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The Undoing Effect of Positive Emotions

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Positive emotions are hypothesized to undo the cardiovascular aftereffects of negative emotions. Study 1 tests this undoing effect. Participants (n = 170) experiencing anxiety-induced cardiovascular reactivity viewed a film that elicited (a) contentment, (b) amusement, (c) neutrality, or (d) sadness. Contentment-eliciting and amusing films produced faster cardiovascular recovery than neutral or sad films did. Participants in Study 2 (n = 185) viewed these same films following a neutral state. Results disconfirm the alternative explanation that the undoing effect reflects a simple replacement process. Findings are contextualized by Fredrickson's broaden-and-build theory of positive emotions (B. L. Fredrickson, 1998).

Positive emotions feel good. Plus, the balance of people's positive and negative emotions contributes to their judgments of life satisfaction (Diener & Larsen, 1993). Beyond this, however, positive emotions may also be useful, pointing to reasons for the pursuit of happiness beyond intrinsic enjoyment. Existing evidence suggests that positive emotions reliably alter people's thinking and actions. Together with this past work, the experiments described in this article suggest that one reason positive emotions are worth pursuing is that they can help regulate negative emotions.

EFFECTS OF NEGATIVE EMOTIONS

Negative emotions can be viewed as evolved adaptations that aided our ancestors' survival in life-threatening situations. The adaptive value of negative emotions

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appears to be carried by their ability to spark *specific action tendencies* (Frijda, 1986; Lazarus, 1991). Anger, for instance, creates the urge to attack, fear the urge to escape, and so on. These action tendencies infuse both mind and body: As thoughts about actions narrow to these specific urges, the body mobilizes optimal physiological support for the action called forth (Levenson, 1994).

Those negative emotions that create urges for specific actions requiring substantial physical energy (e.g., attack, flee) also produce heightened cardiovascular reactivity that redistributes blood flow to relevant skeletal muscles. Such cardiovascular reactivity—if large, recurrent, or prolonged—is thought to place individuals at risk for developing or exacerbating coronary heart disease (Blascovich & Katkin, 1993; Williams, Barefoot, & Shekelle, 1985). For instance, individuals in demographic groups at greatest risk for coronary heart disease (e.g., men, African Americans, those with hostile personalities) show heightened and prolonged cardiovascular reactivity to negative emotions relative to those at lesser risk (Anderson, McNeilly, & Myers, 1993; Fredrickson et al., 2000; Matthews & Stoney, 1988; Schuler & O'Brien, 1997; Suarez & Williams, 1989). Moreover, recurrent emotion-related cardiovascular reactivity appears to injure inner arterial walls, initiate atherosclerosis, and impair vascular responsiveness (Kaplan, Manuck, Williams, & Strawn, 1993).

To the extent that negative emotions generate cardiovascular reactivity that may damage people's health, it becomes critical to discover effective ways to regulate negative emotions. Certainly, effective negative emotion regulation has multiple benefits beyond health promotion, including (but not limited to) enhanced subjective well-being (Diener & Larsen, 1993) and improved cognitive and social functioning (Eisenberg, Fabes, & Losoya, 1997; Salovey, Bedell, Detweiler, & Mayer, 2000). Positive emotions may hold a key to these various benefits.

EFFECTS OF POSITIVE EMOTIONS

Although most emotion theorists who discuss specific action tendencies extend their theories to include positive emotions like joy, contentment, interest, and love (e.g., Frijda, 1986; Lazarus, 1991), Fredrickson (1998, 2000, in press-a; Fredrickson & Levenson, 1998) has argued that such extension is unwarranted. This conclusion is based on multiple observations within the scattered empirical and theoretical literature on positive emotions. One is that the action tendencies identified for positive emotions (e.g., free activation, approach) are better described as *nonspecific* than specific. A second is that positive emotions are often characterized by a relative *lack* of autonomic reactivity (Levenson, Ekman, & Friesen, 1990). To the extent that autonomic reactivity supports specific action tendencies, these two observations go hand-in-hand: If no specific action is called forth during positive emotional states, then no particular pattern of autonomic reactivity should be expected.

The psychophysiological effects and adaptive functions of many positive and negative emotions, then, do not seem isomorphic. Instead, Fredrickson (1998) proposed they are distinct and complementary: Many negative emotions narrow individuals' thought–action repertoires by calling forth specific action tendencies (e.g., attack, flee), whereas many positive emotions *broaden* individuals' thought–action repertoires, prompting them to pursue a wider range of thoughts and actions than is typical (e.g., play, explore). Experiments on the cognitive and behavioral effects of positive emotions support this claim. Most notably, Isen and colleagues have demonstrated that people experiencing positive emotions show patterns of thought that are significantly broadened and diverse (Isen, Johnson, Mertz, & Robinson, 1985), flexible (Isen & Daubman, 1984), creative (Isen, Daubman, & Nowicki, 1987), integrative (Isen, Rosenzweig, & Young, 1991), open to information (Estrada, Isen, & Young, 1997), and efficient (Isen & Means, 1983; Isen et al., 1991). People experiencing positive emotions also show increased preference for variety and broader arrays of behavioral interests (Cunningham, 1988; Kahn & Isen, 1993). In general terms, Isen has suggested that positive emotions produce a "broad, flexible cognitive organization, and ability to integrate diverse material" (Isen, 1990, p. 89). She has recently linked these effects of positive emotions to increases in brain dopamine levels (Ashby, Isen, & Turken, 1999).

The broadened thought–action repertoires accompanying positive emotions are thought to be important because they can *build* a variety of enduring personal resources (Fredrickson, 1998, in press-a). Being playful, for instance, can build physical resources (Boulton & Smith, 1992), social resources (Aron, Norman, Aron, McKenna, & Heyman, 2000; Lee, 1983), and intellectual resources (Leslie, 1987; Panksepp, 1998). The observation that positive emotions lead to increments in enduring resources suggests that the evolved adaptive value of positive emotions is distinct from that associated with negative emotions: Negative emotions are thought to promote survival in the moment of threat by sparking specific, life-preserving actions, whereas positive emotions may promote survival over the long run by incrementing the resources that could be drawn on when facing later, inevitable threats (Fredrickson, 1998). Readers interested in the *broaden-and-build theory* of positive emotions are directed to Fredrickson (1998, in press-a, in press-b) for a review of the theory's rationale and empirical support.

POSITIVE EMOTIONS AND NEGATIVE EMOTION REGULATION

The complementarity between negative and positive emotions outlined in the broaden-and-build theory has implications for negative emotion regulation. If positive emotions broaden individuals' thought–action repertoires, they should also serve as particularly efficient antidotes for the lingering effects of negative emotions, which narrow individuals' thought–action repertoires. In other words, positive emotions might "correct" or "undo" the aftereffects of negative emotions; we call this the *undoing hypothesis* (Fredrickson & Levenson, 1998; Levenson, 1988). Earlier research on motivation (Solomon, 1980), anxiety disorders (Wolpe, 1958), and aggression (Baron, 1976) demonstrated key incompatibilities between negative and positive affect. More recent research on self-regulation (Aspinwall, 1998; Reed & Aspinwall, 1998; Trope & Pomerantz, 1998) and coping (Folkman, 1997; Folkman & Moskowitz, 2000) has similarly shown that positive emotion may function as a resource, as individuals manage threats and stress. The present research reframes these findings in terms of the broaden-and-build theory, and posits that people might harness the effects of a range of positive emotions to regulate a range of negative emotions.

Notably, the undoing hypothesis suggests a novel relationship between positive emotions and cardiovascular reactivity. Perhaps positive emotions do not themselves generate cardiovascular reactivity, but instead quell any existing cardiovascular reactivity caused by negative emotions. Put differently, a prior state of negative emotional arousal may be a necessary backdrop to illuminate the cardiovascular impact of positive emotions (Levenson, 1988). Assuming (as most emotion theorists do) that the cardiovascular reactivity sparked by certain negative emotions prepares the body for specific actions, the broaden-and-build theory suggests that positive emotions speed recovery from—or undo—this cardiovascular reactivity and return the body to mid-range levels of activation more suitable for pursuing a range of behavioral options. According to this view, positive emotions have a unique ability to down-regulate lingering negative emotions and the psychological and physiological preparation for specific action that they generate. If true, this would be one good reason to pursue positive emotions.

PRELIMINARY EVIDENCE

Fredrickson and Levenson (1998) conducted an initial test of the undoing hypothesis. They first induced cardiovascular reactivity by showing research participants a film clip that elicited fear. Immediately following this fear clip, participants were shown a second clip that varied across experimental condition to elicit (a) contentment, (b) amusement, (c) neutrality, or (d) sadness. These four films elicited comparable amounts of interest in viewers, and so none was more distracting than the others. Sadness was chosen as the negative emotion comparison because it, like the positive emotions, has not been clearly linked to a high-energy action tendency, and as such could be a contender for aiding cardiovascular recovery. Results supported the undoing hypothesis: Those who viewed either of the two positive emotion clips showed the fastest cardiovascular recovery.

OVERVIEW OF STUDIES

Although this initial experiment provided compelling preliminary support for the undoing hypothesis, a number of shortcomings and a viable alternative explanation motivated the current work. One shortcoming of the Fredrickson–Levenson experiment was that the pattern of cardiovascular reactivity elicited by the fear clip included heart rate deceleration, and so was not the typical sympathetic response associated with fear, anxiety, and other health-damaging negative emotions. Additionally, the sample tested, though ethnically diverse, included only women. Study 1 improves upon the Fredrickson–Levenson experiment in three ways: First, the initial negative emotion (from which speed of cardiovascular recovery is assessed) was elicited by having participants prepare to deliver a speech under considerable time pressure, a more active and self-relevant aversive task than film viewing. Our expectation was that the speech task would produce negative affect plus a pattern of cardiovascular reactivity clearly indicative of increased sympathetic arousal. Second, we collected a wider array of cardiovascular measures that included continuous measures of systolic and diastolic blood pressure. Third, we tested two independent samples, each with comparable numbers of women and men, and one with African Americans oversampled. Men and African Americans are important to study because these groups are known to be at greater risk for cardiovascular disease and have exhibited greater cardiovascular reactivity to negative emotions. Learning whether positive emotions also undo negative emotions for men and African Americans would suggest practical health-promoting interventions for these at-risk populations. We hypothesized that positive emotions would be unique in their ability to speed recovery from the cardiovascular reactivity that lingers following a negative emotion. In other words, we expected to solidify empirical support for the undoing effect using stronger, more definitive tests. We also expected that the undoing effect would generalize across sexes and ethnicities.

Study 2 tests an alternative explanation for the undoing effect that contrasts undoing with replacement. The favored, undoing explanation suggests that positive emotions have a unique ability to speed recovery from negative emotions, and that this effect of positive emotions only surfaces within the context of negative emotional arousal. The alternative, replacement explanation suggests that positive emotions simply replace the cardiovascular signature of negative emotions with their own signature, which is one of low arousal. Which view holds? As Fredrickson and Levenson (1998) discussed following their initial test of the undoing effect, the distinction between undoing and replacement is potentially murky. Even so, insight can be gained by examining the cardiovascular signatures associated with the four films used in this experimental paradigm when viewed following a resting baseline. A replacement explanation would be viable if the two positive emotion films created lower cardiovascular activation than both the neutral and sad films. It would not be viable if, as we suspect, the cardiovascular reactions produced by viewing the two positive emotion films are minimal and not appreciably different from those produced by viewing the emotionally neutral film. We conducted Study 2 to test the viability of the replacement explanation. Ruling out replacement would favor the undoing explanation: that the cardiovascular effects of positive emotions emerge only when features of negative emotions are present to be undone.

STUDY 1

Method

Participants

Two samples of university students were tested. Each provides an independent test of the undoing hypothesis. Sample 1 included 95 university students (50% women) recruited for a study on emotions through flyers and newspaper advertisements. Each was paid $30 to participate in a series of studies lasting 2 hr. Of them, 71 were European American (50% women) and 24 were African American (50% women). Sample 2 included 75 university students (45% women) enrolled in an introductory psychology course. Each received course credit in exchange for their participation. In this sample, 58 were European American, 13 were ethnic minorities (8 Asian, 3 African American, and 2 Hispanic), and 4 were of other or unspecified ethnic backgrounds.

Materials

Written. Subjective experiences were assessed using Emotion Report Forms (adapted from Ekman, Friesen, & Ancoli, 1980). Participants rated the greatest amount felt of the following emotions: amusement, anger, anxiety, contentment, disgust, fear, sadness, and surprise. Ratings were made on 9-point Likert scales (0 = *none*, 8 = *a great deal*).

Visual. Four videotaped film clips, each 100-s long and without sound, served as the experimental manipulation in this research. These film clips were virtually identical to those used in the initial test of the undoing effect (Fredrickson & Levenson, 1998). Two clips elicited two distinct positive emotions: “Waves” shows ocean waves breaking on a beach and primarily elicits contentment (this was a different, more effective clip of waves than that used in Fredrickson & Levenson, 1998); “Puppy” shows a small dog playing with a flower and primarily elicits amusement. Two additional clips were used as neutral and emotion control conditions, respectively: “Sticks” shows an abstract dynamic display of colored sticks piling up and elicits virtually no emotion; “Cry” shows a young boy crying as he watches his father die and primarily elicits sadness. Emotion ratings gathered from pilot participants who viewed these four film clips are reported in Fredrickson and Levenson (1998, Fig. 1). These data also confirmed that the four clips elicit comparable levels of interest.

Cardiovascular Measures

Continuous recordings were made of six cardiovascular measures at a sampling rate of 1000 Hz. From these recordings, second-by-second averages were computed. (1) *Heart rate* (HR): disposable snap electrodes were placed in a bipolar configuration on opposite sides of the chest to measure the participant's echocardiogram (ECG). (2) *Finger pulse amplitude* (FPA): a photoplethysmograph was attached to the distal phalange of the first finger of the nondominant hand and the trough-to-peak amplitude of each finger pulse was measured to assess the amount of blood in the tip of the finger and provide an index of peripheral vasoconstriction. (3) *Pulse transmission times to the finger* (PTF): the interval was timed between the R-wave of the ECG and the upstroke of the pulse wave at the finger. (4) *Pulse transmission time to the ear* (PTE): a photoplethysmograph was attached to the right ear and the interval was timed between the R-wave of the ECG and the upstroke of the pulse wave at the ear. The two pulse transmission times index the contractile force of the heart along with distensibility of the blood vessels (Newlin & Levenson, 1979). Finally, an Ohmeda Finapres Blood Pressure Monitor (Model 2300) was used to assess beat-by-beat measures of (5) *diastolic blood pressure* (DBP) and (6) *systolic blood pressure* (SBP): a self-regulating finger cuff was attached to the middle phalange of the second finger of the participant's nondominant hand; a sling was used to immobilize the participant's arm at heart level.

This set of measures was selected to allow for continuous, noninvasive assessment of cardiovascular reactivity. Although HR, and to a lesser extent DBP, are under both sympathetic and parasympathetic control, four measures (FPA, PTF, PTE, and SBP) track changes mediated solely by the sympathetic nervous system. Together, these six cardiovascular measures provide a larger window onto sympathetic activation of the cardiovascular system than does any single cardiovascular index.

Anxiety Induction

The initial negative emotion was elicited using a speech preparation task. Before the experimental session began, the experimenter told participants that they would be given precisely 60 s to prepare a 3-min speech on a to-be-determined topic. They were also told that there was a 50% chance that "the computer" would select them to deliver their speech, and that if so, a 3-min timer would appear on the video monitor, cueing them to look into the video camera and begin their speech, speaking clearly. They were told that their videotaped speech would later be shown to and evaluated by students in another study. If "by chance" they were not selected to deliver their speech, they were told that a film clip would begin on the video monitor. In actuality, no participants delivered a speech, and each viewed a film clip. This cover story was used both to boost the anxiety induced by the speech task and to justify the switch to an unrelated film clip.

Procedure

Participants were tested individually by a female experimenter. (For Sample 1, participant and experimenter were matched on ethnicity.) Upon arrival, participants were seated in a comfortable chair in a small well-lit room. They were told that the study was about people's emotional reactions, that they would be videotaped, and that their bodily reactions would be monitored using physiological sensors. After participants signed a consent form, the experimenter attached physiological sensors as described here.

The experimental session began with a 5-min adaptation period. Participants then received the videotaped instructions to "relax, and empty your mind of all thoughts, feelings and memories." This commenced a 2-min resting baseline period, the second minute of which was used as the pretask baseline. Next, participants received videotaped instructions to begin preparing a speech on "Why you are a good friend" and were given 60 s to do so. This speech preparation task was followed by the Waves, Puppy, Sticks, or Cry film clip, which was randomly assigned, blocked by participant sex, and (in Sample 1) participant ethnicity. The film was followed by a 3-min postfilm period during which the video monitor was blank. Afterwards, participants completed one Emotion Report Form to describe how they felt while preparing their speech, and a second Emotion Report Form to describe how they felt viewing the randomly assigned film clip.

Data from Fredrickson and Levenson (1998) and Sample 1 in the present study each clearly demonstrated that the Cry film produces prolonged cardiovascular recovery relative to positive films. With this difference well established, the sadness condition was omitted when testing Sample 2. Another comparison condition to consider is a "no-film" control, in which the presumably natural course of cardiovascular recovery might be assessed and compared to that produced by positive emotions. A no-film condition is problematic for two, related, reasons. First, cardiovascular activity is sensitive to perceptual and attentional processes, as well as to emotional processes. As such, comparing responses to film viewing to "doing nothing" confounds emotional content with differences in basic cognitive demands. The neutral Sticks film provides a superior comparison condition because it holds cognitive demands constant, yet is devoid of emotion. Second, people rarely (if ever) do nothing, perhaps especially when they are experiencing a potent emotion. As such, a no-film condition is more likely to reveal heterogeneity in self-chosen emotion regulation strategies than the so-called "natural" course of emotion recovery. For these reasons, we did not include a no-film condition. (For further discussion of this issue, see Fredrickson & Levenson, 1998.)

Results

Overview of Analytic Strategy

We first confirmed that the speech preparation task successfully induced anxiety and cardiovascular reactivity, then conducted a manipulation check to confirm that the film clips altered subjective experience as intended. We then used a priori contrasts to test the undoing hypothesis, which is both theory-driven and directional. Specifically, we tested whether the durations of cardiovascular reactivity for participants who viewed each of the two positive films were shorter than (a) the duration of cardiovascular reactivity for those who viewed the neutral film, and (b) the duration of cardiovascular reactivity for those who viewed the sad film (Sample 1 only). We tested for sex and ethnic differences throughout. Sample 1 permitted comparisons of African Americans ($n = 24$) to European Americans ($n = 71$); Sample 2 permitted comparisons of various ethnic minorities ($n = 17$) to European Americans ($n = 58$).

Responses to the Speech Preparation Task

Subjective Experience. Analyses of the Emotion Report Forms completed for the speech preparation task confirmed that this task elicited significantly higher levels of anxiety than any other emotion. For Sample 1, mean anxiety ratings were 4.79 ($SD = 2.16$). These anxiety ratings did not differ by sex. However, they did differ across ethnic groups, with African Americans reporting less anxiety ($M = 3.92$, $SD = 2.32$) than European Americans, $M = 5.08$, $SD = 2.04$; $F(1, 91) = 5.38$, $p < .05$. Even so, anxiety received the highest mean ratings within each ethnic group. For Sample 2, mean anxiety ratings were 4.96 ($SD = 2.10$), and did not differ by sex or ethnicity.

Cardiovascular Reactivity. For each participant, and for each cardiovascular measure (HR, FPA, PTF, PTE, DBP, and SBP), we determined the mean reactivity over the 60-s pretask baseline and over the 60-s speech preparation task. These means, averaged across participants are shown in Table I.[4] Within-subject *t*-tests confirmed that the cardiovascular reactivity during the speech task was significantly different than baseline levels for all six cardiovascular variables across both samples (see Table I). HR increased an average of 9.80 beats/min in Sample 1 and 12.18 beats/min in Sample 2; FPA decreased an average of 0.34 mv in Sample 1 and 0.57 mv in Sample 2; PTF and PTE decreased an average 0.013 and 0.008 s, respectively, in Sample 1, and 0.008 and 0.007, respectively, in Sample 2; and DBP and SBP increased an average of 1.97 and 8.99 mmHg, respectively, in Sample 1, and 4.65 and 19.06 mmHg, respectively, in Sample 2. Cardiovascular reactivity to the

[4]Due to equipment failure, indices of blood pressure were not available for two participants in Sample 1.

Table I. Mean and Standard Deviation of Cardiovascular Activity During Baseline and Speech Preparation in Study 1

	Sample 1		Sample 2	
Variable	Baseline	Speech preparation	Baseline	Speech preparation
HR	75.24 (11.89)	85.05*** (14.98)	76.10 (12.60)	88.28*** (14.37)
FPA	0.90 (0.58)	0.56*** (0.46)	1.39 (0.57)	0.82*** (0.55)
PTF	0.278 (0.021)	0.265*** (0.027)	0.270 (0.021)	0.262*** (0.026)
PTE	0.210 (0.025)	0.202*** (0.025)	0.197 (0.023)	0.190*** (0.023)
DBP	64.90 (13.65)	66.86*** (13.25)	61.20 (13.89)	65.85*** (15.51)
SBP	120.59 (21.52)	129.58*** (24.09)	122.87 (24.44)	141.93*** (28.60)

Note. HR: heart rate in beats per min; FPA: finger pulse amplitude in mv; PTF: pulse transmission time to the finger in seconds; PTE: pulse transmission time to the ear in seconds; DBP: diastolic blood pressure in mmHg; SBP: systolic blood pressure in mmHg. Values represent *M* (*SD*).
*** $p < .001$.

speech task did not differ by sex, ethnicity, or Film Group in either sample. Taken together, these cardiovascular changes include heart rate acceleration and a clear pattern of sympathetic activation (e.g., increased blood pressure and peripheral vasoconstriction).

Manipulation Check

Analyses of the Emotion Report Forms completed for the film clips confirmed that each altered subjective experience as expected, thus replicating data reported in Fredrickson and Levenson (1998). Tukey pairwise comparisons revealed that Waves elicited significantly more contentment (Sample 1: $M = 4.75$, $SD = 1.94$; Sample 2: $M = 4.83$, $SD = 1.43$) than any other clip, Puppy elicited more amusement (Sample 1: $M = 4.67$, $SD = 1.97$; Sample 2: $M = 5.21$, $SD = 1.18$), and Cry elicited more sadness (Sample 1 only: $M = 4.09$, $SD = 2.52$). Modal emotion reports for Sticks were zero for all eight emotion terms, confirming its emotional neutrality. Emotion ratings did not differ by sex or ethnicity in either sample.

Duration of Cardiovascular Reactivity

The duration of cardiovascular reactivity was quantified as the time elapsed (in seconds) from the start of the film clip until each participant's cardiovascular responses on each measure returned to within the interval defined by his or her own baseline mean on that measure plus and minus one standard deviation of that mean, and remained within this interval for 5 of 6 consecutive seconds. (Fewer than 5% of duration scores were considered missing because a measure did not return to baseline during the data collection period.) Initial analyses of duration scores for individual cardiovascular measures revealed supportive trends across all measures, but no significant effects. To increase power, we created an aggregate measure of the duration of cardiovascular reactivity by computing each participant's mean duration score across the six cardiovascular indices, a strategy also used in Fredrickson and Levenson (1998).

In Sample 1, across all participants, the mean duration of cardiovascular reactivity was 30.08 s ($SD = 25.80$). We analyzed these data for group differences using a $4 \times 2 \times 2$ ANOVA (Film Group $\times$ Sex $\times$ Ethnicity). No main effects for, or interactions with, Sex or Ethnicity were significant. The main effect for Film Group was the sole significant effect, $F(3, 81) = 3.40$, $p < .05$. Figure 1 presents mean durations of cardiovascular reactivity for each of the four Film Groups. The pattern of means shows that contentment and amusement clips produced the fastest cardiovascular recovery. As is typical with time-based data, the duration scores exhibited a large positive skew. To test whether the significant effect for Film Group (depicted in Fig. 1) was unduly influenced by outliers, we also computed a Kruskal–Wallis nonparametric test on ranked data. This more conservative test confirmed that the group differences were significant, $\chi^2(3) = 9.89$, $p < .05$. Moreover, a priori contrasts confirmed that those who viewed the contentment clip exhibited faster recovery than those who viewed the neutral clip, $t(91) = 1.79$, $p = .038$, and faster recovery than those who viewed the sad clip, $t(91) = 2.68$, $p = .004$. Likewise, those who viewed the amusement clip exhibited faster recovery than those who viewed the neutral clip, $t(91) = 1.66$, $p = .050$, and faster recovery than those who viewed the sad clip, $t(91) = 2.55$, $p = .006$.

In Sample 2, across all participants, the mean duration of cardiovascular reactivity was 37.78 s ($SD = 35.88$). Again, analyzing the duration data with a $3 \times 2 \times 2$ ANOVA (Film Group $\times$ Sex $\times$ Ethnicity), no main effects for, or interactions with, Sex or Ethnicity emerged. As for Sample 1, the sole significant effect was that for Film Group, $F(2, 63) = 3.29$, $p < .05$. Figure 2 presents mean

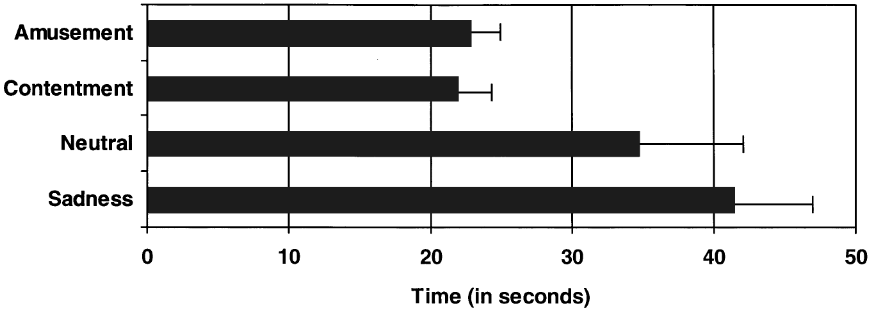

Fig. 1. Mean duration of cardiovascular reactivity by Film Group in Sample 1 of Study 1. Error bars represent standard errors of the means.

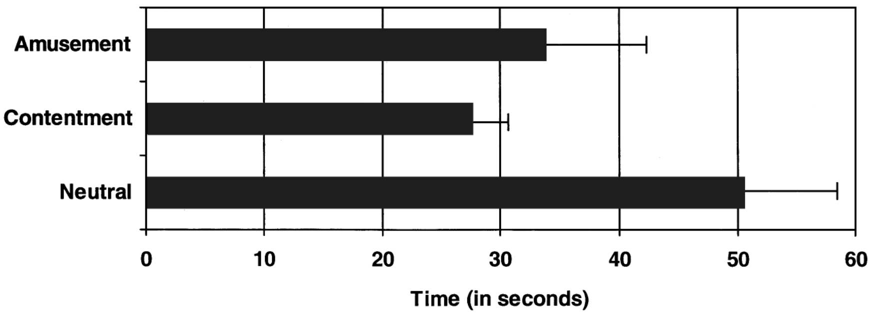

Fig. 2. Mean duration of cardiovascular reactivity by Film Group in Sample 2 of Study 1. Error bars represent standard errors of the means.

durations of cardiovascular reactivity for each of the three Film Groups. Again, the pattern of means shows that contentment and amusement clips produced the fastest cardiovascular recovery. As for Sample 1, a Kruskal–Wallis nonparametric test confirmed that the group differences evident in Fig. 2 remained significant when the effects of outliers were controlled, $\chi^2(2) = 5.88$, $p = .05$. Again as for Sample 1, a priori contrasts confirmed that those who viewed the contentment clip exhibited faster recovery than those who viewed the neutral clip, $t(72) = 2.43$, $p = .008$. Likewise, those who viewed the amusement clip exhibited faster recovery than those who viewed the neutral clip, $t(72) = 1.78$, $p = .039$.

Discussion

The two samples tested in Study 1 provide two independent tests of the undoing effect of positive emotions. Results from both tests support the undoing hypothesis, exactly replicating the preliminary findings reported by Fredrickson and Levenson (1998). Study 1 also extends the evidence for the undoing effect of positive emotions in three important ways. First, the undoing effect occurs when the initial negative emotion generates a clear pattern of heightened sympathetic cardiovascular reactivity that is typical of anxiety, fear, and other health-damaging negative emotions. Second, the undoing effect is not limited to women, but occurs for men as well. Third, the undoing effect occurs comparably for African Americans and European Americans. Importantly, the undoing effect has now been demonstrated experimentally three times for two distinct types of positive emotion: a low-activation pleasant state of contentment and a higher-activation pleasant state of amusement. This evidence suggests that these two positive emotions—although distinct in their phenomenology and activation level—share the ability to regulate lingering negative emotional arousal. Additional studies will be needed to assess whether the undoing effect generalizes to other positive emotions, such as interest, love, pride, or excitement.

Most important, data from Study 1 indicate that the undoing effect of positive emotions is not a spurious finding, but is instead replicable and real. In addition, these data provide indirect support for Fredrickson's broaden-and-build theory of positive emotions (Fredrickson, 1998). If we take the cardiovascular activation that accompanies negative emotions to be the body's preparation for specific action, then by quelling this activation, positive emotions may help the body move from a (no longer useful) narrow thought–action repertoire toward a broader one, allowing the individual to pursue a wider array of thoughts and actions. Moreover, laboratory evidence showing that both contentment and amusement can undo lingering negative emotional arousal provides footing for the suggestion that individuals can harness the undoing effect of positive emotions to regulate negative emotions in daily life (Fredrickson, 2000).

Despite the augmented empirical support for the existence of the undoing effect, a viable alternative explanation remains. Perhaps the neutral and sad films elicit cardiovascular arousal, whereas the positive films do not. If so, instead of concluding that the positive films facilitate cardiovascular recovery, we should conclude that the neutral and sad films prolong recovery. In other words, perhaps our findings represent replacement rather than undoing: Perhaps each film simply replaces the cardiovascular reactivity produced by the speech task with its own cardiovascular signature, and the two positive films produce lower sympathetic activation than both the neutral and sad films. We now turn to Study 2 to test the viability of this replacement explanation by examining cardiovascular responses to the positive, neutral, and sad films against the backdrop of a resting baseline.

STUDY 2

Method

Participants

One hundred eighty-five university students (49% women) were recruited for a study on emotions through flyers and newspaper advertisements. Each was paid $30 to participate in a series of studies lasting 2 hr. Of the participants, 137 were European American (48% women) and 48 were African American (50% women). Approximately half of the participants in Study 2 later participated in Study 1, as Sample 1. For these participants, random assignment to experimental condition across Studies 1 and 2 was yoked such that no participant viewed the same film clip across the two studies.

Materials

The written and visual materials were the same as used in Study 1.

Cardiovascular Measures

These were identical to those used in Study 1.

On-Line Affect Report

A positive–negative affect rating dial, developed by Levenson and Gottman (1983), was used to obtain on-line, continuous reports of affect during the study. Participants manipulated a dial whose pointer moved on a 180-deg scale divided into nine divisions ranging from *very negative* to *neutral* to *very positive*. The dial was attached to a potentiometer in a voltage diving circuit monitored by the same computer that monitored the cardiovascular data. Participants were instructed to adjust the dial position as often as necessary so that it always reflected how positive or negative they were feeling moment-by-moment throughout the session. Validity data for this affect rating dial procedure can be found in Gottman and Levenson (1985; see Fredrickson & Kahneman, 1993, for a similar on-line affect rating procedure).

Procedure

Participants were tested individually by a female experimenter of their same ethnicity. The laboratory environment and introductory remarks to participants were the same as in Study 1. After physiological sensors were attached and a 5-min adaptation period, the experimenter introduced the study in more detail. Participants were told that they would view film clips that would depict either positive, negative, or neutral images and that they should watch the video monitor at all times. They were also instructed in the use of the affect rating dial. Participants were given an opportunity to practice manipulating the dial without looking down at their hand. During the actual data collection, participants were alone in the room.

Following an additional 5-min adaptation period, participants received instructions on the video monitor to “relax, and empty your mind of all thoughts, feelings and memories.” This commenced a 2-min resting baseline period, the second minute of which was used as the prefilm baseline. Immediately following this resting baseline phase, participants (blocked by sex and ethnicity) were randomly assigned to view the Waves, Puppy, Sticks, or Cry film. At the end of this film viewing trial, participants completed an Emotion Report Form to describe how they felt viewing the film clip.

Table II. Mean and Standard Deviation of Subjective and Cardiovascular Changes for the Four Film Groups in Study 2

	Film Group			
Variable	Waves	Puppy	Sticks	Cry
RATE	1.70_{a}^{***} (1.28)	1.23_{a}^{***} (1.38)	0.11_{b} (0.80)	-1.07_{c}^{***} (1.21)
HR	-0.83_{a} (3.11)	0.44_{a} (2.67)	-0.26_{a} (2.56)	-0.89_{a}^{**} (2.25)
FPA	-0.06_{a}^{*} (0.20)	-0.02_{a} (0.20)	0.00_{a} (0.16)	-0.10_{a}^{**} (0.24)
PTF	0.0007_{a} (0.005)	-0.0010_{a} (0.005)	0.0007_{a} (0.003)	-0.0002_{a} (0.005)
PTE	0.0007_{a} (0.004)	0.0004_{a} (0.005)	0.0002_{a} (0.004)	-0.0004_{a} (0.004)
DBP	0.44_{a} (1.96)	0.31_{a} (2.15)	-0.49_{a} (2.21)	0.36_{a} (2.16)
SBP	$2.09_{a,b}^{**}$ (4.93)	$0.92_{a,b}$ (5.41)	-0.53_{a} (5.69)	3.93_{b}^{**} (8.63)

Note. RATE: affect rating dial, ranging from 0 to 9; HR: heart rate in beats per min; FPA: finger pulse amplitude in mv; PTF: pulse transmission time to the finger in seconds; PTE: pulse transmission time to the ear in seconds; DBP: diastolic blood pressure in mmHg; SBP: systolic blood pressure in mmHg. Means in the same row with the same subscript are not significantly different at $p < .05$ by Tukey pairwise comparisons. Asterisks indicate changes significantly different from resting baseline measures by within-subject *t*-tests ($df = 45$ or 46). Values represent *M* (*SD*).
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Results

Data Reduction

For each participant, we calculated mean affect rating dial reports and cardiovascular activity averaged across the 60-s prefilm baseline period and the 100-s film period.[5] To quantify participants' responses to the films, we subtracted baseline period means from film period means. The resulting change scores for each of the four film clips are presented in Table II. For each film, and for each variable, we computed within-subject *t*-tests to examine whether these change scores represented significant differences from the prefilm resting baseline. The results of these tests are also reported in Table II.

Manipulation Check

We wished to confirm that the four films altered subjective experiences as intended. Data from the on-line affect rating dial, presented in the first row of Table II, provided this confirmation. We explored sex and ethnicity differences by using a 2 × 2 × 4 ANOVA (Sex × Ethnicity × Film Group). Beyond the expected effect for Film Group, $F(3, 169) = 51.25$, $p < .001$, no main effects for, or interactions with, Sex or Ethnicity were significant. Moreover, Tukey pairwise comparisons (reported in row 1 of Table II) confirmed that rating dial responses

[5]Due to experimenter error, the ECG was not recorded for one participant, rendering all variables derived from ECG (i.e., HR, PTF, and PTE) missing for that participant. Due to equipment failure, indices of blood pressure were not available for two additional participants.

to both the Waves and the Puppy films were more positive than those to both the Sticks and the Cry films. Additionally, rating dial responses to the Cry film were more negative than those to the Sticks film.

These group differences in on-line subjective ratings were corroborated by the retrospective subjective ratings provided on the Emotion Report Forms: Tukey pairwise comparisons revealed that Waves elicited significantly more contentment ($M = 5.24$, $SD = 1.82$) than any other clip, Puppy elicited more amusement ($M = 4.74$, $SD = 2.25$), and Cry elicited more sadness ($M = 4.15$, $SD = 2.29$). As in prior studies, modal emotion reports for Sticks were zero for all eight emotion terms, confirming its emotional neutrality. Differences in retrospective emotion ratings by sex and ethnicity were explored using $2 \times 2 \times 4$ ANOVAs (Sex × Ethnicity × Film Group). Beyond the expected main effects for Film Group, only one main effect for Ethnicity emerged: Across all films, African Americans reported less contentment ($M = 2.54$, $SD = 2.37$) than European Americans, $M = 3.36$, $SD = 2.62$, $F(1, 169) = 6.23$, $p = .014$.

Is Replacement a Viable Alternative Explanation?

Recall that the replacement explanation requires the two positive films to elicit lower sympathetic activation than both the neutral film and the sad film. Inspection of mean cardiovascular change scores in Table II suggests that the cardiovascular responses to the four films were minimal (cf., Table I showing cardiovascular responses to the anxiety-producing speech task in Study 1). In fact, no cardiovascular responses were significantly different from resting baseline levels for the Puppy or Sticks film groups. Within the Waves film group, the slight decrease in FPA was statistically significant, as was the slight increase in SBP (see Table II, column 1). Within the Cry film group, the slight decreases in HR and FPA were significant, as was the increase in SBP (see Table II, column 4).

To test for differences in cardiovascular reactivity elicited by the four films, and to explore possible differences by sex and ethnicity, we conducted a series of univariate $2 \times 2 \times 4$ ANOVAs (Sex × Ethnicity × Film Group) on each of the six cardiovascular variables. We followed these with post hoc pairwise comparisons where indicated. We found that only FPA and SBP distinguished the Cry film from the other films, yet only for certain subgroups: Greater vasoconstriction during the Cry film was evident only among women (women: $M = -0.19$, $SD = 0.27$; men: $M = -0.03$, $SD = 0.20$, Film Group × Sex: $F(3, 169) = 3.09$, $p = .029$), and greater increases in SBP during the Cry film were strongest for women (women: $M = 7.29$, $SD = 11.72$; men: $M = 1.99$, $SD = 5.13$, Film Group × Sex: $F(3, 169) = 3.64$, $p = .014$), particularly African American women ($M = 14.96$, $SD = 17.65$, Film Group × Sex × Ethnicity: $F(3, 169) = 3.06$, $p = .030$). The results of Tukey pairwise comparisons across Film Groups (collapsing across sex and ethnicity) are indicated in Table II. From these findings we can conclude that the sad film elicits somewhat more sympathetic reactivity than the positive and neutral films do, especially for women.

The most critical comparisons for disconfirming the replacement explanation, however, are between the neutral and positive films. Although some degree of cardiovascular reactivity was evident for one of the two positive films (Waves, see Table II, column 1), are these changes appreciably different from those produced by the neutral film? To test this, we conducted a series of $2 \times 2 \times 3$ ANOVAs (Sex $\times$ Ethnicity $\times$ Film Group, excluding the Cry film) on the set of six cardiovascular measures. No main effects or interactions emerged as significant for any of the six variables. These null findings suggest that positive and neutral films produced statistically indistinguishable cardiovascular responses.

Discussion

As expected, data from Study 2 demonstrated that althogh the selected positive and neutral films clearly differed in the subjective responses they produced, they did not differ in the cardiovascular responses they produced. In fact, cardiovascular responses to these positive and neutral films were almost nonexistent. This disconfirms the replacement hypothesis: If the positive and neutral films do not differ in their cardiovascular signatures, then the undoing effect observed in Study 1 could not result from a simple replacement process. It bears note, however, that our prediction that cardiovascular responses to positive and neutral films would not differ parallels the null hypothesis, and by consequence, we had a disproportionate chance to support it. With this limitation in mind, we consider this to be a demonstration study concerning the two positive emotion films used in this research, rather than rigorous hypothesis testing about positive emotions more generally. We conservatively conclude that—when viewed in a neutral context—the contentment-eliciting Waves clip and the amusing Puppy clip do not do much to the cardiovascular systems of those who view them.

Undoing Versus Replacement

Yet even this conservative conclusion contributes to a key issue that lingered following Fredrickson and Levenson's initial test of the undoing effect, namely the choice between interpreting the results in terms of undoing versus replacement. An undoing explanation holds that negative emotions produce cardiovascular reactivity that may linger for variable amounts of time, and that positive emotions have a unique ability to speed the return to baseline levels of arousal. By contrast, a replacement explanation holds that the data do not reflect differential rates of recovery from negative emotion, but instead that the cardiovascular reactivity produced by the initial negative emotion has been swiftly replaced by the cardiovascular reactivity produced by the subsequent positive emotion. Such replacement implies that positive emotions quickly assume control of the cardiovascular system and substitute their own patterns of activation for that produced by the initial negative emotion.

Yet the data from Study 2 suggest that the positive and neutral films produce indistinguishable patterns of cardiovascular activation. Taking this into consideration, the replacement explanation must predict positive and neutral films to be comparable in their ability to switch to their own patterns of cardiovascular activation following negative emotional arousal, and thus comparable in their ability to facilitate returns to baseline. Moreover, to the extent that the contentment-eliciting Waves film produces slight increases in sympathetic cardiovascular activation (decreased FPA, indicative of vasoconstriction, and increased SBP), and the neutral Sticks film produced no sympathetic changes, the replacement explanation would predict slightly faster returns to baseline for the neutral film than for the contentment film. Yet data from Study 1 (and the Fredrickson–Levenson experiment) show that this is not the case. Both positive emotion films brought cardiovascular levels back to baseline faster than the emotionally neutral film. In light of data from Study 2, the replacement explanation is not sufficient to explain this pattern of results. The alternative explanation that the undoing effect operates by simple replacement can thus be ruled out.

GENERAL DISCUSSION

Taken together, Studies 1 and 2 suggest that positive emotions are unique, not in what they *do* to the cardiovascular system, but rather in what they can *undo* within this system. Put differently, the cardiovascular effects of positive emotions appear to emerge only when negative emotions have already generated cardiovascular reactivity.

Although the undoing effect of positive emotions now has demonstrated reliability, additional studies are needed to address lingering questions. For instance, what physiological mechanism mediates the effect? To date, we have explored changes in parasympathetic cardiac control (indexed by respiratory sinus arrhythmia, or RSA) both in the undoing paradigm (e.g., Study 1) as well as in comparisons across positive, neutral, and negative films (e.g., Study 2). In neither context have we observed any differences in RSA responses across experimental conditions. We thus tentatively conclude that the undoing effect of positive emotions does not occur through phasic changes in parasympathetic cardiac control. Discerning the operative underlying mechanism remains a task for future work.

Other questions linger as well. For example, is the undoing effect limited to the cardiovascular concomitants of emotions? Or, as the broaden-and-build theory would imply, can positive emotions also undo the cognitive and behavioral narrowing produced by negative emotions, and thereby restore flexible thinking and action? To the best of our knowledge, no experiments have tested this prediction directly. Even so, indirect evidence can be drawn from correlational studies. Individuals who express or report higher levels of positive emotion show more constructive and flexible coping, more abstract and long-term thinking, and greater emotional distance following stressful negative events (Keltner & Bonanno, 1997; Martin, Kuiper, Olinger, & Dance, 1993; Lyubomirsky & Tucker, 1998; Stein, Folkman, Trabasso, & Richards, 1997).

Another question to ask is whether evidence for the undoing effect also implies that positive emotions will buffer against cardiovascular reactivity triggered by subsequently experienced negative emotions. We have explored this possibility both empirically and theoretically. At an empirical level, we have reversed the order of film viewing used in Fredrickson and Levenson's initial test of the undoing effect, showing people first the contentment, amusement, neutral, or sad film (by random assignment), and then showing the fear clip immediately after. No evidence for a buffering effect of positive emotions emerged (Fredrickson & Mancuso, 1996). At a theoretical level, we concur with other theorists that personally relevant circumstances that elicit negative emotions should reliably interrupt people's actions and capture their attention, both psychologically and physiologically (Levenson, 1994; Mandler, 1984; Pratto & John, 1991; Simon, 1967; Tomkins, 1995). We suspect that such interruption should occur no matter what people's prior affective state. Thus, we speculate that positive emotions do not buffer against negative emotional arousal in any direct or simple way. Even so, positive emotions might, over time, bolster people's resources for coping with circumstances that elicit negative emotions. That is, positive emotions might play an indirect buffering role by incrementing coping resources (Folkman & Moskowitz, 2000). These coping resources might take the form of the physical, intellectual, or social resources described by Fredrickson's broaden-and-build theory of positive emotions (Fredrickson, 1998), the hedonic surplus described by Aspinwall (1998), or—if the undoing effect of positive emotions were deployed regularly to speed recovery from negative emotions—the physiological toughness described by Dienstbier (1989).

In sum, the work reported here illuminates one reason, beyond intrinsic pleasure, for the pursuit of happiness: Positive emotions help downregulate the potentially health-damaging cardiovascular reactivity that lingers following negative emotions. This effect may be especially critical for those most at risk for developing coronary heart disease. Nonetheless, the undoing effect is likely to be just one of many reasons to pursue positive emotions. The broaden-and-build theory describes many others (Fredrickson, 1998, in press-a, in press-b). Chief among these is that experiences of positive emotions are thought to build individuals' lasting personal resources. By consequence, positive emotions could be tapped to optimize people's health and well-being (Fredrickson, 2000). It appears then that we have reasons other than pure hedonism to pursue positive emotions. Evidence that positive emotions do more than simply feel good underscores the need to study them further.

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