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Age Differences in Emotion Regulation Effort: Pupil Response Distinguishes Reappraisal and Distraction for Older But Not Younger Adults

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In previous research, older adults show greater emotional benefits from distracting themselves than from reappraising an event when strategically regulating emotion. Older adults also demonstrate an attentional preference to avoid, while younger adults show a bias toward approaching negative stimuli. This suggests a possible age-related differentiation of cognitive effort across approach and avoidance of negative stimuli during emotion regulation. In this study, we tracked cognitive effort via pupil dilation during the use of distraction (avoidance) and reappraisal (approach) strategies across age. Forty-eight younger adults ($M = 20.94$, $SD = 1.78$; 19 men) and 48 older adults ($M = 68.82$, $SD = 5.40$; 15 men) viewed a slideshow of negative images and were instructed to distract, reappraise, or passively view each image. Older adults showed greater pupil dilation during reappraisal than distraction, but younger adults displayed no difference between conditions—an effect that survived when controlling for gaze patterns. Gaze findings revealed that older adults looked less within images during active emotion regulation compared with passive viewing (no difference between distraction and reappraisal), and younger adults showed no difference across strategies. Younger adults gazed less within the most emotional image areas during distraction, but this did not significantly contribute to pupil response. Our findings support that distraction is less cognitively effortful than reinterpreting negative information in later life. These findings could be explained by older adults' motivational bias to disengage from negative information because of the age-related positivity effect, or compensation for decreased working memory resources across the life span.

Keywords: emotion regulation, cognitive effort, aging, reappraisal, distraction

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Older adults prefer to disengage from negative and/or selectively engage with positive information more than younger people in the laboratory (Reed, Chan, & Mikels, 2014). For instance, older adults are slower to detect dots appearing in the same spatial location as a preceding negative image compared with a positive image (Mather & Carstensen, 2003) and spend less time fixating negative than positive images compared with younger adults (Isaacowitz, Allard, Murphy, & Schlangel, 2009; Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Knight et al., 2007). Age-related preference for selective engagement with positive over negative information in basic research may represent an emotion regulatory utility, serving to enhance positive affect in the moment and regulate emotions (Kryla-Lighthall & Mather, 2009).

Attentional engagement is an important component of emotion regulation. One can choose to leave a stressful situation or contemplate and make meaning out of the negative experience. Attention can be directed away from negativity to avoid engagement with the source of distress (disengagement/avoidance strategies) or promote cognitive engagement with a negative situation to better comprehend it (engagement/approach strategies). *Distraction* is an avoidance strategy that involves directing attention away from a stressor toward unrelated

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neutral information to improve affect (Kanske, Heissler, Schönfelder, Bongers, & Wessa, 2010; Martins, Ponzio, Velasco, Kaplan, & Mather, 2014; McRae et al., 2010; Van Dillen & Koole, 2007). In contrast, *reappraisal* promotes engagement with each distressing stimulus to reinterpret its meaning in a less upsetting light (Kalisch, Wiech, Herrmann, & Dolan, 2006).

Many studies support that older adults benefit more from disengagement than reappraisal strategies. For instance, older adults show greater benefit from cognitive distraction (attending to thoughts of loved ones) than from engaging with and reinterpreting negative ruminative thoughts (Smoski, Labar, & Steffens, 2014). Furthermore, a series of studies show that older adults self-report smaller benefits from reappraisal of negative stimuli than do younger adults (Opitz, Rauch, Terry, & Urry, 2012b; Tucker, Feuerstein, Mende-Siedlecki, Ochsner, & Stern, 2012; Winecoff, Labar, Madden, Cabeza, & Huettel, 2011). However, distraction is equally or more beneficial for older adults than younger people (Phillips, Henry, Hosie, & Milne, 2008; Tucker et al., 2012). It is important to note that a few studies demonstrate that older adults benefit from reappraisal more than younger adults. Lohani and Isaacowitz (2014) reported that older adults benefitted more from both instructed attentional deployment and positive reappraisal than did younger adults and showed greater emotional improvements from reappraisal than attentional deployment. Another study found that older adults benefited most (both in terms self-report and physiological response) from engaging in positive reappraisal, and younger adults benefited most from taking a disengaged third-person perspective when regulating emotional reactions to negative emotional films (Shiota & Levenson, 2009).

While most studies do indicate that older adults benefit from disengagement strategies, the explanation remains unclear but may be related to ease of strategy use. Reappraisal involves not only engaging with negative situations, but also generating and keeping competing cognitive reinterpretations in mind, and then updating the emotionally favored interpretation in working memory. In contrast, when a mental distraction is internally generated (i.e., imagining making coffee in the morning), the same distraction can be used across different situations—a cognitive luxury that reappraisal does not provide, because reappraisals require unique interpretations for each emotional context encountered. A wide network of cognitive control regions of the prefrontal and anterior cingulate cortices is likely to work in concert during reappraisal use (Ochsner, Silvers, & Buhle, 2012), and these regions are especially subject to structural degradation with age (Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998; Salat, Kaye, & Janowsky, 2002). While there is limited empirical literature on the link between working memory ability and distraction, previous work has demonstrated that low working memory ability (low flanker performance) increases preference for distraction over reappraisal during the regulation of negative emotion in older adults (Scheibe, Sheppes, & Staudinger, 2015). Based on this previous work and theory, we were interested in whether distraction may be less cognitively effortful for older adults to employ than reappraisal.

Previous research suggests that emotion regulation is effortful and associated with greater cognitive effort than passive image viewing, as tracked by pupil dilation—an involuntary biomarker of autonomic nervous system activity, sensitive to environmental lighting conditions, as well as with increases in cognitive effort and emotional arousal (Granholm & Steinhauer, 2004; Kahneman & Beatty, 1966). Older adults show greater pupil dilation when decreasing emotional responses than when viewing or increasing emotional reactions to negative images (van Reekum et al., 2007). Urry et al. (2006) found that greater pupil response during reappraisal was proportional to decrease in amygdala activity (biomarker of successful emotion regulation in the brain). To our knowledge, only one study has contrasted cognitive effort across instructed use of distraction and reappraisal emotion regulation strategies. This study reported greater pupil response during instructed reappraisal than instructed distraction use (imagining a geometric shape or common neighborhood scene) or passive negative image viewing in a sample of younger adults (Strauss, Ossenfort, & Whearty, 2016). However, previous studies have not assessed the cognitive effort during instructed emotion regulation strategy use across age.

While our primary interest was clarifying differences in cognitive effort while gaze was fixed on images, age differences in gaze must also be considered. One report found that older adults remained more engaged with images than younger adults while distracting to a pleasant memory during emotion regulation (Phillips et al., 2008). Others have similarly reported than younger adults gaze less at negative stimuli during distraction than while using other strategies (Allard & Kensinger, 2017; Strauss et al., 2016). A report with an older adult sample found decreased fixation within negative images when decreasing emotional reactions to them via reappraisal, and that gaze explains a large proportion of variance reappraisal brain activity (van Reekum et al., 2007). In contrast, Allard and Kensinger (2017) found no differences in gaze across reappraisal and selective attention among older adults, while Lohani and Isaacowitz (2014) reported both younger and older adults gaze more within emotional areas of films during reappraisal than selective attention. Thus, gaze patterns across emotion regulation strategy remain unclear.

In this study, we tracked age differences in pupil dilation during use of instructed cognitive distraction, reappraisal, and a passive viewing condition as younger and older adults regulated emotional reactions to a slideshow of negative images. We utilized a cognitive distraction task that promoted thinking of a neutral self-focused mental image (i.e., walking around a familiar block, or making coffee in the morning), rather than a secondary working memory task as in previous studies of distraction (Kanske et al., 2010; Martins et al., 2014; McRae et al., 2010; Van Dillen & Koole, 2007). We did this to minimize age differences in cognitive effort that may arise because of the cognitive load associated with the distraction task itself, given age-related decline in working memory performance (Salthouse, 2009). In addition, we allowed participants to utilize a broad range of reappraisal tactics, including decreasing negativity (focusing on how the situation was not as bad as it first seemed) and/or increasing positive reactions to the image (focusing on how the situation would turn out better than expected, or was more positive than it first seemed), to allow for more flexible use of the strategy.

We also tracked percentage gaze within the entire image and emotionally salient portions of images, to clarify the role that gaze might play in cognitive effort across strategies. Finally, we tracked self-reported strategy use difficulty, and pre- and postregulation affect ratings on each trial to track subjective measures of cognitive effort and regulation success. We hypothesized that distraction would be less cognitively effortful than reappraisal for older adults to employ given age-related processing biases to avoid negative information. Finally, we investigated whether participants would fixate less within images and emotionally salient areas of images during distraction than reappraisal, and the effect of gaze on pupil response.

Method

Prior to running the study, a post hoc empirical power analysis was run on pilot data (six younger, six older adults) to determine the required sample size to detect the three-way interaction of Age (Younger Adults, Older Adults) × Condition (Rethink, Distract, Attend) × Time (16 bins) via bootstrapping and analyzed by using mixed effects linear regression in STATA (B = 1000). The proportion of the simulated data sets with a significant three-way interaction was considered the measure of empirical power. It was determined that $n = 45$ in each age group would achieve greater than 80% power to detect the Age × Condition × Time interaction.

Participants

Fifty-three students from the University of Southern California (USC; aged $M = 20.94$, $SD = 1.78$) and 55 older adults recruited from the community through the USC Healthy Minds volunteer database (aged $M = 68.82$, $SD = 5.40$) participated in the study. Participants completed demographic measures on one day (and participated in an unrelated study), then returned for a second session during which they completed the Emotion Regulation Task. The study was approved by the USC Institutional Review Board, and all participants provided separate written informed consent for the two studies and were paid on each day of participation. Participants were screened for neurological, cardiovascular, and ophthalmic illness, and corrected-to-normal vision and hearing. In addition, older adults were screened for cognitive impairment by a minimum score of 30 on the Telephone Interview for Cognitive Status (TICS; Brandt, Spencer, & Folstein, 1988). Five younger and seven older participants' data were excluded because of computer issues recording the pupillometry data, and the final sample included 48 younger and 48 older adults. One older adult participant failed to complete the full demographics session, but their experimental data are included in the reported analyses. The final sample demographics are given in Table 1.

Eyetracking Procedure

To control for ambient lighting, each participant session was conducted in the same individual eyetracking experiment room with fixed florescent lighting and no windows. Eyetracking was measured using an iView X RED eye-tracker (SensoMotoric Instruments; Teltow, Germany) at a sampling rate of 120 Hz. Fixation and pupil dilation data for each participant were collected using SMI BeGaze 2 software (SensoMotoric Instruments; Teltow, Germany). A 9-point calibration sequence was displayed at the start of each task. Tasks were presented using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA), and task events were labeled using the iViewX SDK package (SensoMotoric Instruments; Teltow, Germany). Preprocessing and data management were performed using the in-house python software PyPsych (Florjanczyk, 2016). Fixation events automatically detected in BeGaze2 were isolated, and timeseries were interpolated using a cubic spline function.

Pupil response preprocessing. To correct for subjective pupil diameter range, participants viewed two black and two white 10-s fixation screens for calibration at the start of the experiment, and their pupil diameter (mm) was recorded at a rate of 120 Hz (see Piquado, Isaacowitz, & Wingfield, 2010). For each participant, a pupil diameter maximum was calculated by averaging the pupil diameters over the last 7 s of the trial for the two black

Table 1
Demographic Breakdown of Final Analysis Sample

Variable	Younger adults ($N = 48$)	Older adults ($N = 48$)
Age*	21.06 (1.83)	69.10 (5.33)
Years of education*	14.97 (1.52)	16.96 (2.29)
Ethnicity (%)		
Hispanic	12.5	2.1
Non-Hispanic	85.4	91.7
Decline to State	2.1	4.2
Unknown	0	2.1
Race (%)*		
African American	8.3	25.0
Asian	39.6	6.3
Biracial	6.3	2.1
Caucasian	41.7	58.3
Pacific Islander/Native Hawaiian	2.1	2.1
Decline to state	2.1	4.2
Unknown	0	2.1
Gender (%)		
Male	39.6	31.3
Female	60.4	68.8

Note. *SD*s are reported in parentheses.
* $p < .05$ across age groups for Pearson χ^2 test for categorical variables, and independent samples *t*-tests for quantitative variable.

calibration screens, and a pupil diameter minimum was calculated averaging the pupil diameters over the last 7 s of the trial for the two white calibration screens. The average pupil range (mm) was calculated for each participant by subtracting the pupil diameter maximum from the pupil diameter minimum. Note that the first three seconds of data were excluded from calibration screen averages to minimize pupillary light reaction artifacts. For task data collected, we averaged the 120-Hz pupil diameter metrics into 0.5-s bins and focused our analyses on the emotion regulation period of each trial (8 s). We calculated the average pupil diameter for each 0.5 s of the regulation period of the trial (16 time bins), and the average pupil diameter for the last second of the baseline fixation period that directly preceded the emotion regulation period. We baseline corrected the pupil response by subtracting the average regulation period pupil diameter (mm) from the baseline fixation pupil diameter (mm), and then dividing this by the average pupil range for that participant (mm), thus giving us a dependent variable of percent pupil response (%).

Gaze preprocessing. Coordinates (*X*,*Y*) of participant gaze at each pupil measurement were collected at a sampling rate of 120 Hz. Percentage of coordinate data located within the *X-Y* coordinates of each 1,024 × 768 image were calculated for each 0.5-s fixed time bin ("On-Image" fixation percentage), and we also calculated the average "On-Image" fixation percentage for each trial as a whole. In addition, we tracked gaze patterns within the most emotionally salient portions of each image. Two independent coders drew regions-of-interest for each experimental image that carried the most emotional information. Binary masks for each image were combined, and these aggregate masks represented the salient Regions-of-Interest (ROIs) for each image. The percentage of the time that participants spent fixating within the *X*,*Y* coordinates of each ROI within each 0.5-s fixed time bin was calculated ("On-ROI" fixation percentage), as was the average "On-ROI" fixation percentage across the trial as a whole.

Emotion Regulation Task

To track baseline affect, mood ratings were collected using the Positive Affect and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988; Supplemental Table 1, available in the online supplemental material) Participants were then instructed on how to utilize each of the strategies: Attend (the control condition), Distract, and Rethink (aka, reappraise). On Attend trials, participants experienced the pictures naturally without regulating their emotions toward the images. For Distract trials, participants imagined one specific, neutral mental image unrelated to the negative image they were viewing, and utilized it throughout the task. Examples of distraction images included imagining taking a walk in one's neighborhood or going through one's morning routine. Participants generated a distraction image after being instructed on how to utilize the strategy, and were instructed to utilize this mental image throughout the task. For the Rethink strategy, participants reinterpreted the negative image, either focusing on how the situation would soon be resolved, or might not be as bad as it first seemed. Rethink examples included reinterpreting someone crying as someone experiencing tears of joy or focusing on how the experienced sadness would be short-lived. Participants viewed practice negative images and verbalized aloud how they would utilize the three strategies, to ensure that they understood the task instructions. They practiced utilizing two trials of each strategy aloud, and were provided corrective feedback was provided if there was any confusion regarding strategy use. Participants then did six practice trials with the same trial timing as the actual task silently. Practice images were not seen again during the actual task.

The trial diagram and timing are outlined in Figure 1. On each trial, a scrambled image was displayed, and then the corresponding unscrambled negative image was shown. After viewing the image, participants indicated aloud how emotionally intense the image seemed to them on a scale of 1 to 9 (*mild* to *very intense*), and the experimenter logged the response on the computer. We utilized oral reports rather than button-press because of the introduction of

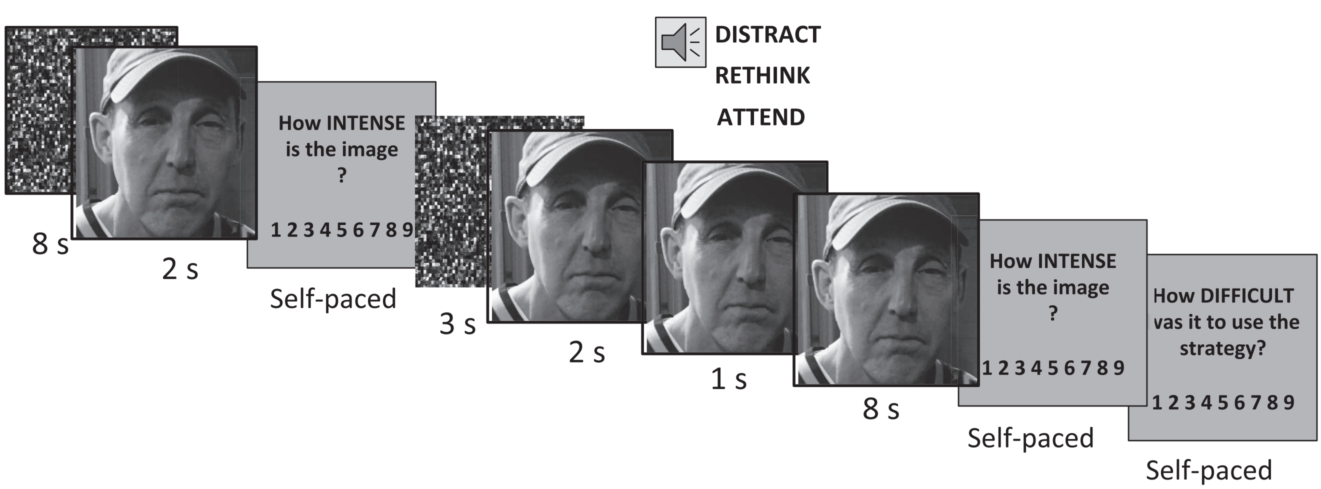

Figure 1. Emotion regulation trial diagram. On each trial, a scrambled image (8 s) and then the unscrambled image was seen (2 s). Subjects verbally rated the emotional intensity of the image on a scale of 1 to 9. The scrambled image was redisplayed (3 s), and then the unscrambled image was seen for 2 s. Participants were then cued to use one of the three strategies via a 1-s audio cue played in their headphones. They used the instructed strategy (8 s), then verbally rated the emotional intensity and difficulty of strategy usage on a scale of 1 to 9.

head motion artifacts when participants rated images that led to loss of pupil signal, and need for multiple recalibrations during pilot testing. The scrambled image was then shown again, and the unscrambled image was then displayed a second time. A 1-s auditory cue then instructed participants to either "Attend," "Distract," or "Rethink" the image. Once cued, participants used the indicated strategy while the image remained on screen for 8 s. Participants then rated the postregulation emotional intensity of image aloud on a scale of 1 to 9 (*mild* to *very intense*), verbally rated the difficulty of using the strategy on a scale of 1 to 9 (*easy* to *very difficult*), and the experimenter logged these responses on the computer. After participants completed the task, they completed a posttask questionnaire, describing the three emotion regulation strategies and how they used each one. This served as a manipulation check of whether participants encoded the instructions and used the strategies correctly.

The task consisted of 51 negative images from the International Affective Picture Systems (Lang et al., 2008; $M_{valence} = 2.56$, $SD_{valence} = 0.58$, $M_{arousal} = 5.42$, $SD_{arousal} = 0.67$). We chose these images based on published age norms (Grühn & Scheibe, 2008) and were able to equate age ratings of stimulus valence. Although it was not possible to statistically equate age groups in terms of arousal, differences across groups were small ($M_{younger} = 6.61$, $SD_{younger} = 0.79$; $M_{older} = 6.88$, $SD_{older} = 0.80$; Supplemental Table 2). Images were presented in three blocks, each 17 trials long, and cued strategies were randomized for each trial. Images were 1,024 × 768 in size, and displayed at the center of the 1,680 × 1050 gray background display. Images were luminance corrected to one another, and a fixation image was generated by randomly scrambling images into a 16 ×16 matrix of pixels, using the SHINE toolbox (Willenbockel et al., 2010) in MATLAB software (The MathWorks, Natick, MA). The background slide color was set to the average Red, Green, Blue (RGB) value of all images within the image set to minimize artifacts because of luminance differences across trials.

Statistical Methods

We analyzed our physiological data using linear Mixed Linear Models (MLMs), with the lme4 package in R (Bates, Maechler, Bolker, & Walker, 2014). MLMs allows for control of the variance associated with random factors without data aggregation (Judd, Westfall, & Kenny, 2012). By using random effects for subjects and stimuli, we modeled variance associated with both sources concurrently. MLMs included fixed effects of Age (younger adults, older adults), condition (Attend, Distract, Rethink), time (16 time bins spanning the 8-s emotion regulation period), prior condition (Attend, Distract, Rethink), with crossed random effects of subject and trial, and dependent variable was average baseline corrected pupil percent response (%) during emotion regulation use. Follow-up MLM analyses were conducted to clarify the nature of interactions. These follow-up analyses, described in the Results section, split the data into separate age groups and conditions, but otherwise retained the same structure.

We also ran a series of follow-up MLMs that included the above variables and either percent fixation On-Image (%) or percent fixation On-ROI (%) as fixed effects to clarify the role of gaze on cognitive effort. Behavioral findings were analyzed via 2 × 3 mixed repeated-measures mixed ANOVAs with factors of Age and Condition in SPSS. DVs in each analysis of variance (ANOVA) are outlined in the Results section. It is important to note that statistical power to detect follow-up interactions of Age × Condition collapsed across time and trial were estimated to be 48%–52%, so we are careful to not overstate these findings because of power limitations.

Results

Pupil Response Differentiates Emotion Regulation Use Across Age

MLM results revealed a significant three-way interaction of Age × Condition × Time, driven by a significant two-way interaction of Age × Condition ($p < .01$; Table 2 and Figure 2). Follow-up MLMs looking at pairwise differences revealed that both younger and older adults had greater pupil responses while utilizing the Distract ($b_{younger} = 2.30$, $b_{older} = 1.85$), and Rethink conditions ($b_{younger} = 2.34$, $b_{older} = 3.81$) than the Attend condition (Supplementary Table 3). Older adults showed greater pupil response during Rethink than Distract ($b_{older} = 1.96$, $t = 5.20$, $p < .001$), whereas younger adults showed no significant difference in pupil responses between these two strategies ($b_{younger} = 0.02$, $t = 0.22$, $p = .91$; Supplemental Table 2).

As would be expected because of habituation, there was also a significant main effect in which pupil response linearly decreased across time ($b = -0.45$, $t = -22.43$, $p < .001$, Table 2). MLM results also revealed a significant two-way interaction of Age × Time, in which older adults had a steeper slope for pupil response across time ($b = -0.55$, $t = -17.35$) than younger adults ($b = -0.34$, $t = -16.01$, $p < .001$; Supplemental Table 3). Finally, we found a main effect of Condition, in which both younger and older adults showed greater pupil responses for the Distract and Rethink conditions than the Attend condition ($p < 0.001$; Supplemental Table 4).

Gaze Contributes But Does Not Fully Explain Age Differences in Pupil Response

We ran two follow-up MLMs that investigated the three-way interaction of Age × Condition × Time, with added fixed effect of 1). Fixation percentage "On-Image" and 2). Fixation percentage "On-ROI" during each 0.5-s time bin. The interaction of Age × Condition × Time remained significant both when including the "On-Image" predictor, as well as when including the "On-ROI" predictor (both $p < .001$, Supplemental Table 5). The model including "On-Image" fixation percentage as a fixed effect significantly explained more variance than the MLM without the gaze predictor ($p < .001$). In contrast, the model with "On-ROI" fixation percentage fixed effect did not significantly explain more variance than the model without a gaze predictor ($p = .36$).

Older Adults Avert Gaze From Images More Than Younger Adults; Both Fixate Less Within Emotional Areas During Distraction

On-image analyses. There was a significant main effect of Age, where older adults fixated within images ($M = 67.78\%$,

Table 2
Pupil Response During Emotion Regulation Use

Variable	*B*	*SE*	*T*	Significance	*p*	Baseline model
Age	−.05	1.42	−.03	*n. sig*	.97	Intercept
Condition (Distract − Attend)	2.07	.23	9.13	**	<.001	Intercept
Condition (Rethink − Attend)	3.20	.23	14.11	**	<.001	Intercept
Condition (Rethink − Distract)	1.13	.23	5.00	**	<.001	Intercept
Time	−.45	.02	−22.40	**	<.001	Intercept
Age × Time	.21	.04	5.26	**	<.001	Age + Time ME
Age × Condition (Distract − Attend)	.19	.45	.42	**	<.001	Age + Condition ME
Age × Condition (Rethink − Attend)	−1.79	.45	−3.95	**	<.001	Age + Condition ME
Age × Condition (Rethink − Distract)	−1.98	.45	−4.37	**	<.001	Age + Condition ME
Condition × Time (Distract − Attend)	.10	.05	2.11	**	<.001	Condition + Time ME
Condition × Time (Rethink − Attend)	.22	.05	4.51	**	<.001	Condition + Time ME
Condition × Time (Rethink − Distract)	.12	.05	2.40	**	<.001	Condition + Time ME
Age × Condition × Time (Distract − Attend)	−.02	.10	−.20	*	.01	Age + Condition + Time + Age × Cond + Age × Time + Age × Cond
Age × Condition × Time (Rethink − Attend)	−.28	.10	−2.85	*	.01	Age + Condition + Time + Age × Cond + Age × Time + Age × Cond
Age × Condition × Time (Rethink − Distract)	−.26	.10	−2.65	*	.01	Age + Condition + Time + Age × Cond + Age × Time + Age × Cond

Note. Significance levels are given by * $p < .01$ and ** $p < .001$ for the analysis of variance (ANOVA) of the model stipulated contrasted with the baseline model indicated. Model included nuisance fixed effect of previous trial condition, and random effects of subject and trial. Time condition is modelled as sixteen 0.5-s time bins during regulation period. Age comparisons all refer to younger-older adults.

SD = 18.44%) less frequently than did younger adults (*M* = 79.77%, *SD* = 18.44%), $F(1, 94) = 10.14$, $p = .002$, partial $\eta^2 = 0.097$. There was also a significant main effect of Condition, with greater on-image fixation during the Attend condition than during either active regulation strategy, (Rethink: $t(95) = 2.00$, $p < .05$, Distract: $t(95) = 2.34$, $p = .02$, $F(2, 188) = 3.5$, $p = .032$, partial $\eta^2 = 0.036$, Figure 3). There was no significant interaction of Age ×Condition, $F(2, 188) = 2.63$, $p = .08$, partial $\eta^2 = 0.027$.

On-ROI analyses. There was also a significant main effect of Condition, with lower percent fixation in the Distraction condition

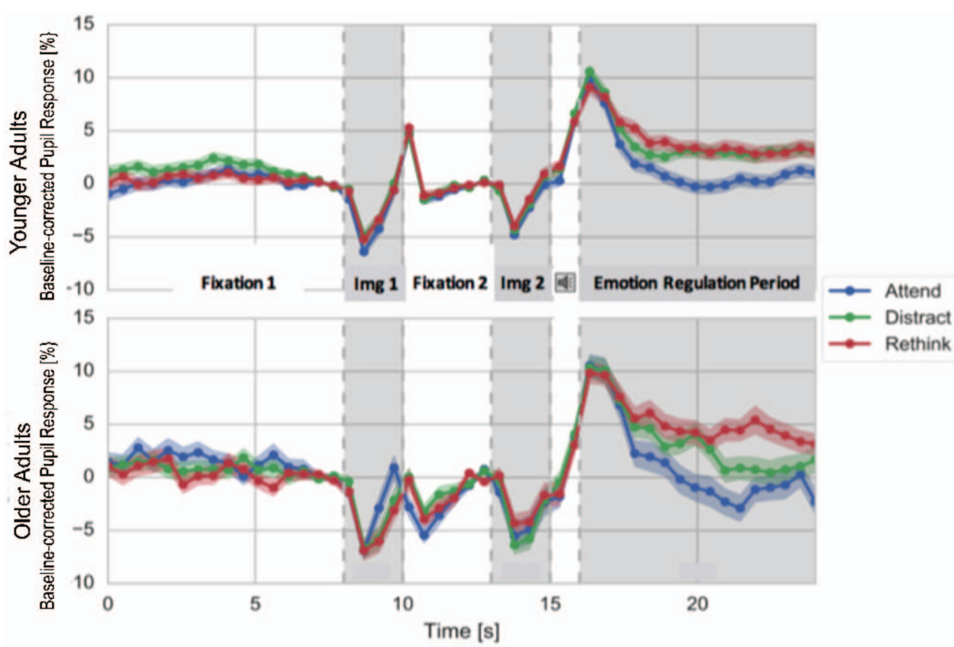

Figure 2. Baseline-corrected pupil response during emotion regulation use across age and condition. Line graphs represent average baseline-corrected pupil response as a function of Condition and Age, with each dot representing a 0.5-s bin. Shaded bars represent interpolated *SEM* (at trial level). Trial epochs are as follows: Fixation 1 (initial scrambled image: 8 s), Img 1 (initial image viewing period: 2 s), Fixation 2 (Second scrambled image: 3 s), Img 2 (second image viewing period: 2 s), auditory regulation cue (Attend, Rethink, or Distract sound played for 1 s), and emotion regulation period (8 s). Self-reported rating screens are omitted from this graph, because they were of variable length per trial. See the online article for the color version of this figure.

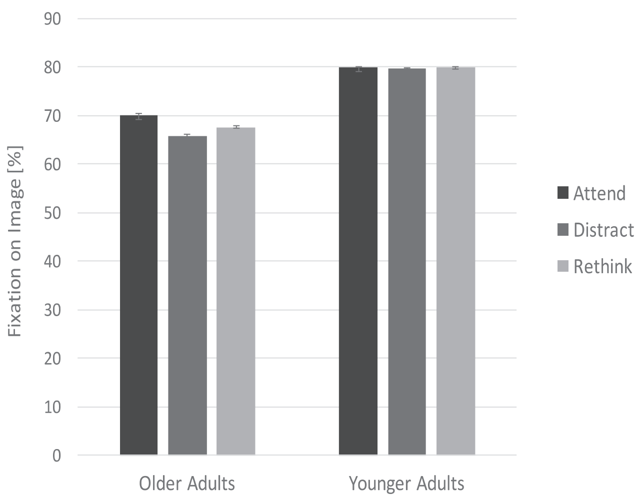

Figure 3. On-image fixation percentage across age and condition. Figure indicates average percentage of trial during each condition that participants spent gazing within the image boundary based on gaze coordinates. Error bars indicate *SEM*.

(M = 26.26, SD = 5.01) than either the Attend (M = 28.49, SD = 4.79) or Rethink conditions (M = 28.37, SD = 4.50), $F(2, 188) = 7.58$, $p = .001$, partial $\eta^2 = 0.075$ (Figure 4). There was no significant main effect of Age, $F(1, 94) = 1.37$, $p = .25$, partial $\eta^2 = 0.014$, nor significant interaction of Age × Condition, $F(2, 188) = 2.34$, $p = .1$, partial $\eta^2 = 0.024$.

Self-Report Measures Fail to Distinguish Emotion Regulation Use Across Age

Post-regulation effort ratings. There was a significant main effect of Condition, in which Distract and Rethink strategies were rated as more difficult than Attend, $t(95) = 7.84$, $p < .001$, $d = 0.74$, $F(2, 188) = 33.95$, $p < .001$, partial $\eta^2 = 0.27$ (Supplemental Figure 1). No significant difference was found between effort ratings for the Rethink and Distract strategies, $t(95) = 0.28$, $p = .78$, $d = 0.03$. No significant main effect of Age, nor interaction of Age × Condition were found, $F < 1$ (Supplemental Figure 1).

Pre- and post-emotion regulation intensity ratings. To compare relative success of our two active strategies of interest across age, we ran a repeated-measures 2 × 2 × 2 ANOVA of Age × Condition × Time (pre-regulation, post-regulation) on intensity ratings. Results indicated a significant main effect of Time in which regulation intensity decreased across time (M_{pre} = 5.97, SD_{pre} = 0.11; M_{post} = 4.80, SD_{post} = 0.11), $F(1, 94) = 211.50$, $p < .001$, partial $\eta^2 = 0.69$. In addition, there was a significant Age × Time interaction in which older adults showed a smaller improvement through time than younger adults did (Δ_{older} = 0.99, SD_{older} = 0.15; $\Delta_{youngerr}$ = 1.35, $SD_{younger}$ =0.15; Supplemental Figure 2), $F(1, 94) = 5.08$, $p < .03$, partial $\eta^2 = 0.05$. Furthermore, there was a significant Condition × Time interaction, $F(1, 94) = 92.89$, $p < .001$, partial $\eta^2 = 0.50$. However, no main effects of Age or Condition, nor interactions of Age × Condition, or Age × Condition × Time were found, $F < 1$.

Follow-up ANOVAs and post hoc t-tests were run to clarify of the Condition × Time interaction. As expected, preregulation intensity rating results yielded no significant main effects of Age or Condition, nor any significant interaction of Age × Condition, $F < 1$ (Older Adults- M_{Attend} = 6.00, SD_{Attend} = 1.08, $M_{Distract}$ = 5.91, $SD_{Distract}$ = 1.04, $M_{Rethink}$ = 6.02, $SD_{Rethink}$ = 1.07; Younger Adults- M_{Attend} = 6.03, SD_{Attend} = 0.90, $M_{Distract}$ = 6.00, $SD_{Distract}$ = 1.09, $M_{Rethink}$ = 5.94, $SD_{Rethink}$ = 1.11). Post-regulation intensity ratings did yield a significant effect of Condition, in which pictures seen during Attend (M = 5.94, SD = 1.11) were rated as more intense than those seen during Distract (M = 4.84, SD = 1.26), $t(95) = 8.75$, $p < .001$, $d = 0.92$, and Rethink conditions (M = 4.75, SD = 1.11), $t(95) = 10.44$, $p < .001$, $d = 1.07$, $F(2, 188) = 68.115$, $p < .001$, partial $\eta^2 = 0.42$. No significant differences were found between post-regulation intensity between Distract and Rethink conditions, $t(95) = 0.89$, $p = .38$, $d = 0.08$. No significant main effect of Age, $F(1, 94) = 1.36$, $p = .25$, partial $\eta^2 = 0.01$, nor interaction of Age × Condition, $F(2, 188) = 2.02$, $p = .14$, partial $\eta^2 = 0.02$ were found.

Discussion

In this study, we explored whether engagement with negative images during use of a reappraisal strategy was more cognitively effortful than distraction across older and younger adults. Our results confirmed our hypothesis that distraction was less effortful (lower pupil response) for older adults than reappraisal, a strategy that relies on engagement with negative stimuli. These results could be explained by at least two possible mechanisms: (1) an age-related motivational account and (2) age differences in available working memory resources.

Motivationally, *Socioemotional Selectivity Theory* (SST) argues that as people age, they may perceive their life span as more time-limited, and prefer to maximize positive emotion in the present moment (Carstensen, Isaacowitz, & Charles, 1999; Charles & Carstensen, 2008; Lang & Carstensen, 2002). Thus, older adults may be motivated to disengage from negative and/or engage with positive information in the service of emo-

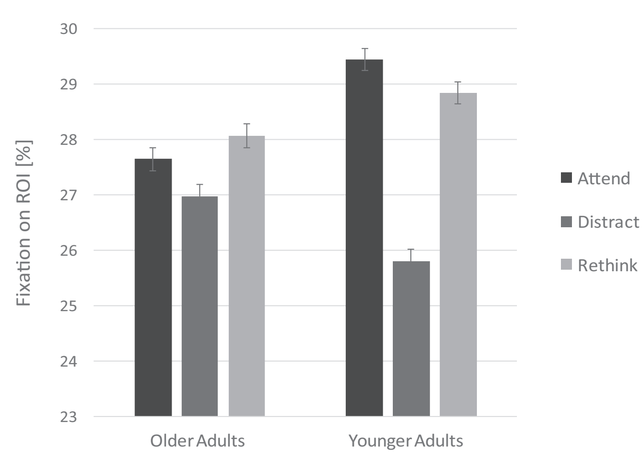

Figure 4. On-Region-of-Interest (ROI) fixation percentage across age and condition. Figure indicates average percentage of trial during each condition that participants spent gazing within the most emotionally salient coordinates within each image. Error bars indicate *SEM*.

tion regulation (Mather, 2012). Previous work shows that when induced into a negative mood, older adults tend to naturally look more at positive images and away from angry/sad faces, whereas younger adults focus attention on negative faces (Isaacowitz, Toner, Goren, & Wilson, 2008). Deeper processing of positive and disengagement from negative stimuli thus appear to serve an emotion regulatory function in later life.

While we focused this study on utilization of emotion regulation strategies, our findings have implications for emotion regulation choice. When allowed to select between distraction and reappraisal while viewing a slideshow of negative images, older adults prefer to distract as much as (Martins, Sheppes, Gross, & Mather, 2016) or more from negative stimuli than younger adults (Scheibe et al., 2015). Recent research from our lab also revealed that older men prefer to distract less (and reappraise more) when interacting with high intensity positive images than younger men (Martins et al., 2016). Taken together, this suggests that distraction represents a less global and more context-dependent strategy that largely depends on the valence of the situation encountered. Motivation, rather than global age-related changes, appear to play a big role in positivity, since when younger adults are instructed to prioritize their emotional experience while processing positive and negative information, they too demonstrate negativity avoidance and focus on the positive (Kennedy, Mather, & Carstensen, 2004; Wadlinger & Isaacowitz, 2008; Xing & Isaacowitz, 2006). For instance, when younger participants are primed to gaze more at positive images than neutral words in a discrimination task (a dot appeared consistently on the side of the screen with a positive word), they were more likely to look away from a subsequent slideshow of negative images than those trained to look at neutral words in the preceding task (Wadlinger & Isaacowitz, 2008). Thus, priming a positivity bias induces disengagement from negative information, and suggests that gaze preferences may represent a motivational bias in emotion regulation (Mather, 2012). Our findings fit with the expectations of *Socioemotional Selectivity Theory*, as reappraisal might be less automatic and more effortful for older adults to employ when regulating emotional reactions to negative images. In this study, we only utilized negative images, but future investigations could build on our findings and track whether reappraisal of positive stimuli is less cognitively effortful for older adults than distraction.

Another possibility is that distraction is less cognitively effortful for older adults in a more global sense, due greater working memory load during reappraisal use. Reappraisal requires keeping situation-specific reappraisals in mind and selecting an optimal interpretation, whereas the same distraction image can be used across situational contexts, at least theoretically suggestive that reappraisal may be more cognitively demanding than distraction (Sheppes & Levin, 2013). Working memory regions required for reappraisal use (Ochsner et al., 2012) decline in structural integrity across the life span (Raz, Gunning-Dixon, Head, Dupis, & Acker, 1998; Salat et al., 2002). Studies support that working memory is crucial to reappraisal use. For instance, Pe, Raes, and Kuppens (2013) found that participants with high working memory updating ability (based on an n-back task) had a negative relationship between self-reported daily reappraisal and negative affect, such that greater reappraisal use led to lower negative affect, but those low in updating ability did not show that relationship. Opitz, Lee, Gross, and Urry (2014) found that cognitive ability (working memory, perceptual reasoning, and processing speed) moderated reappraisal benefits across the life span (Opitz et al., 2014). These studies suggest that working memory ability is crucial to reappraisal processing. Scheibe, Sheppes, and Staudinger (2015) found that low working memory inhibitory performance led to increased preference for distraction over reappraisal during the regulation of negative emotion in older adults.

The Compensation-Related Utilization of Neural Circuits Hypothesis (CRUNCH) suggests older adults overrecruit brain regions relative to younger adults in order to compensate for aging declines in processing. At low levels of impairment, the model predicts that increased effort leads to maintained behavioral performance, and moderate levels of impairment compensatory efforts do not translate into behavioral gains, and at high levels compensation stops altogether and performance is low (Reuter-Lorenz & Cappell, 2008). Our findings revealed greater pupil response during reappraisal than distraction for older adults, but that self-reported strategy efficacy was equated across age. Thus, during reappraisal, trials with high effort by older adults may represent an ineffective attempt to compensate for declining working memory resources. However, the lack of significant age differences may reflect limited power because of sample size limitations, so we are cautious to not overinterpret these findings.

While it may be possible that older adults exert greater cognitive effort during use of reappraisal because of lower working memory ability in later-life, our current experiment did not track working memory ability or directly manipulate the load of working memory during distraction, so we cannot make direct claims for or against this possibility. Future studies could benefit from collecting a large sample of older adults with wide ranging working memory capacity (possibly including older adults with mild cognitive impairment), to directly track the relationship between cognitive effort during distraction use and working memory capacity. Another important area for investigation would be utilizing a working memory distraction task that incrementally manipulates working memory load on a trial basis (i.e., encoding digits, etc.). These manipulations would help clarify whether the motivational and/or working memory account best capture the findings from the current study.

It is important that our results support that older adults require more effort to engage with and reinterpret negative images, but that gaze differences did not fully explain this effect. Older adults did gaze less within negative images than younger adults, and all age groups looked at images more when passively viewing than when regulating their emotional reactions toward them. While gaze information explained significant variance in pupil responding, even when gaze was controlled for, older adults showed significantly greater pupil response for distraction than reappraisal. We thus replicate previous work demonstrating fewer fixations within images during reappraisal use than passive viewing for older adults (van Reekum et al., 2007), and our findings extend previous work, as older adults demonstrated less gaze on images during distraction use, and showed lower fixation rates compared with younger adults across both strategies.

Our ROI analyses replicate previous research demonstrating decreased gaze on emotional areas of images during instructed distraction use, as both age groups fixated less within the most emotional portions of the images they viewed during distraction strategy use. This aligns with previous work demonstrating that both older and younger adults show lower rates of visual fixation during instructed selective attention (Lohani & Isaacowitz, 2014), and decreased fixation rates for younger adults images during distraction than reappraisal of negative images (Strauss, Ossenfort, & Whearty, 2016). However, ROI gaze patterns did not significantly explain variance in pupil response. Thus, differences in cognitive effort cannot be explained by lower gaze within emotional regions during distraction compared with reappraisal.

We highlight several limitations of this study. First, our discussions of emotion regulation choice based on the current study are speculative, since we instructed participants on the strategies they utilized. While we investigated emotion regulation strategy use, we did not track participant preferences in emotion regulation strategy. Previous research demonstrates that regardless of age, participants choose to distract more when confronted with highly arousing stimuli (Martins et al., 2016; Scheibe et al., 2015; Sheppes et al., 2013; Sheppes, Scheibe, Suri, & Gross, 2011). However, it is not clear whether this is because of limited cognitive capacity to regulate in high intensity settings, or better efficacy regulating high intensity emotion via distraction strategies. Follow-up studies that track regulation strategy choice and both intensity ratings and effort could help disentangle these possible mechanisms.

Second, we utilized pupil response as a metric of cognitive effort in this study, and it is important to note that pupillometry is sensitive to light, arousal, and cognitive effort (Bradley, Miccoli, Escrig, & Lang, 2008; Steinhauer, Siegle, Condray, & Pless, 2004). Images were luminance corrected to one another, and background color was chosen based on the mean RGB values of the images in each study in order to minimize luminance differences across trials. Furthermore, all participants were run individually in the same experiment room, with the same ambient lighting, to keep luminance controlled. In addition, while we were able to equate image valence ratings across age, emotional arousal ratings were higher for older than for younger adults, as seen in previous age norms (Grühn & Scheibe, 2008). While we carefully corrected for these factors, we cannot be certain that these additional factors did not contribute to the reported effects. However, if differences across conditions were driven by arousal during the Emotion Regulation Task, we would expect the control (Attend) condition to show the greatest resulting pupil diameter, and our results showed greater pupil dilation during active strategies than attend for both age groups. Therefore, it is highly unlikely that these results are driven by differences in arousal rather than effort. Future explorations could aim to replicate our reported findings using other metrics of cognitive effort. Lower heart rate variability (HRV) tracks cognitive load in working memory tasks, as well as target detection difficulty in discrimination tasks (Aasman, Mulder, & Mulder, 1987; Jorna, 1992; Mulder & Mulder, 1981; Veltman & Gaillard, 1993). Assuming that the age-related interaction effect found in the pupil were replicated (and not sensitive to picture arousal during the Attend condition), an HRV follow-up would strengthen our interpretation that greater cognitive effort, and not arousal effects, drive age-related differences in regulation strategy use.

In addition, while we found limited differences across self-reported intensity and effort across strategies and age, participants were aware that the study was exploring emotion regulation, and may have reported decreased emotional intensity in the postregulation period because of demand characteristics. Previous work shows that older adults tend to portray themselves in a more socially positive manner than younger adults (Soubelet & Salthouse, 2011), and tend to make downward comparisons when evaluating their behavior (Hess & Blanchard-Fields, 1999). It is possible that older adults may have felt the need to downplay cognitive effort and/or overreport efficacy of the emotion strategies utilized. Thus, we cannot be certain that these self-reports of cognitive effort are accurate representations of what the participants actually experienced during the task. In addition, trial data was collapsed across trials for these analyses, and limited sample size may have limited our ability to statistically detect differences between conditions. Future studies with larger samples of subjects would help clarify whether our findings replicate with a more powered design.

Another limitation is that we utilized a more open-ended reappraisal instruction, which allowed participants to both increase positivity and/or decrease negativity of images. These two aspects of reappraisal have previously been linked to differential electrodermal responses during the regulation of negative emotion (McRae, Ciesielski, & Gross, 2012). In addition, we did not hold constant whether participants reframed the meaning of images in the present moment (the situation is less negative than it seems), or in the future (things will be okay in the end). It is unclear whether this source of heterogeneity may have impacted our results, and clarifying the cognitive effort involved in utilizing specific types reappraisal across the life span would be an important area for future studies to address. Based on their postquestionnaire self-reports, participants properly encoded the reappraisal and distraction strategy instructions. In terms of reappraisal, all participants reported utilizing situation-based reappraisals. However, many participants provided abstract responses (i.e., "I thought of how the picture was not as bad as it first seemed"), which could refer to enhancing an explicitly positive strategy, or enhancing positive or negative aspects of the situation with either focus on the present moment, or focus on how the outcome will be okay in the future. Given that older adults show a tendency to focus on more on present than future affective goals (Carstensen et al., 1999; Charles & Carstensen, 2008; Lang & Carstensen, 2002), it may be the case that differences in time perspective may affect cognitive effort. An important area of future research would be to contrast specific reappraisal tactics (positivising, present-focused situational change, future-focused situational change), and how they differ in terms of cognitive effort across age (McRae et al., 2012).

In contrast with previous research (Strauss et al., 2016), we found no differences between pupil responses during reappraisal and distraction for younger adults. This lack of replication could have resulted from greater power, since the previous study investigated a limited sample of 25 participants, and we had nearly double their sample size in our experiment. Another possibility is that the reappraisal instructions in the current study allowed participants to reappraise stimuli either by reinterpreting the image as more neutral or by focusing on how things would resolve in the future. The previous study instructed participants to utilize present-focused reappraisals, which may have led to increased task difficulty, and decreased flexibility in reappraisal generation. Thus, future studies should aim to clarify how reappraisal effort varies as a factor of differing reappraisal instructions.

Conclusion

Understanding whether effort drives emotion regulation preferences for distraction is a helpful step in clarifying how older adults can remain emotionally resilient. Our study supports that distraction is less cognitively effortful for older adults, even when gaze is controlled for. It may be the case that older adults are motivationally biased to disengage from negative information, and thus have greater difficulty engaging with and reappraising negative stimuli. On the other hand, it may be the case that preferences for older adults to engage in distraction strategies may be partially driven by management of decreased working memory resources in later life. An important area for future studies would be to confirm whether, as cognitive abilities decline with age, the success of emotion regulation strategies that depend on these resources must either be complemented by other resources (compensation), or used less frequently (SOC-ER; Opitz, Gross, & Urry, 2012a; Urry & Gross, 2010).

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