Research Article

Looking at the Sunny Side of Life

Age-Related Change in an Event-Related Potential Measure of the Negativity Bias

Michael A. Kisley,[1] Stacey Wood,[2] and Christina L. Burrows[1]

[1]University of Colorado at Colorado Springs and [2]Scripps College

ABSTRACT—*Studies of the negativity bias have demonstrated that negative information has a stronger influence than positive information in a wide range of cognitive domains. At odds with this literature is extensive work now documenting emotional and motivational shifts that result in a positivity effect in older adults. It remains unclear, however, whether this age-related positivity effect results from increases in processing of positive information or from decreases in processing of negative information. Also unknown is the specific time course of development from a negative bias to an apparently positive one. The present study was designed to investigate the negativity bias across the life span using an event-related potential measure of responding to emotionally valenced images. The results suggest that neural reactivity to negative images declines linearly with age, but responding to positive images is surprisingly age invariant across most of the adult life span.*

The *negativity bias* refers to the tendency for humans to pay more attention to negative than to positive information in a wide range of domains, including perception, decision making, and evaluative judgment (Cacioppo & Berntson, 1994; Rozin & Royzman, 2001; Taylor, 1991). Baumeister, Bratslavsky, Finkenauer, and Vohs (2001), after reviewing a broad array of research, concluded that this bias is pervasive in psychological function, and that there are only a very limited number of exceptions (e.g., optimism in predicting the future).

Recent research has documented age-related shifts in emotional and attentional function that could affect the strength or even the presence of the negativity bias (Mather & Carstensen, 2005; Mroczek, 2001). For example, pioneering work by Carstensen and her colleagues demonstrated that, despite stereotypes to the contrary, older adults typically report higher well-being than younger adults, apparently because of motivational changes to optimize social and emotional goals (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Charles & Carstensen, 1999). Further, these changes appear to affect cognitive functioning as well as mood, resulting in a generalized increase in attention to positive stimuli compared with negative stimuli. This has been described as a *positivity effect* in information processing for older adults (Charles, Mather, & Carstensen, 2003; Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Mather & Carstensen, 2003; Pennebaker & Stone, 2003; Wood, Busemeyer, Koling, Cox, & Davis, 2005). Although the positivity effect has been studied among adults in different age ranges (e.g., young, middle, and old), the life-span developmental timeline for this effect has not been empirically characterized (e.g., Carstensen, 1995). Further, it is unclear whether the bias reversal arises from an age-related increase in responding to positive information or an age-related decrease in responding to negative information (Blanchard-Fields, 2006).

Because event-related potential (ERP) methodology has been applied to the investigation of emotional processing in general, and the negativity bias in particular (Bartholow, Pearson, Gratton, & Fabiani, 2003; Schupp et al., 2000; Smith et al., 2006), this methodology might prove useful in addressing some of the unresolved issues concerning age-related changes in the processing of positive and negative information. For example, using this method, Ito, Larsen, Smith, and Cacioppo (1998) determined that the negativity bias is measurable in younger adults even within 500 ms of stimulus onset during an evaluative categorization task. In this paradigm, emotionally valenced images (positive and negative) occur infrequently against a background of frequently presented neutral images. A characteristic ERP waveform, the late positive potential (LPP), is elicited by these positive and negative stimuli, which are evaluatively inconsistent with the neutral background. Ito et al.

Christina Burrows is now at the Department of Psychology, University of Houston. Address correspondence to Michael A. Kisley, Department of Psychology, University of Colorado at Colorado Springs, 1420 Austin Bluffs Parkway, PO Box 7150, Colorado Springs, CO 80933-7150, e-mail: mkisley@uccs.edu.

showed that, in younger adults, negative images produced larger LPP waveforms than positive images, even though the positive and negative images were equal in subjective emotional impact and arousal. In short, this ERP-based measurement demonstrated a negativity bias by showing increased allocation of neural resources to negative, compared with positive, information.

A recent investigation has demonstrated that the negativity bias exhibited by the LPP waveform is eliminated in older adults. We (Wood & Kisley, 2006) replicated the original ERP study of the negativity bias in younger adults, but also included a sample of older adults (mean age of 68.5 years). For the latter group, the LPP waveform elicited by valenced images was significantly larger than the LPP waveform for neutral images (as in the younger adults), but there was no evidence of differential response amplitude elicited by positive versus negative images. However, the particular pattern of results left it unclear whether the lack of bias in the older group reflected a specific change in the balance between processing of positive information and processing of negative information or, perhaps more trivially, a generalized age-related dampening in the processing of all valenced images.

In the present study, we collected ERP measures of brain activity elicited by emotionally valenced images from an adult life-span sample (18–81 years). This study was designed to provide evidence regarding the adult developmental timeline of the negativity bias in the LPP waveform and to shed light on the issue of whether the reduced negativity bias in older adults reflects age-related changes in response to positive images, in response to negative images, or perhaps both. On the basis of our previous study (Wood & Kisley, 2006), we predicted that aging would be related to a decline in the negativity bias exhibited by the LPP waveform. We tested hypotheses using a model of linear change with advancing age.

METHOD

Subjects

Statistical analyses were performed with the data from 51 adults between 18 and 81 years old ($M = 43.16$, $SD = 19.23$; 34 female). A total of 65 individuals originally participated, but 14 were excluded for the following reasons: difficulties performing the behavioral task ($n = 2$), an insufficient number of trials available for computing ERP average waveforms ($n = 10$), and recording problems ($n = 2$). The latter two problems are unique to electrophysiological methodology, and we implemented criteria for number of trials and recording quality to avoid including in the analysis ERP waveforms with degraded signal strength. We discuss the rationale for these exclusions further in the Procedure and Analysis section.

All included subjects had no self-reported visual problems, tested 20/40 or better with at least one eye on the Snellen visual acuity chart, and read textual instructions on a computer screen at a distance of 2.5 ft with no difficulty. They scored 28 or higher on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975). Years of education ranged from 12 to 20 ($M = 14.82$, $SD = 1.88$). Because age was significantly correlated with years of education, $r = .34, p < .05$, and visual acuity, $r = -.49, p < .01$, the latter two variables were controlled for in the analyses described here.

Materials

Images were presented on a 17-in. LCD color computer monitor 2.5 ft from the subject. E-Prime (Psychological Software Tools, Inc., Pittsburgh, PA) was used for presenting the images and recording responses. Electroencephalographic signals were recorded on a Neuroscan NuAmps amplifier system under control of a laptop computer running Scan 4.2 (Compumedics Neuroscan, El Paso, TX).

Affectively neutral, positive, and negative images were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005) on the basis of normative ratings from younger adults (Lang et al., 2005) and previous ERP studies (Ito et al., 1998; Wood & Kisley, 2006). Of these 30 images, 6 (2 positive, 2 negative, and 2 neutral) were used to compute ERPs. For these 6 images (the oddball and control images—see Procedure and Analysis), we collected quantitative ratings of bipolar valence (from 1, *most negative*, to 9, *most positive*) and arousal (from 1, *least arousing*, to 9, *most arousing*) using the Self Assessment Manikin instrument (SAM; Lang et al., 2005). The mean bipolar valence rating for the neutral images (IAPS Pictures 6150 and 7550: electrical outlet and man at computer, respectively) was 5.28 ($SD = 0.89$), and the mean arousal rating was 2.25 ($SD = 1.40$). The mean ratings for the positive images (IAPS Pictures 7340 and 7350: chocolate ice cream and pizza, respectively) were 7.49 ($SD = 1.75$) for bipolar valence and 5.08 ($SD = 2.74$) for arousal. For the negative images (IAPS Pictures 9140 and 9571: decomposing calf and dead cat, respectively), the mean ratings were 1.26 ($SD = 0.61$) for bipolar valence and 5.71 ($SD = 2.53$) for arousal.

These mean ratings for arousal and valence generally fall within normative ranges established in previous publications (e.g., they fall between the values obtained by Ito et al., 1998, and Lang et al., 2005). However, unlike in the study by Ito et al. (1998), the mean valence ratings for the stimuli suggest that the negative and positive images were not experienced as equally distant in valence from neutral. Specifically, the mean absolute-value difference between the negative image's ratings and theoretical neutral was 3.74 (i.e., $|1.26 - 5|$), whereas the difference between the positive image's ratings and neutral was 2.49 ($|7.49 - 5|$), and these distances were significantly different from each other, $F(50) = 28.53, p < .001$. For this reason, we computed for each subject the difference between the distance from theoretical neutral for positive images and the distance from theoretical neutral for negative images (i.e., |negative valence − 5| − |positive valence − 5|) and included this measure of *behavioral bias* as a covariate for all statistical analyses presented here. Partial correlations ($df = 47$) controlling for education and visual acuity and zero-order correlations ($N = 51$) revealed no significant effect of age on the ratings of subjective valence or arousal, or on the index of behavioral bias.

Procedure and Analysis

The procedure and ERP analysis for this study were identical to those we used in our previous investigations of the LPP negativity bias (Wood & Kisley, 2006) and are described here very briefly. During an evaluative categorization task, electrophysiological signals were recorded (1000-Hz sampling, 0.1- to 100-Hz band pass) from standardized scalp electrode sites (referenced to average signal on left and right mastoids), as well as sites near the eyes, which were used to monitor movements and blinks. Subjects for whom adequate electrode contact could not be maintained (i.e., impedances > 5 kΩ; $n = 2$) were excluded from further analysis because high impedances lead to decreased signal-to-noise ratios in the measurement.

The task required subjects to view each image for 1 s and subsequently categorize it as positive, negative, or neutral by pressing one of three buttons on a response pad. A 1.2-s lag separated response from presentation of the next image. The 450 trials were divided into blocks of 5, with a pause between blocks. Individuals with an excessive number of nonresponses (5 or more during the entire task) or very high mean response latency (1,500 ms or longer) were excluded from the final analysis ($n = 2$). Twenty-four different neutral filler images were presented 15 times each, to provide a neutral context. At pseudorandom positions, 60 *oddball* images and 30 neutral *control* images were presented within this series. The oddball images were evaluatively inconsistent with the majority of images because of their emotional valence; 30 oddball images were positive (2 different images presented 15 times each), and 30 were negative (2 different images presented 15 times each). The 30 control images also consisted of 15 presentations each of 2 different images. Subjects responded as expected (i.e., responded “neutral” to neutral images, “negative” to negative images, and “positive” to positive images) on 81.4% ($SD = 14.0\%$) of the 90 oddball and control trials; this variable was not significantly correlated with age.

Average ERP waveforms (spanning from 100 ms before image onset to 900 ms after onset) were computed for the oddball-image presentations and the control-image presentations using standard procedures for ERP analysis (Wood & Kisley, 2006). Any ERP waveform corrupted by movement artifact (i.e., a waveform with a recording channel exceeding ± 100 µV) was excluded from further analysis. Valence-specific average waveforms (neutral, positive, and negative) were computed from the remaining trials and smoothed (low-pass filtered at 9 Hz). To avoid including individuals with potentially unreliable average waveforms in the analysis, we excluded any subject for whom an insufficient number of single trials was available for computing an average ERP waveform (i.e., five trials or fewer per valence category remaining after removal of artifactual trials; $n = 10$). The mean number of trials used to compute average ERP waveforms in the remaining 51 subjects was 22.0 ($SD = 6.4$) for neutral images, 22.3 ($SD = 5.4$) for negative images, and 22.0 ($SD = 6.5$) for positive images; the three valence categories did not differ significantly in the number of trials used to compute average waveforms.

Previous research has shown that LPP amplitude is largest at recording site Pz (Cacioppo, Crites, Berntson, & Coles, 1993; Ito et al., 1998; Wood & Kisley, 2006), which is over the parietal lobe and along the midline of the head. Thus, LPP amplitude for each waveform was taken from the largest peak voltage on electrode Pz between 400 and 900 ms after image onset (Coles, Gratton, & Fabiani, 1990).

RESULTS

For the entire sample, peak LPP amplitude was larger in response to negative than in response to positive images (Fig. 1); this result replicates previous demonstrations of a negativity bias for this ERP component. LPP amplitude at electrode Pz was examined in an analysis of variance (Wilks’s lambda approximation) with the factor of valence (three levels: neutral, negative, positive), and with behavioral bias (i.e., difference between subjective negativity and positivity of the images) as a covariate. A main effect of valence was found, $F(2, 48) = 29.00, p < .001, \eta^2 = .547$; behavioral bias did not have a significant effect, and the interaction between valence and behavioral bias was not

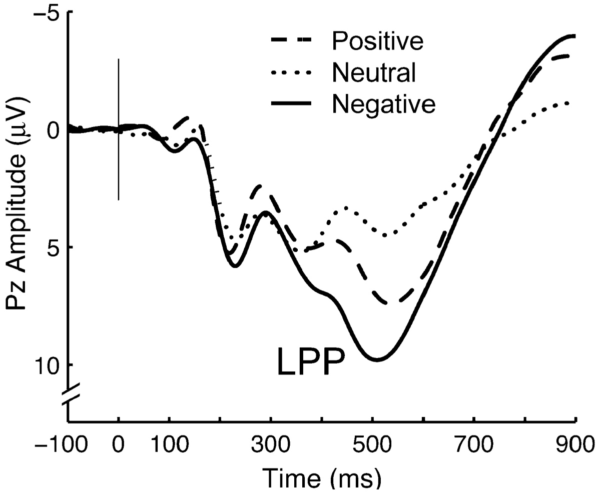

Fig. 1. Grand-averaged event-related potential waveforms recorded from site Pz during presentation of neutral, negative, and positive images embedded in a series of mostly neutral images. Positivity is plotted downward. The label on the graph indicates the late positive potential (LPP) elicited by the positive and negative images, which were evaluatively inconsistent with the majority of the images.

significant. Bonferroni pair-wise comparisons revealed that LPP amplitude differed significantly between each valence category and the other two ($p < .01$); amplitude was smallest for neutral images ($M = 5.40$ μV, $SD = 2.89$ μV), intermediate for positive images ($M = 8.87$ μV, $SD = 4.91$ μV), and largest for negative images ($M = 11.89$ μV, $SD = 5.75$ μV).

Peak LPP amplitude varied with age, although differentially depending on image valence. We computed partial correlation coefficients between LPP amplitude and age, controlling for years of education, visual acuity, and behavioral bias. The amplitude of the waveform elicited by negative images was significantly correlated with age, $r(46) = -.32$, $p_{\text{rep}} = .918$, whereas the amplitude of the waveforms elicited by positive and neutral images was not. By Hotelling's t test, the difference between correlation coefficients for negative ($r = -.32$) and positive ($r = .00$) images was significant (negative-to-positive correlation coefficient = .47), $t(43) = -2.18$, $p_{\text{rep}} = .936$. In summary, amplitude of the LPP elicited by negative images decreased with age more rapidly than did amplitude of the LPP elicited by positive images. This effect can be seen in Figure 2.

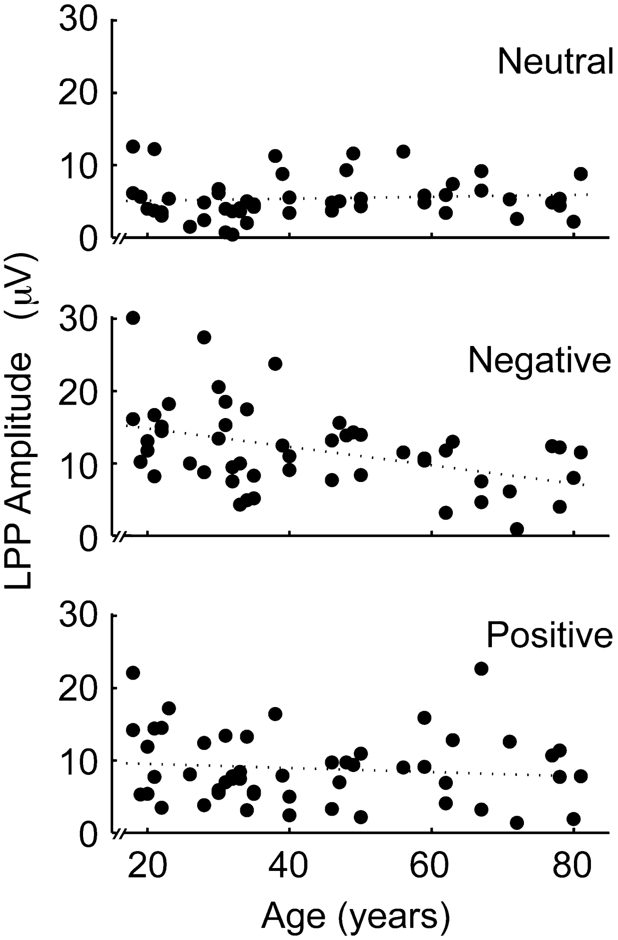

Fig. 2. Scatter plots showing the relation between amplitude of the late positive potential (LPP) and age, separately for neutral, negative, and positive images. Best-fitting regression lines are shown for reference.

DISCUSSION

The present results are consistent with the hypothesis that the magnitude of the negativity bias in adults decreases with advancing age because of a gradual age-related reduction in responding to negative images. The results do not support two other possible explanations for the change in the negativity bias: a general dampening of neural activation in response to all images and an increase in responding to positive images. In our previous work (Wood & Kisley, 2006), we could not draw any conclusions regarding whether or not responses to negative information and responses to positive information showed the same age-related changes. In that work, we studied only two extreme groups: 19- to 22-year-olds and 56- to 81-year-olds. The latter group exhibited statistically indistinguishable response amplitudes for positive and negative images, or an effective lack of response bias. However, amplitudes of responses to both negative and positive images were reduced in the older adults relative to the younger adults, leaving open the possibility that the observed elimination of the negativity bias arose simply from global reduction in the amplitude of response to images in both categories.

The life-span approach employed in the present study, however, highlights a different pattern of age-related change. Younger adults did appear to be at least slightly more reactive to both positive and negative stimuli, relative to older adults. For example, Figure 2 shows that the youngest adults tested (those below age 25) had relatively high mean LPP amplitude in response to the positive images ($M = 12.22$ μV), especially compared with the oldest adults (i.e., those over age 55: $M = 8.78$ μV). This finding is consistent with the findings of our previous work (Wood & Kisley, 2006). Nevertheless, unlike the amplitude of the LPP elicited by negative images, the amplitude of the LPP elicited by positive images did not seem to decrease consistently across the large age range studied. Indeed, a test using a linear model indicated there was very little change overall. By contrast, the amplitude of response to the negative images exhibited a gradual, consistent, and significant linear decrease beginning in the 20s and continuing until late life. So although there appears to be some generalized age-related dampening for the LPP waveform—similar to the dampening of other late positive ERP components that are elicited by nonevaluative expectancy violations (e.g., Federmeier, Van Petten, Schwartz, & Kutas, 2003; Jerger & Martin, 2005), including the P300 (reviewed by Kok, 2000)—the results of the present study demonstrate an interaction between age and emotional valence. Specifically, the LPP responses to positive and negative information exhibited differential age-related patterns of change.

The observed age-related change in LPP amplitude, including the reduction in the negativity bias, does not appear to solely reflect individual variation in subjective ratings of the emotional images. The relation between the LPP waveform and the emotional valence of the images changed with age even though subjective ratings for those very same images did not. This finding is similar to past findings that autonomic responses (heart rate, skin conductance, etc.) to emotional films and images exhibit age-related reductions in magnitude even when the corresponding subjective ratings are stable (Gavazzeni, Wiens, & Fischer, 2005; Tsai, Levenson, & Carstensen, 2000). We nevertheless included a measure of behavioral bias (i.e., the relative distance from neutral for valence ratings of negative vs. positive images) as a covariate in order to remove the potential influence of subjective emotional biases. But the pattern of findings, including the linear decrease in responding to negative stimuli with advancing age, did not change when this covariate was omitted (results not reported here).

Socioemotional selectivity theory (SST) provides a framework to explain some, but not all, findings from the current study. This theory emphasizes that as adults age, their attention shifts toward positive information. This shift is driven by a motivation to maximize emotional goals as one's perceived remaining lifetime becomes shorter (Carstensen et al., 2000). Indeed, it has recently been demonstrated that the amplitude of the LPP evoked by negative images can be suppressed by intentional efforts to minimize negative emotional experience (Moser, Hajcak, Bukay, & Simons, 2006). This finding fits nicely with SST's claim that motivational factors drive older adults toward a change in the balance between processing of negative information and processing of positive information. In the present study, we have shown that, at least for the neural activity that underlies the LPP waveform, the change appears to take the form of a reduction in the processing of negative information, rather than an increase in the processing of positive information. Further, it has yet to be directly tested whether changes in time perception, the mechanism postulated by SST to cause increased attention to positive information, could be influential early enough to play a role in the changes in the ERP-based negativity bias observed in the present study (e.g., starting around age 25; see also Carstensen, 1992).

It remains unclear whether the age-related change in the negativity bias observed in this study was caused by top-down (voluntary) processes, bottom-up (involuntary) processes, or possibly a combination of both. The LPP waveform is elicited even when individuals are not voluntarily attending to the affective salience of the images, and in fact an implicit negativity bias is detectable under these conditions in younger adults (Ito & Cacioppo, 2000). But voluntary allocation of attention to the emotional valence of each image has nevertheless been shown to modulate LPP amplitude (Hajcak, Moser, & Simons, 2006), a finding consistent with the hypothesis that this ERP component is affected by top-down processes. These demonstrated top-down modulation effects fit with the suggestion that the increased suppression of neural activity associated with processing of negative information in older adults might originate from the prefrontal cortex (Mather & Carstensen, 2005), a brain area known to be important for controlled, voluntary processes. A recent life-span study of behavioral and neural responding to faces provides support for this hypothesis. Williams et al. (2006) demonstrated an age-related dissociation in prefrontal cortex responses to positive and negative facial expressions (i.e., increasing response to negative expressions and decreasing response to positive expressions). As in the present study, these changes were surprisingly well described by a linear model of aging. On the basis of their results, Williams et al. proposed that as people age, they devote more resources to controlling negative emotional responses, but allow automatic responses to positive stimuli to proceed without restraint. This model fits well with the results of the current study, which specifically demonstrated age-related reductions in responding to negative information, but relatively little age-related change in responding to positive information.

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