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### Title

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### Permalink

<https://escholarship.org/uc/item/61n1711q>

### Journal

Psychophysiology, 48(4)

### ISSN

1540-5958

### Authors

Ottaviani, Cristina  
Shapiro, David  
Fitzgerald, Leah

### Publication Date

2011-04-10

Peer reviewed

## Rumination in the laboratory: What happens when you go back to everyday life?

CRISTINA OTTAVIANI,<sup>a</sup> DAVID SHAPIRO,<sup>b</sup> AND LEAH FITZGERALD<sup>c</sup>

<sup>a</sup>Department of Psychology, University of Bologna, Bologna, Italy

<sup>b</sup>Department of Psychiatry, University of California, Los Angeles, Los Angeles, California, USA

<sup>c</sup>School of Nursing, University of California, Los Angeles, Los Angeles, California, USA

### Abstract

Rumination has been suggested to mediate the physiological consequences of stress on health. We studied the effects of rumination evoked in the laboratory and subsequent changes over 24 h. Heart rate (HR) and systolic and diastolic blood pressure (SBP, DBP) were monitored in 27 male and 33 female participants during baseline, reading, an anger recall interview, and recovery. Half of the sample was assigned to a distraction condition. The lab session was followed by a 24-hour ambulatory (A)HR and BP recording and self-reports of moods and rumination. Rumination was associated with higher SBP, DBP, and HR and increased negative mood compared to distraction. Rumination during the day was a strong predictor of AHR, ABP, and mood. BP reactivity in the laboratory and increases in ABP during rumination were related. The effects of negative cognition on health go far beyond the recovery periods usually measured in the laboratory, thus playing a pathogenic role.

**Descriptors:** Rumination, Distracter, Ambulatory, Moods, Cardiovascular

The “reactivity hypothesis” posits that people who are at risk for cardiovascular diseases are likely to be hyperreactive to stressors (Schwartz et al., 2003). A recent meta-analysis of prospective evidence (Chida & Steptoe, 2010) showed that greater reactivity to stress is associated longitudinally with poor cardiovascular status, including elevated blood pressure (BP), hypertension, left ventricular mass, subclinical atherosclerosis, and clinical cardiac events. Recent findings, however, suggest the need to improve this concept. It is now considered adaptive to react when we have to face a stressful event, but hyperreactivity becomes maladaptive if it continues when the source of stress is no longer present (Brosschot, Gerin, & Thayer, 2006). A clear example is provided by the recurrent physiological activation that has been associated with perseverative cognitions evoked by past stressful or anger-provoking events, that is, rumination (Rusting & Nolen-Hoeksema, 1998). Gerin, Davidson, Christenfeld, Goyal, and Schwartz (2006) proposed a theoretical model in which prolonged anger may promote ruminative thoughts, and increased autonomic arousal may prolong anger, with these two processes operating as a feed-forward process. This hypothesis is consistent with the findings of slower physiological recovery following personally relevant negative stressors (Glynn, Christenfeld, & Gerin, 2002) and with the findings that a distracter reduces the

negative effects of rumination on sustained physiological activation (Rusting & Nolen-Hoeksema, 1998). It is likely that this recurrent and prolonged activation, rather than a single spike of activation, is more relevant as a potential risk factor in the gradual development of cardiovascular disease.

One experimental task that has been demonstrated particularly effective in evoking ruminative thoughts is the anger recall interview (Ironson et al., 1992). Although instructions for the interview vary across studies, all of them report greater cardiovascular arousal and negative affect (Greeson et al., 2009; Prkachin, Mills, Zwaal, & Husted, 2001; Suarez, Saab, Llabre, Kuhn, & Zimmerman, 2004) compared to the effects of other commonly used laboratory stressors. The anger recall interview is an effective tool for evaluating emotional and physiological response differences, but it poses methodological issues that must be taken into consideration when evaluating sympathetic nervous system arousal. With the exceptions of the speech stressor (Saab, Matthews, Stoney, & McDonald, 1989) and mental arithmetic (Glynn et al., 2002), the anger recall interview differs significantly from traditional laboratory stressors in the degree of vocalization required from the participants. Vocalization alone, in the absence of emotional content, has been shown to elicit significant hemodynamic responses (Girdler, Turner, Sherwood, & Light, 1990; Lynch, Long, Thomas, Malinow, & Katcher, 1981). To account for the degree of sympathetic arousal associated with vocalization, in the first phase of the study we compared the effects of anger recall with the effects of a neutral speaking control condition, a reading task.

A commonly used way to manipulate rumination after the recall task is to distract half of the sample (Gerin et al., 2006; Glynn et al., 2002; Rusting & Nolen-Hoeksema, 1998). In the

The authors thank Sarah Lee, Dave Bugayong, and Xiao Chen, Statistical Consulting Group, UCLA Academic Technology Services for their assistance.

Address correspondence to: Cristina Ottaviani, Dipartimento di Psicologia, viale Berti Pichat, 5 – 40127 Bologna, Università degli Studi di Bologna, Italy. E-mail: cristina.ottaviani@unibo.it

present study, the experimenter pretended to receive a phone call right after the interview as a distracter. We considered this more realistic and ecological compared to the distracters that have been usually employed, such as puzzles or graphic effects on a computer screen. Thus, the first aim of this study was to replicate the important findings of others that a distracter after anger recall is effective in speeding cardiovascular recovery.

Our second and main purpose was to examine the consequences of perseverative cognition on cardiovascular responses outside the laboratory. In fact, in order to be pathogenic, rumination has, indeed, to be associated with sustained physiological activity in the laboratory but primarily with this sustained activity in everyday life. A major shortcoming in reactivity-based research is the failure to capture laboratory-to-life generalizability (Carroll et al., 2001). Cardiovascular reactivity in the laboratory, together with the recovery that immediately follows the end of a negative event, provides us with a small window inside a wider and chronic pattern of stress response. Portable instrumentation makes the recording of cardiovascular changes possible in everyday life and allows us to capture the presence of physiological alterations exactly at the moment when they are likely to happen, that is, in response to environmental demands. The diary is the instrument that allows us to get information on these environmental stimuli and the real-time subjective response to them. Although laboratory studies have yielded suggestive evidence that slow cardiovascular recovery after emotional stress is due to worry or rumination, only two studies have tested this hypothesis in everyday life (Brosschot, Van Dijk, & Thayer, 2007; Pieper, Brosschot, van der Leeden, & Thayer, 2007). The first study showed the direct effects of worry on cardiac activity during both waking and subsequent nocturnal sleep, thus demonstrating that these responses extend even into periods in which “concrete” stressors are absent. The second study further confirmed that worry in daily life has substantial cardiac effects in addition to the immediate effects of stressful events, especially during work-related and anticipatory stress.

By using an ambulatory session that immediately followed the laboratory phase, we were able (1) to test if participants who are characterized by greater reactivity to the anger recall task and to the ruminative thoughts evoked in the laboratory also show higher cardiovascular reactivity to rumination during the day and (2) to examine the relationship between daily rumination and ambulatory BP and heart rate (HR).

As previous ambulatory studies on rumination focused on cardiac activity, this is the first study to study the effect of daily rumination on BP in an ecological environment. Moreover, in the recent literature on ruminative thoughts and cardiovascular mechanisms, the link between the tendency to ruminate and concurrent mood has not been studied. If rumination is accompanied by negative affect, we can expect it to have an impact on the moods experienced during the day. Considering the role played by daily experiences of negative moods in determining higher BP levels (Shapiro, Jamner, Goldstein, & Delfino, 2001), we can hypothesize that the tendency to ruminate affects ambulatory BP by worsening daily mood. Thus, we examined the relationship between mood states and ruminative thoughts occurring during the day following the laboratory session.

Finally, we tested if the tendency to ruminate as a personality trait (Porter, Stone, & Schwartz, 1999) has an effect on daily frequency and duration of rumination episodes, frequency of rumination episodes about the content of the laboratory task, and ambulatory cardiovascular parameters.

## Methods

### Sample Description

Participants were recruited in the general community using ads and flyers and via weekly updated postings on Craig’s List, an online classified advertisement system. Exclusionary criteria were psychiatric disorders, diagnosis of hypertension or heart disease, history of cancer, pulmonary problems, active chronic infections, autoimmune diseases (e.g., rheumatoid arthritis, multiple sclerosis), diabetes, endocrine disorders, immunosuppression resulting from a disease (e.g., malignancy, HIV infection), use of drugs or medications that might affect cardiovascular function and/or catecholamines, obesity (body mass index  $>32 \text{ kg/m}^2$ ), menopause, use of oral contraceptives during the previous 6 months, and pregnancy or childbirth within the last 12 months. The sample was composed of 27 men (mean age =  $31.8 \pm 10.1$  years; age range 21–54 years), 5 Asian, 13 Caucasian, 2 African, and 7 Latino Americans, and 33 women (mean age =  $34.7 \pm 8.6$  years; age range 20–54 years), 7 Asian, 10 Caucasian, 15 African, and 1 Latino American. Participants were paid \$100. The protocol was approved by the University of California, Los Angeles, Institutional Review Board.

### Procedure

The laboratory session took place between 7:00 a.m. and 12:00 p.m. Participants were asked to refrain from drinking alcohol, tea, or coffee and strenuous exercise the morning of testing. After providing written informed consent, participants were seated in a comfortable chair and instrumented for electrocardiogram (ECG) and continuous BP monitoring. The laboratory protocol consisted of an initial 10-min baseline period, followed by a 5-min reading task in which participants were instructed to read aloud a passage about the ocean using “a normal tone of voice and normal rate of speech.” To ensure minimal emotional arousal, participants were informed that they would not be evaluated for reading style or comprehension. The reading task was followed by a 10-min rest period and a 5-min anger recall interview. Participants were asked to verbally describe a personal event that occurred within the last 3 to 4 months that elicited anger and “when thinking about it today” continues to arouse anger (Ironson et al., 1992). After a 1-min period for preparation, participants were asked to verbally describe the event to the experimenter for approximately 5 min. To assist the participant in recalling the event, the experimenter used prompts, such as “How did that make you feel when it happened?” The session ended with a 10-min resting period. During the first 2 min of this resting period, half the sample was randomly assigned to the distraction condition, in which the laboratory phone rang, the experimenter went into an adjacent room leaving the door open, and spoke loudly about job issues for approximately 2 min. For the nondistracted subjects the experimenter left the room and closed the door. Affect ratings were collected at baseline and at the end of each recovery period.

At the end of the laboratory session, participants were instructed about the use of the diary and the Accutacker II (Suntech Medical Instruments, Raleigh, NC) ambulatory BP and HR device. The electrodes and apparatus were attached, and the participants left the laboratory. The next morning, the participants returned the diary and apparatus to the laboratory, filled out the personality questionnaire, were debriefed, and received monetary compensation.

### Psychophysiological Assessment

ECG was monitored with a multitrace recorder (AcqKnowledge, Biopac System, Santa Barbara, CA) and a standard electrode configuration (right clavicle and precordial site V6). Three disposable Ag-AgCl electrodes (ConMed Corp.) were used.

Beat-to-beat BP was measured noninvasively using a Finapres Continuous NIBP Monitor (Ohmeda, Englewood, CO) via a finger cuff attached to the third finger of the nondominant hand. The Finapres has been shown to be a suitable device for reliable tracking of changes in BP (Imholz, Wieling, van Montfrans, & Wesseling, 1998).

### Affect Ratings

Participants' affect ratings were collected immediately following baseline and after the recovery periods following the reading and anger recall tasks. Participants were asked to rate their level of arousal using a 5-point Likert scale with 1 representing *not at all* and 5 representing *very strong feelings* for the following affects: stressed, happy, irritated, sad, frustrated, relaxed, depressed, optimistic, tired, anxious, annoyed, calm, aggravated, cool, and angry.

### State and Trait Rumination

At the end of the recovery period following the anger recall, participants were asked to report if they had been thinking back about the content of the interview throughout the 10-min period following the task. This information (yes/no) was used as an indicator of the presence of rumination as a state.

The Stress-Reactive Rumination Scale (SRRS) was administered at the end of the ambulatory session as a measure of the tendency to ruminate after stressful events. The scale was designed to measure rumination in a manner that is not confounded with depressive symptoms, a limitation of many other self-report rumination scales (Robinson & Alloy, 2003). The scale has the following subscales: Negative Inferential Style, Hopelessness, and Active Problem-Solving.

### Ambulatory Assessment

Ambulatory 24-h systolic and diastolic BP (SBP, DBP) were obtained during a work day. The Accutacker II has been widely used with established reliability and validity in clinical and research studies (Jyothinagaram, Watson, & Padfield, 1990). The Accutacker II was programmed to operate at varying intervals approximately every 20 min during waking hours and once an hour during sleep. Ambulatory data were edited for artifacts based on Accutacker reading error codes, insufficient electrocardiogram or Korotkoff sounds, and extreme values ( $> 200/120$  or  $< 70/40$  mm Hg). We obtained a mean number of 41.2 ( $SD: 8.8$ , median: 42, range: 26–61) readings per subject. Given the reasonable number of readings, all subjects were included in the analysis. The average number of rumination readings per subject was 12.2 ( $SD: 6.9$ , median: 11, range: 2–34).

### Diary

Participants were provided with a paper-and-pencil diary that had the definition of rumination as "the process of thinking perseveratively about one's feelings and problems" on the first page. Each time they felt the BP cuff inflate during waking hours, participants were asked to complete the diary. Each entry asked for the presence and duration of rumination, stressors, or both during the preceding entry period and information on factors that may affect BP, including posture, physical activity, and food, caffeine, nicotine, and alcohol consumption since the last

diary report. Ruminative thought frequency was measured by the number of times the presence of intrusive ruminative thoughts were reported divided by the total number of readings. Rumination duration was noted by the participant for each rumination episode using the following scale: 0–1 min, 1–5 min, 5–20 min, or more than 20 min. Participants reported the last option (more than 20 min) if they did not stop ruminating since the previous BP measurement. If participants reported ruminating, they were also asked to report if it was on the content of the laboratory task. Stressors were assessed by asking participants whether they experienced one or more annoying or disturbing events in the preceding period (for a positive answer, they were also asked to describe the events). On each cuff inflation, participants also rated moods (stressed, happy, irritated, sad, frustrated, relaxed, depressed, optimistic, tired, anxious, annoyed, calm, aggravated, cool, and angry) using a 5-point scale from *not at all* to *very much*.

### Statistical Analyses

All data are expressed as means ( $SD$ ). Differences at  $p < .05$  were regarded as significant. Laboratory data processing and data analyses were performed with the software modules of Systat 9.0 (Systat Software Inc., Richmond, CA).

Reactivity change scores ( $\Delta$ ) were computed by subtracting the initial baseline average value from each average task value. Recovery scores were determined by subtracting the mean level obtained during the baseline from the average level measured during the recovery period after each task. Averages for baseline, tasks, and recovery were computed for each entire time period (10, 5, and 10 min, respectively). Raw change scores were used instead of residuals (Llabre, Spitzer, Saab, Ironson, & Schneiderman, 1991). To have a more reliable measure, recovery was also computed according to the method suggested by Christenfeld, Glynn, and Gerin (2000; "Curve Fitting Technique").

With regard to moods, five representative moods (happy, stressed, tired, anxious, and angry) were selected following the methodology used by Shapiro et al. (2001). Based on exploratory principal components analysis, the authors chose one negative word (stressed), one positive word (happy), and one indicator of energy level (tired). We also included anxious and angry because of the commonly explored role of anxiety and anger in BP regulation. For the same reason, the mood "sad" was added because of the role played by depression in rumination, cardiovascular activity, and health.

To evaluate the effects of sociodemographic factors, Pearson correlations were performed between BMI, age, physical activity, caffeine, alcohol, nicotine consumption, and baseline levels of each physiological variable.

Differences due to gender and ethnicity were analyzed by  $t$  test and analysis of variance (ANOVA).

To control for the presence of preexisting differences between the distraction and the nondistraction subgroups, the groups were compared by  $t$  tests for the following variables: age, rumination tendencies (total and subscale scores of the SRRS), habitual consumption of caffeine, nicotine, and alcohol, and baseline levels of SBP, DBP, and HR. Chi square comparisons were conducted for gender, ethnicity, and moods at baseline.

To determine the effectiveness of the anger recall interview in inducing psychophysiological activation compared to baseline and to the neutral reading task that acted as a control for vocalization, ANOVAs with task as a repeated measure (baseline, anger recall, reading) were conducted for HR, SBP, DBP, and

each mood. To evaluate the effectiveness of the distracter condition in determining greater recovery to baseline levels after the anger recall task, *t* tests by group were performed on change scores for each physiological and mood variable.

To test the relationship between cardiovascular reactivity and rumination in the laboratory and in daily life, Pearson correlations were performed between laboratory SBP, DBP, and HR reactivity and recovery change scores and ambulatory SBP, DBP, and HR change scores (rumination periods minus nonrumination periods) for the nondistracted participants. To test the effect of the distraction condition outside the laboratory, *t* tests by group were performed on frequency and duration of daily rumination episodes, frequency of rumination about the anger recall topic, and ambulatory SBP, DBP, and HR.

To determine the effects of trait rumination, Pearson correlations were performed between scores on the SRRS (total score and subscales) and frequency and duration of daily rumination episodes and frequency of rumination about the anger recall topic.

Random effects regression models are the most appropriate methods of analysis for the relationship between daily rumination and ambulatory BP and HR, as the ambulatory measures consist of repeated measures of SBP, DBP, HR, and diary variables (Shapiro et al., 2001). PROC MIXED (SAS Institute) was the program employed for general linear mixed modeling. This approach is particularly suitable, as the periodicity of rumination periods, moods, and physiological measurement is likely to be highly heterogeneous, and it also deals with missing values. Because it models each participant as a random effect, using this procedure accommodates interindividual variation in rumination–mood–BP or rumination–mood–HR relationships. At this step, only the bibehavioral variables that had a significant bivariate correlation with a given cardiovascular variable were entered, because the number of measured bibehavioral variables was so large that entering them all would greatly decrease the degrees of freedom for the present sample size. As to posture, under conditions controlled for activity level, sitting and standing BP differ only slightly (Goldstein & Shapiro, 1988), and there is no basis for assuming that mood is related to BP as a function of specific bodily position. Slight differences in sample sizes are due to missing values for some of the variables. First, rumination was related to each dependent variable: SBP, DBP, and HR during wake. Then, rumination was related to each single mood. To derive the variance of daily BP, HR, and moods accounted for by rumination in each model, the random effects regression models (Proc Mixed) required the use of the “Pseudo R-Squared method,” as recommended by Singer and Willett (2003).

To correct for multiple comparisons, Pearson correlations, post hoc tests, and *t* tests have been performed with the use of the “Bonferroni correction” option provided by Systat. Adjusted *p* values are presented. By default, PROC MIXED adjusts all pairwise differences.

## Results

### Sociodemographic and Trait Characteristics

Pearson correlations showed an association between BMI and baseline SBP ( $r = .32$ ;  $p = .01$ ). No associations were found for age, caffeine, alcohol, nicotine, exercise, and baseline physiological levels. Baseline differences between the distracted and the

**Table 1.** Sociodemographic Characteristics

	Distracted ( $n = 30$ )	Nondistracted ( $n = 30$ )
Age (years)	34.1 (9.8)	32.7 (9.3)
BMI (kg/m <sup>2</sup> )	25.3 (5.1)	24.8 (6.2)
Education (years)	15.1 (3.2)	15.9 (3.3)
Income <sup>a</sup>	2.4 (1.5)	2.1 (1.1)
Caffeine (cups/day)	1.0 (1.3)	0.8 (1.2)
Alcohol (glasses/week)	3.6 (3.7)	4.4 (6.5)
Physical activity (h/week) <sup>b</sup>	11.7 (7.9)	8.9 (6.8)
Smoking status	20 never, 5 past, 5 present	20 never, 6 past, 4 present

<sup>a</sup>1 = <\$20,000; 2 = \$20,000–\$35,000; 3 = \$35,000–\$50,000; 4 = \$50,000–\$65,000; 5 = \$65,000–\$80,000; 6 = \$80,000–\$95,000; 7 = >\$95,000.

<sup>b</sup>Subjects were asked to indicate the types and amounts of exercise they did (hours/week) among the following: household chores; golf, softball, & baseball; yoga & stretching; tennis, handball, & other active sports; walking & dancing; jogging, running, & swimming; weight lifting; other.

nondistracted groups were not significant for the examined variables (see Table 1).

No gender differences emerged.

Significant ethnicity differences appeared for ambulatory SBP,  $F(3,56) = 3.95$ ,  $p = .01$ , and DBP,  $F(3,56) = 4.84$ ,  $p = .001$ , during wake. Post hoc comparisons showed that African Americans had higher ambulatory SBP during wake (126.2 mm Hg) than Caucasians (118.4 mm Hg) and Asians (110.4 mm Hg), but no differences emerged with Latinos (124.8 mm Hg). African Americans had also higher ambulatory DBP during wake (75.8 mm Hg) compared to Asians (66.2 mm Hg).

Trait rumination did not have an effect on frequency or duration of rumination episodes or frequency of rumination episodes about the content of the anger recall interview or ambulatory BP or HR.

### Laboratory Findings

The repeated measures ANOVAs revealed a significant effect of task for SBP,  $F(2,58) = 164.77$ ,  $p < .0001$ , DBP,  $F(2,58) = 143.68$ ,  $p < .0001$ , HR,  $F(2,58) = 42.15$ ,  $p < .0001$  (see Figure 1). Pairwise *t* tests indicated that the anger interview led to greater activation compared to baseline for SBP,  $\Delta = 18$  mm Hg,  $t(1,59) = -13.13$ ,  $p < .0001$ , DBP,  $\Delta = 13$  mm Hg,  $t(1,59) = -13.03$ ,  $p < .0001$ , and HR,  $\Delta = 6$  bpm,  $t(1,59) = -9.79$ ;  $p < .0001$ , and compared to the reading task for SBP,  $\Delta = 18$  mm Hg,  $t(1,59) = -13.54$ ,  $p < .0001$ , DBP,  $\Delta = 13$  mm Hg,  $t(1,59) = -12.61$ ,  $p < .0001$ , and HR,  $\Delta = 3$  bpm,  $t(1,59) = -4.04$ ,  $p < .0001$ .

With regard to moods, the repeated measures ANOVAs revealed a significant effect of task for the following moods: happy,  $F(2,58) = 15.64$ ,  $p < .0001$ , stressed,  $F(2,58) = 15.95$ ,  $p < .0001$ , angry,  $F(2,58) = 31.02$ ,  $p < .0001$ , tired,  $F(2,58) = 5.66$ ,  $p < .001$ , and sad,  $F(2,58) = 7.63$ ,  $p < .001$  (see Figure 2). Anxious,  $F(2,58) = 0.40$ ,  $p = .67$ , did not yield a significant effect. Specifically, participants were less happy and more stressed, angry, tired, and sad after the anger recall interview compared to baseline and to the reading task. No differences between baseline and the reading task emerged. Table 2 shows means and standard deviations for each mood in the three conditions.

Twenty-eight out of 30 participants (93.3%) assigned to the distracter condition reported having not thought about the event during the recovery period following the anger recall, whereas all

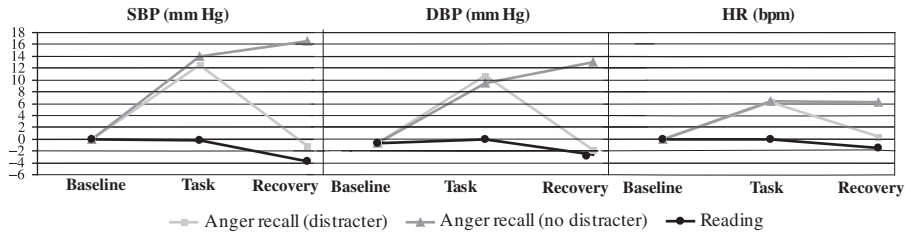


Figure 1. Effects of task (anger recall, reading) and distracter on change scores from baseline for HR, DBP, and SBP.

participants who were assigned to the nondistracter condition thought back about that specific event during the 10 min following the interview. Thus, self-reported state rumination during recovery depended on the presence/absence of the distracter.

The distracter condition was effective in determining greater recovery to baseline values (smaller change scores) compared to the nondistracter condition for SBP,  $t = 9.31, p < .0001$ , DBP,  $t(2,58) = 9.20, p < .0001$ , and HR,  $t(2,58) = 6.94, p < .0001$ . Figure 1 shows the effects of task (anger recall, reading) and distracter on change scores from baseline for each of the examined physiological variables. The use of the curve fitting technique did not significantly change the results.

The distracter condition was effective in determining a change in moods compared to baseline values (change scores) compared to the nondistracter condition for angry,  $t(2,58) = 5.12, p < .0001$ , happy,  $t(2,58) = -4.20, p < .0001$ , and stressed,  $t(2,58) = 4.79, p < .0001$  (see Figure 2) and was not effective for tired, anxious, and sad. Specifically, there was an increase in happy levels (-0.1 vs. -1.2) and a decrease in angry (0.3 vs. 1.5) and stressed (-0.1 vs. 1.2) levels.

**Ambulatory Findings**

Table 3 shows mean ambulatory SBP, DBP, and HR, mood intensity, stressor frequency, and rumination frequency and duration. Preliminary analyses showed significant effects only for age and BMI in determining ambulatory cardiovascular measures. Consequently, only these two biobehavioral variables were included as covariates in the random effects regression models.

Pearson correlations showed an association between SBP and DBP reactivity during the anger interview and ambulatory SBP and DBP change scores between rumination and nonrumination periods,  $r = .38, p = .04$ , and  $r = .61, p < .0001$ , respectively. For the nondistracted subsample, partial correlation analyses were performed to control for the effect of reactivity on the relationship between SBP and DBP recovery after the interview and

ambulatory SBP and DBP change scores between rumination and nonrumination periods.

Rumination about the task was higher in nondistracted participants (50%) compared to distracted participants (30%), but the difference was not significant. Among all rumination episodes, the daily mean percentage of those related to the content of the anger interview was 43%. Daily moods and ambulatory SBP, DBP, and HR were not significantly different for distracted and nondistracted participants.

The first random effects regression model tested the effect of daily state rumination on ambulatory SBP, DBP, and HR during wake. Age was not a significant predictor in the model. BMI had a significant effect on SBP and DBP,  $F(1,2381) = 22.13, p < .0001$ , and  $F(1,2381) = 12.08, p = .0005$ , respectively. After controlling for the effects of age and BMI, rumination was a significant predictor in the model,  $F(1,2381) = 1541.9, p < .0001, \Delta R^2 = .29$  for SBP,  $F(1,2381) = 594.3, p < .0001, \Delta R^2 = .18$  for DBP, and  $F(1,2375) = 22.13, p < .0001, \Delta R^2 = .05$  for HR. Figure 3 shows relationships between rumination, SBP, DBP, and HR.

The second random effects regression model tested the effect of daily state rumination on daily moods. Rumination was a significant predictor of moods for levels of stressed,  $F(1,2375) = 831.27, p < .0001, R^2 = .18$ , happy,  $F(1,2375) = 503.67, p < .0001, R^2 = .09$ , sad,  $F(1,2375) = 166.13, p < .0001, R^2 = .04$ , anxious,  $F(1,2375) = 115.66, p < .0001, R^2 = .05$ , and angry,  $F(1,2375) = 1315.08, p < .0001, R^2 = .35$ . Specifically, participants rated themselves as more stressed, angry, anxious, and sad and less happy during rumination compared to nonrumination periods (Figure 4).

**Discussion**

Our study replicated previous results about the effectiveness of a distracter, in this case a simple one such as occurs in everyday life—a phone call—to stop rumination and speed cardiovascular recovery. Moreover, the findings showed that rumination

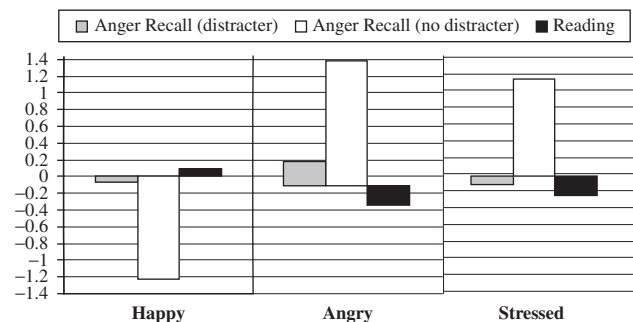


Figure 2. Effects of task (anger recall, reading) and distracter on mean mood rating (change scores from baseline).

Table 2. Mean and Standard Deviation of Each Mood during Baseline and after Recovery from the Reading Task and the Anger Recall Interview

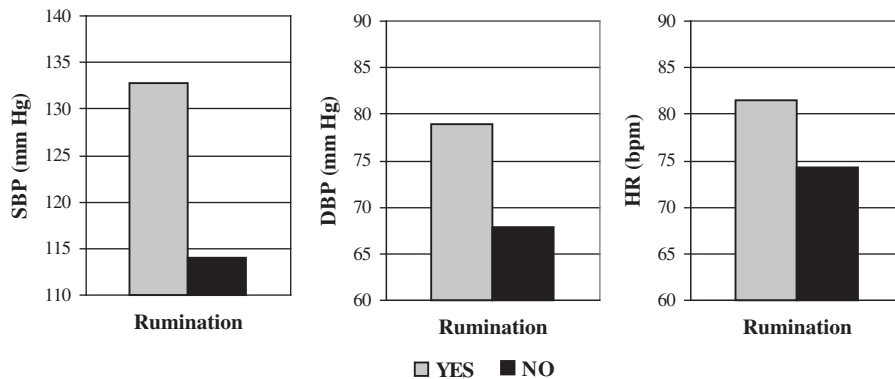
	Baseline	Reading	Anger
Happy	3.4 (1.0)	3.4 (1.0)	2.7 (1.2)
Stressed	2.1 (1.0)	1.8 (1.0)	2.6 (1.3)
Angry	1.2 (0.5)	1.2 (0.6)	2.1 (1.1)
Anxious	2.2 (1.3)	2.1 (1.2)	2.1 (1.3)
Sad	1.4 (0.8)	1.4 (0.8)	1.8 (1.1)
Tired	2.7 (1.4)	2.7 (1.4)	2.4 (1.3)

**Table 3.** Mean, Standard Deviation and Range for Ambulatory Variables

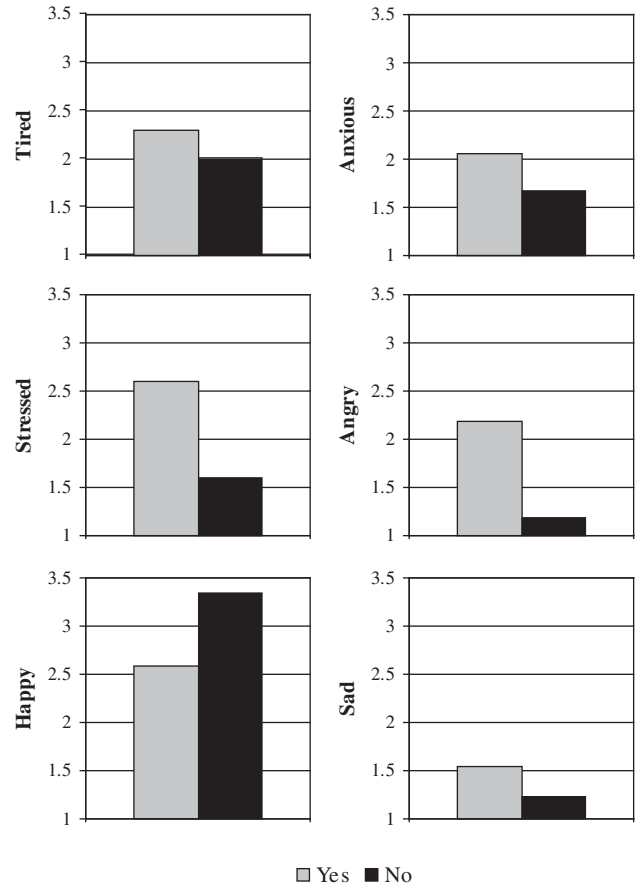
	Mean (SD)	Range
HR wake	76.3 (8.9)	51.9–93.5
HR sleep	66.3 (10.7)	48.4–91.0
SBP wake	119.9 (11.3)	99.6–148.1
SBP sleep	106.9 (15.5)	82.2–149.3
DBP wake	71.3 (6.4)	57.9–85.8
DBP sleep	60.0 (7.6)	44.5–84.5
Stressful events (freq.)	0.2 (0.2)	0–0.8
Rumination		
Duration	0.6 (0.4)	0.1–2.1
Frequency	0.3 (0.2)	0–0.7
Task	0.4 (0.4)	0–0.8
Mood		
Happy	3.1 (0.9)	1.1–4.8
Stressed	1.9 (0.7)	1.0–4.6
Angry	1.5 (0.4)	1.0–2.9
Anxious	1.8 (0.7)	1.0–4.3
Sad	1.3 (0.5)	1.0–2.8
Tired	2.2 (0.9)	1.0–4.8

Note: Rumination duration is the average duration for the times participants were ruminating before each reading (1 = 0–1 min; 2 = 1–5 min; 3 = 5–20 min; 4 = more than 20 min). Frequencies for stressful events and rumination periods were computed by the number of times the event/rumination occurred by the total number of readings. Frequency for rumination on task was computed by dividing the number of episodes dedicated to rumination on the laboratory task by the total number of rumination periods. Moods ratings are the means of the intensity ratings for each mood (1 = not at all; 5 = very much).

outside the laboratory was associated with large increases in ambulatory SBP and DBP, 19 mm Hg and a 11 mm Hg, respectively, after statistical adjustments for age and BMI. This result is particularly intriguing if we consider the prognostic value of BP for the development of cardiovascular disease (Boggia et al., 2007), and that a 10 mm Hg change is the target to evaluate the efficacy of antihypertensive medications (Ishikawa, Carroll, Kuruvilla, Schwartz, & Pickering, 2008). We also showed a relationship between BP reactivity to the anger interview in the laboratory and ambulatory BP increases from nonrumination to rumination periods in daily life. The present data suggest that individuals have a cardiovascular reaction of about the same magnitude when they ruminate about an emotional episode as when they talk about it in detail. Thus, in terms of cardiovascular arousal, thinking about a negative event is as stressful as the event itself.



**Figure 3.** Mean ambulatory SBP, DBP, and HR for the periods that participants were ruminating or not, adjusted for age and BMI.



**Figure 4.** Mean mood rating for the periods that participants were ruminating or not ruminating.

With regard to laboratory findings, reading aloud determined a lower level of activation compared to the effects of the anger recall interview, as shown by the direct statistical comparison between the two tasks for change scores in cardiovascular variables. We can, therefore, conclude that vocalization by itself did not account for the cardiovascular reactivity to the anger interview and subsequent delayed recovery.

The use of a simulated phone call as a distraction condition was effective in stopping rumination. In fact, 93% of participants who were distracted reported not having thought about the recalled event during the poststress period. In contrast, 100% of



those who were not distracted had intrusive cognitions about it. It has to be acknowledged, however, that the interpretation of the effects of a distracter has been questioned by a few studies (Gerin et al., 2006; Key, Campbell, Bacon, & Gerin, 2008), in which rumination in the nondistracter condition did not explain or only partially and inconsistently (i.e., moderated by trait rumination) explained the slower cardiovascular recovery in that condition. In our study, however, besides the effects at a physiological level, participants who ruminated in the laboratory also became less happy and more stressed, angry, tired, and sad, although rumination/distraction did not have any effect on anxiety levels. This confirms the theoretical distinction between worry and rumination, where the first regards a concern for future events and is associated with anxiety- and depression-related symptoms, and the second is related to past events and seems to be characterized only by a depressed mood (Hong, 2007). Moreover, as previously noted for anger experience (Rusting & Nolen-Hoeksema, 1998), the distracter turns out to be efficient in reducing stress and anger levels and to increase self-reported happiness levels but is not sufficient to diminish sadness and tiredness levels evoked by the interview.

The phone call distraction simulation had only an immediate effect in stopping rumination: As soon as participants went back to everyday life, rumination frequency, mood, BP, and HR levels were not affected by having been distracted or not during the laboratory session. Our result of only a short-term effect of the distracter in stopping rumination is consistent with previous findings for shorter time lags (Gerin et al., 2006). In fact, these authors found that as soon as they removed the distracter during the laboratory setting, BP increased again, although not as much as during the stressful task itself. It seems plausible that these participants started to ruminate again when the distracter was no longer there. Taken together, these results have therapeutic implications, such as the ineffectiveness of distraction as a clinical practice to treat rumination.

Contrary to results from our previous study (Ottaviani, Shapiro, Davydov, Goldstein, & Mills, 2009), which indicated a stronger vagal withdrawal in women compared to men, but in agreement with other authors' findings (Glynn et al., 2002; Suarez et al., 2004), gender differences in autonomic activation were not shown during the anger recall task. It has to be noted that our previous study only required participants to think about the anger episode, whereas in the present and other studies that got comparable results, participants had to talk about this episode (Glynn et al., 2002; Suarez et al., 2004). Therefore, inconsistencies in the results could be explained by this differences in methodology.

With regard to the individual propensity to ruminate, results fail to show gender differences or associations with physiological variables. The lack of trait rumination effects found in this study could be explained by the questionnaire used to evaluate this dispositional characteristics. We chose SRRS because it is the only questionnaire that distinguishes rumination from other depressive symptoms; however, it should be noted that previous studies that showed gender differences or correlations between trait rumination and cardiovascular parameters used different questionnaires.

The present study did not show differences in the BP and HR effects of rumination due to ethnicity. Likewise, Suarez et al. (2004) failed to demonstrate ethnicity effects on catecholamines levels but did show higher BP during rumination for African Americans. Moreover, difficulties in cardiovascular recovery af-

ter a stressful task for this ethnic group were previously highlighted (Dorr, Brosschot, Sollers, & Thayer, 2007). Again, the divergence could be due to task differences, considering that the authors used the simulation of two debates to elicit rumination, and one of them was on ethnic issues. As the recalled episodes did not have any kind of ethnic connotation, the neutralization of differences between ethnic groups becomes plausible.

There are only two studies that have monitored the effects of anger induction after a time lag (Glynn, Christenfeld, & Gerin, 2007; Wimalaweera & Moulds, 2008). Wimalaweera and Moulds demonstrated the importance of focusing on one event in order to see the negative consequences of rumination after 24 h of time. Glynn et al. (2007) showed that being harassed during a mental arithmetic task leads to BP increases of the same degree when recalled after 30 min and an entire week. In both cases, subjects were required to go back to the laboratory and recall the episode during psychophysiological monitoring. Responses were not monitored during the day.

Again, only two studies (Brosschot et al., 2007; Pieper et al., 2007) monitored the relationship between spontaneous episodes of worry and ambulatory HR and HR variability. Unlike in the present study, however, rumination was not induced in the laboratory, and ambulatory BP was not recorded. Consistent with the noxious effects of worry on cardiac activity observed by those studies, we extended the results to BP, showing that rumination is responsible for relevant changes in ambulatory BP. Moreover, we found preliminary evidence of a possible link between BP response to emotional stress in the laboratory and to perseverative cognition in daily life.

The present study further supports the notion of negative mood as a fundamental component of rumination (Lyubomirsky & Nolen-Hoeksema, 1995). In fact, participants reported higher levels of sadness, stress, and anger and lower levels of happiness during ruminative thoughts in both the laboratory and the ambulatory sessions. Contrary to what we observed in the laboratory, rumination in everyday life was associated with a concomitant increase in anxiety levels. A possible explanation comes from the findings of lower self esteem and less confidence associated with rumination in doing routine activities (Ward, Lyubomirsky, Sousa, & Nolen-Hoeksema, 2003). It is plausible that the consequences on anxiety are more evident in daily life, when people face ordinary events. Results accord with previous findings on the perpetuation of negative mood, assessed on a daily basis, by the recall of a past negative feeling (Verduyn et al., 2009). Negative life events, rumination, and moods were likewise registered for an entire week, showing that daily stress level, obtained by a composed score of anxiety, sadness, and irritation levels, was mostly determined by ruminative thoughts (Moberly & Watkins, 2008). Present results further extend these observations, showing the crucial role of rumination in mediating the relationship between moods and ambulatory BP.

Several limitations have to be acknowledged. First, the use of distraction has been sometimes criticized because it has been considered more appropriate to compare rumination with, for example, reappraisal, that is, an equivalent mental process without the negative component that characterizes rumination (Mauss, Bunge, & Gross, 2007). Second, cardiovascular activity outside the laboratory has been recorded only during a single work day, whereas Kamarck et al. (2002) recommended a period of recording that includes, at least, one nonwork day. We used one day because cardiovascular measures between a work and a nonwork day did not differ (Ottaviani, Shapiro, Goldstein,



James, & Weiss, 2006; Ottaviani, Shapiro, Goldstein, & Mills, 2007). Third, a binary variable (yes/no) was used for ruminative thoughts: The use of a continuous measure derived from composite information (How many? How often? How long? How negative?) could have led to a more precise prediction and is warranted for future studies. Finally, several prospective studies examined the relationship between delayed poststress recovery and the development of essential hypertension (Steptoe & Marmot, 2005; Stewart, Janicki, & Kamarck, 2006) and indicated poststress recovery as an independent risk factor for the development of hypertension and coronary diseases (Steptoe, Donal, O'Donnell, Marmot, & Deanfield, 2006; Bigi, Gregori, Cortigiani, Colombo, & Fiorentini, 2005; Heponiemi et al., 2007; Steptoe & Wardle, 2005) but, up to now, there are no studies on the noxious effect of rumination that obtained a follow-up objective measure of health status. A few exceptions are the demonstration of the consequences of worry on myocardial infarction (Kubzansky et al., 1997) and another study showing that worry mediates long-term cardiovascular effects of a major stressor (Holman et al., 2008). Another prospective study showed a relationship between worry and somatic complaints and the possibility of reducing both the latter by a worry reduction intervention (Brosschot & Van Der Doef, 2006). Our study does not represent an exception, given that the consequences of prolonged activation can only be hypothesized on

the basis of theoretical knowledge on the effects of impaired cardiovascular recovery, ambulatory BP, and moods. Moreover, our participants were relatively young and generally healthy. The phenomenon of delayed cardiovascular recovery to emotionally stressful tasks may have quite different prognostic implications in patients with significant coronary disease. However, the ambulatory effects that we obtained are striking and larger compared to any other study in the field. As a possible bias, it has to be acknowledged that the text of our posting—"Want to know what happens in your body when you get angry?"—might have attracted people who are particularly prone to experience anger in their life, thus affecting the magnitude of the effects.

To conclude, in order to be pathogenic, rumination has, indeed, to be effective in determining sustained physiological activity outside the laboratory in everyday life. Present data further confirmed this hypothesis, further suggesting a relationship between cardiovascular reactivity to an emotional stressor in the laboratory and BP increases during negative thoughts. It is therefore becoming clear that not only are stressful life events pathogenic but also thoughts related to stressful events. Given these findings, we need to conduct prospective studies to demonstrate the long-term health consequences of rumination on health and the subsequent development of therapeutic approaches to the control of stress rumination.

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(RECEIVED January 21, 2010; ACCEPTED June 29, 2010)