Journals of Gerontology: Psychological Sciences
cite as: *J Gerontol B Psychol Sci Soc Sci*, 2022, Vol. 77, No. 5, 895–904
https://doi.org/10.1093/geronb/gbab203
Advance Access publication October 26, 2021

THE GERONTOLOGICAL SOCIETY OF AMERICA®

OXFORD

Research Article

High- and Low-Arousal Daily Affect Dynamics Vary Across the Adult Lifespan

Hio Wa Mak, PhD[1,2,*] and **Stefan Schneider, PhD[1]**

[1]Dornsife Center for Self-Report Science, University of Southern California, Los Angeles, California, USA. [2]Present address: Department of Psychiatry and Behavioral Sciences, University of California, San Francisco, San Francisco, California, USA.

*Address correspondence to: Hio Wa Mak, PhD, Department of Psychiatry and Behavioral Sciences, University of California, San Francisco, 401 Parnassus Avenue, San Francisco, CA 94143, USA. E-mail: hiowa.mak@ucsf.edu

Received: June 15, 2021; Editorial Decision Date: October 19, 2021

Decision Editor: Derek Isaacowitz, PhD, FGSA

Abstract

Objectives: Age differences in affective experience across adulthood are widely documented. According to the circumplex model of affect consists of 2 aspects—valence (positive vs negative) and arousal (low activation vs high activation). Prior research on age differences has primarily focused on the valence aspect. However, little is known about age differences in daily affect of high and low arousal.

Method: The present study examined age differences in daily dynamics (i.e., mean levels, variability, and inertia) of negative affect (NA) and positive affect (PA) of high and low arousal in a sample of 492 adults aged 21–91. Participants completed daily affect ratings for 21 consecutive days.

Results: Age was negatively and linearly related to mean levels of both high-arousal and low-arousal NA. Both high-arousal and low-arousal PA mean levels showed increases after middle age. Further, age was related to lower variability in both NA and PA regardless of arousal. Additionally, high-arousal NA inertia showed a linear decrease with age, whereas low-arousal PA inertia showed an inverted-U pattern with age. After controlling for mean levels of affect, the associations between age and affect variability remained significant, whereas the associations between age and affect inertia did not.

Discussion: The affective profile of older age is characterized by lower mean levels of NA, higher mean levels of PA, lower affect variability, and less persistence in high-arousal NA and low-arousal PA in daily life. Our results contribute to a nuanced understanding of which affective processes improve with age and which do not.

Keywords: Affect dynamics, Age differences, Arousal, Negative affect, Positive affect

Age differences in affective experience across adulthood are widely documented. The majority of existing research suggests a generally favorable picture of affective experience in older adults compared to younger adults (Carstensen et al., 2011; Charles & Carstensen, 2010; Charles et al., 2001; Mroczek & Kolarz, 1998). Specifically, older adults have been shown to experience less negative affect (NA) and affect variability than younger adults. Overall, evidence suggests that affective well-being improves with age across adulthood.

Theories on Emotional Aging

Various theories offer explanations for how individuals maintain affective well-being across adulthood (Baltes & Baltes, 1990; Brandtstädter & Renner, 1990; Carstensen & Mikels, 2005; Carstensen et al., 1999; Charles, 2010; Heckhausen et al., 2010). According to the socioemotional selectivity theory (SST; Carstensen et al., 1999), older adults tend to prioritize optimizing their emotional well-being as they perceive limited time to live, which is in contrast to younger adults who tend to focus on long-term goals such as knowledge acquisition because they perceive their future as expansive. Relatedly, existing evidence suggests that older adults not only process emotional relative to nonemotional information more deeply, but compared to younger adults, they preferentially process positive relative to negative information more thoroughly, a phenomenon called the *positivity effect* (Carstensen & Mikels, 2005). While the distinction between positive versus negative affective experiences has predominated in theories on aging, some theories also suggest that high-arousal versus low-arousal affect states play distinctive roles in emotional aging. Building on SST, Charles' (2010) strength and vulnerability integration (SAVI) theory postulates that individuals show age-related improvement in affective well-being across adulthood because they have accrued more effective affect regulation skills (e.g., reducing exposure to negative stimuli) over the time that they have lived and also because they increasingly prioritize maintaining emotional well-being as they perceive limited time left to live. At the same time, the theory argues that older adults have physiological vulnerabilities such that when they experience sustained high-arousal affect, it is presumably harder for their physiology to return to homeostasis (Charles, 2010). SAVI predicts that under these circumstances, their age-related advantages in psychological well-being will be reduced or even vanish. This highlights the importance of examining affect arousal when studying age differences in affective experience.

Affect Dynamics in Daily Life

Affect has been traditionally studied using recall surveys asking participants to summarize how they have been feeling over a period of time in the past (e.g., the last 7 days). Given the limitations of this approach, recent research on affect has increasingly assessed participants in their natural environment in near real time as they go about their daily life using intensive longitudinal assessments such as daily diaries and ecological momentary assessments (Bolger & Laurenceau, 2013; Stone & Shiffman, 1994). These densely repeated assessments allow for the measurement of affect states with limited recall bias and high ecological validity. Furthermore, they provide opportunities to examine within-person affect dynamics—patterns of affect fluctuation across time, often reflecting meaningful underlying affective processes—some of which individuals may not be consciously aware of (Kuppens & Verduyn, 2015). Individual differences in affect dynamics have been shown to relate to a range of well-being and psychopathology outcomes (Houben et al., 2015; Lydon-Staley et al., 2019; Mak & Schneider, 2020; Trull et al., 2015).

The most common affect metric derived from intensive longitudinal assessments is a person's *mean* affect, represented by the average level of affect across assessment occasions. It is arguably one of the most important affect metrics (Dejonckheere et al., 2019), yet taken by itself, it provides only an incomplete picture of the role of affect dynamics in psychological well-being. Affect *variability* refers to the degree of affect fluctuations across repeated assessments (Röcke et al., 2009). Higher affect variability is related to higher depressive and anxiety symptoms (Houben et al., 2015). In addition, *inertia* of affect refers to how strongly the intensity of an affect is predicted by the same affect at a previous time point. Inertia of an affect state has been conceptualized as the tendency that one's affect is resistant to change. Higher inertia is thought to indicate reduced recovery from negative events or that one's affect is less responsive to ongoing events (Koval et al., 2012, 2015; Kuppens et al., 2010). Affect inertia is positively associated with negative emotionality, depression, and anxiety, and negatively associated with positive emotionality and eudemonic well-being (Houben et al., 2015).

Age, Affect Dynamics, and the Role of Arousal

According to Russell's (2003) circumplex model, affective experiences differ in valence (positive–negative) and in arousal (low activation–high activation), such that a person may display uniquely different affect dynamics across both aspects. The valence aspect captures how pleasant or unpleasant an individual's affect state is, whereas the arousal aspect captures the energy level of that state (Russell, 2003). Prior research has suggested that both valence and arousal aspects of affect are associated with distinct cognitive and health outcomes (Armon et al., 2014; Cerino et al., 2021). However, research on age differences in affect dynamics has predominantly focused on the distinction between positive affect (PA) and NA, emphasizing the valence aspect of affect. Research in this area suggests that the affective profile of older adults, as compared to younger adults, is characterized by higher levels of PA, lower levels of NA, less pronounced variability in both PA and NA, and lower inertia in NA (Burr et al., 2021; Carstensen et al., 2000, 2011; Hamaker et al., 2018; Röcke & Brose, 2013).

By contrast, affect arousal has found relatively scant attention in aging research. This is surprising given that the arousal aspect may be particularly relevant for psychological well-being at older ages. As SAVI highlights, despite significant strengths in affect regulation and affect experience, older adults are likely more vulnerable to situations that elicit sustained high-arousal affect. Further, high-arousal affect entails higher cognitive costs in information processing in older adults than in younger adults (Wurm et al., 2004). Therefore, for a more complete understanding of how the affective profile varies across age, it is important to examine not just the valence, but also the arousal aspect.

Regarding mean levels of affect, existing theories such as SST, the positivity effect, and SAVI converge to suggest that older adults, compared to younger adults, are more likely to experience lower levels of NA and higher levels of PA. SAVI suggests that older adults are likely to experience lower levels of high- and low-arousal NA due to better affect regulation, and because it is more physiologically costly to older adults to experience sustained high-arousal affect, they may experience lower levels of high-arousal NA as a result. However, empirical evidence regarding age differences in high-arousal and low-arousal NA is mixed. Some studies indicate that decreases in NA with older age are limited to high-arousal NA (Kunzmann et al., 2013; Stone et al., 2010; Wang et al., 2020), others suggest that they are limited to low-arousal NA (English & Carstensen, 2014), and others find that age is related to lower levels of both high-arousal and low-arousal NA (Kessler & Staudinger, 2009).

For mean levels of PA, SAVI suggests that older adults are likely to experience higher levels of PA due to better affect regulation but this effect may be limited to low-arousal PA because of the higher physiological costs involved in sustained high-arousal affect. There is consistent evidence that older age is related to higher levels of low-arousal PA, including relaxation, calmness, and contentment (English & Carstensen, 2014; Kessler & Staudinger, 2009; Scheibe et al., 2013; Wang et al., 2020). The existing evidence for high-arousal PA is less consistent. Specifically, some studies suggest that older age is related to lower levels of excitement (Wang et al., 2020), while others suggest no such age differences (English & Carstensen, 2014; Kessler & Staudinger, 2009; Scheibe et al., 2013). Similarly, some studies suggest that older age is related to higher levels of happiness (English & Carstensen, 2014), whereas others have shown no such differences (Wang et al., 2020). Another study has shown that older adults rated their levels of happiness higher when it was described as a low-arousal emotion and lower when it was described as a high-arousal emotion (Bjalkebring et al., 2015). Overall, it should be noted that the evidence regarding mean levels of high-arousal and low-arousal NA and PA discussed here comes from studies with widely varying recall periods (ranging from momentary experiences to recall over years), which may have contributed to the mixed findings. Based on existing theories and empirical evidence, we hypothesize that age is negatively associated with mean levels of NA, regardless of arousal. Regarding PA, we hypothesize that age is positively associated with mean levels of low-arousal PA, but not with high-arousal PA.

Apart from mean affect levels, little is known about how age is related to *variability* and *inertia* of high- and low-arousal affect, in part because intensive longitudinal studies are required for this purpose. For affect variability, past research suggests that older age is related to lower variability in both PA and NA (Burr et al., 2021; Röcke et al., 2009), but most has not distinguished high-arousal versus low-arousal affect. One study has examined age differences in variability in various affect states and shows that older age is related to lower variability in frustration, excitement, and happiness, which are high-arousal affect states (Wang et al., 2020). As SAVI suggests that older adults are exposed to fewer negative or stressful events (especially those that elicit high-arousal affect), that they are less reactive to negative events due to accumulated life experiences in dealing with stress, and that they are more likely to disengage from negative experiences (Charles, 2010), we hypothesize that older age is related to lower variability in both PA and NA. Due to the potential psychological costs associated with high-arousal affect at older ages, we speculate that older adults may tend to avoid extremes or "peaks" of high-arousal affect in particular; accordingly, we hypothesize that age differences in affect variability may be limited to high-arousal NA and PA.

Regarding inertia, there is very limited work examining age differences in affect inertia and the preliminary evidence is mixed. Some evidence suggests that age is related to lower inertia in NA but not in PA (Hamaker et al., 2018), whereas other research suggests that age is not related to affect inertia (Wang et al., 2020). However, consistent with SAVI's prediction, some evidence shows that older adults recover more quickly from daily hassles and stressors than younger adults (Scott et al., 2017), except for complex stressors affecting multiple life domains that happen relatively infrequently (Wrzus et al., 2013). Therefore, we hypothesize that age is related to lower inertia in both low-arousal and high-arousal NA. Regarding PA inertia, there is less consensus regarding the affective process that underlies it. Some researchers conceptualize this persistence (inertia) in PA as affect context insensitivity, which is found to be related to low self-esteem and depression (Kuppens et al., 2010, 2012); other researchers have suggested that PA inertia reflects the ability to savor PA, given that it has been found to predict better treatment outcomes for depression (Höhn et al., 2013). As older adults are more focused on emotionally meaningful goals and maintaining emotionally satisfying states (Carstensen et al., 2000), we speculate that older age is associated with higher persistence (inertia) in PA. However, as SAVI suggests that high-arousal affect is costly to older adults if maintained, we expect that age is only related to higher inertia in low-arousal PA, which may reflect higher levels of equanimity in daily life in older adults.

In sum, examining both valence and arousal of affect when studying possible age differences in affect dynamics helps paint a more detailed picture of how affective experience varies across adulthood. This, in turn, may provide important clues about specific affective processes that contribute to the age-related increase in overall affective well-being that has been repeatedly observed. The present study examines the relationship between age and affect dynamics (i.e., mean affect levels, affect variability, affect inertia) for both *valence* and *arousal* across the adult lifespan.

Method

Recruitment

Participants were recruited through Dynata Inc., an opt-in online research panel. Panel members were notified by

Dynata that they could participate in a daily diary study and those who were interested were sent a Qualtrics link with information about the study. Panel members were screened for eligibility to ensure that they (a) were 21 or older, (b) lived in the U.S. Central or Eastern time zone (a constraint imposed by the online data collection system used), (c) were fluent in English, (d) had access to a computer at home with high-speed internet, (e) had no difficulty reading a computer screen, (f) had no major events upcoming that they expected would interfere with their completion of daily diaries, (g) did not work the night shift, and (h) were willing to participate consecutively for 25 days. Panel members who met these criteria were asked to provide contact information to the research team. Recruitment was stratified by gender (50% male) and age groups (21–44, 45–64, and 65 or older). Invitations to participate were sent to eligible panel members in batches until comparable sample sizes across the strata were reached. The data were collected between October, 2018 and September, 2019. The study was approved by the internal review board of the University of Southern California.

Procedure

Participants provided informed consent before participating in the study. Participants were trained in an introductory phone call on how to complete their assessments through Assessment Center (AC; http://www.assessmentcenter.net/), a secure online data collection platform supported by the National Institutes of Health. Participants first completed a baseline questionnaire on the AC website. Starting from the following day, participants completed daily assessments each evening between 6 p.m. and 12 a.m. for 25 consecutive days. The first 4 days of daily assessments were considered training assessments and therefore were not used in the current analyses. Participants could opt in for daily reminders (emails or text messages) to assist with daily completion. Participants were compensated up to $150 in the form of an Amazon Gift Card for completing the study (participation included assessments that are not reported here). Participants who completed 100% of the assessments were entered into a lottery for a $50 Amazon Gift Card for every one out of nine participants.

Participants

A total of 495 participants completed daily surveys. The final sample consisted of 492 participants who completed daily surveys on at least 10 out of the 21 days and provided complete demographic information used in the current study. On average, individuals completed 20.1 days (*SD* = 1.58) out of the 21 days. The mean age of participants was 51.01 (*SD* = 16.08; range = 21–91). Among participants, 54.7% were female, and 65.7% had a college degree. Participants reported their race as White (84.6%), Black or African American (7.1%), Asian (4.1%), American Indian or Alaska Native (0.2%), Native Hawaiian or other Pacific Islander (0.2%), and other/mixed (3.9%). The median family income was $50,000–$74,999.

Measures

Affect states

Affect items were selected based on the circumplex model of affect (Russell, 1980). In the circumplex model, each affect state can be classified by both valence (negative vs positive) and arousal (low vs high), corresponding to four affect quadrants. Each affect quadrant was measured by three items. High-arousal NA items consisted of "distressed," "frustrated," and "tense"; low-arousal NA items consisted of "unhappy," "sad," and "depressed"; high-arousal PA items consisted of "happy," "excited," and "enthusiastic"; and low-arousal PA items consisted of "calm," "relaxed," and "content." Each affect item was presented with the words "Since waking up today, I felt …" Because this was a multipurpose study, the rating scales differed slightly across affect items; participants rated all affect items on a 7-point scale from 1 (not at all) to 7 (extremely), except for low-arousal NA items, which were rated on a 5-point scale from 1 (never) to 5 (always).

Demographics

Participants reported their age, gender, race, education, and income at baseline.

Analysis Plan

A basic assumption of the analyses of individual differences in affect dynamics is that the affect states show both between-person and within-person variation. To check this assumption, initial descriptive analyses examined the between- and within-person variance components for each affect item using intraclass correlation coefficients (ICCs), calculated as the amount of between-person variance divided by the total (between-person and within-person) variance. Further, before examining age differences in affect dynamics, a multilevel confirmatory factor analysis (CFA) was conducted to examine whether the specific affect items corresponded to the four latent factors they were hypothesized to represent. The use of multilevel CFA takes into account the nested data structure (with observations for multiple days nested within respondents; Silva et al., 2020). Rather than assuming that the same underlying factor structure fits both of these levels, the multilevel CFA explicitly evaluates whether the same four-factor structure on both the between- and within-person levels fits the data well. Model fit indices were used to determine whether the hypothesized four-factor solution fitted the data well. Besides examining the chi-squared test (χ^2) of global model fit, a model was considered to fit the data well if comparative fit index (CFI) and Tucker–Lewis index (TLI) >.95, root mean square error of approximation (RMSEA) <.06, and standardized root mean square residual (SRMR) <.08 (Hu & Bentler, 1999). Additionally, we used multilevel CFA to calculate the overall two-level (ω^{2l}), between-person (ω^{b}), and within-person (ω^{w}) internal consistency reliability coefficients for the set of items pertaining to each affect quadrant (see Lai [2021] for details). The three items in each affect quadrant (high- and low-arousal NA and PA) were averaged into composite variables for subsequent analyses.

Age differences in affect dynamics were estimated using dynamic structural equation modeling (DSEM). Using this approach, affect dynamic indices were modeled as latent variables. This overcomes limitations of prior research in which unreliability due to sampling error in the measurement of affect dynamics was typically ignored (Lüdtke et al., 2008). With DSEM, it is possible to estimate indices of intraindividual day-to-day affect dynamics at the within-person level while simultaneously modeling differences in these dynamics across individuals as random effects (i.e., as latent variables) at the between-person level. A sample DSEM model for high-arousal NA is shown in Figure 1 (identical models were estimated for all four affect composites). At the within-person level, each affect state at day t was regressed on the same affect state at day $t-1$. The within-person level thus consists of three parameters (an intercept, an autoregressive slope, and a residual) that were represented as random effects at the between-person level: (a) the random intercepts indicate individual differences in mean affect levels across all days, (b) the random autoregressive parameters indicate individual differences in affect inertia, and (c) the random residual variance parameters represent individual differences in affect variability. It should be noted that variability has been traditionally studied using the intraindividual standard deviation, however, this index varies as a function of both the autoregressive (i.e., inertia) and residual variance (i.e., variability) parameters (Jongerling et al., 2015). Therefore, studying these two parameters separately allows for the examination of age differences in these distinct processes. At the between-person level, all three affect dynamic indices (random effects) served as multivariate outcomes that were regressed on age (linear and quadratic terms) while controlling for gender (0: male, 1: female), race (0: non-White, 1: White), and education (0: without a college degree, 1: with a college degree). Age was centered at age 50 and was scaled to 10 years per unit increase to enhance estimation stability; gender, race, and education were grand mean centered. To enhance the interpretability of the linear age trend in affect dynamics, the quadratic age trend for each affect dynamic was only retained if significant. The residuals of the three affect dynamic indices at the between-person level were allowed to correlate with each other. Separate models were estimated for low-arousal and high-arousal NA and PA.

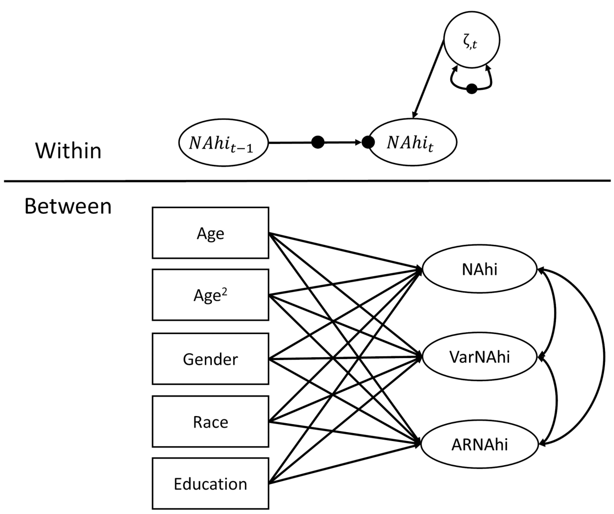

Figure 1. A sample dynamic structural equation model examining the associations between age and affect levels, variability, and inertia. *Note*: NAhi = mean levels of high-arousal negative affect. VarNAhi = residual variances (variability) of high-arousal negative affect. ARNAhi = autoregressive parameters (inertia) of high-arousal negative affect.

An additional set of models was performed to examine whether age differences in affect variability and inertia persist after controlling for mean levels of affect. The setup of these models was identical at the within-person level, but at the between-person level, affect variability and inertia were regressed on the random intercepts (i.e., the index representing within-person mean affect levels) in addition to age (linear and quadratic terms), gender, race, and education.

Affect scores were between-person standardized before conducting the DSEM models to increase the comparability of the parameter estimates across models for graphical display purposes. All DSEM models were conducted in M*plus* version 8.2 (Muthén & Muthén, 2017) using Bayesian estimation with default non-informative priors. The convergence criterion for potential scale reduction factor ($\hat{R}$) was set at $\hat{R}$ <1.01, consistent with recent recommendations (Gelman et al., 2013). In addition, at least 10,000 iterations were required to facilitate proper convergence at the global maximum. Standardized coefficients were reported along with 95% credible intervals (CIs).

Results

Confirmatory Factor Analysis

Descriptive analyses of the variance components in each of the affect items showed that ICCs ranged between .45 and .67, indicating a moderate degree of stability across days with adequate variation both between and within individuals. Results from multilevel CFA supported the hypothesized four-factor solution in affect. The four-factor solution showed acceptable fit: χ^2 (96) = 1531.768, p < .001; CFI = .95; TLI = .93; RMSEA = .04; SRMR = .04 for within-person and .07 for between-person levels. The reliability for all four affect composite scores was satisfactory (high-arousal NA: ω^{2l} = .88, ω^{b} = .91, ω^{w} = .80;

low-arousal NA: ω^{2l} = .92, ω^{b} = .94, ω^{w} = .84; high-arousal PA: ω^{2l} = .92, ω^{b} = .95, ω^{w} = .81; low-arousal PA: ω^{2l} = .92, ω^{b} = .95, ω^{w} = .80).

Associations Between Age and Affect Dynamics

We examined how age was related to mean affect levels, affect variability, and affect inertia. Regarding mean levels, age was negatively and linearly related to high-arousal NA (β = −0.28, 95% CI [−0.34, −0.21]) and low-arousal NA (β = −0.19, 95% CI [−0.26, −0.13]), indicating lower average NA levels at higher ages (Figure 2). Quadratic age trends were evident for mean levels of high-arousal PA (linear: β = 0.03, 95% CI [−0.04, 0.10]; quadratic: β = 0.11, 95% CI [0.04, 0.17]) and low-arousal PA (linear: β = 0.17, 95% CI [0.10, 0.23]; quadratic: β = 0.09, 95% CI [0.03, 0.15]), both showing a J-shaped relationship with age. For affect variability, age was negatively and linearly related to both NA and PA variability regardless of arousal, indicating less variability in all four quadrants of affect at higher ages (high-arousal NA: β = −0.23, 95% CI [−0.29, −0.17]; low-arousal NA: β = −0.23, 95% CI [−0.29, −0.17]; high-arousal PA: β = −0.17, 95% CI [−0.24, −0.11]; low-arousal PA: β = −0.21, 95% CI [−0.27, −0.14]; Figure 3). For inertia, high-arousal NA inertia decreased linearly with age (β = −0.14, 95% CI [−0.24, −0.04]; Figure 4). Inertia in low-arousal NA was not significantly related to age (β = −0.09, 95% CI [−0.19, 0.003]). The quadratic age trend was significant for low-arousal PA inertia, showing an inverted U-shape across age (linear: β = 0.08, 95% CI [−0.05, 0.20]; quadratic: β = −0.12, 95% CI [−0.24, −0.00]). High-arousal PA inertia was not significantly related to age (β = −0.00, 95% CI [−0.11, 0.10]).

Next, we examined whether age was still associated with affect variability and affect inertia after controlling for mean levels of affect. Results showed that age was still associated with lower affect variability in both high-arousal and low-arousal NA and PA (high-arousal NA: β = −0.06, 95% CI [−0.12, −0.001]; low-arousal NA: β = −0.11, 95% CI [−0.17, −0.05]; high-arousal PA: β = −0.16, 95% CI [−0.22, −0.10]; low-arousal PA: β = −0.13, 95% CI [−0.20, −0.07]). However, age was no longer significantly associated with high-arousal NA inertia (β = 0.04, 95% CI [−0.06, 0.15]) and low-arousal PA inertia (linear: β = 0.12, 95% CI [−0.01, 0.24]; quadratic: β = −0.10, 95% CI [−0.21, 0.02]) when mean affect levels were statistically controlled.

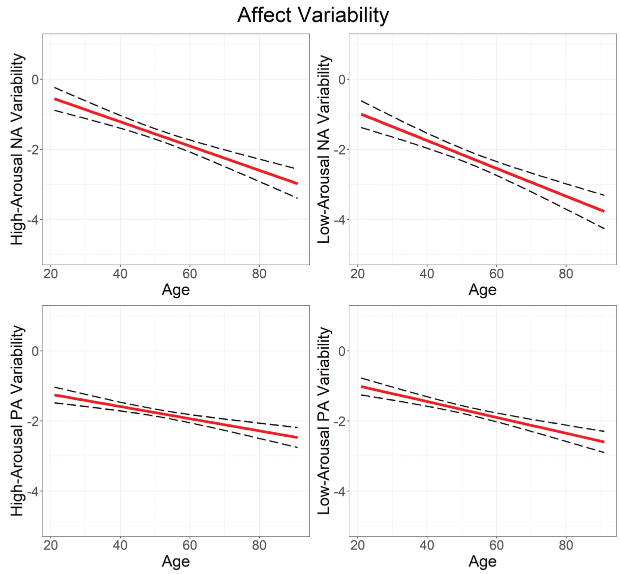

Figure 3. The predicted relationship between age and affect variability. *Note.* Affect variability is in log variance units. Dashed lines mark the 95% credible intervals. NA = negative affect; PA = positive affect. Full color version is available within the online issue.

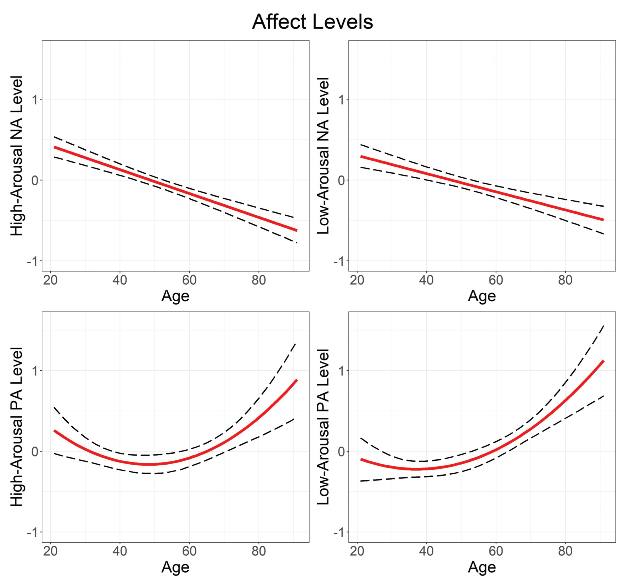

Figure 2. The predicted relationship between age and affect levels. *Note.* Dashed lines mark the 95% credible intervals. NA = negative affect; PA = positive affect. Full color version is available within the online issue.

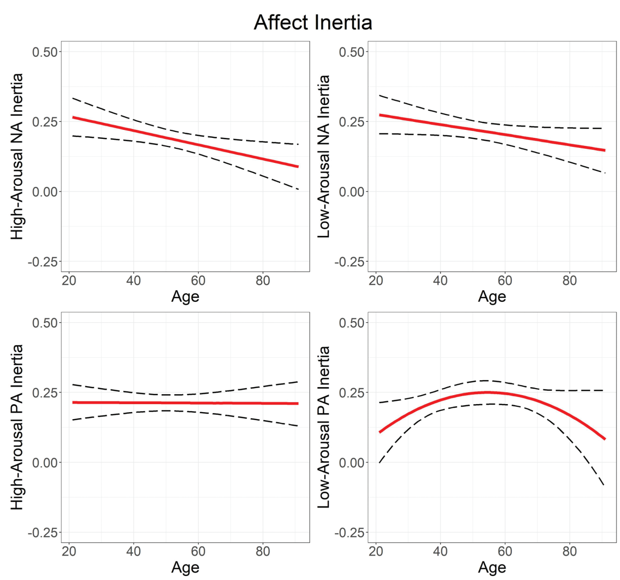

Figure 4. The predicted relationship between age and affect inertia. *Note.* Dashed lines mark the 95% credible intervals. NA = negative affect; PA = positive affect. Full color version is available within the online issue.

Discussion

The present study extends prior research on the relationship between age and affect dynamics by examining not only the valence aspect of affect, but also the arousal aspect. Furthermore, using DSEM, this study examined a combination of various affect dynamics (i.e., mean levels, variability, and inertia) by valence and arousal. There were five key findings. First, age was negatively and linearly related to mean levels of both high-arousal and low-arousal NA. Second, age was curvilinearly related to both high-arousal and low-arousal mean levels of PA such that they both only increased after middle adulthood. Third, age was related to lower variability in both NA and PA regardless of arousal and the associations persisted after controlling for mean levels of affect. Fourth, age was related to lower inertia in high-arousal NA but was not related to low-arousal NA inertia. Fifth, age was not related to high-arousal PA inertia but showed an inverted-U pattern with low-arousal PA inertia. The associations between age and inertia did not persist after controlling for mean levels of affect. Overall, the magnitude of associations between age and affect dynamics, when present, was small.

Our findings indicated that age was negatively related to both high-arousal and low-arousal NA levels across the adult lifespan. This is consistent with the prediction of SAVI that older adults experience lower levels of NA as they have accrued more emotion regulation skills over the life course (Charles, 2010). SAVI suggests that older adults are better at minimizing exposure to negative stimuli compared to younger adults through attentional, appraisal, and behavioral strategies (Charles, 2010). The current study suggests that perhaps the emotion regulation strategies older adults use are not limited to those affecting high-arousal NA, but NA in general. For example, by surrounding themselves with a smaller but closer social circle, older adults may effectively decrease the occurrence of both high-arousal NA (e.g., anger arising from arguments with others) and low-arousal NA (e.g., sadness due to low social connection or social exclusion). Besides emotion regulation strategies, older adults may also experience lower levels of NA due to changes in the environment (e.g., activities and leisure time due to retirement; Charles, 2010). Although these environmental factors are likely to contribute to the decline in NA, prior research has shown that age differences in affect remain after accounting for these factors (Charles, 2010; Riediger & Freund, 2008). Consistent with SST and SAVI, older age is related to higher mean levels of PA. However, our findings suggest that PA only increases after middle age, consistent with some prior evidence (Stone et al., 2010). Contrary to our prediction based on SAVI, age-related increases in PA levels were not limited to low-arousal PA, which perhaps suggests that experiencing high-arousal PA is not necessarily taxing for older adults if it is not sustained for a long time (see later discussion on high-arousal PA inertia).

Our findings on affect variability are consistent with existing evidence that both PA and NA variability decreases with age (Burr et al., 2021; Röcke et al., 2009). However, it differs from our hypotheses that age is related to lower variability in high-arousal affect only. This suggests that the higher physiological cost associated with sustained high-arousal affect in older adults may not be the explanation, or at least not a sufficient explanation, for why older adults have lower variability in *both* high- and low-arousal affect. Of note, the negative relationship between age and affect variability remained after controlling for mean affect levels. This is an important finding given recent concerns that affect variability is often correlated with the mean, and that effects observed in affect variability are often accounted for by mean level differences (Dejonckheere et al., 2019). As affect variability is thought to result from the exposure or reactivity to events, age-related decreases in affect variability could be due to older adults avoiding negative situations and disengaging from negative events early in the process to avoid escalation (e.g., try to do nothing during a conflict; Charles, 2010).

Regarding inertia, we found a decrease in high-arousal NA inertia with age, which may indicate that older adults' high-arousal NA is less resistant to change and more responsive to ongoing influences. Prior research has shown that NA inertia is associated with rumination (Koval et al., 2012), such that having repetitive negative thoughts may be one of the pathways through which NA is perpetuating over time. Consistent with this is evidence showing that older adults ruminate less compared to younger adults (Ricarte et al., 2016; Sütterlin et al., 2012). Interestingly, age was not related to low-arousal NA inertia, which suggests that older adults may be better at disengaging from high-arousing negative thoughts, but not from thoughts that are associated with low-arousal NA (e.g., sadness). Our finding prompts researchers to expand existing theories such as SAVI to provide answers as to why older adults may not be better at disengaging themselves from low-arousal NA (e.g., sadness) across days despite experiencing lower levels of it than younger adults. For PA inertia, there is little research on its relationship with age and there is limited theoretical consensus regarding its underlying affective process (Höhn et al., 2013; Kuppens et al., 2012; Ong & Ram, 2017). We speculated that low-arousal PA inertia may be higher at older ages as a reflection of an increased tendency to feel calm and content in a way that is resistant to change (i.e., equanimity). Contrary to our speculation, low-arousal PA inertia showed an inverted U-shaped age pattern with decreases at older ages. Given that this is the first study to show age-related differences in low-arousal PA inertia across the adult lifespan, we call for future replications. Finally, our finding that older age is related to higher mean levels of high-arousal PA (after middle age) but not related to inertia of high-arousal PA suggests that although older adults experience more high-arousal PA, their high-arousal PA is not necessarily more resistant to change compared to that of younger adults. This is in line with SAVI that experiencing *sustained* high-arousal PA (as reflected in higher inertia) is taxing to older adults due to decreased physiological flexibility associated with aging (Charles, 2010). Our finding suggests that affect inertia may perhaps be a more suitable construct than average affect levels to study in future research if the goal is to examine sustained affect arousal.

Although our study suggests that age differences in mean affect levels and variability are similar for high-arousal versus low-arousal affect, we believe that examining the arousal component of affect is an important contribution to aging research. First, high-arousal and low-arousal affect have quite different presentations (e.g., frustration versus sadness), and examining arousal in addition to valence provides a more nuanced picture of emotion experience across the lifespan. Knowing that older age is related to lower levels of *both* high-arousal and low-arousal NA and higher levels of *both* high-arousal and low-arousal PA is important because mean affect of high and low arousal is associated with differential cognitive and health outcomes (Armon et al., 2014; Cerino et al., 2021) and processing high-arousal affect entails higher cognitive costs for older adults (Wurm et al., 2004). Second, our study showed differential age relationships in inertia by arousal, which suggests that arousal is an important aspect to consider when examining affect inertia. As higher inertia indicates that one's affect is more resistant to change, higher inertia in high-arousal affect suggests that one's physiology could be aroused for an extended period of time, though prior work shows only modest connections between affect and physiology (Mauss et al., 2005). Nevertheless, prior work has shown that traits related to high-arousal affect are associated with poor cardiovascular health (Matthews et al., 1998; Olafiranye et al., 2011).

Besides a focus on arousal, research suggests the importance of examining age-related trends in discrete emotions (Kunzmann et al., 2014). For instance, findings suggest that anger and sadness show distinct age trends across adulthood (Kunzmann et al., 2013). Future research should investigate the extent to which the discrete emotion approach provides additional information over the dimensional approach in explaining age differences in affect dynamics. The present study examined age-related trends of various affect dynamics, but questions remain as to how these affect dynamics are associated with individuals' functioning. For instance, is high inertia in high-arousal NA (e.g., anger) more detrimental to cardiovascular health than low-arousal NA inertia (e.g., sadness)? What is the optimal degree of variability in high-arousal PA (e.g., excitement) for older adults' life satisfaction?

There are several limitations in this study. First, our study is a cross-sectional study and it is possible that the age differences in affect were due to cohort differences rather than developmental changes. Future studies should examine whether affect dynamics change longitudinally across adulthood. This would require studies to follow individuals using measurement burst designs to capture longer-term changes in within-person affect dynamics (Nesselroade, 1991). Further, future research could examine how certain lifespan transitions (e.g., retirement) contribute to differences in affect dynamics across valence and arousal domains independent of age. Second, we only examined affect dynamics on one timescale (i.e., across days). Affect dynamics on other timescales (e.g., across hours) may represent different underlying processes. Ideally, future research will examine age differences in affect dynamics across multiple timescales in the same study. This will allow for a careful examination of whether age differences are the same across different timescales, which is especially important for time-structured affect dynamics such as inertia (Ram & Gerstorf, 2009). Third, the majority of our sample is White. This limits the generalizability of our findings to other populations. Future studies should examine age differences in affect dynamics in other racial subgroups. Fourth, low-arousal NA was measured by frequency items on a 5-point scale whereas the other three affect constructs were measured by intensity items on a 7-point scale. Although prior studies have suggested that self-reports on frequency and intensity of symptoms give essentially equivalent results (Chang et al., 2003; Elhai et al., 2006) and that the reliability and validity of ratings are comparable for 5-point and 7-point rating scales (Krosnick & Fabrigar, 1997), we cannot exclude that this might have affected the results of the study.

Research consistently shows that affective well-being improves with age across the adult lifespan and we have gained an increasingly nuanced understanding about which affective processes improve with age and which do not. We argue that arousal is an important aspect of affect to consider because it bears unique significance for aging. Our study also encourages existing theories on emotional aging to embrace a more holistic view of affective well-being by considering not just levels, but also variability and inertia, of affect.

Funding

This study was supported by grants from the National Institute on Aging (R01 AG042407, R21 AG061364, and R37 AG057685). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute on Aging or the National Institutes of Health.

Conflict of Interest

None declared.

Acknowledgments

This study has not been preregistered. The study's data, analytic methods, and study materials will be made available to other researchers upon request.

References

Armon, G., Melamed, S., Berliner, S., & Shapira, I. (2014). High arousal and low arousal work-related positive affects and basal cardiovascular activity. *Journal of Positive Psychology*, **9**, 146–154. doi:10.1080/17439760.2013.848375

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences* (pp. 1–34). Cambridge University Press. doi:10.1017/cbo9780511665684.003

Bjalkebring, P., Västfjäll, D., & Johansson, B. E. (2015). Happiness and arousal: Framing happiness as arousing results in lower happiness ratings for older adults. *Frontiers in Psychology*, **6**, 706. doi:10.3389/fpsyg.2015.00706

Bolger, N., & Laurenceau, J.-P. (2013). *Intensive longitudinal methods: An introduction to diary and experience sampling research*. The Guilford Press.

Brandtstädter, J., & Renner, G. (1990). Tenacious goal pursuit and flexible goal adjustment: Explication and age-related analysis of assimilative and accommodative strategies of coping. *Psychology and Aging*, **5**(1), 58–67. doi:10.1037//0882-7974.5.1.58

Burr, D. A., Castrellon, J. J., Zald, D. H., & Samanez-Larkin, G. R. (2021). Emotion dynamics across adulthood in everyday life: Older adults are more emotionally stable and better at regulating desires. *Emotion (Washington, D.C.)*, **21**(3), 453–464. doi:10.1037/emo0000734

Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously: A theory of socioemotional selectivity. *American Psychologist*, **54**, 165–181. doi:10.1037/0003-066X.54.3.165

Carstensen, L. L., & Mikels, J. A. (2005). At the intersection of emotion and cognition: Aging and the positivity effect. *Current Directions in Psychological Science*, **14**, 117–121. doi:10.1111/j.0963-7214.2005.00348.x

Carstensen, L. L., Pasupathi, M., Mayr, U., & Nesselroade, J. R. (2000). Emotional experience in everyday life across the adult life span. *Journal of Personality and Social Psychology*, **79**(4), 644–655. doi:10.1037/0022-3514.79.4.644

Carstensen, L. L., Turan, B., Scheibe, S., Ram, N., Ersner-Hershfield, H., Samanez-Larkin, G. R., Brooks, K. P., & Nesselroade, J. R. (2011). Emotional experience improves with age: Evidence based on over 10 years of experience sampling. *Psychology and Aging*, **26**(1), 21–33. doi:10.1037/a0021285

Cerino, E. S., Hooker, K., Settersten, R. A. Jr., Odden, M. C., & Stawski, R. S. (2021). Daily linkages among high and low arousal affect and subjective cognitive complaints. *Aging & Mental Health*, **25**(5), 844–855. doi:10.1080/13607863.2020.1711863

Chang, C. H., Cella, D., Clarke, S., Heinemann, A. W., Von Roenn, J. H., & Harvey, R. (2003). Should symptoms be scaled for intensity, frequency, or both? *Palliative & Supportive Care*, **1**(1), 51–60. doi:10.1017/s1478951503030049

Charles, S. T. (2010). Strength and vulnerability integration: A model of emotional well-being across adulthood. *Psychological Bulletin*, **136**(6), 1068–1091. doi:10.1037/a0021232

Charles, S. T., & Carstensen, L. L. (2010). Social and emotional aging. *Annual Review of Psychology*, **61**, 383–409. doi:10.1146/annurev.psych.093008.100448

Charles, S. T., Reynolds, C. A., & Gatz, M. (2001). Age-related differences and change in positive and negative affect over 23 years. *Journal of Personality and Social Psychology*, **80**(1), 136–151. doi:10.1037/0022-3514.80.1.136

Dejonckheere, E., Mestdagh, M., Houben, M., Rutten, I., Sels, L., Kuppens, P., & Tuerlinckx, F. (2019). Complex affect dynamics add limited information to the prediction of psychological well-being. *Nature Human Behaviour*, **3**(5), 478–491. doi:10.1038/s41562-019-0555-0

Elhai, J. D., Lindsay, B. M., Gray, M. J., Grubaugh, A. L., North, T. C., & Frueh, B. C. (2006). Examining the uniqueness of frequency and intensity symptom ratings in posttraumatic stress disorder assessment. *The Journal of Nervous and Mental Disease*, **194**(12), 940–944. doi:10.1097/01.nmd.0000243011.76105.4b

English, T., & Carstensen, L. L. (2014). Emotional experience in the mornings and the evenings: Consideration of age differences in specific emotions by time of day. *Frontiers in Psychology*, **5**, 185. doi:10.3389/fpsyg.2014.00185

Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., & Rubin, D. (2013). *Bayesian data analysis* (3rd ed.). CRC Press.

Hamaker, E. L., Asparouhov, T., Brose, A., Schmiedek, F., & Muthén, B. (2018). At the frontiers of modeling intensive longitudinal data: Dynamic structural equation models for the affective measurements from the COGITO study. *Multivariate Behavioral Research*, **53**(6), 820–841. doi:10.1080/00273171.2018.1446819

Heckhausen, J., Wrosch, C., & Schulz, R. (2010). A motivational theory of life-span development. *Psychological Review*, **117**(1), 32–60. doi:10.1037/a0017668

Höhn, P., Menne-Lothmann, C., Peeters, F., Nicolson, N. A., Jacobs, N., Derom, C., Thiery, E., van Os, J., & Wichers, M. (2013). Moment-to-moment transfer of positive emotions in daily life predicts future course of depression in both general population and patient samples. *PLoS One*, **8**(9), e75655. doi:10.1371/journal.pone.0075655

Houben, M., Van Den Noortgate, W., & Kuppens, P. (2015). The relation between short-term emotion dynamics and psychological well-being: A meta-analysis. *Psychological Bulletin*, **141**(4), 901–930. doi:10.1037/a0038822

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, **6**, 1–55. doi:10.1080/10705519909540118

Jongerling, J., Laurenceau, J. P., & Hamaker, E. L. (2015). A multilevel AR(1) model: Allowing for inter-individual differences in trait-scores, inertia, and innovation variance. *Multivariate Behavioral Research*, **50**(3), 334–349. doi:10.1080/00273171.2014.1003772

Kessler, E. M., & Staudinger, U. M. (2009). Affective experience in adulthood and old age: The role of affective arousal and perceived affect regulation. *Psychology and Aging*, **24**(2), 349–362. doi:10.1037/a0015352

Koval, P., Brose, A., Pe, M. L., Houben, M., Erbas, Y., Champagne, D., & Kuppens, P. (2015). Emotional inertia and external events: The roles of exposure, reactivity, and recovery. *Emotion (Washington, D.C.)*, **15**(5), 625–636. doi:10.1037/emo0000059

Koval, P., Kuppens, P., Allen, N. B., & Sheeber, L. (2012). Getting stuck in depression: The roles of rumination and emotional inertia. *Cognition & Emotion*, **26**(8), 1412–1427. doi:10.1080/02699931.2012.667392

Krosnick, J. A., & Fabrigar, L. R. (1997). Designing rating scales for effective measurement in surveys. In L. Lyberg, P. Biemer, M. Collins, E. de Leeuw, C. Dippo, N. Schwarz, & D. Trewin (Eds.), *Survey measurement and process quality* (pp. 141–164). John Wiley & Sons, Inc. doi:10.1002/9781118490013.ch6

Kunzmann, U., Kappes, C., & Wrosch, C. (2014). Emotional aging: A discrete emotions perspective. *Frontiers in Psychology*, **5**, 380. doi:10.3389/fpsyg.2014.00380

Kunzmann, U., Richter, D., & Schmukle, S. C. (2013). Stability and change in affective experience across the adult life span: Analyses with a national sample from Germany. *Emotion (Washington, D.C.)*, **13**(6), 1086–1095. doi:10.1037/a0033572

Kuppens, P., Allen, N. B., & Sheeber, L. B. (2010). Emotional inertia and psychological maladjustment. *Psychological Science*, **21**(7), 984–991. doi:10.1177/0956797610372634

Kuppens, P., Sheeber, L. B., Yap, M. B., Whittle, S., Simmons, J. G., & Allen, N. B. (2012). Emotional inertia prospectively predicts the onset of depressive disorder in adolescence. *Emotion (Washington, D.C.)*, **12**(2), 283–289. doi:10.1037/a0025046

Kuppens, P., & Verduyn, P. (2015). Looking at emotion regulation through the window of emotion dynamics. *Psychological Inquiry*, **26**, 72–79. doi:10.1080/1047840X.2015.960505

Lai, M. H. C. (2021). Composite reliability of multilevel data: It's about observed scores and construct meanings. *Psychological Methods*, **26**(1), 90–102. doi:10.1037/met0000287

Lüdtke, O., Marsh, H. W., Robitzsch, A., Trautwein, U., Asparouhov, T., & Muthén, B. (2008). The multilevel latent covariate model: A new, more reliable approach to group-level effects in contextual studies. *Psychological Methods*, **13**(3), 203–229. doi:10.1037/a0012869

Lydon-Staley, D. M., Xia, M., Mak, H. W., & Fosco, G. M. (2019). Adolescent emotion network dynamics in daily life and implications for depression. *Journal of Abnormal Child Psychology*, **47**(4), 717–729. doi:10.1007/s10802-018-0474-y

Mak, H. W., & Schneider, S. (2020). Individual differences in momentary pain–affect coupling and their associations with mental health in patients with chronic pain. *Journal of Psychosomatic Research*, **138**, 110227. doi:10.1016/j.jpsychores.2020.110227

Matthews, K. A., Owens, J. F., Kuller, L. H., Sutton-Tyrrell, K., & Jansen-McWilliams, L. (1998). Are hostility and anxiety associated with carotid atherosclerosis in healthy postmenopausal women? *Psychosomatic Medicine*, **60**(5), 633–638. doi:10.1097/00006842-199809000-00021

Mauss, I. B., Levenson, R. W., McCarter, L., Wilhelm, F. H., & Gross, J. J. (2005). The tie that binds? Coherence among emotion experience, behavior, and physiology. *Emotion (Washington, D.C.)*, **5**(2), 175–190. doi:10.1037/1528-3542.5.2.175

Mroczek, D. K., & Kolarz, C. M. (1998). The effect of age on positive and negative affect: A developmental perspective on happiness. *Journal of Personality and Social Psychology*, **75**(5), 1333–1349. doi:10.1037//0022-3514.75.5.1333

Muthén, L. K., & Muthén, B. (2017). *Mplus user's guide* (8th ed.). Muthén & Muthén.

Nesselroade, J. R. (1991). The warp and the woof of the developmental fabric. In R. M. Downs, L. S. Liben, & D. S. Palermo (Eds.), *Visions of aesthetics, the environment, and development: The legacy of Joachim F. Wohlwill* (pp. 213–240). Lawrence Erlbaum Associates, Inc.

Olafiranye, O., Jean-Louis, G., Zizi, F., Nunes, J., & Vincent, M. (2011). Anxiety and cardiovascular risk: Review of epidemiological and clinical evidence. *Mind & Brain*, **2**(1), 32–37.

Ong, A. D., & Ram, N. (2017). Fragile and enduring positive affect: Implications for adaptive aging. *Gerontology*, **63**(3), 263–269. doi:10.1159/000453357

Ram, N., & Gerstorf, D. (2009). Time-structured and net intraindividual variability: Tools for examining the development of dynamic characteristics and processes. *Psychology and Aging*, **24**(4), 778–791. doi:10.1037/a0017915

Ricarte, J., Ros, L., Serrano, J. P., Martínez-Lorca, M., & Latorre, J. M. (2016). Age differences in rumination and autobiographical retrieval. *Aging & Mental Health*, **20**(10), 1063–1069. doi:10.1080/13607863.2015.1060944

Riediger, M., & Freund, A. M. (2008). Me against myself: Motivational conflicts and emotional development in adulthood. *Psychology and Aging*, **23**(3), 479–494. doi:10.1037/a0013302

Röcke, C., & Brose, A. (2013). Intraindividual variability and stability of affect and well-being. *The Journal of Gerontopsychology and Geriatric Psychiatry*, **26**, 185–199. doi:10.1024/1662-9647/a000094

Röcke, C., Li, S. C., & Smith, J. (2009). Intraindividual variability in positive and negative affect over 45 days: Do older adults fluctuate less than young adults? *Psychology and Aging*, **24**(4), 863–878. doi:10.1037/a0016276

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, **39**, 1161–1178. doi:10.1037/h0077714

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, **110**(1), 145–172. doi:10.1037/0033-295x.110.1.145

Scheibe, S., English, T., Tsai, J. L., & Carstensen, L. L. (2013). Striving to feel good: Ideal affect, actual affect, and their correspondence across adulthood. *Psychology and Aging*, **28**(1), 160–171. doi:10.1037/a0030561

Scott, S. B., Ram, N., Smyth, J. M., Almeida, D. M., & Sliwinski, M. J. (2017). Age differences in negative emotional responses to daily stressors depend on time since event. *Developmental Psychology*, **53**(1), 177–190. doi:10.1037/dev0000257

Silva, B. C., Bosancianu, C. M., & Littvay, L. (2020). *Multilevel structural equation modeling* (Vol. **179**). SAGE Publications.

Stone, A. A., Schwartz, J. E., Broderick, J. E., & Deaton, A. (2010). A snapshot of the age distribution of psychological well-being in the United States. *Proceedings of the National Academy of Sciences of the United States of America*, **107**(22), 9985–9990. doi:10.1073/pnas.1003744107

Stone, A. A., & Shiffman, S. (1994). Ecological momentary assessment (EMA) in behavioral medicine. *Annals of Behavioral Medicine*, **16**, 199–202. doi:10.1093/abm/16.3.199

Sütterlin, S., Paap, M. C., Babic, S., Kübler, A., & Vögele, C. (2012). Rumination and age: Some things get better. *Journal of Aging Research*, **2012**, 1–10. doi:10.1155/2012/267327

Trull, T. J., Lane, S. P., Koval, P., & Ebner-Priemer, U. W. (2015). Affective dynamics in psychopathology. *Emotion Review*, **7**(4), 355–361. doi:10.1177/1754073915590617

Wang, D., Schneider, S., Schwartz, J. E., & Stone, A. A. (2020). Heightened stress in employed individuals is linked to altered variability and inertia in emotions. *Frontiers in Psychology*, **11**, 1152. doi:10.3389/fpsyg.2020.01152

Wrzus, C., Müller, V., Wagner, G. G., Lindenberger, U., & Riediger, M. (2013). Affective and cardiovascular responding to unpleasant events from adolescence to old age: Complexity of events matters. *Developmental Psychology*, **49**(2), 384–397. doi:10.1037/a0028325

Wurm, L. H., Labouvie-Vief, G., Aycock, J., Rebucal, K. A., & Koch, H. E. (2004). Performance in auditory and visual emotional Stroop tasks: A comparison of older and younger adults. *Psychology and Aging*, **19**(3), 523–535. doi:10.1037/0882-7974.19.3.523