

The Role of Rumination in Recovery from Reactivity: Cardiovascular Consequences of Emotional States

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Objective: While most investigations of the link between blood pressure responses and later disease have focused on acute reactivity during stressful tasks, there is some theoretical and empirical reason to believe that examining recovery and later re-creations of BP responses may also be useful. Two experiments explored situational determinants of sustained BP elevations, examining whether the extent of recovery and the ability to later mentally recreate the response are influenced by the magnitude or emotionality of the initial task and also whether preventing rumination after a stressor has ended speeds recovery. **Method:** Experiment 1, with 72 normotensive male and female undergraduates, examined BP and heart rate before, during, and after a task and also before, during, and after the mental re-creation of that task. Four tasks were used, designed to produce high initial reactivity with an emotional component (mental arithmetic with harassment), low reactivity with emotion (shock avoidance), high reactivity without emotion (physical exercise), or low reactivity without emotion (cold pressor). Experiment 2, with 20 normotensive male and female undergraduates, compared the cardiovascular recovery of persons who were either given a distractor task or just sat quietly immediately after a mental arithmetic task. **Results:** Study 1 revealed that only the emotional tasks were associated with delayed BP recovery and elevations during later rumination. Blood pressure during recovery and later rumination was independent of the original reactivity. Experiment 2 found that participants with the distractor, who presumably could not ruminate, showed better BP recovery. **Conclusions:** Situations that put people at risk may include not just those that cause large BP elevations, but also emotion-producing situations that lead to sustained and recurring elevations. **Key words:** stress, blood pressure, rumination, recovery, cardiovascular reactivity, emotion.

BP = blood pressure; BPM = beats per minute; ER = emotional reactivity.

INTRODUCTION

Laboratory research on the connection between cardiovascular responses to stress and morbidity has largely focused on acute responses during stress. However, some work has suggested that the total amount of time that the cardiovascular system is activated may usefully be examined in addition to the magnitude of the acute response. If elevations in BP and heart rate in the presence of a stressor are damaging to the cardiovascular system (1–4), then it should be that other stress-associated elevations outside the immediate presence of the stressor are damaging as well. McEwen (5) and McEwen and Stellar (6) have suggested, along these lines, that the allostatic load, or the total time that the BP and heart rate are elevated, may be the important factor in the development of later hypertension and cardiovascular disease.

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One way that the physiological response to a stressor could extend beyond the immediate presence of the stressor itself is through slow return to prestress levels. Work examining cardiovascular recovery can be traced back to early studies by Hines and Brown (7, 8), who noted that not only did hypertensive patients show greater BP responses to the cold pressor than normotensive controls but that they also exhibited slower poststressor recovery. More recent work has uncovered a variety of individual difference factors that affect cardiovascular recovery and has also suggested that these differences may be linked to later disease. For example, physically fit people return more rapidly to prestress levels (9, 10), and women have been shown to exhibit faster recovery than men (11). It also appears that race affects recovery, although the pattern of results is not consistent. In some cases, blacks exhibit delayed recovery compared with whites (11, 12), while in some cases, the opposite has also been found (13). Research on anger and hostility suggests that Type A individuals show slower recovery than Type B individuals (14) and that anger expression style can affect recovery (15, 16). In addition, there is some evidence that delayed recovery may be a risk factor for the development of cardiovascular disease (17) and hypertension (18–21).

Another factor in addition to slow recovery that might serve to extend the stress response after the stressor is removed is the later mental re-creation of the original response. Although poststress rumination has been studied as a factor in other illnesses, such as depression (22, 23) and posttraumatic stress disorder (24, 25), the role of rumination in cardiovascular dis-

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ease has received little attention. Ruminating about a stressful experience could lead to later reactivation of the cardiovascular system as well as being one of the factors influencing cardiovascular recovery immediately following a stressor. There is some work examining the role of individual differences in ruminative tendencies on cardiovascular responses. Melamed (26, 27) suggests that those high on emotional reactivity (ER) easily enter into and maintain emotional responses in the face of stressful events in part because they are unable to regulate emotional thoughts and images before, during, and after emotional experiences. These ruminative tendencies are thought to be associated with increased cardiovascular responding and so to contribute to poorer cardiovascular health. Those high on ER exhibit greater resting BPs than those with low scores (26, 27). Further, ambulatory monitoring reveals that, while at work, high ER individuals display greater BP levels than low ER individuals, even after adjusting for baseline BP (27). While these studies reveal a correlation between the tendency to ruminate and higher BP both at rest and at work, they do not show that rumination is the source of the increased BP.

The evidence reviewed so far considers extended cardiovascular responses to stress (eg, slow recovery and later re-creations of the cardiovascular response) in the context of individual differences. Linking a tendency to exhibit delayed recovery to later disease and showing a correlation between the tendency to ruminate and BP levels are both consistent with the idea that certain individuals are at increased risk for developing cardiovascular disease. However, extended cardiovascular responses to stress can also be considered from a situational perspective. From this view, the focus is not on the people who are at risk but rather on situations that put people at risk for later disease (28). Some of the work on reactivity responses falls into this domain. For example, work on social support (29) and also work with the job strain model (30) seek to identify situations that buffer or that increase cardiovascular reactivity and that thus may promote or impair health.

Two studies have investigated extended cardiovascular responses from a situational perspective and both suggest that it may be the emotional nature of the stressor that is associated with the extended response. Earle et al. (31) examined recovery following a mental arithmetic task in which half of the participants were harassed and half were not. Those who were harassed exhibited delayed BP recovery following the task while those who were not recovered rapidly. The authors posit that the anger component of the task prevented recovery because the participants were still

thinking about how irritating they had found the task. However, during the mental arithmetic task, the reactivity levels of the harassed group were significantly greater than those of the nonharassed group, and so one cannot conclude that the posttask differences are due to the anger component of the task and not to the differences in the BP responses during the task. In a study of the physiological effects of recalling stressful experiences, women who mentally recalled conflict at work and in their marriage displayed elevated BP and heart rate responses (32). As with the Earle et al. (31) finding, these data suggest that emotional stressors may be associated with cardiovascular elevations that occur when the stressor is not present. However, we cannot draw a definitive conclusion about the importance of the emotional nature of the task without a nonemotional comparison. It could be that the recall of any task, regardless of whether or not it was an emotional stressor, is associated with BP and heart rate elevations.

In the two experiments presented here, we examined the relation between cardiovascular responses, rumination, and recovery. In the first study, we explored whether certain types of stressors are associated with delayed recovery and with increased BP during rumination. In the second study, we tested whether delayed recovery following a stressor might plausibly be attributed to spontaneous rumination. These two experiments enabled us to address several questions. First, does ruminating on any stressor produce increases in BP and heart rate, or must the stressor have an emotional component? In other words, would thinking about this morning's jog produce as much reactivity as thinking about last night's fight with a spouse? Second, are the tasks that are associated with large responses during rumination the same ones that are associated with a failure to recover? Third, is it the case that delayed recovery following a stressor is due to people continuing to think about the experience after it has ended? In other words, would preventing rumination speed cardiovascular recovery?

EXPERIMENT 1

Method

Overview. Participants experienced one of four stressors and then, after a delay, were asked to recall the stressor as vividly as possible. We manipulated both whether the stressor had a significant emotional component and whether the task produced moderate or high initial reactivity. These manipulations resulted in an emotion (emotional vs. nonemotional) by response magnitude (high vs. low) factorial design. Blood pressure and heart rate were monitored during the stressor task, during the rumination period, and also during recovery periods following both the task and the rumination.

Participants. Seventy-two undergraduates at a large western university participated in the study. There were 47 females and 25 males with a mean age of 20.3 years ($SD = 3.7$). None reported either being in poor health or taking any medications that might affect cardiovascular measurements. Participants received course credit in exchange for participation.

Physiological recording. Systolic BP, diastolic BP, and heart rate were collected using an Ohmeda Finapres 2300 BP monitor (TNO Biomedical Instrumentation, Belgium). This instrument takes beat-to-beat pressures in a noninvasive manner using the Peñaz method (33). The participant wears an inflatable finger cuff on the third finger of the nondominant hand. The Finapres has been demonstrated to be a useful alternative to intra-arterial BP measurement in laboratory testing (34) and clinical practice (35, 36). In addition, it has been shown to track intra-arterial readings extremely well, even during sudden changes of BP (37), making it a good candidate for use during reactivity testing.

Procedure. When the participants arrived at the laboratory, the experimenter explained to them that they would be performing two tasks and that their BP and heart rate would be monitored. No mention was made at this time of the nature of the tasks.

After the description of the experiment, the participant was instrumented with the BP cuff and a 6-minute baseline was taken. Because the Finapres produces a reading for every heartbeat, 6 minutes is more than enough time to provide a very reliable estimate of resting levels (38). The participant was asked to sit quietly and not move around during the baseline period. The experimenter left the room during this period.

Following the baseline, the participant was given the instructions for one of the four tasks described below. The participant was told that, as soon as the task was completed, the experimenter would be leaving the room and the participant was to sit quietly just as during the baseline. This was done so that recovery following the stressor could be assessed uncontaminated by further interaction with the experimenter. After the procedure was explained, the participant performed the assigned task. Following this, the experimenter quickly left the room, telling the participant that she would be back in 10 minutes. The participant then sat quietly for a 10-minute recovery period.

At the end of the poststressor recovery period, the experimenter reentered the room and turned off the Finapres to give the participant's finger a break from the inflating cuff. The cuff was left on the participant's finger so that no error from repositioning it would be introduced. The participant then spent 6 minutes filling out questionnaires. These included general demographic questions as well as questions about exercise habits. Participants who finished the questionnaires early were given a magazine to read.

After the questionnaire period, the Finapres was restarted and the participant sat quietly for 6 minutes. Following this, the participant was given the instructions for the rumination task. Participants were told: "What I would like you to do for the next 3 minutes is try to recreate the mental-arithmetic (physical-exercise, reaction-time, cold-pressor) task in your head the best that you can. Try to remember all of the details as vividly as possible. It is very important that you focus on exactly how you felt for the whole 3 minutes. Pretend you are going through the entire experience in your mind. Remember this is going to take place entirely in your mind, so do not move around at all." The experimenter remained in the room during this rumination period and busied herself with paperwork. This was done to control for the effects of the experimenter's presence on BP levels because she had been in the room during the original stressor task. At the end of the rumination period, the experimenter again left the room for a 5-minute recovery period.

After the postrumination recovery period, the experimenter re-

entered the room and removed the BP cuff. The participant then completed additional questionnaires about the stressor task and the rumination task. On completion of the questionnaires, the participant was fully debriefed, thanked for his or her participation, and dismissed.

Stressor task manipulation. Participants were randomly assigned to one of the four stressor tasks: mental arithmetic, shock avoidance, physical exercise, and cold pressor. Pilot testing had suggested that the mental-arithmetic and physical-exercise tasks would reliably produce roughly equal and high levels of cardiovascular reactivity, while the shock-avoidance and cold-pressor tasks would produce roughly equal and more moderate levels of reactivity. Pilot testing also suggested that, orthogonal to the reactivity dimension, the mental-arithmetic and shock-avoidance tasks would be regarded as emotionally engaging, while the physical-exercise and cold-pressor tasks would be seen as more neutral. The success of the response magnitude manipulation can be checked by examining physiological responses during the task. The emotionality manipulation was assessed with self-reports from participants at the end of the experimental session.

Mental arithmetic (emotional, high response magnitude). Participants counted backward while being interrupted and harassed repeatedly by the experimenter. The interruptions were standardized and independent of the participants' performances and so participants received the same scripted interruptions at the same intervals during the task. These included such comments as, "OK, you are going to have to start again and this time I will let you count by sevens so it is easier for you" and "I am going to start you one more time and if you do not speed up, I am not going to be able to use your data."

Shock avoidance (emotional, low response magnitude). Participants were told that they would be performing a reaction time task and if their responses were not fast enough they would receive a mild electric shock. No shock was ever administered, but to make the threat seem real, electrodes attached to a fake shock generator were affixed to the participants' nondominant hands. The participants then spent the 3 minutes engaged in a reaction-time task that required that they press a button as soon as a light on a panel in front of them flashed on. This occurred approximately every 30 seconds.

Physical exercise (nonemotional, high response magnitude). Participants performed a moderately taxing walking in place task. This was standardized by having participants lift each foot to a specified level (27 cm above the floor) and a metronome set at 150 beats per minute controlling the rate of foot movement. This "walking in place" was done while seated so that posture could be standardized across the four tasks.

Cold pressor (nonemotional, low response magnitude). Participants held one hand and forearm in cold water for the 3-minute period. The water temperature was 43°F. This task was not presented as a challenge, and participants were told that, although the cold water might be uncomfortable, they would be able to leave their arm in it for the 3 minutes.

Manipulation checks. To assess whether the emotionality manipulation was successful, participants reported on the general emotional content of the stressor tasks as well as specific emotions the tasks elicited. We asked participants to rate the stressor task with a question asking, "How emotionally involving did you find the task?" In addition, participants were asked how much fear, nervousness, and anger they experienced during the stressor task. All ratings were made on a seven-point Likert-type scale with the endpoints 1 = not at all to 7 = extremely. If our manipulation was successful, the ratings of the mental arithmetic and shock avoidance tasks should be reported as eliciting greater emotional responses than the physical-exercise and cold-pressor tasks.

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We also assessed whether the tasks differed on two dimensions in addition to emotionality. It is possible that effort or engagement might affect cardiovascular responses during rumination and recovery, and so the participants reported how difficult and challenging they had found the stressor task (these variables were rated on the same seven-point scale described above). A second factor that could affect responses during the rumination task is how easy it was to recall the task. To address this, participants answered the question "How vividly do you feel you were able to recall the experience?" (1 = not at all vividly to 7 = very vividly).

Data reduction and analysis procedures. Three cardiovascular variables were examined: systolic BP, diastolic BP, and heart rate. The cardiovascular dependent measures were change scores, computed using the difference between the mean of the period of interest and the mean of the baseline period. The periods for which a change score was computed were stressor task, poststressor recovery, directed rumination task, and postrumination recovery. For example, systolic reactivity during the task was calculated as the difference between mean baseline and mean stressor task systolic BP levels. Similarly, the systolic dependent measure for the rumination task was the difference between the mean baseline and mean rumination task levels. Poststressor and postrumination systolic recoveries were computed by subtracting baseline levels from the mean systolic BP during the poststressor and postrumination recovery periods. All BP means were computed using the pulse-based technique (39). Raw change scores rather than residualized change scores were used as recommended by Llabre et al. (40).

RESULTS

Manipulation Checks

Participants' reports of how emotionally involving they found the stressor tasks indicated that the emotionality manipulation was effective. The emotional tasks were rated as more emotionally involving than the nonemotional tasks (Table 1). A two-way ANOVA revealed a significant main effect of emotion ($F(1,68) = 10.87$; $p < .01$), no main effect of response magnitude, and no emotion by magnitude interaction (both p values $> .18$).

There were some differences in the specific emotions elicited by the tasks. Both the mental-arithmetic and shock-avoidance tasks received high fear ratings

and the physical exercise and cold pressor both received low ratings (Table 1), producing a significant effect of emotionality, $F(1,68) = 29.61$; $p < .01$. The mental arithmetic and shock avoidance also received higher nervousness ratings than physical exercise and cold pressor. For anger, the mental arithmetic received the highest rating, and shock avoidance, physical exercise, and cold pressor were lower, with a significant emotion by reactivity interaction, $F(1,68) = 11.04$; $p < .01$. Thus, both emotional tasks produced fear and nervousness, but the mental arithmetic task also appears to have produced some anger.

The task difficulty and challenge questions revealed different patterns from the emotional questions. The mental arithmetic task was rated highest on difficulty and challenge, while the shock-avoidance task received the lowest ratings on difficulty and challenge (Table 1). Physical exercise and cold pressor received intermediate ratings on both difficulty and challenge. For both questions, there was no main effect of emotionality (both p values $> .47$), but there were effects of response magnitude and emotionality by response magnitude interactions for both questions (p values $< .01$).

Participants' answers to the question "How vividly do you feel you were able to recall the experience?" revealed no significant differences in how memorable the stressor tasks were (Table 1). There were no main effects or interactions of emotionality or magnitude on how vividly participants were able to recreate the task in their minds (all p values $> .12$).

Baseline Measures

The mean baseline BP was 119.8/73.8 mm Hg, and the average baseline heart rate was 80.1 BPM. There was no effect of either experimental manipulation on baseline levels of BP and heart rate (Table 2; two-way ANOVA, all p values $> .28$).

TABLE 1. Self Reports of Emotion, Difficulty, and Memorability of Tasks in Experiment 1 (With Standard Deviations)^a

	High Response Magnitude		Low Response Magnitude	
	Emotional	Nonemotional	Emotional	Nonemotional
How emotionally involving did you find the task?	4.3 (1.7)	2.6 (1.4)	3.8 (1.4)	3.1 (1.7)
How fearful did you feel during the task?	3.0 (1.5)	1.2 (0.4)	2.8 (1.4)	1.7 (1.0)
How nervous did you feel during the task?	4.4 (1.8)	1.9 (0.8)	3.1 (1.4)	2.6 (1.7)
How angry did you feel during the task?	3.1 (1.7)	1.6 (1.1)	1.5 (1.3)	2.4 (1.8)
How difficult did you find the task?	5.2 (1.3)	3.3 (1.8)	1.4 (0.6)	2.9 (1.9)
How challenging did you find the task?	5.6 (1.2)	3.7 (1.7)	1.4 (0.6)	3.3 (1.6)
How vividly were you able to recall the task?	4.8 (1.1)	4.1 (1.6)	4.0 (0.9)	3.8 (1.9)

^a High response magnitude/emotional = mental arithmetic; high response magnitude/nonemotional = physical exercise; low response magnitude/emotional = shock avoidance; low response magnitude/nonemotional = cold pressor. All answers given on seven-point Likert-type scale with the endpoints 1 = not at all and 7 = extremely.

TABLE 2. Baseline Physiological Levels for Experiment 1 (With Standard Deviations)^a

	High Response Magnitude		Low Response Magnitude	
	Emotional	Nonemotional	Emotional	Nonemotional
Systolic BP	120.4 (12.5)	122.7 (18.1)	116.8 (11.2)	118.0 (12.7)
Diastolic BP	73.5 (8.1)	77.1 (18.0)	73.0 (12.0)	71.7 (9.3)
Heart rate	79.9 (11.4)	80.9 (9.8)	78.3 (12.1)	81.1 (11.4)

^a High response magnitude/emotional = mental arithmetic; high response magnitude/nonemotional = physical exercise; low response magnitude/emotional = shock avoidance; low response magnitude/nonemotional = cold pressor.

Physiological responses to the stressor task and manipulation check of response magnitude.

Blood pressure. The blood pressure responses to the four stressor tasks are shown in Table 3. Consistent with our expectations, the response magnitude manipulation did significantly affect BP responses while emotion manipulation did not. The two high-magnitude tasks (mental arithmetic and physical exercise) produced greater systolic and diastolic BP responses than the two low-magnitude tasks (shock avoidance and cold pressor). A two-way analysis of variance revealed main effects of magnitude for systolic and diastolic BP ($F(1,68) = 15.35; p < .01$ and $F(1,68) = 9.44; p < .01$, respectively). There were no significant effects of emotionality of the task on BP nor were there significant interactions (all p values $> .25$).

Heart rate. Similar to the results for BP, there was a main effect for heart rate of response magnitude, with the high-magnitude tasks producing greater responses than the low-magnitude tasks (Table 3; $F(1,68) = 91.65; p < .01$). In addition, there was a main effect of emotionality and an emotionality by magnitude interaction ($F(1,68) = 14.87; p < .01$ and $F(1,68) = 23.07; p < .01$, respectively). Both of these emotionality effects can be attributed to the fact that the physical-exercise (high magnitude, nonemotional) task resulted in heart

rate increases that were much larger than those for any of the other tasks (Table 3, part C).

Physiological responses to the directed rumination task.

Blood pressure. The size of the blood pressure response to vividly recalling the initial task depended on the emotional nature of that task (Table 3). Participants who had completed an emotional task exhibited elevated BP during directed rumination (systolic mean = 16.2 mm Hg; diastolic mean = 6.2 mm Hg), while those who had completed a nonemotional task did not exhibit elevated BPs (systolic mean = 0.5 mm Hg; diastolic mean = -0.4 mm Hg). These differences were reflected in a significant main effect of emotion for both systolic and diastolic BP (two-way ANOVA; systolic $F(1,68) = 24.02, p < .01$; diastolic $F(1,68) = 7.88, p < .01$). For neither systolic nor diastolic BP was there a main effect of response magnitude or a significant interaction term (all p values $> .32$). Thus, the data suggest that the emotional nature of the task and not the size of the initial response to the task determined BP responses during rumination.

Heart rate. The rumination task was not associated with increases in heart rate (Table 3, part C). The means for all four groups were at or slightly below baseline levels. There was, however, a main effect of

TABLE 3. Cardiovascular Responses to the Stressor Task and to Directed Rumination; Means Represent Increases Over Baseline Levels (With Standard Deviations)^a

	Task Response		Rumination Response	
	Emotional	Nonemotional	Emotional	Nonemotional
Systolic BP				
High response magnitude	33.5 (15.1)	29.3 (18.5)	17.9 (15.6)	1.2 (10.5)
Low response magnitude	17.9 (15.2)	14.9 (15.9)	14.5 (15.1)	-0.2 (12.5)
Diastolic BP				
High response magnitude	21.9 (7.9)	18.4 (11.1)	6.9 (8.9)	-2.1 (7.2)
Low response magnitude	13.1 (16.8)	10.2 (9.0)	5.7 (13.0)	1.4 (10.3)
Heart rate				
High response magnitude	13.8 (8.2)	35.4 (12.9)	-3.4 (4.9)	2.0 (7.9)
Low response magnitude	1.9 (8.5)	-0.5 (12.0)	-5.9 (5.2)	-3.8 (7.3)

^a High response magnitude/emotional = mental arithmetic; high response magnitude/nonemotional = physical exercise; low response magnitude/emotional = shock avoidance; low response magnitude/nonemotional = cold pressor.

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emotion such that those who had experienced an emotional task displayed lower heart rates than those who had experienced a nonemotional task (means = -4.7 vs. -0.9 BPM, respectively; $F(1,68) = 6.23$; $p < .05$). In addition, those who had completed a low-magnitude task exhibited lower heart rates than those who had completed a high-magnitude task (means = -4.8 BPM vs. -0.7 BPM, respectively; $F(1,68) = 7.35$; $p < .01$).

The response magnitude by emotionality interaction was not statistically significant ($p = .28$).

Recovery after stressor task. The effects of the emotionality manipulation were not confined solely to BP levels during directed rumination but were also evident for recovery from the stressor task. Figure 1, A and B shows the average BP change scores for each minute for the four conditions (these change scores are

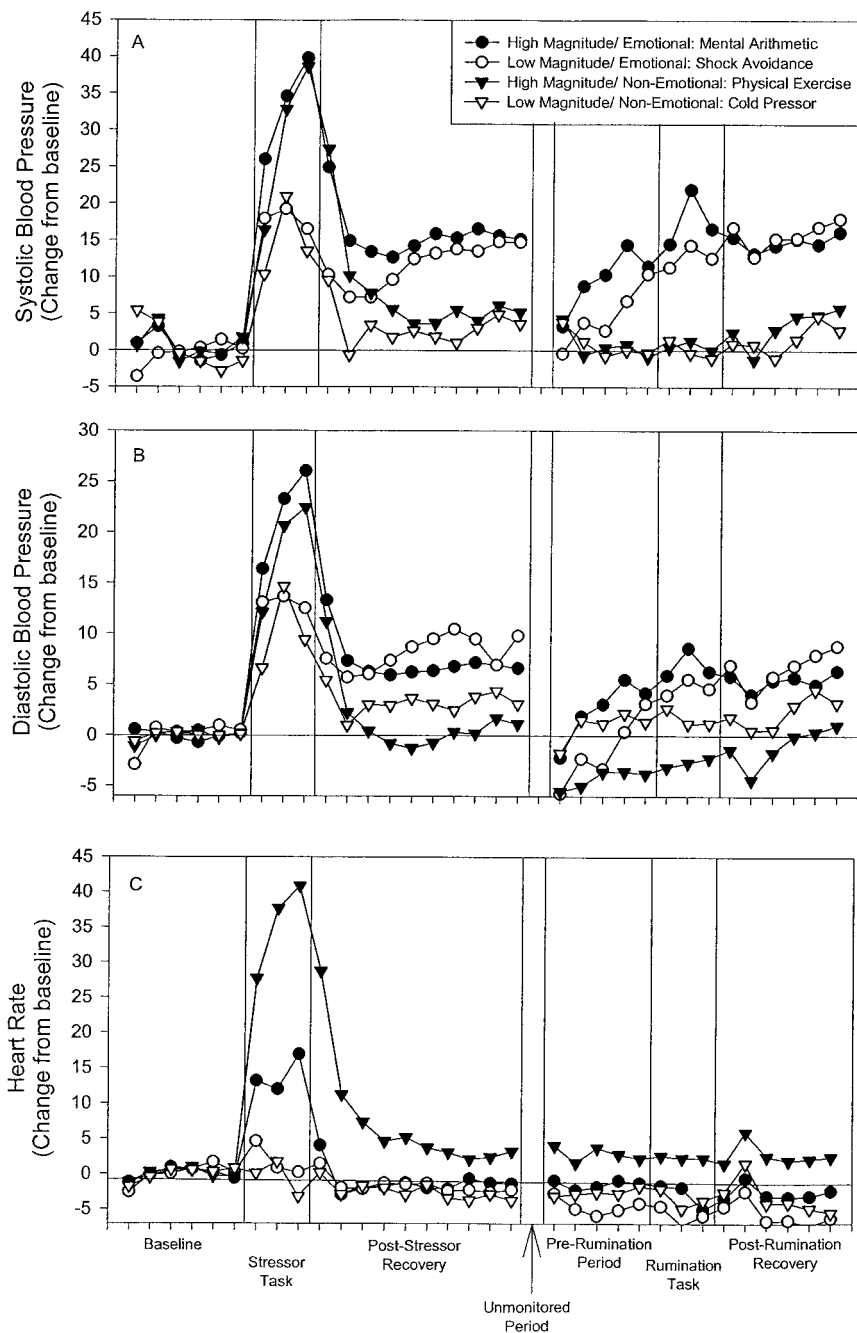


Fig. 1. Average change score (by minute) across the experimental session for the four groups in Experiment 1. A, systolic blood pressure; B, diastolic blood pressure; C, heart rate.

the mean level of each minute minus the mean level for the 6-minute baseline). The BP of participants in the two emotional task conditions did not approach baseline during the 10-minute poststressor period, although the BP of participants in the nonemotional conditions returned quickly to baseline levels after the stressor task. There was a main effect of emotionality on both systolic and diastolic BP during recovery ($F(1,68) = 9.24$; $p < .01$ and $F(1,68) = 5.84$; $p < .05$, respectively). There were no main effects of magnitude and no magnitude by emotionality interactions (all p values $> .1$). Heart rate returned to baseline during the recovery period, regardless of the emotionality of the task (Figure 1C). Blood pressure elevations during the recovery period were predicted by the emotional nature of the task and not the reactivity the task produced.

Recovery after rumination task. Further examination of Figure 1, A and B reveals that participants in the emotional conditions also exhibited delayed recovery after the rumination task. There were no such elevations apparent for those in the nonemotional conditions. As with the poststressor recovery period, there was a statistically significant main effect of emotionality for both systolic and diastolic BP ($F(1,68) = 11.10$; $p < .01$ and $F(1,68) = 4.33$; $p < .05$, respectively) and no effect of response magnitude or magnitude by emotionality interaction (all p values $> .36$).

Prerumination period. One additional, unanticipated finding was the pattern of BPs in the prerumination period (Figure 1, A and B). The unmonitored questionnaire period was designed to give participants a rest from the BP cuff, but it appears to have had an effect on BP. At the end of the poststressor recovery period, the systolic BPs of the two emotional conditions were still approximately 15 mm Hg above baseline, while the two nonemotional conditions were essentially at baseline. However, after the questionnaire period, the BPs of all four were within a few mm Hg of baseline. Over the next few minutes, when participants were no longer engaged in an external task, the BP of those who had performed an emotional task began to rise. The BPs of those in the two groups who had not performed an emotional task remained steadily at baseline during this period. The pattern was similar for diastolic BP.

Effects of gender on cardiovascular responses. Although not a primary focus of analyses, there were some significant effects of gender on cardiovascular responding. There was a tendency for men to show higher BP responses during the initial stressor task, but only for the two emotional tasks. This difference was also present during directed rumination and recovery. During the emotional tasks, the men showed an aver-

age systolic BP response that was 17.2 mm Hg (13.2 mm Hg for diastolic) greater than women. The mean systolic BP difference between men and women during the rumination task was 10.3 mm Hg (11.7 mm Hg for diastolic) and was 10.4 mm Hg (9.6 mm Hg for diastolic) during poststress recovery. These differences were reflected in a significant emotionality by gender interaction for BP during the stressor task (systolic $F(1,66) = 6.33$, $p < .05$ and diastolic $F(1,66) = 8.14$, $p < .01$), during directed rumination (systolic $F(1,66) = 5.71$, $p < .05$ and diastolic $F(1,66) = 13.28$, $p < .01$), and during recovery following the stressor task (systolic $F(1,66) = 3.74$; $p < .06$ and diastolic $F(1,66) = 6.86$; $p < .05$.) Both men and women responded to an emotional task by showing increased BP responses during the task, during rumination, and during recovery; however, these elevations were greater for men.

Discussion of Experiment 1

The effects of directed rumination depended on the nature of the task about which participants were ruminating. The BP of those who recalled the mental-arithmetic or shock-avoidance task exhibited an average of 16 mm Hg of reactivity for systolic and 6 mm Hg for diastolic, while the BP of those who recalled the physical-exercise or cold-pressor task hovered around baseline during rumination. The BP response during the rumination task was independent of initial reactivity. During directed rumination, both the high- and low-magnitude emotional stressors were associated with similar and elevated BP responses, and high- and low-magnitude nonemotional stressors were associated with no appreciable elevations over baseline. The emotionality of the task affected not only BP during directed rumination but also during recovery after the stressor task and after the directed rumination task. Those who experienced a nonemotional task recovered, whereas those who experienced an emotional task did not. In sum, stressor tasks with an emotional component were associated with BP elevations during directed rumination and with delayed recovery, and all these effects were independent of the original reactivity the task evoked.

The self-report questionnaires are capable of shedding some light on the factors that influence cardiovascular recovery and cardiovascular correlations of later mental re-creations of tasks. Not only did the initial reactivity during the actual task not serve as a predictor of the cardiovascular data following the task, it also appears that reports of task difficulty and challenge were not predictive. The shock-avoidance task, which was rated as least difficult and challenging,

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showed the same marked posttask elevations as the mental-arithmetic task, which was rated most difficult and challenging. The reports of fear and nervousness, however, were associated with slow recovery and large responses during directed rumination. In the present data, the addition of anger did not appreciably change the pattern. The mental-arithmetic task involved about the same levels of fear and nervousness as the shock avoidance, but it also included significantly more anger. These data cannot address the question of whether a task that did not involve fear or nervousness (such as one that produced fairly pure anger) would have the same effects following the task.

Although our tasks differed on emotionality, it is possible that there are other dimensions over which they also differed that could be responsible for the observed patterns of recovery and rumination-created responses. That is, it might not be the emotional component of the shock-avoidance and mental-arithmetic tasks that delayed recovery but instead a difference in the original physiological response that those two tasks engendered. There might, eg, be a difference in active coping, with one pair of tasks producing more alpha-adrenergic activation and the other more beta-adrenergic activation. While a physiological explanation of this sort could account for differences in initial recovery, it cannot readily account for the complete pattern of data. A physiological difference in the initial reactivity between what we call the emotional and nonemotional tasks should not produce the observed differences in response during directed rumination. It also seems unlikely that it could explain the finding that, during the questionnaire period, the BP for the emotional tasks returned to baseline, only to drift upward again when participants were no longer engaged in an external task. The importance of these psychological interventions suggests that the difference between the sets of tasks is not simply physiological. We believe that the difference in the complete pattern of BP responses between the emotional and nonemotional groups results from the tasks differing in emotional content.

Our best explanation for the pattern of elevated BP levels following the stressor in the emotional conditions is that participants were spontaneously ruminating. Delayed recovery may have been due to the fact that those who just experienced an emotionally involving episode were dwelling on this experience and this maintained elevated poststress BP levels. This sort of spontaneous rumination may also have been responsible for the gradual elevation during the prerumination period and the failure to recover after the rumination task. Two findings suggest that spontaneous rumination may have been responsible for the

failure to recover. First, the two tasks associated with BP elevations during directed rumination were the same tasks associated with delayed recovery. Second, the BP of those in the emotional conditions had returned to baseline during the brief questionnaire period and then began to rise again as soon as the participants were sitting quietly without performing a task. It is possible that the questionnaires served to distract the participants from the stressor task, prevented rumination, and thus allowed recovery.

If it was spontaneous rumination after the emotional task that maintained elevated BP, then preventing rumination should facilitate a return to baseline BP levels. The purpose of the second experiment was to explore this possibility. After an emotionally involving task, participants were either left to sit quietly for 10 minutes (as in the first experiment) or were given a distractor task during a 10-minute recovery period. If the participants are spontaneously ruminating, and this rumination is preventing recovery, then we should find that the BP of those who are not allowed to ruminate would return to baseline levels shortly following the stressor, while the BP of those with an opportunity to spontaneously ruminate should remain elevated during the recovery period.

EXPERIMENT 2

Method

Participants. Participants included 13 female and 7 male students participating for course credit. The mean age was 20.1 years ($SD = 3.9$). There were no reports of poor health or medication that might affect cardiovascular measurements.

Stressor task. The stressor task was the mental-arithmetic task described in Experiment 1.

Distractor task. The distractor task consisted of a lengthy questionnaire. The participant read various moral-dilemma scenarios and then responded to questions about these scenarios. These scenarios were adapted from Colby and Kohlberg's classic moral judgment interview (41). This task was intended to be engaging but not stressful. Explicit instructions assured the participant that there were absolutely no right or wrong answers in order to minimize evaluation apprehension.

Procedure. Participants were told that they would be participating in an experiment examining BP responses to different tasks. They were fitted with the BP cuff and sat through a 10-minute baseline period. Following the baseline, all participants performed the 3-minute mental arithmetic task. After this stressor task, in the no-distraction condition, the experimenter told the subject to relax and sit quietly for another 10 minutes. In the distraction condition, the experimenter told the participant to relax, sit quietly, and work on the questionnaire for 10 minutes, adding that there were no right or wrong answers. During the 10-minute recovery period, the experimenter left the room. At the end of this period, the experimental session ended and participants were debriefed and thanked for their efforts.

Data reduction and analysis procedures. As in the first study, we examined systolic and diastolic BP as well as heart rate. The depen-

dent variables were change scores representing the difference between the baseline and the period of interest, either the task or the recovery period.

Results

Baseline measures. The two experimental groups did not differ in resting levels of systolic BP, diastolic BP, or heart rate (Table 4, part A; all p values $> .28$).

Physiological responses to the stressor task. The mental arithmetic task produced increases in systolic and diastolic BP and heart rate (Table 4, part B). As expected, the means of the two groups did not differ significantly for any of the physiological measures (all p values $> .27$). For systolic BP, the overall mean increase was 31.3 mm Hg; for diastolic, the overall increase was 21.1 mm Hg; and for heart rate, the overall increase was 10.4 BPM.

Effects of distraction on recovery.

Blood pressure. Figure 2 shows the minute-by-minute mean responses for the two groups. At the end of the 10-minute recovery period, the BPs of participants in the no-distraction group were still elevated an average of 20 mm Hg above baseline for systolic BP and 15 mm Hg for diastolic BP. In contrast, both systolic and diastolic BP of those in the distraction condition recovered to within 6 mm Hg of baseline after only 2 minutes. The absence of a distracting task was associated with failure to recover. A one-way analysis of variance confirmed the difference in recovery for both systolic and diastolic BP ($F(1,18) = 7.50, p < .01$; $F(1,18) = 5.35, p < .05$, respectively).

Heart rate. Consistent with the findings in the first study, the distractor manipulation did not alter heart rate recovery (see Figure 2C; $F(1,18) = 0.19, p = .67$): recovery occurred quite quickly in each group. Both groups recovered to within 2 BPM of baseline by the end of the first minute of recovery.

Effects of gender on cardiovascular responses.

There were no main effects of gender or gender by distraction group interactions for BP or heart rate during the mental arithmetic task or during recovery (all p

TABLE 4. Baseline Levels and Stressor Task Responses (Change From Baseline) for Experiment 2 (With Standard Deviations)

	Distraction Group	No-Distraction Group
Baseline levels		
Systolic BP	106.4 (19.4)	113.8 (19.0)
Diastolic BP	64.8 (10.4)	70.2 (11.7)
Heart rate	75.0 (12.1)	78.2 (13.5)
Stressor task reactivity		
Systolic BP	29.6 (7.9)	33.0 (12.2)
Diastolic BP	19.7 (7.5)	22.5 (10.2)
Heart rate	8.7 (7.7)	12.1 (6.1)

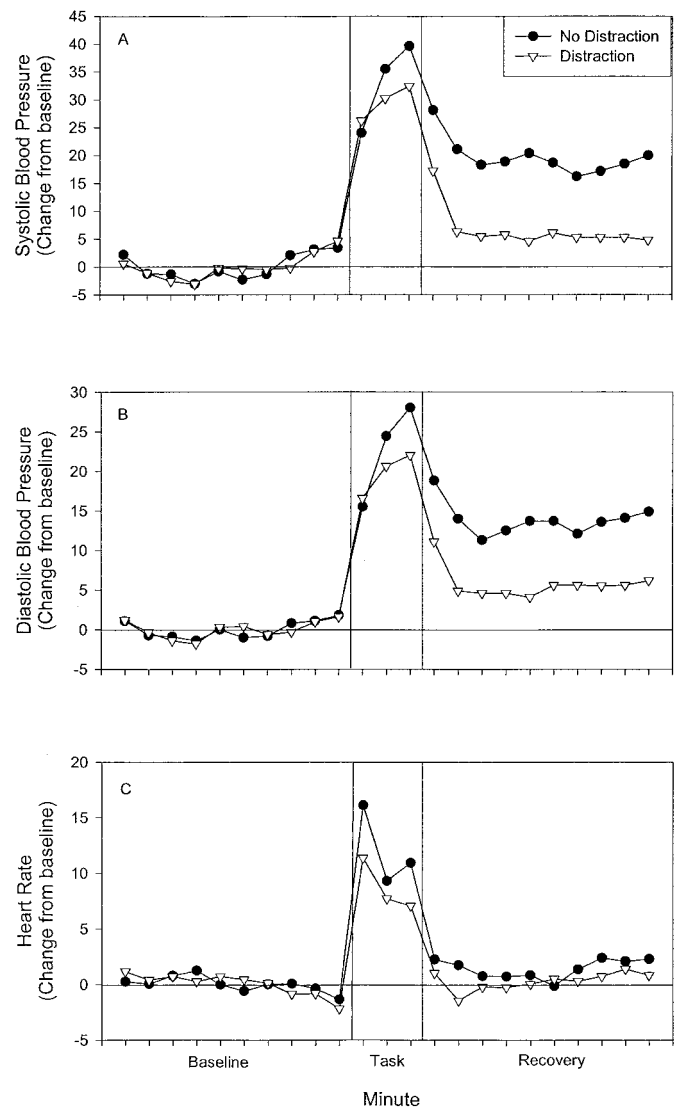


Fig. 2. Average change score (by minute) across the experimental session for the distraction and no-distraction groups in Experiment 2. A, systolic blood pressure; B, diastolic blood pressure; C, heart rate.

values $> .36$). These null findings should be regarded with caution, however. Of the 10 individuals in the distraction group, only 3 were male, and of the 10 in the no-distraction group, only 4 were male. It is quite possible that the lack of gender differences was due to low power.

Discussion of Experiment 2

The results of the second experiment are consistent with the idea that a failure to return to pre-task BP levels following an emotional task can be attributed to spontaneous rumination. Participants given a distracting task immediately following the stressor showed

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significantly lower BP levels following the task than did those not provided with a distractor. It is worth noting that those in the distraction condition had lower BP levels in spite of the fact that they were actively engaged in a task. The higher BP levels were displayed by those who were not engaged in any explicit task. It could well be that a small response to the distractor task itself accounts for their not showing complete recovery to base-line levels. We feel that the best explanation for these data is that the distractor prevented the participants from ruminating and this allowed the almost complete BP recovery. Those without the distractor were not prevented from ruminating and this maintained elevated BP following the stressor. Although we do not have direct evidence that those without a distractor were ruminating during the post-task period, we believe that their BP elevations were driven by task-related thoughts because the post-task period is higher than pretask baseline only when participants are provided with an opportunity to think about the task they just completed (no-distraction condition). If thoughts of another experimental task or even a postexperiment event such as an examination, were causing BP increases, then these thoughts should be driving BP during the pretask baseline as well, and this is not seen in the pattern of results.

As with the difference between emotional and non-emotional tasks in the first experiment, the difference between groups here is very large. In the first experiment, 11 mm Hg of systolic BP separated the emotional and nonemotional groups 10 minutes after the task. In this experiment, 15 mm Hg separated the distracted and nondistracted groups after 10 minutes.

GENERAL DISCUSSION

The results of the two experiments suggest that the emotional nature of a cardiovascular stressor plays a critical role in the duration of the BP response. Directed rumination about an emotional task resulted in increased BP, although rumination about a nonemotional task did not. Furthermore, emotional tasks were associated with delayed recovery whereas nonemotional tasks were associated with very rapid recovery. These rumination and recovery effects were independent of the size of the reactivity response during the stressor task.

Feldman et al. (42) suggested "negative emotions play a small role in physiological responses to acute laboratory stressors." Our data argue against this conclusion. The emotional nature of the task profoundly affects the duration of the cardiovascular response to a stressor (even in the case of acute laboratory stressors).

Although the evidence is indirect, part of an emo-

tional stressor's effects on BP recovery may be due to rumination. The role of spontaneous rumination in delayed recovery is supported now by three pieces of evidence. In the first experiment, the two tasks associated with BP elevations during directed rumination were the same ones associated with delayed recovery. Furthermore, in that experiment, just after a potentially distracting questionnaire period, participants in all conditions had returned to baseline, even though BP for the emotional-condition participants was elevated just before and drifted back up right afterward. Finally, and most directly, in the second experiment, when participants were given a task for which recovery was normally delayed, providing distraction following the task facilitated BP recovery. If delayed recovery following the emotional stressor was due to some physiological difference in initial activation, then providing a distractor should not have had this effect. The results provide support for a psychological rather than physiological explanation for the delayed recovery following emotional tasks.

It may be the case that rumination re-creates a physiological response for emotional tasks because a significant part of the original stressor response was due to thoughts. For example, in the shock-avoidance task, no shocks were ever administered and the participants were not required to perform any serious motor activity. As a result, a good part of the physiological response presumably resulted from participants thinking about the possibility of getting a shock. On the other hand, in the physical-exercise task, thoughts were likely to be largely irrelevant, with the motor activity presumably producing the response. In this case, mentally re-creating the task would not produce any of the original physiological response. In contrast, with the shock task, because the response was originally due to thoughts, re-creating the thoughts should be capable of recreating at least some of the response. After the task, either spontaneously or when they were directed to ruminate, participants could recall their trepidation or fear during the task and re-create the BP response.

There is some evidence that exposure to emotional stimuli activates specific brain areas (see (43, 44) for reviews). It may be the case that similar brain centers are involved when an emotional experience is re-created mentally, the difference being that the stimulus is now internal rather than external. Along these lines, George et al. (45) have shown that, during recall of a sad event, individuals show activation of the limbic and paralimbic structures, and two other PET studies have shown that, in persons suffering from posttraumatic stress disorder, the amygdala appears to be involved in response to reminders of traumatic events

(46, 47). These results could be considered analogous to the finding that re-created visual images involve the same neural centers that are active during the viewing of an external stimulus (48, 49).

Heart rate responses do not appear to be sensitive to the emotionality of a task or to rumination. The only observed elevations in heart rate occurred during the stressors themselves. There was no indication that either spontaneous or directed rumination resulted in increased heart rate. In fact, there was some tendency for the heart rate after the tasks to dip below baseline. These decreases occurred in the conditions with large BP increases and so may be due to a compensatory mechanism (50). It is not clear why BP but not heart rate should respond to rumination. Additional investigation of the hemodynamics of this process is clearly warranted.

One approach to exploring the role of rumination in recovery and later re-creations of cardiovascular responses is to correlate self-reports of thoughts, either as they occur or retrospectively, with the BP response to determine, eg, whether the people who report more task-related thoughts are the ones who show slower recovery. While this approach has advantages, it is inherently correlational and thus must leave important questions unanswered. The approach we chose was to manipulate experimentally the opportunity to have task-related thoughts and determine whether this has a causal impact on the physiological response. In the first experiment, we directed people to think about the prior task and observed that this caused increases in BP, and in the second experiment, we prevented people from thinking about the prior task and observed that this caused BP decreases.

Gender differences in cardiovascular responses to stress are common in the cardiovascular reactivity literature (51–53), and so it is not surprising that our findings revealed some differences as well. In the first experiment, rumination elevated BP levels for both men and women, but these elevations were greater for men. Moreover, for the tasks associated with delayed recovery, men exhibited higher BP levels during recovery than did women. These differences in BP are consistent with the BP responses during the stressor task; men displayed larger responses than women for the emotional tasks. It is not clear whether the differences between men and women in recovery rates and in the effects of directed rumination were due to physiological or psychological factors. These data do not provide insight into whether the tendency to ruminate differs based on gender, whether certain tasks are likely to elicit rumination from one gender or the other, or whether the cardiovascular reaction to rumination is different for men and women.

Future research related to rumination and recovery might explore how long after a stressful experience rumination can still produce BP increases. Will thinking about a hostile highway interaction shortly after it has ended produce BP excursions of the same magnitude as thinking about that experience a week or a month later? Are there meaningful individual differences in the tendency to ruminate about emotional events? Is the tendency to ruminate stable across situations so that the people who ruminate after an argument with a spouse are the same individuals who ruminate about an offensive coworker? It may be possible to connect this research on rumination with personality variables such as anger-expression style, hostility, and family history of hypertension.

Future work might also examine the possibilities for interventions designed to reduce ruminative activities. Much recent work in the cardiovascular reactivity vein focuses on social support, and such work might profitably be extended to rumination and recovery following stressors. The presence of a supportive ally could expedite cardiovascular recovery or reduce the tendency to spontaneously ruminate. It might be that real-world social support provides its benefits largely through speeding recovery or reducing rumination, not through dampening cardiovascular responses in the face of stressors. There are several ways that social support could influence rumination and recovery. Social support could mitigate the stress response through the reassurance of a social comparison process (54). A person could be comforted by being told that his or her view of the world is reasonable and justified, thus reducing the person's need to keep thinking over an unpleasant event. It could also be that social support works most effectively through distraction. Perhaps the best thing a friend can do after an aversive event is simply change the topic.

Our findings indicate that a broader definition of the stress response may prove fruitful in examining the link between reactivity and cardiovascular disease. The data suggest that the effects of an emotional stressor do not end with the removal of that stressor. Simply thinking about a stressful experience can produce significant and sustained BP responses, which in some cases are as large as the initial response to the stressor. It may be the case that exposure to emotional stressors is of greater potential harm to the cardiovascular system than exposure to nonemotional stressors—even ones that provoke initial responses of the same magnitude. Expanding slightly the reactivity hypothesis, the damage from elevated BP levels with emotional stressors may be amplified by the extended duration of such activation and by the more profound later re-creations of that response through delayed rumination.

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This argument suggests that the search for situations that put people at risk (eg, high-stress jobs) should focus not just on tasks that cause large elevations but on emotion-producing tasks that lead to sustained and recurring elevations.

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