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Behavioral Inhibition and Amplification During Emotional Arousal: A Comparison of Two Age Groups

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This study investigated age differences in the ability to suppress and amplify expressive behavior during emotional arousal. Young and old participants viewed 3 film clips about medical procedures while their behavioral, autonomic, and subjective responses were recorded. Half of the participants viewed all 3 films without additional instructions; the other half was asked to suppress and amplify their behavioral expression during the 2nd and 3rd films. Except for heart rate, suppression and amplification produced similar patterns of autonomic activation. Neither suppression nor amplification had effects on self-reported emotion. There were no age differences in the ability to suppress or amplify emotional expression or in their physiological or subjective consequences. Considering that older people's unregulated reactivity was lower than that of young adults, suppression may have been easier and amplification more difficult for older adults. Voluntary emotion regulation might be one domain of human performance that is spared from age-related losses.

Old age is often portrayed as a period of life characterized by losses in multiple domains. Consistent with this view, empirical evidence suggests that declines in physical health and basic cognitive functioning become increasingly prevalent in old age (e.g., Baltes & Mayer, 1999; Salthouse, 1996; Schaie, 1989). Much of the diminishing in physical strength and cognitive flexibility is directly predictable from changes that occur at the biological level as we age (i.e., from age-related changes in cellular, neural, endocrine, and immunological systems). In the realms of physical and basic cognitive functioning, scientific evidence is consistent with lay opinion: Old age is synonymous with loss.

In the realm of emotion, however, predictions about what kinds of age-related changes should occur are not as easy to make. Emotions are influenced by a complex interplay of biological, psychological, and social factors (e.g., Carstensen & Turk-Charles, 1998; Lawton, 2001; Levenson, 2000). Each of these factors evinces multidirectional changes with age (e.g., loss in neural conductivity, greater expertise in dealing with life's challenges, fewer interactions with unfamiliar individuals) that, acting separately or in congress, could have quite different effects on emotion. The multifaceted nature of emotion adds to this complexity. Thus, the impact of age on emotion may not be uniform but rather may depend on the particular emotion (e.g., hostility, sadness), function (e.g., reactivity, regulation), or response system (e.g., autonomic, facial expressive, subjective) being considered.

Only a few laboratory studies have measured age and emotions in vivo, or as they actually occur. These studies have focused on age differences in emotional reactivity (i.e., the type and magnitude of presumably spontaneous and unregulated responses to emotion-eliciting events; e.g., Carstensen, Gottman, & Levenson, 1995; Levenson, Carstensen, Friesen, & Ekman, 1991; Tsai, Levenson, & Carstensen, 2001). Within the limitations of cross-sectional designs, past studies on emotional reactivity suggest that the three response systems of an emotion show different age trajectories: The magnitude of autonomic reactivity has been found to be smaller in older adults, whereas subjective and behavioral reactions to emotion-arousing events seem to be undiminished in old age (e.g., Levenson et al., 1991; Tsai et al., 2001). In one study, there was even evidence for greater emotional expressivity in older people compared with young adults (see Magai & Passman, 1998). Researchers have concluded from this evidence that the basic capacity to react spontaneously to emotion-arousing events on a subjective and behavioral level remains intact in old age despite older adults' lower physiological reactivity (e.g., Lawton, 2001).

In the current study, we extended past work on age and emotion by considering not only younger and older adults' spontaneous reactions to emotion-arousing events but also their ability to regulate emotional reactions voluntarily. Therefore, we were interested not only in what a person spontaneously does do in the context of emotion-arousing events but also what this person can do if he or she wants.

Rather than being a single ability, emotion regulation encompasses multiple distinct skills; it has been defined as referring to all the processes by which people voluntarily modify their subjective experiences or behavioral expressions associated with emotion (e.g., Gross, 1998b; Levenson, 1994; Thompson, 1990). To begin to address the presumably complex relationship between age and emotion regulation, we decided to study one particular emotion regulatory form: the ability to regulate (i.e., suppress and amplify)

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expressive behavior voluntarily during events that arouse negative emotion.

Adult life is replete with situations in which the outward signs of one's negative emotional responses need to be regulated. For example, difficulties with coworkers or family members, health-related problems of loved ones, or problems with our own health potentially lead to everyday situations in which emotional expressions need to be regulated (e.g., we may want to show our sadness about the loss of a loved one or hide our anger when having a conflict with colleagues). Accumulated experience with situations that potentially evoke negative emotions could be responsible for age-related stability or even improvement in suppressing and amplifying negative emotional expressions. In this study, we chose to investigate expressive regulation during exposure to medical procedures that were thought to primarily elicit disgust because they involve violations of what Rozin et al. have called the ideal body "envelope" (i.e., the body's surface; Rozin, Haidt, & McCauley, 2000).

Emotion Regulation: Age-Related Decline, Continuity, or Growth?

Despite its ubiquity in adult life and its importance to physical and psychological well-being (e.g., Gross & Levenson, 1997), emotion regulation has rarely been studied in aging research. Thus, we do not know whether the ability to inhibit or amplify emotions (expressive behavior or inner feelings) is a competence that shows decline, continuity, or growth during adulthood.

The Same or Gain Theme: Psychological Antecedent Factors

According to prominent life span theories, becoming older is associated with the continued development of several motivational and cognitive processes that presumably are highly relevant to the ability to regulate emotional reactions, including expressive behavior (e.g., Blanchard-Fields, 1998; Carstensen & Turk-Charles, 1998; Lawton, 2001).

Carstensen's (1991) socioemotional selectivity theory (SST) suggests, for example, that emotional goals become increasingly important with age. This motivational shift may contribute to developing an increasingly higher level of emotion regulatory ability. Empirical work growing out of SST has found that age-related gains do occur in certain areas of emotion (e.g., in recalling emotional material from narratives; Carstensen & Turk-Charles, 1994). Work conducted by Blanchard-Fields is largely consistent with SST and suggests that older adults, compared with younger adults, focus more on emotional aspects when grappling with everyday problems (Blanchard-Fields, Chen, & Norris, 1997; Blanchard-Fields, Jahnke, & Camp, 1995).

According to Labouvie-Vief's theory of adult development, knowledge about the self and the people around us becomes more complex with age; consequently, older adults are better able to differentiate, organize, and integrate information about the self and others. Labouvie-Vief (1998) specifically hypothesized that knowledge about emotion, including about how people can modify their emotions, shows greater elaboration with age. Empirical work supports this view and suggests increases in the complexity of emotional understanding (Labouvie-Vief, DeVoe, & Bulka, 1987) and self-descriptions (Labouvie-Vief, Chiodo, Goguen, Diehl, & Orwoll, 1995) at least into late midlife.[1]

In sum, age-related changes in motivation (i.e., emotional goals becoming increasingly more salient) and cognition (i.e., knowledge about emotion becoming increasingly complex) are factors that argue for maintenance or even improvement in the ability to regulate one's emotional reactions during the adult years.

The Loss Theme: Biological Antecedent Factors

Although work on biological aging has pointed to a certain degree of interindividual and domain variability, aging generally is associated with reduced efficiency and a slowing of basic physical processes (e.g., Schneider & Rowe, 1996; Timiras, 1994; Woodruff-Pak, 1997). These changes in biological functioning could produce losses in the realm of emotion regulation.

The autonomic nervous system, which plays an important role in emotion, is one of several biological systems that are clearly affected by age. Numerous studies have shown that sympathetic and parasympathetic innervations decrease during the adult years (e.g., Evans & Williams, 1992; Frolkis, 1977). Given the general dampening of end-organ autonomic reactivity, it is not surprising that autonomic responses also show diminution with age (for a review, see Levenson, 2000). Considering that the emotional response systems mutually influence one another (e.g., Levenson, 2000), age-related decline in autonomic responding might render one's ability to voluntarily regulate emotional expressions more difficult.

Another biological system more directly involved in behavioral regulation is the somatic nervous system, which includes the facial muscles. Empirical evidence indicates that muscle atrophy and a decline in muscle strength are inevitable concomitants of old age (e.g., Evans & Williams, 1992; Faulkner, Brooks, & Zebra, 1991). Indeed, there is evidence that older adults are less skilled at voluntarily producing certain facial configurations than their younger counterparts (e.g., Levenson et al., 1991).

Reductions in the efficiency and strength of autonomic and somatic processes with age are factors that might reduce the ability to regulate emotional expressions and thus generally support the prediction of a loss in emotion regulation with age. Emotion regulation is, however, a complex process, and the effects of these age-related changes could be similarly complex. For example, a reduction in the strength of autonomic and somatic responses could actually make it easier to downregulate certain aspects of emotion.

Emotion Regulation: Loss, Gain, or Same?

Which theme best captures the nature of emotion regulation in adulthood? Whereas research on psychological aging generally supports predictions of continued growth into old age, research on

[1] Inconsistent with her theoretical work, Labouvie-Vief also reported evidence for a dedifferentiation of knowledge in old age and very old age (Labouvie-Vief, 1998). In our view, however, it would be too early to reject Labouvie-Vief's theoretical idea of a linear increase in emotional understanding and knowledge. Doing so would require more empirical work that examines age differences on the basis of longitudinal data and alternative operationalizations of complexity that emphasize integration rather than conflicting or ambivalent perspectives on the self and others.

biological aging paints a less favorable picture. It is likely that any performance in the realm of emotion regulation is simultaneously influenced by physiological and psychological factors, which may interact in multiple and complex ways. Therefore, many forms of emotion regulation, including the one studied here (i.e., behavioral suppression and amplification) might remain stable during the adult years despite the decline in general physiological functioning. Unfortunately, there have been only few empirical studies on age differences in different forms of emotion regulation.

In our review of the literature, we found only two studies that have investigated emotion regulation in adults of different ages (Gross et al., 1997; Lawton, Kleban, Rajagopal, & Dean, 1992), and both examined beliefs about emotion regulation rather than measuring actual emotion regulatory skills. In Gross et al.'s study, older adults saw themselves as more successful in regulating their inner feelings and outer expressions of emotions than younger adults did. Similarly, in Lawton et al.'s study, older adults reported higher levels of emotion regulation (control of inner feelings and behavior) than younger adults.

These two studies provide some indication that emotion regulation might remain stable or even improve in adulthood; however, they are based on questionnaire data and not on observed performance. We know from studies of other domains of human functioning that people's subjective evaluations of what they can do often are not accurate reflections of their objective competencies (e.g., Heckhausen & Schulz, 1995; Taylor & Brown, 1988). Thus, to supplement the few existing studies of beliefs about emotional regulation, there is a clear need for well-controlled studies of actual performance levels.

The Current Study

This study was designed to test age differences in a particular aspect of emotion regulation, namely the ability to regulate one's emotional reactions to emotion-eliciting events voluntarily. Specifically, young (18–28 years) and old (60–85 years) adults were told to suppress or amplify their expressive behavior while viewing films of medical procedures known to elicit strong negative emotions, particularly disgust.

In our initial investigation of age differences in emotion regulation, we decided to study the ability to regulate expressive behavior as opposed to the ability to regulate inner experiences. The rationale for this was twofold. First, regulating the outward signs of emotion is a type of emotion regulation that is common at all ages, especially in its voluntary form. Second, our visible emotional expression has strong effects on others, and its regulation has profound implications for how others interact with us. In the context of medical procedures, one can easily think of situations in which it is important to show and communicate one's disgust and other situations in which it may be more adaptive to suppress the expression of disgust.

In addition to age differences in the ability to regulate emotional expressive behavior, we were also interested in age differences in the autonomic consequences of this regulation. In our past work with young adults, we consistently found that suppressing expressive behavior while being emotionally aroused leads to increases in automatic activity, especially in sympathetically mediated cardiovascular responses (e.g., skin conductance level, finger pulse amplitude, or finger temperature; Gross, 1998a; Gross & Levenson, 1993, 1997). We believe that this cardiovascular activation reflects the metabolic demands associated with the effort involved in inhibiting powerful tendencies toward emotional expression. Our previous work has only examined emotional suppression in younger participants. The current study extends this work in two ways. By examining suppression and amplification of emotion, we will learn whether autonomic activation accompanies any direction of emotion regulation or just suppression. By examining younger and older adults, we will learn more about the ability to regulate emotion and its physiological costs as a function of age.

Past research suggests that there are no gender differences in behavioral suppression of emotion or its autonomic consequences (Gross & Levenson, 1993). Because we extended this research in several aspects (i.e., by investigating emotion amplification, studying older adults), we included both female and male participants. This provides an opportunity to reexamine the issue of gender differences in emotion regulation using new procedures and populations.

Hypothesis 1

Our primary hypothesis is that older adults will be at least as successful as younger adults in regulating their emotional expressions despite the age-related declines in autonomic and somatic functions. This hypothesis is based both on theoretical accounts suggesting that emotional motivation and knowledge increase with age as well as on the results of previous self-report studies indicating that older persons believe they are better at regulating their emotions than young adults.

Hypothesis 2

A second hypothesis addresses the possible consequences of suppression and amplification on people's level of physiological activity. We view the effort involved in modulating the emotional response once an emotion has been activated as being responsible for our previous findings of sympathetically mediated cardiovascular activation when emotional expression is suppressed. We predicted that amplifying emotional expression will require a similar level of effort and thus will have similar autonomic effects. On the basis of our prior research (e.g., Gross & Levenson, 1993), however, we expected that suppression of emotional behavior would result in lowered levels of somatic activity and attendant lowering of heart rate (Obrist, 1981). In contrast, we expected that amplification of emotional behavior would result in increased levels of somatic activity and attendant increases in heart rate. Because of the complexities introduced by age-related changes in autonomic reactivity, we did not advance a specific hypothesis about age differences in the magnitude of the physiological changes associated with emotion regulation. Although we had no basis to predict gender differences in emotion regulation, we included gender in our central analyses to pursue this issue in an exploratory manner.

Method

Participants

The sample was composed of 48 younger (M = 21 years; range = 18–28 years; 50% male) and 47 older (M = 71 years; range = 60–85 years; 50% male) adults residing in Berkeley, California.[2] Participants were recruited by advertisements and fliers distributed at the Berkeley campus, local senior centers, and other public places. We explained to potential participants that they would be viewing instructions and films on a TV monitor and completing questionnaires. We only included participants who indicated that they had no trouble viewing and hearing a TV and who could read texts such as the newspaper (use of hearing aid or eyeglasses was acceptable). Most of the young participants were undergraduates at the University of California, Berkeley (2 young participants had recently graduated and were working full time); the undergraduate participants received credit in a psychology course in exchange for their participation. The older participants were not paid for their participation but were entered in a lottery held after the experiment was completed in which two $100 prizes were awarded.

Expected differences between the two age groups were found in marital status, $\chi^2(5, N = 95) = 55.17, p < .01$ (older participants were more likely to be married, divorced, or widowed, whereas young adults were more likely to be single), employment status, $\chi^2(3, N = 94) = 87.00, p < .01$ (older participants were more likely to be employed or retired, whereas young adults were more likely to be students), and years of education, $F(1, 94) = 56.39, p < .01$ (older participants had more years of education). There were no age differences in socioeconomic status and ethnicity; the majority of participants were middle- or upper-middle-class Caucasians.

There were no age differences in self-reported general health as measured by a single item that rates the overall health of participants (Mean ratings were 4.17 and 4.10 for the old and young groups, respectively, on a 5-point scale ranging from *very poor* [1] to *very good* [5].) There were also no age differences in self-reported functional health as measured by the single item that rates health problems that interfere with daily life ($M_{\text{old}} = 3.67$ and $M_{\text{young}} = 3.81$ on a 5-point scale ranging from *very often* [1] to *not at all* [5].) These general self-report health measures have been shown to exhibit satisfactory reliability and validity (e.g., Lawton & Lawrence, 1994). However, to gain a better understanding of our participants' health status, we also asked them to indicate how often they had experienced each of 42 physical symptoms during the last year (e.g., headaches, chest pains, shakiness, intestinal or stomach trouble, backaches). This measure was designed for the current purposes and covers a broad range of physical symptoms typically included in existing measures (see Lawton & Lawrence, 1994). Older participants did not differ from young participants in the average frequency of these symptoms ($M_{\text{old}} = 1.75$, $SD = .36$; $M_{\text{young}} = 1.65$, $SD = .44$ on a 5-point scale [1 = *rarely*, 5 = *very often*]). There were also no age differences in the average number of daily activities (e.g., sports, dancing, restaurant visits, or political activities). As expected given the age range of the group, 10 older participants were on some form of cardiovascular medication.

Film Stimuli

We chose five films from Gross and Levenson's (1995) set of emotion-eliciting films. One film showed birds on a beach (58 s in length). This neutral film elicits minimal levels of self-reported emotion. Three films showed medical procedures. The first showed an eye operation (58 s), the second treatment of a burn victim (55 s), and the third a close-up of the amputation of an arm (62 s). These three medical films elicit equivalent levels of self-reported disgust, with little report of other emotions. The fifth film depicted nature scenes from Alaska and was accompanied by classical music. This film elicits moderate levels of positive emotions, particularly contentment.

Procedure

All participants came to the Berkeley Psychophysiology Laboratory for individual sessions. In the first part of the session, they completed questionnaires designed to assess demographic, health, and personality characteristics. In the second part, they were seated in a comfortable chair in an experiment room decorated with bookcases and pictures on the wall. The experimenter (Ute Kunzmann or Cenita Kupperbusch) attached physiological sensors to the participants and told them that they would perform an isometric exercise and see several short film clips and that the session would be videotaped.[3]

The films and all subsequent instructions were shown on a color TV monitor placed 1.75 m from the participant. Throughout this phase of the experiment, the participant was in the room alone and the experimenter was in an adjacent room that housed the computer, physiological, and video equipment. An intercom system was used for communication between experimenter and participant.[4]

The experimental session was composed of five trials (one film per trial), each consisting of four epochs: (a) a 1-min baseline period, during which participants were asked to relax and clear their minds of all thoughts, feelings, and memories; (b) a film-viewing period; (c) a 1-min postfilm period, during which participants were again asked to relax; and (d) a period during which participants completed an inventory of their subjective feelings during the film (approximately 5 min).

On the first trial, all participants watched a neutral film (i.e., birds on the beach) to adapt to the laboratory procedures. On the second trial, all participants viewed a medical film (i.e., eye operation) under the following ("watch") instruction: "We will now be showing you a short film clip. It is important to us that you watch the film clip carefully, but if you find the film too stressing, just say 'stop.'"

On the third and fourth trials, participants viewed the two other medical films (either treatment of the burn victim or the arm amputation) according to one of three instructions. In the no-regulation condition, participants were given the watch instruction before each film. In the regulation condition, participants watched one film after receiving the "suppress" instruction: "This time, if you have any feelings as you watch the film clip, please try your best not to let those feelings show. In other words, as you watch the film clip, try to behave in such a way that a person watching you would not know you were feeling anything. To summarize, as you watch the film clip, try to hide your feelings as much as you can." Participants watched the other film after receiving the "amplification" instruction: "This time, if you have any feelings as you watch the film clip, please try your best to let those feelings show. In other words, as you watch the film clip, try to behave in such a way that a person watching you would clearly know what you are feeling. To summarize, as you watch the film clip, show your feelings as much as you can."

In all conditions, the order of the arm amputation and burn treatment films was counterbalanced, and in the regulation condition, the order of suppression and amplification instructions was counterbalanced. Finally, on the fifth trial, all participants viewed a film known to elicit moderate levels of positive emotions (scenes from Alaska) under the watch instruc-

[2] A total of 103 adults initially participated. Of these, 7 were excluded from our analyses because they requested one or more of the medical films be stopped (3 younger and 4 older participants; 5 in the no-regulation and 2 in the regulation condition). In addition, we recruited 1 older woman in the control group who later decided not to participate for reasons unrelated to this study. The remaining 95 participants were compliant in watching all film clips. Analyses of two global behavioral categories (off camera and obscured vision) showed that the participants watched the films clips carefully and did not avert their eyes.

[3] The isometric exercise task involves squeezing a handgrip three times as hard as possible for 1 min. Participants did this exercise after they had watched the third film clip. This task is unrelated to the research questions presented here and, therefore, not described further.

[4] The experimenters were instructed to communicate with the participants only if absolutely necessary; however, we cannot exclude the possibility that their being in an adjacent room influenced some participants in some ways.

tion. After the fifth trial, the experimenter returned to the participant's room, removed the physiological sensors, and debriefed the participant.

Participants were randomly assigned to the no-regulation and regulation conditions so that each condition consisted of 23 older (12 males and 11 females) and 24 younger (12 males and 12 females) participants.

Measures

Expressive Behavior

A remote-controlled video camera placed behind darkened glass unobtrusively recorded participants' facial behavior and upper body movement. Participants' behavioral responses to each of the three medical films were coded by four trained raters who were unaware of participants' experimental condition and the nature of the film stimuli. Raters used a modified version of the Emotional Behavior Coding System (Gross & Levenson, 1993). This coding system consists of 20 categories of behavior that include specific emotions (e.g., anger, happiness, confusion, surprise), facial movements not classifiable as specific to emotion (e.g., eyeblinks, lower face movement), and global ratings of emotional pleasantness and expressivity. Because base rates for 16 of the 20 categories were too low to allow for adequate reliability, these were dropped from the analyses. Four categories remained: (a) behavior showing disgust (each scored on a 3-point intensity scale; the sum of these intensity scores was divided by the number of seconds in the film); (b) behavior expressing unpleasantness (a single overall unpleasantness rating on a 3-point intensity scale was given at the end of the film); (c) overall expressivity (a single overall expressivity score on a 5-point intensity scale was given at the end of the film); and (d) eyeblinks (total number of eyeblinks during the film was divided by the number of seconds in the film).

To obtain reliability information on the four behavioral categories, two raters independently scored 21 participants during each of the three medical films. Interrater reliabilities for the four codes across the three films were as follows: disgust (Cohen's $\kappa = .76$ [indicating categorical agreement on whether or not behavior showing disgust was coded for a given participant on a trial-by-trial basis], mean Pearson $r = .85$ [indicating rater agreement on overall intensity of rated disgust across trials]), unpleasantness (Pearson $r = .62$), expressivity (Pearson $r = .79$), and eyeblinks (Pearson $r = .95$; mean number of eyeblinks coded did not differ significantly between reliability coders). When two codes were available for participants, the average of the two ratings was used for data analyses.

Physiological Activity

We assessed 11 measures representing physiological systems that are thought to be important aspects of emotional responding. Continuous recordings of these measures were made using a 12-channel Grass Model 7 polygraph. During the experimental sessions, software developed in our laboratory was used to compute second-by-second values for each of the 11 physiological measures. These second-by-second values were averaged across prefilm, film, and postfilm periods.

Heart interbeat interval. Beckman miniature electrodes with Redux paste were placed in a bipolar configuration on opposite sides of the participant's chest. The interbeat interval was calculated as the interval (in milliseconds) between successive R waves. Shorter intervals (faster heart rates) indicate higher activation. Interbeat intervals become longer when disgust was elicited, however, suggesting that disgust produces a different cardiovascular state than negative emotions that produce shorter interbeat intervals (e.g., fear or anger; Levenson, 1992).

Skin conductance level. A constant-voltage device was used to pass a small voltage (using an electrolyte of sodium chloride in Unibase) between Beckman regular electrodes attached to the palmar surface of the middle phalanges of the second and third fingers of the nondominant hand. Higher skin conductance levels indicate higher physiological activation.

General somatic activity. An electromechanical transducer attached to the platform under the participant's chair generated an electrical signal proportional to the amount of movement in any direction. Greater somatic activity indicates higher physiological activation.

Finger pulse amplitude. A UFI photoplethysmograph recorded the volume of blood in the finger by means of a photocell taped to the distal phalange of the second finger of the nondominant hand. The peak-to-trough amplitude of this signal was determined on each heartbeat. Smaller finger pulse amplitudes result from vasoconstriction and indicate higher physiological activation.

Pulse transmission time to the finger. The time interval (in milliseconds) was measured between the R wave of the electrocardiogram (ECG) and the upstroke of the peripheral pulse at the finger site. Shorter transmission times are a sign of higher activation. Pulse transmission times to the finger generally become longer under disgust, however, suggesting a different cardiovascular state than other negative emotions (e.g., fear or anger; Levenson, 1992).

Pulse transmission time to the ear. A UFI photoplethysmograph was attached to the right earlobe. The time interval (in milliseconds) was measured between the R wave of the ECG and the upstroke of peripheral pulse at the ear site. Shorter transmission times generally indicate higher physiological activation. Pulse transmission times to the ear become longer under disgust, however, suggesting a different cardiovascular state other negative emotions (e.g., fear or anger; Levenson, 1992).

Respiration period. A pneumatic bellows was stretched around the thoracic region. The intercycle interval (in milliseconds) was measured between successive inspirations. Shorter intercycle intervals (faster respiration rates) indicate higher activation.

Respiration depth. The point of maximum inspiration minus the point of maximum expiration was determined from the respiratory tracing. Smaller values indicate more shallow respiration and higher activation.

Finger temperature. A thermistor was attached to the palmar surface of the distal phalange of the fourth finger and recorded temperature (degrees Fahrenheit).

Systolic and diastolic blood pressure. A fingerpress device consisting of an arterial pressure cuff placed on the middle phalange of the third finger recorded beat-by-beat measures of systolic and diastolic blood pressure. Higher systolic blood pressure and higher diastolic blood pressure both indicate higher levels of activation.

Self-Reported Emotions

After each film, participants rated how they had felt during the film on 16 positive (e.g., interested, happy, surprised, amused, content, relieved) and negative (e.g., anxious, sad, annoyed, disgusted, embarrassed, bored, afraid, angry, contemptuous, stressed) emotion terms on a scale ranging from 0 (*not at all*) to 8 (*very much*). In addition, they provided ratings on two bipolar scales: unpleasantness, ranging from 0 (*positive/pleasant*) to 8 (*negative/unpleasant*), and engagement, ranging from 0 (*disengaged /mellow*) to 8 (*engaged/intense*).

Data Analysis

Our primary analyses involved three overall $2 \times 2 \times 2 \times 3$ repeated measures multivariate analyses of variance (MANOVAs) for the behavioral, physiological, and subjective responses. Between-subjects factors were age (young vs. old), gender (male vs. female), and condition (no regulation vs. regulation). Trial (Film 2 vs. Film 3 vs. Film 4) served as the within-subject factor. To isolate changes in particular variables, these three MANOVAs were followed by parallel univariate repeated measures analyses of variance (ANOVAs) for each of the specific behavioral, physiological, and subjective measures. The partial η^2 representing the proportion of explained variance in the dependent variable is reported for each significant effect. The following η^2 correspond with small (.10), moderate (.25), and large (.40) effect sizes (*f*), respectively: $\eta^2 = .01$, $\eta^2 = .06$, and $\eta^2 = .14$ (Cohen, 1988).

Results

We first analyzed the success of our random assignment of participants to the experimental conditions and the efficacy of our film stimuli in eliciting emotional responses.

Random Assignment

The first disgust film (eye operation), which all participants viewed with the same watch instruction, provided an opportunity to evaluate the effectiveness of our random assignment of participants to experimental conditions. Three overall MANOVAs for the behavioral, physiological, and subjective responses to this film failed to reveal differences between participants assigned to the no-regulation versus regulation groups. There were no significant main effects for condition (no regulation vs. regulation) nor were there interactions between condition and the other factors, indicating that our random assignment had been successful.

Efficacy of Film Stimuli

Previous group testing with young participants had shown that the three medical films we used in this study elicit self-reports primarily of disgust (Gross & Levenson, 1995). There is also experimental evidence suggesting that the burn victim and amputation films elicit expressive behaviors and physiological responses typical of disgust (Gross & Levenson, 1993). To test the efficacy of our films as emotion elicitors in the wider age range of this sample, we examined the physiological, subjective, and behavioral responses of participants who viewed the three medical films under the watch instruction.[5]

Physiological Activity

We tested the physiological effects of each medical film by comparing physiological responses during the film period with those during the pre- and postfilm periods. We conducted three similarly structured MANOVAs with time (prefilm vs. film vs. postfilm) as a within-subject factor and age (young vs. old) as a between-subjects factor. The overall MANOVAs for physiological responses during all three films revealed significant effects for time: amputation film, $F(22, 20) = 1{,}572.70$, $p < .01$, $\eta^2 = .68$; burn victim film, $F(22, 20) = 819.81$, $p < .01$, $\eta^2 = .66$; eye operation film, $F(22, 68) = 2{,}127.85$, $p < .01$, $\eta^2 = .61$. In the eye operation film, there was a significant main effect for age, $F(11, 79) = 3.12$, $p < .01$, $\eta^2 = .30$, and a significant interaction of age and time, $F(22, 68) = 4.86$, $p < .01$, $\eta^2 = .26$.

Follow-up analyses of the effects for time revealed that our participants were more physiologically activated during the three medical films than during the pre- and postfilm periods (see findings for the eye operation film in Table 1). Follow-up analyses of the overall main effect for age, which was only found in the MANOVA for responses to the eye operation, revealed age differences in five physiological measures. Specifically and consistent with past work, for three physiological measures (i.e., heart interbeat interval, skin conductance level, and respiration period), we found that the older participants were generally less activated than the young participants (i.e., older participants' heart interbeat intervals were longer, skin conductance levels were lower, and respiration periods were longer). No age differences were found for six other measures (i.e., somatic activity, finger pulse transit time, finger pulse amplitude, finger temperature, respiration depth, and diastolic blood pressure). There were only two measures—ear pulse transit time and systolic blood pressure—for which we found greater general activation in older adults.

Although physiological activity was measured during the prefilm, film, and postfilm periods, we were most interested in our participants' reactions to the films, which can be defined as the difference between particular periods (e.g., the prefilm and film periods). For this reason, the statistical effect of primary interest was not the age main effect (which combines prefilm, film, and postfilm periods) but rather the interaction effects of age and time. As reported, our overall MANOVA for responses during the eye operation revealed a significant Time $\times$ Age interaction; however, univariate analyses showed that this interaction effect only held for skin conductance (i.e., the decrease in skin conductance between film and postfilm periods lasted longer in older than in younger participants).[6]

Together these findings suggest that the three medical films were effective in eliciting physiological arousal. The patterns of physiological responding over prefilm, film, and postfilm periods were generally consistent with those found for disgust films in our earlier studies (i.e., during the film periods, heart interbeat intervals did not increase, skin conductance level increased, finger pulse transition time was longer, and finger pulse amplitude was smaller). We did not find evidence that older participants have smaller autonomic reactions to the films (i.e., Age $\times$ Time interactions) as we had found in earlier studies (Levenson, 2000).

In addition, the analysis of age main effects revealed lower levels of general activation for older participants than for young participants, at least for three measures. Six physiological measures suggested stable levels of general physiological activation, whereas only two suggested greater activation. There were no age differences in physiological activation during the burn victim and amputation films (i.e., neither main effects of age nor Age $\times$ Time interaction effects).

Given that the analyses of age differences in reactions to the current film clips were based on relatively small sample sizes (especially the analyses of responses to the burn victim and amputation clips), statistical power was limited. We, therefore, calculated for each physiological measure the sample size that would be necessary for a detection of an age effect in reactivity (defined as film minus prefilm baseline difference scores) with a priori power $= .80$ at $p = .05$. For this purpose, we used the program G-Power (Buchner, Faul, & Erdfelder, 2001), which is based on the methods recommended by Cohen (1988). Effect sizes are given as f values and were computed from η^2s provided by ANOVA routines in SPSS.

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[5] Because all participants viewed the eye operation film under the watch instruction, the efficacy analyses for this film clip were based on the full sample.

[6] Given that 10 older participants were on blood pressure medication (4 in the no-regulation and 6 in the regulation condition), which can affect the autonomic measures, we reran our major analyses without these participants. These analyses yielded the same pattern of findings as the analyses using the full sample.

Table 1
Mean Levels in Physiological Activity During the Eye Operation Film

	η^2		Young participants			Old participants		
Indicator	Time	Age	Pre	Film	Post	Pre	Film	Post
IBI	.00	.08**						
M			835.16	844.30	846.23	915.69	910.47	914.83
SD			114.08	129.76	116.12	127.03	128.32	128.53
AC	.06**	.00						
M			0.64	0.60	0.67	0.59	0.57	0.60
SD			0.60	0.60	0.63	0.25	0.22	0.25
SCL	.19**	.31**						
M			4.89	5.26	4.80	2.28	2.49	2.31
SD			2.25	2.60	2.41	1.42	1.67	1.50
FPT	.11**	.02						
M			281.54	286.60	280.88	275.81	277.96	276.50
SD			28.62	28.92	27.69	22.40	23.14	22.43
FPA	.19**	.00						
M			8.00	7.16	8.29	8.12	7.52	8.18
SD			4.80	5.10	4.86	3.66	3.71	3.71
EPT	.03	.07**						
M			200.30	199.45	198.30	187.40	184.94	185.16
SD			27.91	30.64	27.99	19.92	22.02	21.47
FT	.00	.03						
M			83.21	83.20	83.19	85.41	85.46	85.54
SD			6.45	6.49	6.56	6.61	6.51	6.59
RP	.19**	.05*						
M			4,429.71	3,881.75	4,380.47	4,929.12	4,324.03	4,890.59
SD			1,335.52	803.23	1,045.18	1,283.76	1,306.30	1,384.83
RD	.12**	.02						
M			285.34	250.48	290.24	255.50	215.84	255.76
SD			142.18	105.72	112.88	112.95	82.50	100.72
SBP	.04**	.07**						
M			128.56	133.07	127.91	139.08	145.10	139.44
SD			19.21	20.77	20.20	23.65	23.52	23.51
DBP	.16**	.00						
M			77.90	78.42	77.21	76.32	78.14	77.04
SD			12.82	14.12	13.65	14.18	14.81	13.88

Note. IBI = heart interbeat interval; AC = somatic activity; SCL = skin conductance level; FPT = finger pulse transit time; FPA = finger pulse amplitude; EPT = ear pulse transit time; FT = finger temperature; RP = respiration period; RD = respiration depth; SBP = systolic blood pressure; DBP = diastolic blood pressure; Time = effect size for the within-subject factor time (prefilm, film, postfilm); Age = effect size for the between-subject factor age
* $p < .05$. ** $p < .01$.

The critical sample size to detect age differences in reactions to the eye operation film was on average 1,769 (range = 246 for somatic activity [$\eta^2 = .03, f = .18$] to 8,724 for systolic blood pressure [$\eta^2 = .0007, f = .03$]). The critical sample size to detect age differences in reactions to the amputation film was on average 1,857 (range = 110 for respiration rate [$\eta^2 = .07, f = .27$] to 8,724 for respiration depth [$\eta^2 = .001, f = .03$]). The critical sample size to detect age differences in reactions to the burn victim film was on average 1,890 (range = 152 for skin conductance [$\eta^2 = .05, f = .23$] to 8,724 for body temperature [$\eta^2 = .001, f = .03$]). Given the average effect sizes for the eye operation film ($M = .11$, range = .03–.18), amputation film ($M = .12$, range = .001–.270), and burn victim film ($M = .15$, range = .03–.23), we conclude that age differences in autonomic responses to the three medical films (defined as differences between prefilm and film periods), if any, are small.

Self-Report

Because we collected self-report data for the film periods only and not during the prefilm or postfilm periods, our strategy was to compare disgust ratings during the three medical films with those during the neutral film. Specifically, we conducted three ANOVAs; the within-subject factor was film (neutral vs. medical) and the between-subjects factor was age (young vs. old). All three ANOVAs revealed significant main effects for film: amputation film, $F(1, 45) = 58.93$, $p < .01$, $\eta^2 = .57$; burn victim film, $F(1, 45) = 56.62$, $p < .01$, $\eta^2 = .56$; eye operation film, $F(1, 93) = 146.65$, $p < .01$, $\eta^2 = .61$. Significant main effects were also found for age: amputation film, $F(1, 45) = 28.51$, $p < .01$, $\eta^2 = .39$; burn victim film, $F(1, 45) = 28.00$, $p < .01$, $\eta^2 = .38$; eye operation film, $F(1, 93) = 34.10$, $p < .01$, $\eta^2 = .27$. There were also significant Film × Age interaction effects: amputation film, $F(1, 45) = 21.57$, $p < .01$, $\eta^2 = .32$; burn victim film, $F(1, 45) = 23.18$, $p < .01$, $\eta^2 = .34$; eye operation film, $F(1, 93) = 35.01$, $p < .01$, $\eta^2 = .27$. As seen in Table 2, participants in both age groups reported greater disgust during the eye operation, burn victim, and amputation films than during the neutral film. Young participants reported relatively greater disgust during the three medical films than did old participants.

Table 2
Mean Levels in Self-Reported Negative Emotions During a Neutral and Three Medical Films

Emotion	η^2 Film	η^2 Age	η^2 A × F	Film type	Young participants *M*	Young participants *SD*	Old participants *M*	Old participants *SD*
Disgust	.61**	.27**	.27**	E	4.71	2.44	1.64	2.56
	.56**	.38**	.34**	B	4.25	2.58	0.87	1.79
	.57**	.39**	.32**	A	4.71	2.74	1.09	2.04
				N	0.19	0.57	0.09	0.41
Anxiety	.44**	.02	.01	E	3.83	2.23	3.59	2.83
	.22**	.02	.01	B	3.08	2.57	2.91	2.99
	.41**	.04	.01	A	3.79	2.47	3.04	2.53
				N	1.67	2.24	1.06	1.76
Sadness	.13**	.00	.02	E	1.17	1.77	1.46	2.36
	.41**	.03	.05	B	1.75	1.94	2.78	2.97
	.08*	.02	.04	A	0.58	1.02	1.17	2.53
				N	0.69	1.13	0.49	1.21
Annoyance	.12**	.02	.00	E	1.40	2.08	0.96	1.83
	.22**	.06	.00	B	1.88	2.11	1.09	1.81
	.08*	.03	.01	A	1.25	2.09	0.96	1.75
				N	0.73	1.27	0.34	0.98
Fear	.29**	.00	.01	E	1.60	2.26	1.85	2.34
	.16**	.00	.03	B	1.04	1.85	1.30	2.10
	.17**	.01	.01	A	1.21	1.89	1.17	1.83
				N	0.42	1.01	0.30	0.86
Anger	.14**	.00	.01	E	0.85	1.61	0.79	1.76
	.19**	.01	.03	B	1.25	1.70	0.83	1.67
	.11*	.02	.00	A	0.46	0.66	0.70	1.22
				N	0.10	0.47	0.28	0.88
Contempt	.04	.02	.01	E	0.55	1.33	0.23	0.70
	.04	.00	.04	B	0.48	0.95	0.48	1.08
	.03	.00	.03	A	0.48	1.00	0.52	1.22
				N	0.25	0.84	0.13	0.54
Stress	.44**	.00	.01	E	2.75	2.20	3.06	2.78
	.37**	.02	.00	B	2.79	2.23	2.52	1.71
	.40**	.00	.03	A	2.58	2.45	2.83	2.55
				N	0.75	1.26	0.60	1.21
Engagement	.52**	.02	.01	E	5.77	1.24	5.91	1.84
	.32**	.00	.01	B	5.42	1.44	5.04	2.36
	.32**	.03	.01	A	5.04	1.90	5.68	2.01
				N	3.35	1.79	3.84	1.87

Note. Emotion ratings were assessed using an 8-point response format ranging from 0 (*not at all experienced*) to 8 (*very much experienced*). E = eye operation; B = burn victim; A = arm amputation; N = birds on beach (neutral); Film = effect size for within-subject factor film (neutral vs. medical); Age = effect size for between-subject factor age; A × F = effect size for interaction between film and age. Means and standard deviations for the burn victim and amputation films are based on data from the no-regulation group only ($N = 47$).
* $p < .05$. ** $p < .01$.

The age differences in self-reported disgust during the three medical films were greater than expected. We, therefore, conducted similarly structured MANOVAs using six other self-reported specific negative emotions (anxiety, sadness, annoyance, fear, anger, contempt) and two more general emotional states (stress and engagement) as dependent variables. All three of these MANOVAs revealed significant main effects for film—amputation film, $F(8, 36) = 28.43$, $p < .01$, $\eta^2 = .86$; burn victim film, $F(8, 36) = 12.48$, $p < .01$, $\eta^2 = .74$; eye operation film, $F(8, 81) = 43.55$, $p < .01$, $\eta^2 = .81$—but no effects for age. Despite the relatively large age differences in self-reported disgust, young and older adults experienced similar levels of other negative emotions and similar levels of stress and engagement during the films (see Table 2).

Power analyses for the eight negative emotions other than disgust revealed that the critical sample size to detect age differences in reactions to the eye operation film was on average 1,273 (range = 246 for self-reported stress [$\eta^2 = .03, f = .18$] to 3,142 for self-reported anger [$\eta^2 = .003, f = .05$]). The critical sample size to detect age differences in reactions to the burn victim film was on average 746 (range = 152 for sadness [$\eta^2 = .05, f = .23$] to 3,142 for annoyance [$\eta^2 = .002, f = .05$]). The critical sample size to detect age differences in reactions to the amputation film was on average 1,159 (range = 152 for stress [$\eta^2 = .05, f = .23$] to 2,184 for contemptuous [$\eta^2 = .003, f = .06$]). Given the average effect sizes for the eye operation film ($M = .10$, range = .05–.18), amputation film ($M = .11$, range = .06–.23), and the burn victim film ($M = .17$, range = .06–.23), we conclude that, with one exception (i.e., disgust), age differences in subjective reactions to the three medical films used in this study, if any, are small.

Expressive Behavior

Expressive behaviors were coded only during the medical films and not during the pre- or postfilm periods or during the neutral film. Thus, we only analyzed age differences in expressive behaviors during the three medical films. The MANOVA for expressive behaviors during the eye operation film revealed a significant main effect for age, $F(4, 90) = 3.92$, $p < .01$, $\eta^2 = .15$. As seen in Table 3, with the exception of fewer eyeblinks in younger participants, $F(1, 90) = 6.85$, $p < .01$, $\eta^2 = .07$, older participants showed fewer expressive behaviors during the eye operation film than did younger participants: disgust behavior, $F(1, 90) = 5.74$, $p < .01$, $\eta^2 = .06$; unpleasantness behavior, $F(1,90) = 7.40$, $p < .01$, $\eta^2 = .07$; overall expressivity, $F(1, 90) = 8.74$, $p < .01$, $\eta^2 = .09$.[7] The MANOVAs for expressive behaviors during the burn victim and amputation films revealed no effects for age.

Power analyses for the four behavioral variables revealed that the critical sample size to detect age differences in reactions to the burn victim film was on average 189 (range = 110 for overall expressivity [$\eta^2 = .07, f = .27$] to 246 for unpleasantness behavior [$\eta^2 = .03, f = .18$]). The critical sample size to detect age differences in reactions to the amputation film was on average 592 (range = 200 for unpleasantness behavior [$\eta^2 = .04, f = .20$] to 788 for disgust behavior [$\eta^2 = .01, f = .10$]). Given the average effect sizes for the eye operation film ($M = .28$, range = .25–.31), amputation film ($M = .15$, range = .10–.20), and the burn victim film ($M = .21$, range = .18–.27), we conclude that the two age groups did show small to moderate differences in behavioral reactions to the three medical films used in this study.

Summary

The three medical films appeared to be successful at eliciting self-report, behavioral expression, and physiological activation of disgust. When age differences were found, they generally took the form of smaller responses for older participants than for younger participants. Specifically, older participants reported experiencing less disgust (for all three films) and showed fewer behavioral expressions of disgust (for the eye operation film). In contrast to earlier work, we did not find that older adults' physiological responses to the current films were smaller than those of young adults (e.g., Levenson, 2000). Power analyses suggest that age differences in physiological reactivity and self-reported feelings (with the exception of disgust) are small, whereas age differences in behavioral reactions are small to moderate.

Table 3
Mean Levels in Behavior During the Eye Operation Film

Behavior	Young participants *M*	Young participants *SD*	Old participants *M*	Old participants *SD*
Disgust behavior	0.44	0.63	0.17	0.44
Eyeblinks	0.13	0.09	0.24	0.28
Unpleasantness behavior	1.92	0.74	1.51	0.72
Overall expressivity	1.74	1.26	1.01	1.14

Note. Disgust behavior: average intensity/frequency score; eyeblinks: average frequency score; unpleasantness behavior: intensity scale from 1 (*neutral*) to 3 (*very unpleasant*); overall expressivity: intensity scale from 0 (*not expressive at all*) to 4 (*extremely expressive*).

Regulation and Expressive Behavior

Impact of Instructions to Regulate Expressive Behavior

The overall MANOVA for the behavioral variables revealed main effects for condition, $F(4, 84) = 12.20$, $p < .01$, $\eta^2 = .37$, and trial, $F(8, 80) = 153.38$, $p < .01$, $\eta^2 = .80$, as well as a Condition $\times$ Trial interaction effect, $F(8, 80) = 8.89$, $p < .01$, $\eta^2 = .12$. We conducted univariate follow-up ANOVAs to test the generality of this interaction effect across individual behavioral variables. Interaction effects between condition and trial were found for disgust behavior, $F(2, 86) = 10.00$, $p < .01$, $\eta^2 = .19$, unpleasantness behavior, $F(2, 86) = 23.40$, $p < .01$, $\eta^2 = .35$, and overall expressivity, $F(2, 86) = 21.72$, $p < .01$, $\eta^2 = .34$.

Follow-up paired t tests revealed that participants in the regulation condition were less expressive when viewing a medical film under the suppression instruction and more expressive when viewing a medical film under the amplification instruction than when viewing a medical film under the watch instruction. Participants in the no-regulation condition did not show significant changes in expressive behaviors over the three medical films. In the regulation group, there was less disgust behavior under the suppression instruction ($M = .02$, $SE = .02$), $t(47) = 3.88$, $p < .01$, and more disgust behavior under the amplification instruction ($M = .56$, $SE = .10$), $t(47) = 3.66$, $p < .01$, compared with the watch instruction ($M = .27$, $SE = .07$). As expected, the difference in disgust behavior under the suppression versus amplification instruction was also significant, $t(47) = 5.56$, $p < .01$. Similarly, there was less behavior expressing unpleasantness under the suppression instruction ($M = 1.19$, $SE = .06$), $t(47) = 4.52$, $p < .01$, and more under the amplification instruction ($M = 2.21$, $SE = .11$), $t(47) = 4.20$, $p < .01$, compared with the watch instruction ($M = 1.71$, $SE = .11$). The difference in unpleasantness behavior under the suppression versus amplification instruction was also significant, $t(47) = 8.44$, $p < .01$. Finally, there was less overall expressivity under the suppression instruction ($M = .62$, $SE = .95$), $t(47) = 3.65$, $p < .01$, and more overall expressivity under the amplification instruction ($M = 2.21$, $SE = .16$), $t(47) = 5.31$, $p < .01$, compared with the watch instruction ($M = 1.27$, $SE = .17$). The difference in overall expressivity under the suppression versus amplification instruction was also significant, $t(47) = 9.80$, $p < .01$.

In sum, the behavioral data clearly indicate that the suppression and amplification instructions were effective in altering the level of expressive behavior. With the exception of eyeblinks, the expressive behaviors were all affected in the instructed direction.[8]

[7] We cannot exclude the possibility that the greater eyeblinking in older adults was due to a factor unrelated to emotion, namely general eye dryness, which increases with age.

[8] Neither film order nor regulation order had any main effects or interaction effects on behavioral expressions, physiological responses, or self-reported emotions.

Age Differences in Ability to Regulate Expressive Behavior

The effects of our instructions to either suppress or amplify expressive behaviors in the regulation group did not differ by age. That is, our overall MANOVA for the behavioral variables did not reveal an interaction of condition, trial, and age, $F(8, 84) = .41$, $p = .91$. The findings are consistent with our prediction that there would be no age difference in the ability to regulate behavioral signs of emotion.

Gender Differences in Ability to Regulate Expressive Behavior

We found no evidence for gender differences in the ability to regulate expressive behavior. That is, our overall MANOVA for the behavioral variables did not reveal an interaction of gender, condition, and trial. Moreover, there was no interaction of gender, age, condition, and trial.

Age Differences in Regulated Behavior

Follow-up analyses controlling for self-reported disgust. Given that the older compared with the young participants experienced lower levels of disgust during the eye operation film, we conducted our overall MANOVA for the behavioral variables after these variables were controlled for self-reported disgust (i.e., the four behavioral variables were residualized for self-reported disgust). The analysis of these residualized behavioral scores yielded the same results as those of the raw behavioral variables. That is, even after controlling for age differences in reports of how much disgust the films elicited, there were no age differences in the ability to regulate expressive behavior.[9]

Follow-up analyses for the regulation group. As seen in Figure 1 and reported previously, older participants were less expressive when viewing the first medical film (i.e., eye operation) under the watch instruction than were the young participants. Given these age differences in spontaneous expressive reactions, suppressing behavior might have been less difficult and amplifying behaviors more difficult for the older participants. To test this possibility in an exploratory manner, we used paired *t* tests in the regulation group.

The analyses revealed that the difference in disgust behavior under the watch versus suppression instruction was significant only for the young participants, $t(23) = 3.74$, $p < .01$ (young adults: $M_{watch} = .41$ vs. $M_{suppress} = .004$; older adults: $M_{watch} = .13$ vs. $M_{suppress} = .000$). In contrast, the difference in disgust behavior under the watch versus amplification instruction was significant only for the older participants, $t(23) = 3.14$, $p < .01$ (young adults: $M_{watch} = .41$ vs. $M_{amplify} = .59$; older adults: $M_{watch} = .13$ vs. $M_{amplify} = .52$). Notably, differences in disgust behavior when the suppression instruction was directly compared with the amplification instruction were significant in both age groups: young adults, $t(23) = 4.32$, $p < .01$; old adults, $t(23) = 3.51$, $p < .01$ (this analysis removes the effect of the watch instruction). The same pattern of results emerged for unpleasantness behavior and overall expressivity, although the difference in unpleasantness behavior under the watch versus suppression instructions was significant in both age groups.

In sum, although there were no age differences in absolute performance levels either under the suppression instruction or under the amplification instruction, age differences in baseline reactivity levels might have produced age differences in the difficult level of our regulation tasks. Specifically, for older adults suppression might have been easier than for young adults, whereas amplification might have been easier for younger adults than for older adults. This trend was partly confirmed by self-report data. Older participants perceived amplifying behavior as more stressful than the young participants did (old participants: $M = 3.38$, $SD = 2.14$; young participants: $M = 1.92$, $SD = 1.82$), $t(46) = 2.54$, $p < .05$. No age differences were found, however, in self-reported stress during suppression (old participants: $M = 4.29$, $SD = 2.39$; young participants: $M = 4.04$, $SD = 2.18$).[10]

Regulation and Physiology

The overall MANOVA for the physiological variables revealed main effects for age, $F(11, 72) = 3.57$, $p < .01$, $\eta^2 = .35$, and trial, $F(22, 61) = 1948.02$, $p < .01$, $\eta^2 = .99$. Further, we found a Trial × Condition interaction, $F(22, 61) = 2.11$, $p < .01$, $\eta^2 = .43$, and a three-way Trial × Condition × Gender interaction, $F(22, 61) = 1.84$, $p < .05$, $\eta^2 = .40$.

We ran univariate follow-up ANOVAs for each physiological variable to test the generality of the interaction effects involving trial and condition. Interactions of trial and condition were found for heart interbeat interval, $F(2, 86) = 10.47$, $p < .01$, $\eta^2 = .20$, and skin conductance level, $F(2, 86) = 3.16$, $p < .05$, $\eta^2 = .07$. Interaction effects of condition, trial, and gender were found for respiration period, $F(2, 83) = 3.66$, $p < .05$, $\eta^2 = .08$; respiration depth, $F(2, 83) = 3.74$, $p < .05$, $\eta^2 = .09$; and systolic blood pressure, $F(2, 84) = 4.53$, $p < .01$, $\eta^2 = .09$. (See Footnotes 6 and 8.)

Heart Interbeat Interval

Follow-up paired *t* tests in the regulation group showed that heart rate was slower under the suppression instruction ($M = 911.21$, $SE = 19.66$) than under the watch instruction ($M = 876.25$, $SE = 20.30$), $t(47) = 6.31$, $p < .01$, or the amplification instruction ($M = 885.90$, $SE = 19.15$), $t(47) = 3.32$, $p < .01$. Heart rate did not differ across watch and amplification instructions. In the no-regulation group, there were no significant differences in heart rate between the three trials.

Skin Conductance

In the regulation group, skin conductance was greater under the suppression instruction ($M = 4.14$, $SE = .36$), $t(47) = 2.69$, $p < .01$, and under the amplification instruction ($M = 4.28$; $SE = .38$), $t(47) = 2.70$, $p < .01$, than under the watch instruction ($M = 3.78$, $SE = .36$). Skin conductance did not differ between the suppression and amplification instructions. In the no-regulation group,

[9] Inclusion of the sociodemographic variables for which we found age differences did not affect the findings either.

[10] Perceived stress during the amplification and suppression tasks was assessed by a single posttask item, involving the level of stress in following instructions. The response scale ranged from 0 (*strongly disagree*) to 8 (*strongly agree*).

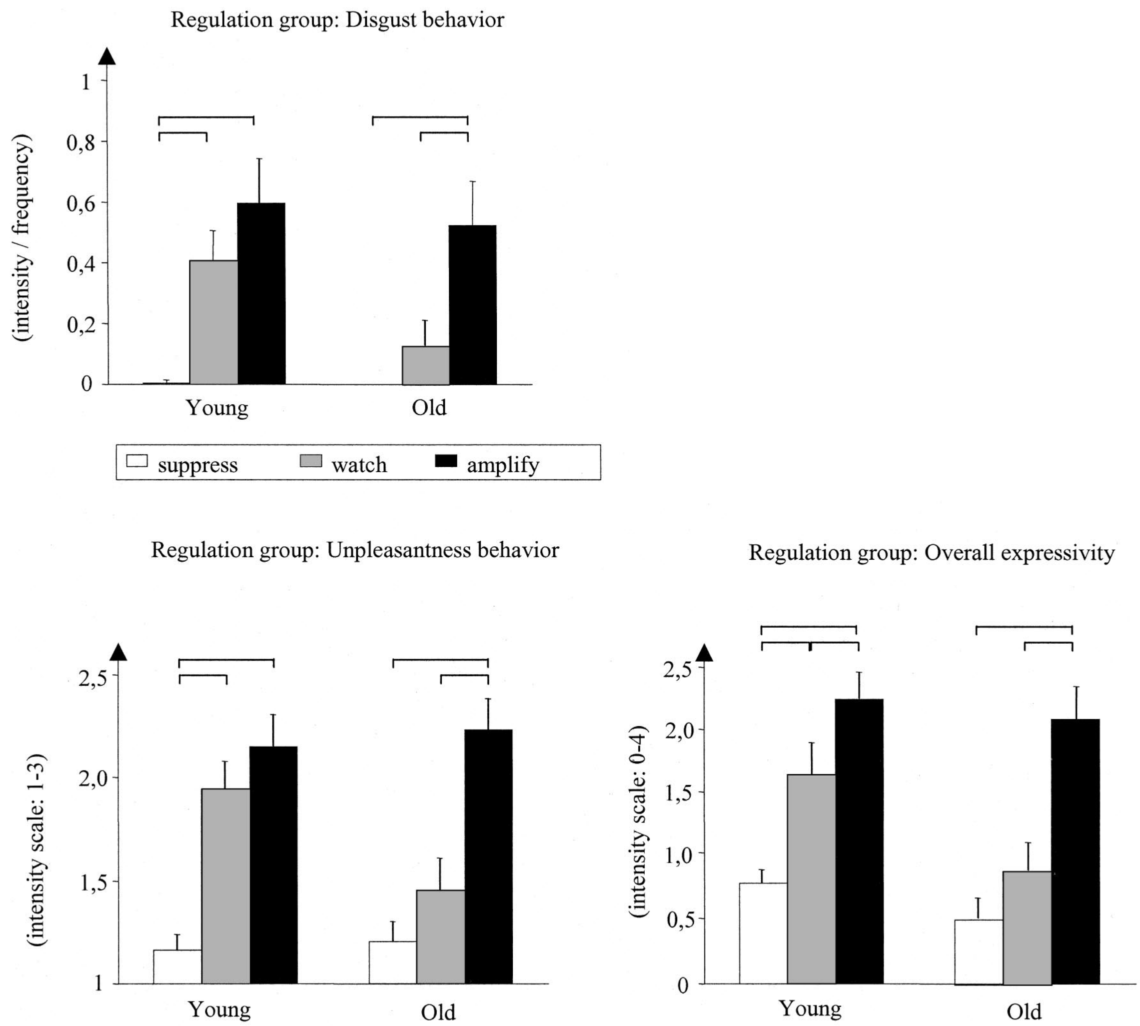

Figure 1. Behavioral expressions during suppression and amplification in young and old participants (based on data from the regulation group only). Changes in behavioral expressions under the different regulation instructions were tested by paired *t* tests conducted separately for the two age groups. All differences indicated by brackets were significant at $p < .01$. Note, however, that these age differences were not significant in the overall multivariate analysis of variance testing three-way interactions of Condition × Trial × Age.

skin conductance was less during the second trial ($M = 3.95$, $SE = .40$) than during third trial ($M = 4.21$, $SE = .43$), $t(46) = 2.51$, $p < .05$.

Systolic Blood Pressure

Follow-up paired *t* tests in the regulation group indicated that, in men, systolic blood pressure was lower under the watch instruction ($M = 134.28$, $SE = 5.36$) than under both the suppression instruction ($M = 139.81$, $SE = 5.86$), $t(22) = 2.18$, $p < .05$, and the amplification instruction ($M = 139.69$, $SE = 5.68$), $t(22) = 2.43$, $p < .05$. There were no differences in systolic blood pressure across different instructions for women. In the no-regulation group, systolic blood pressure did not differ across trials for either men or women.

Other Measures

Although we found significant interaction effects among condition, trial, and gender for respiration period and depth, follow-up *t* tests for participants in the regulation group revealed no consistent differences associated with the regulation instructions for these variables. For the remaining variables (somatic activity, finger pulse amplitude, pulse transmission time to the finger, diastolic blood pressure), there were also no significant effects associated with regulation instructions.

Summary

The findings provide support for our second hypothesis insofar as both kinds of emotion regulation had similar autonomic effects for all but one physiological variable. This similarity in autonomic effects held not only for those variables that did not differ between the regulation and watch conditions but also for those variables that showed greater activation during behavioral regulation (skin conductance in men and women, systolic blood pressure in men). Heart rate was the one autonomic variable for which the two forms of regulation had different effects. Consistent with earlier findings (Gross & Levenson, 1993, 1997), heart rate was slower under the suppression instruction than under the watch instruction, a finding we believe reflects the reduction in metabolic demand associated with the reduction in somatically mediated expressive behavior (Obrist, 1981). Results from this study support our interpretation insofar as heart rate slowing was not found in the amplification condition, which does not have this reduction in expressive behavior and the associated reduction in metabolic demand. Finally, we found no differences between our older and younger participants in the effects of behavioral regulation on physiological responses.

Regulation and Self-Reported Emotion

The overall MANOVA for the self-report variables did not show any effects involving condition (i.e., neither main nor interaction effects), suggesting that the regulation instructions did not affect emotional experience. (See Footnote 8.)

Discussion

Absence of Age Differences in Emotion Regulation During Adulthood

In this study, older and younger adults did not differ in their ability to either suppress or amplify emotional behavior in response to viewing medical procedures. Our follow-up analyses and the generally low effect sizes for the nonsignificant age differences support the conclusion that differences between young and old adults in the type of emotion regulation studied are at most extremely small. Further, there were essentially no age differences in the physiological consequences of behavioral suppression or amplification.

To the best of our knowledge, the current data are the first that examine emotion regulation in adults of different ages by measuring regulation ability in vivo rather than relying solely on participants' judgments about their ability to regulate their emotions. We take the current evidence as supporting prominent life span theories proposing that the portrayal of old age as a time of decreasing abilities may not extend to the realm of emotion regulation (e.g., Blanchard-Fields, 1998; Carstensen & Turk-Charles, 1998; Lawton, 2001).

At the same time, however, our findings suggest that older people's subjective evaluations of their emotion regulatory abilities may be positively biased. As discussed, self-report studies have found that many older people believe they are better at regulating their emotions than younger adults (e.g., Gross et al., 1997; Lawton et al., 1992). Although our evidence refers to only one form of emotion regulation, it suggests maintenance in emotion regulatory abilities rather than age-related gains.

Older people's positively biased self-evaluations could be due to a number of processes, including selective memory, social desirability, impression management, implicit theories about the age appropriateness of certain abilities, or social downward comparisons (Hess & Blanchard-Fields, 1999). Past social–cognitive aging research has shown that many of these processes become more prevalent in old age. For example, older people are increasingly likely to engage in social downward comparisons when evaluating the self (e.g., Wrosch, Heckhausen, & Lachman, 2000), and they have been found to describe themselves in more socially desirable ways than young adults do (e.g., Stöber, 2001). These age-related differences might at least partly explain the gap between subjective and objective indicators of functioning as people age (e.g., Baltes & Smith, 2003).

The discrepancy between past self-report evidence and the current performance-based findings point to the importance of developing objective performance-based tests that assess people's actual emotion regulatory abilities. These tests would supplement self-report studies on people's beliefs about emotion regulation (for a similar argument in the broader realm of emotional intelligence, see Salovey, Mayer, & Caruso, 2002).

Our older participants' spontaneous subjective and expressive reactions to the medical films used in this study tended to be less intense than those of young participants. This finding is inconsistent with past age-comparative studies that used different emotion-evoking stimuli and suggested comparable levels of subjective and behavioral reactivity in young and older adults (e.g., Carstensen et al., 1995; Levenson et al., 1991; Tsai et al., 2001).

One explanation for the current results could be that older adults are more familiar with, and thus more desensitized to, medical procedures than young adults. In other words, our film clips about medical procedures may have presented less of an emotional challenge to older people than the emotion-evoking stimuli used in previous studies. In the current study, however, it is important to note that, despite these age differences in subjective and expressive responses, older people did not differ from their younger counterparts in their autonomic reactions to the current films. Again, this absence of age differences is inconsistent with past relevant work that suggested a decline in autonomic reactivity with age (for a review, see Levenson, 2000). One direction for future research is to study the effects of familiarity with emotion-evoking stimuli on the different aspects of emotional reactivity.

Another possible explanation for older participants' relatively low subjective and behavioral reactions to the current film clips relates to motivational changes with age (e.g., Carstensen & Turk-Charles, 1998). Research growing out of SST suggests that older adults are less inclined to process negative information than young adults (e.g., Charles, Mather, & Carstensen, 2003; Mather & Carstensen, 2003). When one considers the increase in health-related problems with age, the exposure to medical examinations is for many older adults unavoidable (Baltes & Mayer, 1999). Older people might be more aware that their control potential is quite limited in these situations and that it is in their own best interest to direct their attention away from disgusting and threatening aspects. These intentional processes might primarily affect the more socially visible responses and not the less visible physiological reactions to negative emotion-evoking events.

Future research that systematically investigates the motivational and competence-related aspects of emotional reactivity and regulation is needed. In this respect, it is important to note that older adults' performance under the amplification instruction did not differ from that of young adults. Despite the possibility that they were more familiar with medical procedures or less inclined to process the information given, the older adults in this study attained the same level of emotional expressivity as young adults when explicitly asked to show their feelings as much as possible. Therefore, older participants' less intense expressive responses under more natural and uninstructed conditions may not indicate age-related declines in the basic capacity to express negative emotion.

Seen from the perspective of test development, the finding that older people's spontaneous behavioral reactions were smaller than those of young adults points to the possibility that the amplification task was more difficult and the suppression task easier for the older participants. This trend was partially supported by self-report data suggesting that the older adults perceived amplifying behavioral expressions as more stressful than did young adults; however, there were no age differences in perceived stress for the suppression task. In future work it will be important to use stimuli that produce similar levels of spontaneous expressive behavior in all age groups tested.

The Physiological Costs of Regulating Emotional Behavior

Support for the Effort Model Over the Discharge Model

This study replicated findings from previous work indicating that suppressing the behavioral manifestations of emotion is associated with an increase in autonomic nervous system activity (Gross & Levenson, 1993, 1997), especially in those functions served by the sympathetic branch (e.g., skin conductance, systolic blood pressure). In the existing literature (e.g., Gross & Levenson, 1993), two models have been proposed for linking regulation of expressive behavior with autonomic activity. The discharge model states that when one channel of emotional response is reduced (e.g., suppressing expressive behavior), there will be a compensatory increased activation in another channel (e.g., autonomic activity). In contrast, the effort model suggests that regulation of emotional behavior (regardless of whether it is being suppressed or amplified) is effortful work that makes additional metabolic demands requiring increased autonomic arousal. Thus, the discharge model predicts opposite patterns of autonomic activation for suppression (increased activation) and amplification (decreased activation). In contrast, the effort model predicts the same pattern of autonomic activation for both suppression and amplification. Because the current study extended past work on behavioral suppression by also investigating behavioral amplification, we were in a somewhat unique position to test these two models. Our findings most strongly supported the effort model. With one exception (heart rate, which seems to closely track somatic activity), all measured variables showed the same pattern of autonomic activation during the suppression and amplification conditions.

No Age Difference in the Physiological Costs of Behavioral Regulation

Our evidence indicates that there are no age differences in the effects of behavioral regulation on physiological responses. Thus, the previous finding that suppressing emotional behavior has physiological costs (Gross & Levenson, 1993, 1997) generalized not only to another form of behavioral regulation (i.e., amplification) but also to a sample of older adults.

We thought it possible that, because of their greater emotion regulatory experience, older adults would achieve similar levels of emotion regulatory performance as young adults with less effort and, therefore, lower autonomic activation. However, neither our physiological findings (i.e., no age differences in autonomic activation under suppression and amplification) nor our self-report findings (i.e., no age differences in the stressfulness of the suppression task; older participants found the amplification task more stressful) supported this. Based on this evidence, the most accurate description of both the ability to regulate emotion and its associated physiological costs appears to be that they remain constant during adulthood.

The Effect of Behavioral Regulation on Subjective Emotional Experience

We found that voluntarily suppressing or amplifying the behavioral signs of emotion had no effect on reported emotional experience. This finding replicates our past work on emotional suppression (Gross & Levenson, 1993, 1997), in which we consistently found that suppressing the behavioral signs of emotion altered autonomic physiology but had no effect on reported emotional experience. The current study expands this earlier work by showing that amplifying one's emotional behavior also does not influence subjective emotional experience. Moreover, this study suggests that the preservation of emotional experience in the face of behavioral regulation is found in both young and old adults. The integrity of emotional experience during behavioral regulation is impressive, especially because one would expect experimental demand characteristics to push participants toward reporting more or less emotional experience to parallel the changes produced in expressive behavior. If people regulate their emotions by altering appraisals before the emotion is elicited (in contrast to the current study's having participants alter expressive behavior after the emotion has been elicited), emotional experience does appear to be impacted. For example, Gross (1998a) found that having participants appraise an emotional film in a more detached way caused them to report lower levels of emotional experience. Thus, it appears that our emotion system enables us to voluntarily alter our emotional behavior while still maintaining an unchanging estimate of the magnitude of the original emotional event in our subjective emotional experience.

Lack of Gender Differences in Emotion Regulation

In this study, men and women did not differ in their ability to either suppress or amplify emotional behavior in response to viewing medical procedures. This evidence replicates the findings of past studies on behavioral suppression under emotional arousal in young adults (e.g., Gross & Levenson, 1993, 1997) and suggests that the lack of gender differences in behavioral suppression generalizes to (a) another form of emotion regulation (i.e., behavioral amplification) and (b) older people. Gender differences in emotion regulation might, however, be present in more complex and interpersonal situations. Past research on interaction during marital conflict, for example, suggests that women typically are more confronting and affectively negative than men, who tend to be more defensive and more likely to try to escape from conflict (e.g., Carstensen et al., 1995; Levenson, Carstenson, & Gottman, 1994; Gottman & Levenson, 1988). It would be interesting to know whether there are gender differences in the ability to modify emotional behaviors voluntarily in highly self-relevant social situations.

Caveats and Directions for Future Research

This study is one of the first investigations of age differences in the ability to regulate emotions. Moreover, it was one of the few laboratory studies of emotion regulation to investigate both behavioral suppression and amplification in the same sample of participants. In general, the pattern of findings was consistent with our predictions. This study is, however, only a first step toward understanding the ways in which different facets of emotion regulation might change over the adult years.

Although the overall pattern of the current findings is encouraging, one limitation of this study is our focus on one emotion-evoking context (i.e., medical procedures primarily evoking one negative emotion, namely disgust). Future research investigating the regulation of other emotions is needed to supplement the current findings. Considering that irreversible losses typically evoke sadness and that these losses increasingly occur in old age, it would be interesting to determine whether older people are especially adept at regulating sadness. Given that the experience and expression of positive emotions (e.g., interest, joy, or affection) are important contributors to well-being and successful aging (e.g., Fredrickson, 1998), it is important to begin to study age differences in regulating these emotions as well, both under standardized laboratory conditions and in naturalistic settings (e.g., in interactions with others).

A second limitation of this study concerns the form of emotion regulation investigated. Behavioral–expressive regulation in response to emotion-eliciting stimuli is one of the most important forms of emotion regulation; however, other forms of emotion regulation should be studied as well (Gross, 1998b). Investigating antecedent-focused regulation could be particularly informative. This form of regulation, which involves altering situations and appraisals before the onset of emotion, seems to be a good candidate for finding actual improvement with age. Supporting this idea is evidence from Lawton et al.'s (1992, p. 175, Table 2) study, in which older people, compared with middle-aged and young people, were more likely to endorse statements such as "I choose activities carefully so as to give myself just the right amount of emotional stimulation, neither too much nor too little." Future studies should investigate whether people actually improve their ability to select and optimize lifestyles and environments that provide desired types and amounts of affective stimulation.

A third limitation of this study is its cross-sectional design. Age differences in emotion regulation could have been obscured by differences between cohorts. For example, age-related improvement in showing one's inner feelings resulting from increased experience and practice might be obscured by differences among cohorts in upbringing and educational regimen (e.g., members of older cohorts were less encouraged to actually express their emotions). A longitudinal design is needed to begin to disentangle the effects of age and cohort and to address intraindividual changes in emotion regulation over time.

A fourth limitation of this study is our strategy of recruiting a convenience sample. This strategy may sacrifice representativeness. However, an advantage of our recruitment might be that our two age groups were comparable in terms of socioeconomic background and general health. As Cavanaugh and Whitbourne (1999) noted, it may be better to err on the side of testing a more select older sample than a sample that is handicapped compared with the young group.

In addition, the older adults in this sample represent what has been called the young-olds; thus, questions remain about changes in emotion regulation that occur beyond the age of 80. Theoretical propositions about a "fourth age" (e.g., Baltes, 1997) suggest that the oldest-old may have a less desirable biological profile that could cause a decline in the ability to regulate emotion. In future studies it would be important to examine this age group as well.

Finally, the current study was descriptive in nature. Research investigating the mechanisms that underlie stability and change in emotion regulation during adulthood is needed. Studying the dynamic interplay between biological processes and psychological factors (e.g., certain motivational dispositions or certain forms of pragmatic knowledge) could be particularly informative. As noted, multiple changes in biological functioning occur with age. Reduced efficiency, speed, and elasticity in basic biological processes (e.g., Schneider & Rowe, 1996) could make certain forms of emotion regulation more difficult. Evidence that older adults maintain the ability to regulate their emotional reactions despite these declines suggests that there are compensatory processes at work. How these processes function in the realm of an individual's emotional life is an important topic for future inquiry.

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