Greater sadness reactivity in late life

Benjamin H. Seider,[1] Michelle N. Shiota,[2] Patrick Whalen,[1] and Robert W. Levenson[1]

[1]Department of Psychology, University of California, 3210 Tolman Hall #1650, Berkeley, CA 94720-1650 and
[2]Department of Psychology, Arizona State University, P.O. Box 871104, Tempe, AZ 85287-1104, USA

Although previous research suggests that overall emotional reactivity does not change with normal aging, it is possible that different emotions follow different developmental courses. We examined emotional reactivity to films selected to elicit sadness, disgust, and a neutral state in young, middle-aged and older adults (total $N = 222$). Physiology and expressive behavior were measured continuously and reports of subjective emotional experience were obtained following each film. Results indicated that older adults reported greater sadness in response to all films and greater physiological responses to the sadness film than did the younger age groups. There were no age differences found in self-reported disgust or in behavioral expressions of sadness or disgust in response to any film. The age differences that were found were maintained even after controlling for pre-film self-reported sadness and for personal experiences of loss. These findings support the notion that sadness reactivity is heightened with age.

INTRODUCTION

Previous research has posed the question of whether emotional functioning in late life is characterized by overall losses, gains, or lack of change (Levenson, 2000; Lawton, 2001). Unlike cognitive functioning, where losses loom large (Salthouse, 2004), research suggests that most aspects of emotional functioning are preserved well into late life among healthy elders. The aspect of emotional functioning addressed in the present study is emotional reactivity—the intensity of emotional responses (e.g. subjective experience, physiological reactivity and expressive behavior) an individual has to an emotion-inducing stimulus.

Questionnaire-based studies suggest that overall emotional reactivity is maintained in late life (Gross et al., 1997; Carstensen et al., 2000). Studies that measured emotional reactivity under controlled laboratory conditions have also found continuity across adulthood in the intensity of subjective emotional experience and expressive behavior in response to emotional films, voluntary emotional facial actions and relived memories (Levenson et al., 1991; Tsai et al., 2000; Kunzmann et al., 2005). Peripheral physiological reactivity associated with emotion is also maintained, with the exception of cardiovascular reactivity, which appears to diminish with age (e.g. Levenson et al., 1991, 1994; Labouvie-Vief et al., 2003).

Reactivity in specific emotions: sadness in late life

Some studies of emotional reactivity in late life have considered specific emotions (e.g. sadness, disgust, happiness),

but most have aggregated data across all emotions in analyses and reported conclusions in terms of age differences in general emotional reactivity. Despite the absence of age effects on overall emotional reactivity, it is quite possible that specific emotions follow different trajectories as we age. For example, Kunzmann and Gruhn (2005) suggested that sadness might follow a different course than other emotions, with sadness reactivity increasing as we age. The antecedent condition for sadness is thought to be irrevocable loss (e.g. Smith and Ellsworth, 1985; Lazarus, 1991). Old age is a time of increased exposure to losses in a number of realms, including physical health and fitness, cognitive functioning, professional activities and social networks (Lindenberger and Baltes, 1997; Smith and Baltes, 1997). Thus, the antecedent conditions for sadness are likely encountered with increasing frequency as we age.

In particular, social losses may become of greater consequence in late life. Contemporary theories of life span development underscore the importance of close relationships in late life, noting the heavy investment made in maintaining satisfying and emotional meaningful relationships (Carstensen, 1993; Carstensen et al., 2003). Relative to their younger counterparts, older adults prefer spending time with emotionally close social partners (Fredrickson and Carstensen, 1990; Fung et al., 1999); thus, their social networks are densely populated with such individuals (Lang and Carstensen, 1994, 2002; Fung et al., 2001). Although the benefits that older individuals derive from friends and family are often emphasized (e.g. children are a greater source of pleasure for older married couples than for middle-aged couples; Levenson et al., 1993), this investment also creates greater vulnerability to social loss and the emotions (e.g. sadness) that ensue. The profound influence that loneliness and social ties play in predicting late life well-being and

health also speaks to this effect (Berkman and Syme, 1979; Hawkley and Cacioppo, 2007).

Increased exposure to loss may sensitize older adults to loss-related issues, increasing sadness reactivity to events involving loss. A number of studies support this notion. Older adults reveal more painful self-disclosures (e.g. bereavement, health and loneliness; Henwood et al., 1993), and report more intense feelings of sadness in both narrative and scalar measures, during an autobiographical memory task (Alea et al., 2004). Older adults are more likely to report that the protagonist is feeling sad when watching a video of emotionally ambiguous behavior, whereas younger adults are more likely to report that the protagonist is feeling angry (Charles et al., 2001). And, as noted earlier, Kunzmann and Grühn (2005) found that older adults reported feeling more sadness to sad films than younger adults.

These studies suggest that reactivity in self-reported sadness increases with age and that this heightened reactivity can occur in response to a range of stimuli. The evidence concerning behavioral displays of sadness and physiological reactivity to sad stimuli is less clear. Tsai and colleagues (2000) found no differences between old and young Chinese American and European American adults in sad behavioral expressions in response to sad films. The study also assessed physiological reactivity during the sad films and found a mixed pattern, with some measures suggesting less arousal and others suggesting greater arousal with age. In another study, Kunzmann and Grühn (2005) did not observe significant age differences in physiological reactivity during sad films, despite older individuals reporting experiencing more sadness. Thus, the issue of age differences in behavioral and physiological responses to sad stimuli remains unsettled.[1]

The current study

Compared to previous studies of age differences in emotion, the current study had several advantages: (i) it included middle-aged individuals, allowing determination of whether age differences emerge earlier in life; (ii) three aspects of emotional reactivity (self-report, physiological reactivity, expressive behavior) were assessed, which provides a comprehensive account of emotional response (Lang, 1985); (iii) films that target two different negative emotions and emotional neutrality were included to help determine if age differences were specific to films that targeted sadness; (iv) two different sadness and two disgust films were included to determine whether findings were emotion-specific or film-specific; (v) measures of personal exposure to loss and of baseline sadness were incorporated to control for life events and pre-film mood; (vi) a sample was

recruited that was representative of the local community in ethnicity and socio-economic status; and (vii) the sample was larger (total $N = 222$) than in most prior laboratory studies of emotion and aging, thus, providing adequate statistical power for detecting age effects.

Our primary hypothesis was that age would be associated with greater self-reported sadness, greater physiological reactivity, and greater behavioral expression of sadness in response to sad films. We expected no age differences in response to the disgust or emotionally neutral films.

METHODS

Sample

The sample consisted of 222 participants in three age groups: young (20–29 years, $n = 76$), middle-aged (40–49 years, $n = 73$) and old (60–69 years, $n = 73$), with ~50% females in each group (see Table 1 for additional demographic details). Four additional participants completed the study protocol, but their data were unusable due to computer error or problems with physiological signal quality. A professional survey research firm recruited the sample so that it was representative of the Bay Area in terms of ethnicity and socio-economic status. The firm conducted telephone-based screening interviews for all respondents and scheduled eligible participants for a laboratory session at the Berkeley Psychophysiology Laboratory. The screening excluded respondents who: (i) had participated in another research study within the last 6 months; (ii) did not speak English as the primary language at home or work; (iii) had Michigan alcoholism screening test (Selzer, 1971) scores >6; (iv) were wheelchair-bound; (v) had diagnosed diabetes or any other medical condition that would prevent their sitting comfortably in a laboratory chair for 2 h; (vi) were currently using psychoactive medication to treat an affective or anxiety disorder; or (vii) were allergic to the adhesive used to attach the physiological sensors. Participants received $50 for participating in the ~2.5 h study.

Procedures

Upon arrival at the laboratory, participants signed a consent form and had devices for measuring physiological reactivity

[1]Although sadness often leads to behavioral withdrawal that may be accompanied by parasympathetic activation, a rich body of evidence (meta-analyzed by Cacioppo et al., 2000) indicates that the experience of sadness typically involves increased cardiovascular arousal consistent with increased sympathetic activation. In particular, acute social loss-related sadness is expected to elicit increased sympathetic arousal in adults, as in infants experiencing separation distress (e.g. Spangler and Grossman, 1993).

Table 1 Mean gender, age and ethnicity

| | Participants | | |
	20s	40s	60s
N	76	73	73
Mean age	25.4 (2.3)	43.7 (2.7)	64.6 (3.0)
Female	52%	51%	54%
European-American	45%	51%	61%
Asian-American	20%	17%	11%
Latino/Latina	19%	17%	6%
African-American	16%	15%	22%

attached. Participants were assigned to an experimental condition, systematically crossing age, sex, ethnicity and stimulus condition (which determined counterbalanced aspects of trial order and film sequence).

Participants completed three film-viewing trials (the experimental session included other tasks as well, but these were not relevant to the questions posed in the current study). Within each trial, participants viewed: (i) a large 'X' on a television monitor for 60 s, during which they were instructed to clear their minds of thoughts, feelings, and memories (baseline period); (ii) a 5-s image instructing them to 'just watch the film clip as though you were watching television at home, or a movie in a movie theater'; (iii) the film, which lasted ~3 min; and (iv) a blank screen for 60 s. Following each trial, the experimenter entered the room to obtain ratings of subjective emotional experience (see below).

On the first trial, participants viewed the emotionally neutral film; on the second and third trials, they viewed one of two sadness films and one of two disgust films. Film emotion order for the second and third trials (sadness or disgust film first) and the particular sadness and disgust films viewed on each trial were counterbalanced. The neutral film (taken from 'Stranger Than Paradise') showed two men talking about nothing in particular. The sadness films each depicted irrevocable loss. One film (taken from '21 Grams') showed a mother being told of the deaths of her two young daughters in a car accident. The other film (taken from 'The Champ') showed a boy watching his father's death after a boxing match. The disgust films were taken from the television show 'Fear Factor'. Each depicted a person engaged in an unpleasant eating activity (one film showed a young woman eating horse rectum, and the another displayed a young man sucking fluid from cow intestine).

After the final trial, the experimenter removed the physiological measurement devices. Participants then completed a brief interview and were debriefed.

Measures

Exposure to loss

Age differences in sadness reactivity could result from increased exposure to loss in late life and attendant sensitizing or habituating effects. To control for this, we assessed personal experiences with loss. Prior to the laboratory session, participants completed a 67-item life stress inventory (Horowitz *et al.*, 1977), indicating the absence or presence of each item both recently (within the past 2 years) and remotely (more than 2 years ago). From this inventory we selected four life stresses having a core theme of irrevocable loss (death of a parent, close relative, or friend; having a miscarriage/abortion). An aggregated exposure to loss score was determined by calculating the mean of the summed recent and remote scores.

Subjective emotional experience

After each film, participants rated how strongly they experienced each of nine emotions (amusement/humor, anger, contentment, compassion, disgust, enthusiasm/excitement, fear, sadness and surprise) during the film. Ratings were obtained using a scale from 0 (did not experience that emotion at all) to 8 (strongest experience of that emotion ever felt). To provide a measure of baseline mood, the same ratings were also obtained at the beginning of the laboratory session, before any films were viewed. For the analyses, only the two emotions targeted by the films, sadness and disgust, were included.

Physiological reactivity

The physiological measures were selected to sample broadly from major organ systems important for emotional responding (cardiac, vascular, thermoregulatory, electrodermal and somatic muscle), to allow for continuous measurement, to be as unobtrusive as possible, and to include measures used in our previous studies of emotion (e.g. Levenson *et al.*, 1990). Recordings were obtained using a system consisting of a Grass Model 7 12-channel polygraph, a Finapres blood pressure monitor, and a microcomputer with analog and digital input/output capabilities. The measures were: (i) cardiac inter-beat interval (IBI)—Beckman miniature electrodes with Redux paste were placed in a bipolar configuration on opposite sides of the participant's chest and the interval between successive R-waves of the electrocardiogram (EKG) was measured in ms; (ii) skin conductance level—a constant voltage device passed a small voltage between Beckman regular electrodes attached to the palmar surface of the middle phalanges of the first and third fingers of the non-dominant hand using sodium chloride in unibase as the electrolyte; (iii) pulse transmission time to the finger—the time interval was measured between the R-wave of the EKG and the upstroke of the peripheral pulse at the finger; (iv) finger pulse amplitude—a UFI photoplethysmograph attached to the second finger of the non-dominant hand recorded the volume of blood in the finger. The trough-to-peak amplitude of the finger pulse was measured, providing an index of the amount of blood in the periphery; (v) pulse transmission time to the ear—a UFI photoplethysmograph attached to the right earlobe recorded the volume of blood in the ear. The time interval was measured between the R-wave of the EKG and the upstroke of the peripheral pulse at the ear; (vi) finger temperature—a Yellow Springs Instruments thermistor was attached to the palmar surface of the first phalanx of the middle finger of the dominant hand with surgical tape; (vii) systolic and (viii) diastolic blood pressure—an inflating Finapres cuff was placed on the intermediate phalanx of the second finger of the non-dominant hand, and inflation adjusted continuously to provide an estimate of blood pressure with each heartbeat; (ix) respiration period and (x) respiration depth—a cloth belt wrapped around the participant's thorax compressed an inflated bladder to provide a measure

of chest wall movement; and (xi) general somatic activity—an electromechanical transducer attached to a platform under the participant's chair generated an electrical signal proportional to the amount of body movement in any direction.

A computer program written by one of the authors (R.W.L.) was used to calculate second-by-second averages for each physiological measure for each participant. Prior to analysis, all data were examined and edited to remove artifacts and outliers by members of the research team who were blind to participant age, sex and experimental condition.

Physiological data were reduced by calculating mean values for each physiological measure for four epochs of interest during each trial: (i) baseline—the 60 s preceding each film; (ii) orientation—the initial 20 s of each film (this epoch introduced the characters and did not have strong emotional content); (iii) peak responding—data for each measure were aggregated across the entire sample and examined with the goal of identifying 20 s epochs of peak physiological responses for each film. Invariably, the 20 s epoch selected for the films corresponded to the most intense part of the film storyline, as determined by consensus of a group of ten graduate students.[2] (iv) recovery—the 20 s immediately following the end of the film (participants often show a burst of emotional expression once the film ends). For each physiological measure, reactivity scores were then calculated for the orientation, peak responding and recovery epochs by subtracting the baseline mean from the appropriate epoch mean.

Composite physiological reactivity scores were computed by normalizing reactivity scores for each measure across all participants, films, and epochs. We then multiplied the z-scores for cardiac interbeat interval, finger pulse amplitude, ear pulse transmission time, respiration period and temperature by -1 (so that more positive values were consistent with greater autonomic activation); and averaged the z-scores for the 11 measures to compute composite physiological reactivity indices for the orienting, peak responding and recovery epochs. Physiological composite scores such as these offer several benefits: (i) they reduce the number of variables used in analyses, thereby lowering risk of Type I error; (ii) they are sensitive to individual differences in which physiological measures capture the emotional response; and (iii) they generally increase reliability (e.g. Lord and Novick, 1968; Tryon and Bernstein, 2003). Cronbach's alphas for the reactivity scores for the peak responding epoch were 0.57 for the sadness films, 0.55 for the disgust films and 0.46 for the neutral film. Because these composite scores can obscure differences in patterns of response for individual physiological measures, we also conducted exploratory *post-hoc* analyses of the individual measures.

[2]A group of 10 graduate students blind to the film storylines viewed the physiology plots and identified peak physiological responses for each film. When the epochs selected by the team of graduate students were matched with the film storyline, there was complete agreement that the selected epochs captured the most emotional intense part of the film storyline.

Expressive behavior

Participants' emotional behavior was videotaped using a remotely-controlled camera that was partially concealed behind darkened glass in a bookcase. For each trial, expressive behaviors were coded during the stimulus film and the first 10 s after the film by three trained coders who were blind to the film being viewed. Coding criteria for sadness and disgust expressions were derived from the facial affect coding system and EMFACS (Ekman and Friesen, 1978; Friesen and Ekman, 1983), and included both required and optional/enhancing action units. For sadness, the required action units were 1 (inner brow raise) or $1+4$ (inner brow raise plus brow lower) and optional action units were 6 (cheek raise), 15 (lip corners down), 17 (chin raise) and 24 (lip press). For disgust, the required action units were 9 (nose wrinkle) and/or 10 (upper lip raise), and optional action units included 23 (lip tighten) and 24 (lip press).

Behavioral coding during the films was segmented into 5 s 'bins', with expressions rated on a scale from 0 (not present) to 3 (strongly present), with the scale value based on both intensity and duration. For the present study, a composite expressive behavior score was determined for each film, indicating the number of bins in which expressions were observed divided by the total number of bins.[3]

Coding reliability was determined for a subsample of 14 participants who were coded by all three coders. Intraclass correlations were 0.69 for disgust and 0.76 for sadness.

RESULTS
Data analysis

An overall $3 \times 2 \times 2 \times 3$ MANOVA was used to analyze the five dependent measures (self-reported subjective experience of sadness, behavioral expressions of sadness, self-reported subjective experiences of disgust, behavioral expressions of disgust and composite physiological reactivity). Between-subject factors were age group (young, middle-aged, old), sex (male, female), stimulus condition (which sadness and disgust-eliciting films were viewed). Film Type (neutral, sadness, disgust) was treated as a within-subject factor. In this analysis, the composite physiological reactivity was collapsed across the three Epochs (orientation, peak responding, recovery) because the self-report and behavioral dependent variables did not have this epoch structure. This overall MANOVA was followed-up using separate mixed model MANOVAs for each dependent variable to characterize age-related findings. Physiological reactivity variables, this time not collapsed across epochs, were analyzed in an additional set of MANOVAs with Epochs treated as a within-subject factor. These analyses revealed no significant interactions of age × epoch or age × film type × epoch; thus,

[3]A second composite score, representing the average intensity of all coded expressions was also computed. Rerunning the analyses using this other score did not alter the pattern of findings.

only the physiological data collapsed across epochs will be reported.

The 0.05 alpha level was adopted for all significance tests and partial eta squares are reported as measure of effect size (Cohen, 1988).

Manipulation check: film effectiveness in evoking target emotion responses

To ensure that the films elicited the intended target emotions, we examined the impact of the films on subjective emotional experience and expressive behavior. The overall MANOVA revealed a main effect for film type $F(6, 179) = 92.04$, $P < 0.001$, $\eta^2 = 0.84$. This was followed up with repeated measures ANOVAs for self-reported sadness and disgust, and for sadness and disgust expressive behavior.

Subjective emotional experience.

For sadness experience, there was a significant main effect for film type, $F(2, 208) = 166.20$, $P < 0.001$, $\eta^2 = 0.487$. Within-subjects contrasts revealed greater reports of sadness in response to the sadness films than to the neutral film $F(1, 209) = 271.29$, $P < 0.001$, $\eta^2 = 0.565$ or to the disgust films $F(1, 209) = 275.35$, $P < 0.001$, $\eta^2 = 0.568$.

For disgust experience, there was also a significant main effect for film type, $F(2, 208) = 398.72$, $P < 0.001$, $\eta^2 = 0.793$. Within-subjects contrasts revealed greater reports of disgust in response to the disgust films than to the neutral film $F(1, 209) = 801.04$, $P < 0.001$, $\eta^2 = 0.793$ or to the sadness films $F(1, 209) = 350.74$, $P < 0.001$, $\eta^2 = 0.627$.

Expressive behavior.

For sadness expressions, there was a significant main effect for film type, $F(2, 184) = 9.49$, $P < 0.001$, $\eta^2 = 0.094$. Within-subjects contrasts revealed more sadness expressive behavior during the sadness films than during the neutral film $F(1, 185) = 19.04$, $P < 0.001$, $\eta^2 = 0.093$, or during the disgust films $F(1, 185) = 18.88$, $P < 0.001$, $\eta^2 = 0.093$.

For disgust expressions, there was also a significant main effect for film type, $F(2, 184) = 97.44$, $P < 0.001$, $\eta^2 = 0.514$.

Within-subjects contrasts revealed more disgust expressive behavior during the disgust films than during the neutral film $F(1, 185) = 192.30$, $P < 0.001$, $\eta^2 = 0.510$, or during the sadness films $F(1, 185) = 193.91$, $P < 0.001$, $\eta^2 = 0.512$.

In summary, analyses supported the effectiveness of the sadness and disgust films in eliciting the targeted emotional experience and facial expressive behavior.

Age differences in emotional reactivity

We turn next to testing our hypothesis that age would be associated with greater sadness reactivity. Means for subjective emotional experience, expressive behavior and composite physiological reactivity are presented separately for each age group and film in Table 2.

The overall MANOVA revealed a main effect for age $F(10, 360) = 1.92$, $P < 0.05$, $\eta^2 = 0.051$; however, the interactions between age and film type, sex, and stimulus condition were not significant. Because our hypotheses were specific as to dependent measure, we next examined the MANOVAS for the five dependent measures, with particular attention to the age main effect and the interactions involving age. These analyses revealed a significant age effect for self-reported sadness $F(2, 184) = 6.53$, $P < 0.01$, $\eta^2 = 0.066$, but not sadness expressive behavior $F(2, 184) = 0.25$, ns, self-reported disgust $F(2, 184) = 1.71$, ns, disgust expressive behavior $F(2, 184) = 0.06$, ns, or composite physiological reactivity $F(2, 184) = 0.94$, ns. Examining the age × film type interactions, only the interaction for composite physiological reactivity approached significance, Greenhouse–Geisser corrected $F(3.78, 348.11) = 2.29$, $P = 0.063$, $\eta^2 = 0.024$. The interactions between age and either sex or stimulus condition were not significant for any of the dependent measures.

We then decomposed the significant effects. For the age effect for self-reported sadness, mean values (and standard errors) for the three groups were: old $M = 3.32$ (0.18), middle-aged $M = 2.64$ (0.18) and young $M = 2.29$ (0.18). Follow up comparisons revealed that older participants reported experiencing more sadness than both middle-aged participants $t(144) = 2.68$, $P < 0.01$ and younger participants

Table 2 Mean subjective emotion, behavioral expression, and physiology composite by age and film

	Neutral			Sadness			Disgust		
	20s *M* (s.e)	40s *M* (s.e)	60s *M* (s.e)	20s *M* (s.e)	40s *M* (s.e)	60s *M* (s.e)	20s *M* (s.e)	40s *M* (s.e)	60s *M* (s.e)
Subjective emotion									
Sadness	1.61 (0.24)	1.74 (0.25)	2.32 (0.27)	4.25 (0.29)	4.92 (0.29)	5.79 (0.28)	1.03 (0.19)	1.27 (0.24)	1.88 (0.29)
Disgust	0.71 (0.14)	0.73 (0.17)	0.81 (0.17)	1.31 (0.22)	1.84 (0.27)	1.67 (0.28)	5.17 (0.27)	5.85 (0.26)	5.52 (0.31)
Behavioral expressions									
Sadness	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.04 (0.02)	0.05 (0.02)	0.07 (0.02)	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)
Disgust	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.01 (0.00)	0.02 (0.01)	0.00 (0.00)	0.34 (0.04)	0.32 (0.04)	0.34 (0.05)
Physiological composite	−0.09 (0.04)	−0.11 (0.03)	−0.02 (0.25)	−0.12 (0.04)	0.01 (0.04)	0.04 (0.05)	0.14 (0.05)	0.12 (0.04)	0.05 (0.04)

Note: Behavioral expressions are reported as percentage of 5s bins in which expressions occurred.

Table 3 Means for individual physiology variables by age group and film

	Neutral			Sadness			Disgust		
	20s M (s.e)	40s M (s.e)	60s M (s.e)	20s M (s.e)	40s M (s.e)	60s M (s.e)	20s M (s.e)	40s M (s.e)	60s M (s.e)
Cardiac interbeat interval	9.99 (5.14)	3.43 (3.67)	1.58 (2.58)	5.39 (5.02)	−8.09 (3.36)	−3.72 (3.67)	−15.63 (5.53)	−17.05 (4.44)	−6.84 (4.09)
Somatic activity	0.01 (0.05)	−0.02 (0.03)	−0.04 (0.03)	−0.11 (0.06)	0.08 (0.05)	−0.03 (0.04)	0.20 (0.06)	0.23 (0.07)	0.04 (0.05)
Skin conductance	−0.20 (0.04)	−0.10 (0.04)	−0.08 (0.02)	−0.19 (0.06)	−0.11 (0.06)	−0.02 (0.05)	0.03 (0.08)	0.01 (0.05)	−0.00 (0.04)
Finger pulse transmission time	0.89 (1.01)	4.51 (1.08)	2.03 (0.96)	4.71 (1.32)	0.62 (1.58)	3.37 (1.35)	4.53 (1.51)	1.78 (1.32)	1.27 (1.27)
Ear pulse transmission time	−1.45 (1.36)	−0.16 (0.60)	−3.18 (0.70)	0.53 (0.66)	0.21 (0.57)	−1.23 (0.69)	−0.76 (0.68)	−0.61 (0.78)	−0.72 (0.70)
Finger pulse amplitude	−0.45 (0.21)	−0.34 (0.14)	−0.36 (0.12)	−0.90 (0.21)	−0.85 (0.19)	−0.39 (0.16)	−1.25 (0.24)	−0.73 (0.18)	−0.50 (0.15)
Temperature	−0.11 (0.07)	−0.09 (0.05)	−0.05 (0.06)	−0.13 (0.08)	−0.06 (0.09)	−0.22 (0.08)	−0.04 (0.07)	−0.09 (0.06)	−0.11 (0.07)
Respiration depth	−16.69 (5.91)	−17.30 (7.85)	−17.90 (6.51)	−13.14 (9.38)	−22.82 (8.74)	−29.36 (12.20)	1.78 (8.74)	−10.58 (8.84)	−19.34 (8.49)
Respiration period	−234.20 (113.32)	−377.18 (150.76)	−415.88 (82.72)	−435.58 (115.77)	−687.64 (139.90)	−536.48 (113.69)	−171.96 (107.34)	−710.87 (156.95)	−707.35 (129.58)
Systolic blood pressure	0.15 (0.65)	1.24 (0.70)	3.36 (0.89)	2.28 (0.74)	2.80 (0.86)	6.51 (1.29)	5.26 (0.76)	4.34 (0.87)	4.34 (1.11)
Diastolic blood pressure	0.15 (0.31)	0.54 (0.29)	0.99 (0.42)	0.60 (0.38)	0.91 (0.41)	2.06 (0.50)	2.55 (0.44)	1.53 (0.37)	1.66 (0.47)

Note: Physiology variables represent unstandardized change scores (average during film–average during pre-film baseline).

$t(146) = 4.05$, $P < 0.001$. For the age × film type interaction for the physiology composite, group means and standard errors are reported in Table 2. Separate MANOVAs for each film type revealed a significant main effect of age in response to the sadness films $F(2, 210) = 3.66$, $P < 0.05$, $\eta^2 = 0.034$, but not the neutral film $F(2, 210) = 1.80$, ns, or the disgust films $F(2, 209) = 0.89$, ns. Follow up comparisons of the Age effect for the sadness films indicated that older participants $t(147) = 2.40$, $P < 0.05$ and middle-aged participants $t(147) = 2.20$, $P < 0.05$ showed greater physiological reactivity to the sadness films than younger participants, but did not differ from each other $t(144) = 0.40$, ns.

To provide more detailed information about which physiological variables were responsible for age differences in response to the sadness film, we examined each physiological variable separately (means presented in Table 3). Significant Age effects were found for systolic blood pressure $F(2,199) = 5.26$, $P < 0.01$, $\eta^2 = 0.050$; diastolic blood pressure $F(2, 199) = 3.03$, $P < 0.05$, $\eta^2 = 0.030$ and somatic activity $F(2, 207) = 3.46$, $P < 0.05$, $\eta^2 = 0.032$. In terms of systolic blood pressure, follow up comparisons indicated that older participants had greater levels of systolic blood pressure than both middle-aged participants $t(137) = 2.27$, $P < 0.05$ and young participants $t(142) = 2.874$, $P < 0.01$, who did not differ from each other $t(139) = 0.47$, ns. In terms of diastolic blood pressure, older participants had greater levels of diastolic blood pressure than young participants $t(142) = 2.31$, $P < 0.05$, but not middle-aged participants $t(137) = 1.76$, ns, and middle-aged and younger participants did not differ from each other $t(139) = 0.55$, ns. In terms of somatic activity, middle-aged participants had greater levels of somatic activity than young participants $t(145) = 2.42$, $P < 0.05$, but did not differ from older participants $t(139) = 1.81$, ns, and older participants and younger participants did not differ from each other $t(146) = 1.10$, ns. Thus the age differences found in the composite measure of physiological reactivity appeared to be driven primarily by systolic blood pressure, diastolic blood pressure and somatic activity.

Summary

We found strong support for our hypothesis that age would be associated with greater sadness reactivity in self-reported sadness and in physiological response (but not in sadness expressive behavior). Older participants reported experiencing greater sadness in response to all films than did middle-aged and younger participants. Older participants (and middle-aged participants) showed greater physiological reactivity to the sadness films than did younger participants. The findings revealed some specificity as to emotion and film as well. In terms of emotion, no age differences were found in self-reported disgust or disgust expressive behaviors. In terms of film, no age differences were found in physiological response to the disgust or neutral films.

Are age differences in sadness reactivity accounted for by age differences in pre-film sadness or exposure to loss

We considered two explanations for our findings of greater sadness reactivity in older participants: (i) older participants were sadder than participants from the other age groups when they arrived at the laboratory; and (ii) older participants have been exposed to more loss in their lives than participants from the other age groups, which sensitizes them to responding to films portraying themes of loss. Analyses revealed no differences in reports of sadness when participants arrived at the laboratory $F(2, 218) = 0.301$, ns. However, older participants did report greater exposure to loss than participants in the other two age groups $F(2, 208) = 35.22$, $P < 0.001$ [old $M = 2.20$ (1.22), middle-aged $M = 1.62$ (1.16), young $M = 0.70$ (0.82)]. To test the alternative hypotheses, we reran the analyses reported above where age differences in sadness reactivity were found, controlling for both pre-film levels of self-reported sadness and self-reported exposure to loss on our life stress questionnaire. Both the self-reported sadness to the films $F(2, 196) = 5.52$, $P = 0.005$, and the composite physiological responding to the sad film $F(2, 196) = 3.46$, $P = 0.033$, remained significant.

DISCUSSION

To examine age differences in sadness reactivity, we evaluated the impact of films selected to elicit sadness, disgust, or to be emotionally neutral on three aspects of emotional response (subjective emotional experience, emotional expressive behavior, peripheral physiology) in a large representative community sample of young, middle-aged and old participants.

Age differences in sadness reactivity

Our findings indicated that age was associated with increased reactivity in self-reported sadness across all of the films. There was also evidence of increased physiological reactivity to the sadness films, a finding that was primarily accounted for by increased reactivity in cardiovascular (systolic and diastolic blood pressure) and skeletal muscle (somatic activity) measures. These findings of greater sadness reactivity in subjective and physiological measures with age are consistent with those previously reported by others (e.g. Charles *et al.*, 2001; Alea *et al.*, 2004; Kunzmann and Grühn, 2005). However, they must be tempered by our failure to find age differences in sadness behavioral expressions. Thus, older individuals may report feeling greater sadness in response to a range of stimuli and have greater physiological reactivity in response to sadness films, but this is not accompanied by commensurately greater expressive behavior. Previous studies have also failed to find age differences in expressive behavior in response to films (Tsai *et al.*, 2000; Kunzmann *et al.*, 2005). One possibility is that age differences might emerge if film or other stimuli were used that were even

more powerful elicitors of sadness (e.g. only 15% of our participants showed sadness expressions during the sadness films).

Although age increases in self-reported sadness were found across all of our films, there was also evidence of some specificity of age-related increases in responding in terms of emotion and film. In terms of emotion, we found no age differences in self-reported disgust or in disgust expressive behavior. In terms of film, we found age-related increases in physiological responding to the sadness film, but not to the disgust and neutral films. Combining our findings for sadness and disgust lends empirical support to Kunzmann and Grühn's (2005) speculation that the trajectory of age differences in emotional reactivity might be emotion-specific. Of course, a full accounting relative to this notion will require additional studies sampling other emotions.

Alternative explanations for age-related increases in sadness reactivity

It is notable that findings of age-related increases in sadness reactivity withstood statistical controls for two plausible alternative hypotheses, one based on initial mood and the other based on experiences with loss. Ruling out greater exposure to loss-related events is of particular importance because old age is associated with increased losses of family and friends as well as losses in physical and cognitive functioning (Lindenberger and Baltes, 1997; Smith and Baltes, 1997; Salthouse, 2004), all of which could have a sensitizing effect.

Implications for theories of life span socio-emotional development

Finding that older participants report greater subjective experience of sadness across a range of films and greater physiological reactivity to films that depict irrevocable loss may appear inconsistent with theories that associate aging with the optimization of positive emotions (e.g. socio-emotional selectivity theory, Carstensen, 1993; Carstensen *et al.*, 2003). Similarly, these findings may seem to run contrary to empirical research documenting a 'positivity effect' in which older participants demonstrate attention and memory bias towards positive information and away from negative information (Charles *et al.*, 2003; Mather and Carstensen, 2003), maintain well-being (Diener and Suh, 1997; Diener and Lucas, 1999) and have stable rates of depression (e.g. Karel, 1997). However, the centrality of social relationships in late life (Carstensen *et al.*, 2003) and the potency of social losses for eliciting sadness (Smith and Ellsworth, 1985), may make older individuals particularly sensitive to detecting themes of loss and, thus, reporting sadness in response to films that depict social situations. In the present study, we cannot know with certainty if older individuals did in fact sense themes of loss in the disgust and neutral films. They may have reported greater sadness for quite different reasons. For example, functional accounts of

sadness often emphasize its role in conveying empathy and concern for others, thus promoting intimate and meaningful interpersonal relationships (Averill, 1968; Malatesta, 1990; Keltner and Kring, 1998; Bonnano *et al.*, 2008). Viewed in this light, a lower threshold for sadness in older people may act in the service of their heightened motivation to preserve meaningful social relationships (Carstensen *et al.*, 2003). This suggests that adding measures sensitive to participants' appraisals of the films in addition to their self-reported emotional experience would be a useful addition to future studies. Having said this, it is important to note that themes of loss were important in some of our findings. Age-related increases in physiological responding, arguably an aspect of emotional responding less vulnerable to biases than self-reported emotion, only occurred in response to our sadness films, both of which explicitly depicted irrevocable loss.

Limitations and future directions

Conclusions from this study should be tempered by several limitations: (i) films were used to elicit emotion and, thus, the findings might not generalize to other emotion elicitors; (ii) a cross-sectional design was used and, thus, differences between age groups may result in part or wholly from cohort differences rather than from age; (iii) the low base rate of participants showing sadness behavioral expressions (15%) may have contributed to our failure to find age related increases in sadness expressive behavior; and (iv) our measure used to assess loss was a retrospective self-report inventory, with attendant concerns about whether it adequately assessed the full range of possible losses (non-personal, personal, those experienced by close others, etc.).

CONCLUSION

These results support our hypothesis of greater sadness reactivity with age, at least in the domains of self-reported sadness and physiological reactivity. These age-related differences in sadness reactivity could not be accounted for by baseline levels of sadness or by self-reported exposure to loss. We believe that heightened sadness reactivity in older individuals may derive from their greater investment in interpersonal relationships and the attendant increased sensitivity to social loss and to the pain and suffering of others.

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