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BRIEF REPORT

Resting Frontal EEG Asymmetry and Emotion Regulation in Older Adults: The Midlife in the United States (MIDUS) Study

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Lateralized asymmetrical activity in the alpha frequency band over the frontal cortex (i.e., frontal alpha asymmetry [FAA]) is robustly related to motivation and emotion. For example, left FAA is related to approach-motivation, positive emotions, and successful emotion regulation whereas right FAA is associated with avoidance-motivation, negative emotions, and poor emotion regulation. This work has been conducted primarily in undergraduates and young adults despite the important of emotion regulation to healthy aging. The current study examined age-related differences in the relationships between emotion regulation strategy usage and resting frontal EEG asymmetry in a sample of middle-aged to older adults. We found that aging was associated with greater right FAA among both those who habitually used maladaptive emotion regulation strategies (i.e., high suppression/low reappraisal) and those who habitually used adaptive emotion regulation strategies (i.e., low suppression/high reappraisal). However, a slopes difference test revealed that aging was more strongly associated with right FAA among those who habitually used maladaptive (vs. adaptive) emotion regulation strategies. These results suggest that the negative consequences of habitually using maladaptive emotion regulation strategies may be more harmful in older adults. This may explain why some researchers have observed that older adults tend to use maladaptive emotion regulation strategies less often.

Keywords: aging, EEG, emotion regulation, frontal asymmetry, midlife

Emotion regulation is the processes individuals use to influence the intensity, variety, and duration of emotions. The most frequently studied emotion regulation strategies within the process model of emotion regulation (Gross, 1998, 2001) are cognitive reappraisal and expressive suppression. Cognitive reappraisal involves interpreting emotion elicitors in ways that heighten or lessens their emotional impact (Gross & John, 2003; Lazarus & Alfert, 1964) whereas expressive suppression involves inhibiting or suppressing an emotional experience once it has been activated or solidified (Gross, 1998). The habitual use of reappraisal (vs. suppression) is associated with more daily positive affect and less daily negative affect (Nezlek & Kuppens, 2008), less psychopathology (Aldao, Nolen-Hoeksema, & Schweizer, 2010), better physical health (Appleton & Kubzansky, 2014), and better well-being (John & Gross, 2004). The purpose of the current study was to examine how the habitual use of these common emotion regulation strategies relate to frontal electroencephalographic (EEG) asymmetry—a neurophysiological index of emotional processing—during normative aging.

Frontal Asymmetry, Emotion, and Emotion Regulation

Previous research has observed that lateralized asymmetrical activity in the alpha frequency band over the frontal cortex (i.e., frontal alpha asymmetry [FAA]) is robustly related to motivational and emotional processes. For example, greater left FAA is robustly related to approach-motivation and positive emotions. Using EEG recordings, researchers have linked greater left FAA with trait approach motivation (Coan & Allen, 2003; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997) and with individual differences in approach-motivated emotions (Harmon-Jones & Allen, 1998; Tomarken, Davidson, Wheeler, & Doss, 1992). In addition to individual difference variables, the temporary experience of approach-motivated emotion has been correlated with greater left FAA (Harmon-Jones, 2007; Harmon-Jones et al., 2002; Harmon-

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The MIDUS study contains a national probability sample of English-speaking U.S. residents (see http://midus.wisc.edu/scopeofstudy.php). Details of the neuroscience project can be found at http://midus.wisc.edu/midus2/project5.

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Jones, Lueck, Fearn, & Harmon-Jones, 2006; Harmon-Jones & Sigelman, 2001).

Research has also linked right FAA to negative emotions associated with avoidance (e.g., fear, disgust; Coan, Allen, & Harmon-Jones, 2001; Dawson, Panagiotides, Klinger, & Hill, 1992). In rhesus monkeys right FAA has been associated with fear behaviors (Kalin, Larson, Shelton, & Davidson, 1998). In human infants, right FAA has been associated with increased negative emotional reactions (crying) in response to maternal separation. Consistent with these results, others have found a positive association between resting right FAA and negative affective responses to aversive film clips (Tomarken, Davidson, & Henriques, 1990; Wheeler, Davidson, & Tomarken, 1993).

Other studies also point to a relationship between FAA and emotion regulation. Jackson and colleagues (2003) examined the relationship between resting FAA and emotion regulation in a group of older adults age 57–60 using a startle eyeblink paradigm, where eyeblink magnitudes are typically larger in the presence of aversive stimuli (negative affective pictures; Lang, Bradley, & Cuthbert, 1990). Jackson and colleagues defined emotion regulation as reduced startle eyeblink magnitudes *after* the offset of a negative affective picture which reflects an automatic emotion regulation process aimed at reducing negative affectivity. They observed that left FAA was associated with reduced startle offset magnitudes suggesting that greater left FAA at rest may be associated with better emotion regulation. Recently, the ability to successful reappraise anger-evoking events has been linked to increased left FAA (Papousek et al., 2017). In another study reappraisal, but not suppression, was related to increased left FAA (Choi, Sekiya, Minote, & Watanuki, 2016). Similar results have been obtained in studies looking at hemispheric metabolic asymmetry (Kim, Cornwell, & Kim, 2012). Collectively, these results suggest that better emotion regulation is associated with left FAA.

Emotional Regulation and Aging

Although there remains mixed evidence on the topic, older adults generally report stable emotional experiences compared with younger adults (Charles & Carstensen, 2007). In general, aging is associated with more positive everyday life experiences, in part because older adults are more likely to avoid negative situations compared to younger adults (Charles & Piazza, 2009; Charles, 2010). The findings that older adults show a preference for positive information over negative relative to younger adults has been termed the age-related positivity effect (Kennedy, Mather, & Carstensen, 2004; Mather & Carstensen, 2005; Reed & Carstensen, 2012). Proponents argue that the positivity effect is product of socioemotional selectivity theory (SST), which states that adults monitor their life course, adjusting their priorities and motivations according to how much time they believe they have in their life span. The theory posits that changes in emotion regulation over the course of the life span may lead to differences in well-being (Allen & Windsor, 2017; Charles & Carstensen, 2007) and these changes in motivation may alter brain activation (Mather et al., 2004). Dovetailing with SST, the Strength and Vulnerability Integration (SAVI; Charles, 2010) model suggests that emotion regulation strategies change throughout the life span to maximize positive emotional experiences while minimizing negative ones. According to SAVI, life experiences provides older adults with more information about which emotion regulation strategies work in specific contexts, even in the face of declining cognitive resources.

To better reflect the complexities of emotion regulation Gross (2015) proposed an *extended* process model. The extended process model embeds the emotion regulation strategies of the original model (situation selection, situation modification, attentional deployment, cognitive changes, and response modulation) within an iterative framework whereby multiple contextual factors concurrently influence the experience of emotion. These emotions can then be regulated consistent with the original process model. Finally, the effects of emotion regulation then influence subsequent emotion experiences. This iterative process can theoretically go on indefinitely, which can in part account for age-related changes in emotion regulation.

When viewed from this perspective, age-related changes in emotion regulation can be viewed as the result of contextual factors like emotion regulation goals (Coats & Blanchard-Fields, 2008), beliefs (Livingstone, Castro, & Isaacowitz, 2018; Ortner, Briner, & Marjanovic, 2017), cognitive processes (Scheibe & Blanchard-Fields, 2009), or the intensity of the initial emotional response (Blanchard-Fields, Stein, & Watson, 2004; Scheibe, Sheppes, & Staudinger, 2015; Schirda, Valentine, Aldao, & Prakash, 2016). Further, age-related differences may emerge at the level of situation selection (Rook, 2001; Sands, Livingstone, & Isaacowitz, 2018), situation modification (Blanchard-Fields, Jahnke, & Camp, 1995; Folkman, Lazarus, Pimley, & Novacek, 1987), attentional deployment (Livingstone & Isaacowitz, 2018), cognitive changes (Brummer, Stopa, & Bucks, 2014; John & Gross, 2004; Shiota & Levenson, 2009), or response modulation (Eldesouky & English, 2018; John & Gross, 2004; Shiota & Levenson, 2009). Collectively, these results highlight complexity and nuance to age-related differences in emotion regulation.

The Current Study

We conducted secondary data analysis of the MIDUS 2 data set using the reappraisal and suppression scales from Gross and John's (2003) emotion regulation questionnaire (ERQ). Using these measures, one study observed that older adults also tend to use cognitive reappraisal more and expressive suppression less (John & Gross, 2004, see also Brummer et al., 2014). However, others have not replicated these age-related differences in reappraisal and suppression (Livingstone & Isaacowitz, 2018; Nolen-Hoeksema & Aldao, 2011). Finally, another study found no age-related differences in any antecedent-focused emotion regulation strategy (including reappraisal) but did find that older adults used suppression more frequently (Eldesouky & English, 2018). Collectively, these studies highlight mixed support for age-related changes in reappraisal or suppression.

Although there is a rich literature on age-related decreases in both alpha power (Babiloni et al., 2006; Hashemi et al., 2016; Volf & Gluhih, 2011) and individual alpha peak frequency (Aurlien et al., 2004; Bazanova, 2008; Chiang, Rennie, Robinson, Van Albada, & Kerr, 2011; Hashemi et al., 2016) much less is known about age-related changes in FAA. Studies of FAA in older adults have primarily focused on interventions aimed at improving functioning (Deslandes et al., 2010; Moynihan et al., 2013; Vogt, Schneider, Brümmer, & Strüder, 2010), cross-sectional associations between FAA and depression (Carvalho et al., 2011; Deslandes et al., 2010), the effects of mood manipulations on FAA (Kline, Blackhart, Woodward, Williams, & Schwartz, 2000), and emotion regulation processes (Jackson et al., 2003). However, comparisons between older and younger adults are less common in the frontal EEG asymmetry literature. Extant literature reports that older adults show less hemispheric asymmetry particularly in frontal regions (Dolcos, Rice, & Cabeza, 2002) this work has primarily focused on cognitive processes (e.g., memory) and work in the emotional domain has shown that older adults has shown that left FAA predicts better emotion regulation in older adults (Jackson et al., 2003). However, by using an age constrained sample (i.e., 57–60 years) Jackson and colleagues were unable to examine age-related differences in the associations between emotion regulation and FAA. It remains unclear how associations between emotion regulation and FAA change during normative aging. The current study is well-suited to clarify this ambiguity.

Hypotheses

Our first hypothesis predicts that the habitual use of adaptive emotion regulation strategies (high reappraisal/low suppression) would be more strongly associated with left FAA in older (vs. younger) adults. Our second hypothesis predicts an opposite pattern whereby the habitual use of maladaptive emotion regulation strategies (low reappraisal/high suppression) would be more strongly associated with right FAA in older (vs. younger) adults. To test these hypotheses, we examined the relationship between age, resting FAA, and the habitual use of cognitive reappraisal and expressive suppression in a cross-sectional study of normative aging.

Method

Participants

Data for the present study came from the Midlife in the United States (MIDUS) study. The MIDUS study contains a national probability sample of English-speaking US residents (see http://midus.wisc.edu/scopeofstudy.php). The present study included participants ($N = 331$) who completed the neuroscience portion of the MIDUS project (details of the neuroscience project can be found at http://midus.wisc.edu/midus2/project5; see also Ryff & Davidson, 2011).

Participant characteristics. Participants were invited to participate in the neuroscience project if they completed the MIDUS 2 phone interview, a self-paced questionnaire, and a biomarker assessment at University of Wisconsin-Madison. Based on these criteria there are was a 76.3% response rate with the resulting sample being primarily white (64.2%), married (60.2%), female (55.4%), and generally in good health. Approximately two thirds of the sample at least some college experience (65.9%).

Exclusions. Participants were excluded for left-handedness (a convention in EEG asymmetry research), missing emotion regulation questionnaire (ERQ) data, or missing EEG data. Self-report data was classified as missing if a) the data was not recorded or b) fewer than 50% of items were completed. EEG data was classified as missing if they were either a) not recorded or b) contained 50% or more bad EEG channels (i.e., 64 + bad channels of data). The ERQ was added into the MIDUS neuroscience project late and only the last third of participants completed the ERQ. As a result, the following exclusions were made: 190 for missing ERQ data; 5 for missing EEG data, 4 for left-handedness, 5 for missing ERQ and EEG data, 17 for left-handedness and missing ERQ data; 1 for left-handedness and missing EEG data, and 1 for left-handedness and ERQ and EEG data. These exclusions follow published recommendations for use of MIDUS data (Ryff & Davidson, 2011). Our final sample included 108 participants who ranged from 37 to 83 years old ($M = 55.41$, $SD = 11.12$) from the neuroscience portion of the MIDUS project with complete data.

Sample size and power. Power analysis was conducted in G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) using the "linear multiple regression Fixed model, R^2 increase" procedure. We sought to determine the power of our study to detect small ($f^2 = .02$), medium ($f^2 = .15$) and large ($f^2 = .35$). In addition to effect size and alpha level, we specify "Number of tested predictors" = 1 and "Total number of predictors" = 7 as input parameters, because we have 7 predictors (i.e., age, reappraisal, suppression, all two-way interaction terms, and the three-way interaction term) in the full model and only one of these predictors captures the effect of interest—namely the three-way interaction. With a sample of 108 participants at .05 alpha level, we have .31 power to detect a small effect, .98 power to detect a medium effect, and .99 power to detect a large effect. Moreover, we have .80 power to detect a small to moderate effect ($f^2 = .08$). Collectively, these analyses suggest that the current study is adequately powered to detect effects between small and medium in size.

Procedure

Emotion regulation questionnaire. The ERQ is a common and well-validated measure of individual differences in reappraisal and suppression emotion regulation tendencies (see Gross & John, 2003). This measure was completed as part of the neuroscience project of MIDUS II. Participants responded to ERQ items using a scale from 1 (*strongly disagree*) to 7 (*strongly agree*). The reappraisal scale includes 6 items which tap into the tendency to think about potential emotion elicitors in ways which heighten or less their impact, for example "When I want to feel more positive (negative) emotion I change what I'm thinking about". The suppression scale includes 4 items which tap into the tendency to try and change ongoing affective experiences, for example "When I am feeling positive (negative) emotions, I am careful not to express them". In the MIDUS study, the ERQ was administered via paper and pencil. The average score on the reappraisal scale was $M = 4.499$ ($SD = 0.91$, $\alpha = .76$) and the average score on the suppression scale was $M = 3.46$ ($SD = 1.23$, $\alpha = .75$).

EEG recording. EEG data collection was recorded in the Laboratory for Brain Imaging and Behavior, located in the Waisman Center at the University of Wisconsin, Madison. Participants sat in front of a computer screen in a soundproof both where EEG was recorded via a 128-channel geodesic net (Electrical Geodesics, Inc., Eugene, OR) of saline-dampened, sponge-encased silver metal/silver chloride (Ag/AgCl) electrodes. A computer located outside the booth recorded the data. Participants were instructed to rest for six 1-min periods at the beginning of the laboratory session. During three of the 1-min periods they were asked to keep their eyes open; for the other three 1-min periods they were asked to keep their eyes closed. To increase the reliability of the EEG data, we collapsed across conditions (i.e., eyes open/eyes closed) and across minutes. Electrode impedances were reduced to less than 100 KΩ, and analog EEG signals were amplified and sampled at a rate of 500 Hz (bandpass filtered from 0.1–100 Hz) with 16-bit precision using an online vertex (CZ) reference.

Data cleaning. EEG recordings were filtered using 60-Hz notch and 0.5-Hz high-pass filtering. Data were submitted to a principal components analysis/independent components analysis (PCA/ICA). The PCA/ICA was conducted separately for each individual. The purpose of the PCA/ICA was to identify common artifacts in the EEG including eyeblinks, eye movements, and cardiac signals. The PCA/ICA forced the identification 20 components which resulted in ideal artifact decomposition (see Hostinar et al., 2017). Subsequently, components containing obvious eyeblinks, eye movements and other artifacts were then removed from the data. Bad channels were then replaced using a spherical spline interpolation. Two-second epochs were then created and EEGLAB automated artifact identification routine identified epochs containing deviations of ±100 microvolts, which were removed. The average spectral power densities for each participant were computed from each of the 2-s epochs for each electrode. The spectra were then averaged across these epochs. Individual measures of upper (10–13 Hz) and lower (8–10 Hz) bands of alpha were created by averaging the power within these bands separately. These average values were subsequently log-transformed to normalize the distribution.

Frontal asymmetry. Asymmetry scores were calculated for each pair of electrodes in both frequency bands by subtracting the power of the left hemisphere from the power of the right hemisphere. A composite of upper (10–13 Hz) and lower (8–10 Hz) alpha asymmetry across fronto-pollar (Fp1/Fp2), midfrontal (F3/F4), and midlateral (F7/F8) sites was our measure of asymmetric frontal cortical activity ($\alpha = .77$). Because alpha power is inversely related to cortical activation, higher asymmetry scores (i.e., greater relative right alpha power) indicate greater activity in the left (vs. right) frontal region (i.e., greater left FAA). More specifically, positive values reflect left FAA—an index of approach motivation whereas negative values reflect right FAA—an index of avoidance motivation.

Results

FAA scores were regressed onto age (centered), suppression (centered), reappraisal (centered) and all interaction among age, suppression, and reappraisal. Age predicted reduced left FAA, $\beta = -.20$, $t(100) = -2.13$, $p = .036$. No main effects of reappraisal [$\beta = .03$, $t(100) = 0.29$, $p = .77$] or suppression [$\beta = -.08$, $t(100) = -0.89$, $p = .37$] were observed. We also observed no significant two-way interactions, age × reappraisal [$\beta = .14$, $t(100) = 1.47$, $p = .15$], age × suppression [$\beta = -.05$, $t(100) = -0.49$, $p = .63$], and reappraisal × suppression [$\beta = 12$, $t(100) = 1.30$, $p = .20$]. There was a significant age × reappraisal × suppression interaction, $\beta = .29$, $t(100) = 3.03$, $p = .003$.

To unpack the three-way interaction, we conducted simple slopes tests comparing individuals 1 *SD* below the mean age (42.7 years) to those 1 *SD* above the mean (62.2 years) at each combination of high (+1 SD) and low (−1 SD) scores on reappraisal and suppression. As a result, we made the following 4 comparisons of middle aged and older adults: 1) High Reappraisal (+1SD)/High Suppression (+1 SD), 2) High Reappraisal (+1 SD)/Low Suppression (−1 SD), 3) Low Reappraisal (−1 *SD*)/High Suppression (+1 SD), and 4) Low Reappraisal/Low Suppression (−1 SD).

Among the High Reappraisal/High Suppression participants there was no effect of age on FAA, $t = 0.89$, $p = .37$. Among the High Reappraisal/Low Suppression participants, older adults compared to middle aged adults had greater right FAA/reduced left FAA, $t = -2.13$, $p = .04$. Among the low Reappraisal/High Suppression participants, older adults compared to middle aged adults had greater right FAA, $t = -4.35$, $p < .001$. Among the Low Reappraisal/Low Suppression participants there was no effect of age on FAA, $t = 0.03$, $p = .97$. *T* tests comparing the differences between slopes revealed that the effect of age among low Reappraisal/High Suppression participants was significantly difference from all other slopes, *t*s > 2.5, *p*s < .01. See Figure 1.

Discussion

The current study was among the first to examine age related differences in the relationships between emotion regulation strategy usage (reappraisal and suppression) and FAA in a sample of middle-aged to older adults. We observed that older adults (relative to younger adults) demonstrated increased right FAA. Our hypotheses then examined whether this effect was moderated by reappraisal and suppression tendencies.

Our first hypothesis was not supported as older adults (vs. younger adults) who reported habitually using adaptive emotion regulation strategies (i.e., low suppression/high reappraisal) showed a pattern of increased right FAA rather than increased left FAA which has been linked to effective emotion regulation in past research (Jackson et al., 2003). However, our second hypothesis was supported as older adults (vs. younger adults) who reported using maladaptive emotion regulation strategies (i.e., high suppression/low reappraisal) showed a pattern of increased right FAA. Crucially, a slopes difference test revealed that the association between age and FAA was significantly stronger among those habitually using maladaptive emo-

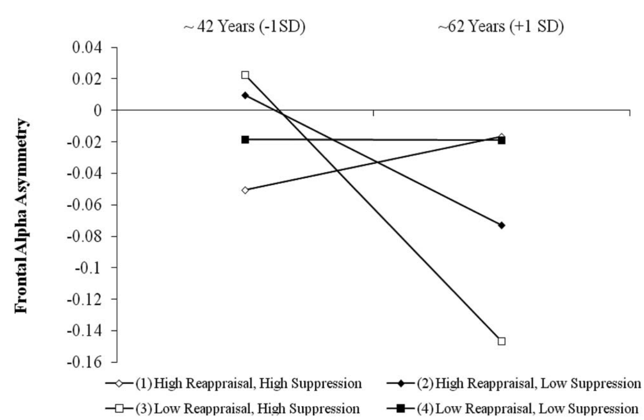

Figure 1. The relationship between frontal electroencephalographic (EEG) asymmetry, suppression, and reappraisal in middle-aged (−1 *SD*, ~42.72 years old) and older (+1 *SD*, ~62.22 years old) adults. Positive values on the frontal alpha asymmetry (FAA) index (Y-axis) reflect greater left FAA whereas negative values reflect greater right FAA. Among the low Reappraisal/High Suppression participants, older adults compared to middle aged adults had greater right FAA, $t = -4.35$, $p < .001$.

tion regulation strategies relative to those habitually using adaptive emotion regulation strategies. Future work is needed to determine causality as well as downstream consequences for affect, behavior, and well-being.

One possibility for the increase in right FAA among older adults employing adaptive emotion regulation strategies is age-related differences in the effectiveness of cognitive reappraisal. One study observed that older adults were less successful using reappraisal to decrease unpleasant emotion and more successful using reappraisal to increase unpleasant emotion (Opitz, Rauch, Terry, & Urry, 2012), suggesting that greater use of cognitive reappraisal among older adults may lead them to experience more negative emotions which have been linked reliably to right FAA. Our findings fit nicely with work by Opitz and colleagues to suggest that high usage of cognitive reappraisal may not necessarily be as adaptive for older adults as it is for younger adults. Future research should consider how both the use and effectiveness of cognitive reappraisal relate to prefrontal brain asymmetries.

We also did observe or predict, age-related differences in FAA among participants who either reported low usage of both emotion regulation strategies or high usage of both strategies. These null findings make sense when one considers the motivational and emotional properties of FAA. With left and right lateralized patterns linked to strong approach and avoidance-oriented emotions respectively, an absence of asymmetry may reflect an absence of strong emotion. From this viewpoint, individuals who report low usage of both strategies may simply not have strong emotional impulses to regulate in the first place, as reflected by asymmetry scores approaching zero. The high use of both strategies may reflect the presence of a larger repertoire of emotion regulation strategies which associated with less depression and anxiety (Lougheed & Hollenstein, 2012). Given that both depression and anxiety have been linked to right FAA, future studies should examine whether a larger repertoire of emotion regulation reduces right FAA and whether this reduction accounts for reductions in depression and anxiety.

We found that a maladaptive repertoire of emotion regulation strategies (high suppression/low reappraisal) was associated with greater right FAA among older (vs. younger) adults. These results suggest that the negative consequences of habitually using maladaptive emotion regulation strategies may be more harmful in older adults. This may explain why some researchers have observed that older adults tend to use maladaptive emotion regulation strategies less often.

References

Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. *Clinical Psychology Review, 30,* 217–237. http://dx.doi.org/10.1016/j.cpr.2009.11.004

Allen, V. C., & Windsor, T. D. (2017). Age differences in the use of emotion regulation strategies derived from the process model of emotion regulation: A systematic review. *Aging & Mental Health*. Advance online publication. http://dx.doi.org/10.1080/13607863.2017.1396575

Appleton, A. A., & Kubzansky, L. D. (2014). Emotion regulation and cardiovascular disease risk. In J. J. Gross (Ed.), *Handbook of emotion regulation* (2nd ed., pp. 596–612). New York, NY: Guilford Press.

Aurlien, H., Gjerde, I. O., Aarseth, J. H., Eldøen, G., Karlsen, B., Skeidsvoll, H., & Gilhus, N. E. (2004). EEG background activity described by a large computerized database. *Clinical Neurophysiology, 115,* 665–673. http://dx.doi.org/10.1016/j.clinph.2003.10.019

Babiloni, C., Binetti, G., Cassarino, A., Dal Forno, G., Del Percio, C., Ferreri, F., . . . Rossini, P. M. (2006). Sources of cortical rhythms in adults during physiological aging: A multicentric EEG study. *Human Brain Mapping, 27,* 162–172. http://dx.doi.org/10.1002/hbm.20175

Bazanova, O. M. (2008). Age related alpha activity change differs for males and females and for low and high alpha frequency EEG pattern. *Revista Española de Neuropsicología, 10,* 82–83.

Blanchard-Fields, F., Jahnke, H. C., & Camp, C. (1995). Age differences in problem-solving style: The role of emotional salience. *Psychology and Aging, 10,* 173–180. http://dx.doi.org/10.1037/0882-7974.10.2.173

Blanchard-Fields, F., Stein, R., & Watson, T. L. (2004). Age differences in emotion-regulation strategies in handling everyday problems. *The Journals of Gerontology: Series B, Psychological Sciences and Social Sciences, 59,* 261–269. http://dx.doi.org/10.1093/geronb/59.6.P261

Brummer, L., Stopa, L., & Bucks, R. (2014). The influence of age on emotion regulation strategies and psychological distress. *Behavioural and Cognitive Psychotherapy, 42,* 668–681. http://dx.doi.org/10.1017/S1352465813000453

Carvalho, A., Moraes, H., Silveira, H., Ribeiro, P., Piedade, R. A., Deslandes, A. C., . . . Versiani, M. (2011). EEG frontal asymmetry in the depressed and remitted elderly: Is it related to the trait or to the state of depression? *Journal of Affective Disorders, 129*(1–3), 143–148. http://dx.doi.org/10.1016/j.jad.2010.08.023

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

Charles, S. T., & Carstensen, L. L. (2007). Emotion regulation and aging. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 307–327). New York: Guilford Press.

Charles, S. T., & Piazza, J. R. (2009). Age differences in affective well-being: Context matters. *Social and Personality Psychology Compass, 3,* 711–724. http://dx.doi.org/10.1111/j.1751-9004.2009.00202.x

Chiang, A. K. I., Rennie, C. J., Robinson, P. A., van Albada, S. J., & Kerr, C. C. (2011). Age trends and sex differences of alpha rhythms including split alpha peaks. *Clinical Neurophysiology, 122,* 1505–1517. http://dx.doi.org/10.1016/j.clinph.2011.01.040

Choi, D., Sekiya, T., Minote, N., & Watanuki, S. (2016). Relative left frontal activity in reappraisal and suppression of negative emotion: Evidence from frontal alpha asymmetry (FAA). *International Journal of Psychophysiology, 109,* 37–44. http://dx.doi.org/10.1016/j.ijpsycho.2016.09.018

Coan, J. A., & Allen, J. J. (2003). Frontal EEG asymmetry and the behavioral activation and inhibition systems. *Psychophysiology, 40,* 106–114.

Coan, J. A., Allen, J. J., & Harmon-Jones, E. (2001). Voluntary facial expression and hemispheric asymmetry over the frontal cortex. *Psychophysiology, 38,* 912–925. http://dx.doi.org/10.1111/1469-8986.3860912

Coats, A. H., & Blanchard-Fields, F. (2008). Emotion regulation in interpersonal problems: The role of cognitive-emotional complexity, emotion regulation goals, and expressivity. *Psychology and Aging, 23,* 39–51. http://dx.doi.org/10.1037/0882-7974.23.1.39

Dawson, G., Panagiotides, H., Klinger, L. G., & Hill, D. (1992). The role of frontal lobe functioning in the development of infant self-regulatory behavior. *Brain and Cognition, 20,* 152–175. http://dx.doi.org/10.1016/0278-2626(92)90066-U

Deslandes, A. C., Moraes, H., Alves, H., Pompeu, F. A. M. S., Silveira, H., Mouta, R., . . . Coutinho, E. S. (2010). Effect of aerobic training on EEG alpha asymmetry and depressive symptoms in the elderly: A 1-year follow-up study. *Brazilian Journal of Medical and Biological Research, 43,* 585–592. http://dx.doi.org/10.1590/S0100-879X2010007500041

Dolcos, F., Rice, H. J., & Cabeza, R. (2002). Hemispheric asymmetry and aging: Right hemisphere decline or asymmetry reduction. *Neuroscience* *and Biobehavioral Reviews, 26,* 819–825. http://dx.doi.org/10.1016/S0149-7634(02)00068-4

Eldesouky, L., & English, T. (2018). Another year older, another year wiser? Emotion regulation strategy selection and flexibility across adulthood. *Psychology and Aging, 33,* 572–585. http://dx.doi.org/10.1037/pag0000251

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41,* 1149–1160. http://dx.doi.org/10.3758/BRM.41.4.1149

Folkman, S., Lazarus, R. S., Pimley, S., & Novacek, J. (1987). Age differences in stress and coping processes. *Psychology and Aging, 2,* 171–184. http://dx.doi.org/10.1037/0882-7974.2.2.171

Gross, J. J. (1998). Antecedent- and response-focused emotion regulation: Divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology, 74,* 224–237. http://dx.doi.org/10.1037/0022-3514.74.1.224

Gross, J. J. (2001). Emotion regulation in adulthood: Timing is everything. *Current Directions in Psychological Science, 10,* 214–219. http://dx.doi.org/10.1111/1467-8721.00152

Gross, J. J. (2015). The extended process model of emotion regulation: Elaborations, applications, and future directions. *Psychological Inquiry, 26,* 130–137. http://dx.doi.org/10.1080/1047840X.2015.989751

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85,* 348–362. http://dx.doi.org/10.1037/0022-3514.85.2.348

Harmon-Jones, E. (2007). Trait anger predicts relative left frontal cortical activation to anger-inducing stimuli. *International Journal of Psychophysiology, 66,* 154–160. http://dx.doi.org/10.1016/j.ijpsycho.2007.03.020

Harmon-Jones, E., Abramson, L. Y., Sigelman, J., Bohlig, A., Hogan, M. E., & Harmon-Jones, C. (2002). Proneness to hypomania/mania symptoms or depression symptoms and asymmetrical frontal cortical responses to an anger-evoking event. *Journal of Personality and Social Psychology, 82,* 610–618. http://dx.doi.org/10.1037/0022-3514.82.4.610

Harmon-Jones, E., & Allen, J. J. (1997). Behavioral activation sensitivity and resting frontal EEG asymmetry: Covariation of putative indicators related to risk for mood disorders. *Journal of Abnormal Psychology, 106,* 159–163. http://dx.doi.org/10.1037/0021-843X.106.1.159

Harmon-Jones, E., & Allen, J. J. (1998). Anger and frontal brain activity: EEG asymmetry consistent with approach motivation despite negative affective valence. *Journal of Personality and Social Psychology, 74,* 1310–1316. http://dx.doi.org/10.1037/0022-3514.74.5.1310

Harmon-Jones, E., Lueck, L., Fearn, M., & Harmon-Jones, C. (2006). The effect of personal relevance and approach-related action expectation on relative left frontal cortical activity. *Psychological Science, 17,* 434–440. http://dx.doi.org/10.1111/j.1467-9280.2006.01724.x

Harmon-Jones, E., & Sigelman, J. (2001). State anger and prefrontal brain activity: Evidence that insult-related relative left-prefrontal activation is associated with experienced anger and aggression. *Journal of Personality and Social Psychology, 80,* 797–803. http://dx.doi.org/10.1037/0022-3514.80.5.797

Hashemi, A., Pino, L. J., Moffat, G., Mathewson, K. J., Aimone, C., Bennett, P. J.,. . . Sekuler, A. B. (2016). Characterizing population EEG dynamics throughout adulthood. *ENeuro*. Advance online publication. http://dx.doi.org/10.1523/eneuro.0275-16.2016

Hostinar, C. E., Davidson, R. J., Graham, E. K., Mroczek, D. K., Lachman, M. E., Seeman, T. E., . . . Miller, G. E. (2017). Frontal brain asymmetry, childhood maltreatment, and low-grade inflammation at midlife. *Psychoneuroendocrinology, 75,* 152–163. http://dx.doi.org/10.1016/j.psyneuen.2016.10.026

Jackson, D. C., Mueller, C. J., Dolski, I., Dalton, K. M., Nitschke, J. B., Urry, H. L., . . . Davidson, R. J. (2003). Now you feel it, now you don't: Frontal brain electrical asymmetry and individual differences in emotion regulation. *Psychological Science, 14,* 612–617. http://dx.doi.org/10.1046/j.0956-7976.2003.psci_1473.x

John, O. P., & Gross, J. J. (2004). Healthy and unhealthy emotion regulation: Personality processes, individual differences, and life span development. *Journal of Personality, 72,* 1301–1334. http://dx.doi.org/10.1111/j.1467-6494.2004.00298.x

Kalin, N. H., Larson, C., Shelton, S. E., & Davidson, R. J. (1998). Asymmetric frontal brain activity, cortisol, and behavior associated with fearful temperament in rhesus monkeys. *Behavioral Neuroscience, 112,* 286–292. http://dx.doi.org/10.1037/0735-7044.112.2.286

Kennedy, Q., Mather, M., & Carstensen, L. L. (2004). The role of motivation in the age-related positivity effect in autobiographical memory. *Psychological Science, 15,* 208–214. http://dx.doi.org/10.1111/j.0956-7976.2004.01503011.x

Kim, S. H., Cornwell, B., & Kim, S. E. (2012). Individual differences in emotion regulation and hemispheric metabolic asymmetry. *Biological Psychology, 89,* 382–386. http://dx.doi.org/10.1016/j.biopsycho.2011.11.013

Kline, J. P., Blackhart, G. C., Woodward, K. M., Williams, S. R., & Schwartz, G. E. (2000). Anterior electroencephalographic asymmetry changes in elderly women in response to a pleasant and an unpleasant odor. *Biological Psychology, 52,* 241–250. http://dx.doi.org/10.1016/S0301-0511(99)00046-0

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological Review, 97,* 377–395. http://dx.doi.org/10.1037/0033-295X.97.3.377

Lazarus, R. S., & Alfert, E. (1964). Short-circuiting of threat by experimentally altering cognitive appraisal. *Journal of Abnormal Psychology, 69,* 195–205. http://dx.doi.org/10.1037/h0044635

Livingstone, K. M., Castro, V. L., & Isaacowitz, D. M. (2018). Age differences in beliefs about emotion regulation strategies. *The Journals of Gerontology: Series B,* gby022.

Livingstone, K. M., & Isaacowitz, D. M. (2018). The roles of age and attention in general emotion regulation, reappraisal, and expressive suppression. *Psychology and Aging, 33,* 373–383. http://dx.doi.org/10.1037/pag0000240

Lougheed, J. P., & Hollenstein, T. (2012). A limited repertoire of emotion regulation strategies is associated with internalizing problems in adolescence. *Social Development, 21,* 704–721. http://dx.doi.org/10.1111/j.1467-9507.2012.00663.x

Mather, M., Canli, T., English, T., Whitfield, S., Wais, P., Ochsner, K., . . . Carstensen, L. L. (2004). Amygdala responses to emotionally valenced stimuli in older and younger adults. *Psychological Science, 15,* 259–263. http://dx.doi.org/10.1111/j.0956-7976.2004.00662.x

Mather, M., & Carstensen, L. L. (2005). Aging and motivated cognition: The positivity effect in attention and memory. *Trends in Cognitive Sciences, 9,* 496–502. http://dx.doi.org/10.1016/j.tics.2005.08.005

Moynihan, J. A., Chapman, B. P., Klorman, R., Krasner, M. S., Duberstein, P. R., Brown, K. W., & Talbot, N. L. (2013). Mindfulness-based stress reduction for older adults: Effects on executive function, frontal alpha asymmetry and immune function. *Neuropsychobiology, 68,* 34–43. http://dx.doi.org/10.1159/000350949

Nezlek, J. B., & Kuppens, P. (2008). Regulating positive and negative emotions in daily life. *Journal of Personality, 76,* 561–580. http://dx.doi.org/10.1111/j.1467-6494.2008.00496.x

Nolen-Hoeksema, S., & Aldao, A. (2011). Gender and age differences in emotion regulation strategies and their relationship to depressive symptoms. *Personality and Individual Differences, 51,* 704–708. http://dx.doi.org/10.1016/j.paid.2011.06.012

Opitz, P. C., Rauch, L. C., Terry, D. P., & Urry, H. L. (2012). Prefrontal mediation of age differences in cognitive reappraisal. *Neurobiology of Aging, 33,* 645–655. http://dx.doi.org/10.1016/j.neurobiolaging.2010.06.004

Ortner, C. N. M., Briner, E. L., & Marjanovic, Z. (2017). Believing is doing: Emotion regulation beliefs are associated with emotion regulation behavioral choices and subjective well-being. *Europe's Journal of Psychology, 13,* 60–74. http://dx.doi.org/10.5964/ejop.v13i1.1248

Papousek, I., Weiss, E. M., Perchtold, C. M., Weber, H., de Assunção, V. L., Schulter, G., . . . Fink, A. (2017). The capacity for generating cognitive reappraisals is reflected in asymmetric activation of frontal brain regions. *Brain Imaging and Behavior, 11,* 577–590. http://dx.doi.org/10.1007/s11682-016-9537-2

Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology, 3,* 339. http://dx.doi.org/10.3389/fpsyg.2012.00339

Rook, K. S. (2001). Emotional health and positive versus negative social exchanges: A daily diary analysis. *Applied Developmental Science, 5,* 86–97. http://dx.doi.org/10.1207/S1532480XADS0502_4

Ryff, C. D., & Davidson, R. (2011). *National survey of midlife development in the United States (MIDUS II): Neuroscience Project ICPSR28683-v2* (pp. 10–25). Ann Arbor, MI: Inter-university Consortium for Political and Social Research.

Sands, M., Livingstone, K., & Isaacowitz, D. (2018). Characterizing age-related positivity effects in situation selection. *International Journal of Behavioral Development, 42,* 396–404. http://dx.doi.org/10.1177/0165025417723086

Scheibe, S., & Blanchard-Fields, F. (2009). Effects of regulating emotions on cognitive performance: What is costly for young adults is not so costly for older adults. *Psychology and Aging, 24,* 217–223. http://dx.doi.org/10.1037/a0013807

Scheibe, S., Sheppes, G., & Staudinger, U. M. (2015). Distract or reappraise? Age-related differences in emotion-regulation choice. *Emotion, 15,* 677–681. http://dx.doi.org/10.1037/a0039246

Schirda, B., Valentine, T. R., Aldao, A., & Prakash, R. S. (2016). Age-related differences in emotion regulation strategies: Examining the role of contextual factors. *Developmental Psychology, 52,* 1370–1380. http://dx.doi.org/10.1037/dev0000194

Shiota, M. N., & Levenson, R. W. (2009). Effects of aging on experimentally instructed detached reappraisal, positive reappraisal, and emotional behavior suppression. *Psychology and Aging, 24,* 890–900. http://dx.doi.org/10.1037/a0017896

Sutton, S. K., & Davidson, R. J. (1997). Prefrontal brain asymmetry: A biological substrate of the behavioral approach and inhibition systems. *Psychological Science, 8,* 204–210. http://dx.doi.org/10.1111/j.1467-9280.1997.tb00413.x

Tomarken, A. J., Davidson, R. J., & Henriques, J. B. (1990). Resting frontal brain asymmetry predicts affective responses to films. *Journal of Personality and Social Psychology, 59,* 791–801. http://dx.doi.org/10.1037/0022-3514.59.4.791

Tomarken, A. J., Davidson, R. J., Wheeler, R. E., & Doss, R. C. (1992). Individual differences in anterior brain asymmetry and fundamental dimensions of emotion. *Journal of Personality and Social Psychology, 62,* 676–687. http://dx.doi.org/10.1037/0022-3514.62.4.676

Vogt, T., Schneider, S., Brümmer, V., & Strüder, H. K. (2010). Frontal EEG asymmetry: The effects of sustained walking in the elderly. *Neuroscience Letters, 485,* 134–137. http://dx.doi.org/10.1016/j.neulet.2010.09.001

Volf, N. V., & Gluhih, A. A. (2011). Background cerebral electrical activity in healthy mental aging. *Human Physiology, 37,* 559–567. http://dx.doi.org/10.1134/S0362119711040207

Wheeler, R. E., Davidson, R. J., & Tomarken, A. J. (1993). Frontal brain asymmetry and emotional reactivity: A biological substrate of affective style. *Psychophysiology, 30,* 82–89. http://dx.doi.org/10.1111/j.1469-8986.1993.tb03207.x

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