blame situations, thereby promoting forgiveness and a lesser anger reaction. Forgiveness is indeed another related area since it can be considered basically the opposite of other-blame. Several studies have shown that people receiving a forgiveness intervention describe significant increases in positive feelings towards the offender as well as significant decreases in grief, anger, and desire for revenge (Coyle and Enright 1997; Hebl and Enright 1993; Freedman and Enright 1996; McCullough and Worthington 1997).

In summary, a higher HRV was associated with a lower perception of other-blame after an interpersonal offense, although this association was only significant under conditions of high intentionality by the offender. In this context, HRV emerges as a direct index of cognitive rather than emotional regulation, affecting anger indirectly via its influence on a cognitive variable, perception of other-blame.

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