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Mobile Eye Tracking Reveals Little Evidence for Age Differences in Attentional Selection for Mood Regulation

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Abstract

We report two studies representing the first use of mobile eye tracking to study emotion regulation across adulthood. Past research on age differences in attentional deployment using stationary eye tracking has found older adults show relatively more positive looking, and seem to benefit more mood-wise from this looking pattern, compared to younger adults. However, these past studies have greatly constrained the stimuli participants can look at, despite real-world settings providing numerous possibilities for what to choose to look at. We therefore used mobile eye tracking to study age differences in attentional selection, as indicated by fixation patterns to stimuli of different valence freely chosen by the participant. In contrast to stationary eye tracking studies of attentional deployment, Study 1 showed that younger and older individuals generally selected similar proportions of valenced stimuli, and attentional selection had similar effects on mood across age groups. Study 2 replicated this pattern with an adult lifespan sample including middle-aged individuals. Emotion regulation-relevant attention may thus differ depending on whether stimuli are freely chosen or not.

Keywords

emotion regulation; attentional deployment; situation selection; mobile eye-tracking; aging

Older adults are thought to show “age-related positivity effects” in their attention and memory – specifically, preferential processing of positive over negative stimuli, motivated by their increased focus on emotional satisfaction goals (Carstensen, 2006). If such positivity effects, when observed, are a product of emotional goals, it makes sense to ask to what extent positivity effects relate to downstream emotion regulation (Isaacowitz &

Blanchard-Fields, 2012). Thus, there are two questions that can be asked about age differences in attention to emotional stimuli. First, are there age differences in the extent of preferences for positive over negative stimuli? Second, are there age differences in the extent to which those preferences predict downstream mood regulation? The second question can accordingly determine the extent to which age-related positivity effects represent emotion regulation strategies that become more or less effective with age (see also Urry & Gross, 2010).

Using stationary eye tracking, one line of research has focused on age differences in looking at emotional stimuli. This corresponds to the emotion regulation strategy of attentional deployment, in which a person directs attention toward or away from an emotion-eliciting stimulus (Gross, 1998). Consistent with age-related positivity effects, numerous studies have found age differences in preferences, such that older adults look less at negative and more at positive stimuli (see Isaacowitz, 2012; Nikitin & Freund, 2011).

Findings have been more mixed regarding whether age differences in positive looking patterns predict downstream mood regulation. Although older adults (but not younger adults) activate positive looking when in bad moods (Isaacowitz, Toner, Goren, & Wilson, 2008), such looking patterns predict successful mood regulation only for older adults with good executive control of attention. Thus, positive looking may be generally preferred by older adults, but may only help a subset of older adults to regulate their mood. In contrast, we have found that younger adults' moods tend to benefit from looking more at negative stimuli (Isaacowitz, 2012).

One problem with our past work on age differences in looking, and with most lab studies of emotion regulation, is that participants have little or no choice over what emotional stimuli they are exposed to. Our studies with stationary eye tracking have typically presented only one valenced stimulus to participants at a time, and assessed attentional deployment within the stimulus (for example, to more vs. less evocative parts). Other studies have presented two stimuli of varying valences and measure how participants direct their attention to one vs. the other (Isaacowitz, Wadlinger, Goren, & Wilson, 2006a; Knight et al., 2007; Mather & Carstensen, 2003). Though these paradigms may mimic some occasions of real-world emotion regulation in giving participants narrow choice between looking at one part of an image on a screen or another, they still constrain options for engagement. People often have more discretion about what they are exposed to. When watching TV or browsing the web, for example, they can choose the content they want to view, not just from what is present on the screen at one time, but from a much wider array of possible choices. When entering an environment (such as a restaurant or doctor's office waiting room), people can actively choose the features they wish to engage with. These aspects of choice are an important part of the way emotion regulation takes place in everyday, real-world settings, which cannot be investigated when the experimenter fully constrains choice to only what is present on a single screen.

Some have argued that older adults may prefer more proactive forms of emotion regulation, such as situation selection—choosing to enter or avoid a situation based on its potential to elicit emotions (Gross, 1998)—over other regulatory strategies. These proactive forms of

emotion regulation may prevent disruptive physiological arousal in older adults (Charles, 2010). In one study examining simple choices of affective stimuli, older and younger adults chose similar amounts of positive and negative material. Though there was no main effect of age on these valenced choices, age interacted with beliefs about emotion regulation, older adults with greater emotion regulation self-efficacy showed positivity effects in situation selection, whereas younger adults with high emotion regulation self-efficacy showed a more negative pattern (Rovenpor, Skogsberg, & Isaacowitz, 2013). This single previous study of situation selection differences by age therefore did not find strong evidence of simple age differences in affective choices. This study also did not include any measures of attention.

Questions remain about whether age-related positivity effects in attention exist when participants are given greater discretion over what they choose to look at, and whether these preferences are related to emotional experience. This process can be thought of as *attentional selection*: a blend of attentional deployment and situation selection, in which visual attention is used as a mechanism to select from various valenced stimuli. Critically, mobile eye tracking allows us to assess how attention is utilized to choose from an array of stimuli, and whether this attentional selection varies by age. Therefore, in the current study, we used mobile eye tracking to evaluate the extent to which younger and older adults looked at stimuli of different valences when able to move freely in the environment and given free reign over what to choose to look at. We also investigated the extent to which patterns of attentional selection were associated with better or worse moods, and whether this varied by age. This represents an important methodological as well as conceptual advance: To the extent that exercising choice over input of emotional stimuli changes the parameters of how attention is used for emotion regulation, this could necessitate major changes in how attentional deployment is conceptualized as a regulatory strategy across adulthood.

Hypotheses about main effects of age could be generated from past work, acknowledging that this paradigm is quite distinct from what has been done before: Freeing the stimuli from experimenter-driven constraints might fundamentally change the nature of age-related differences. In terms of preferences, past work on attentional deployment has found main effects of age (Isaacowitz et al., 2006; Knight et al., 2007; Mather & Carstensen, 2003), whereas work on situation selection has not (Rovenpor et al., 2013). If attentional selection is similar to attentional deployment, we would expect older adults to select to look at relatively more positive than negative stimuli. If attentional selection is instead more similar to situation selection, we would expect age similarity in what material is selected for fixation. The question of emotion regulation effectiveness is much more open (Isaacowitz & Blanchard-Fields, 2012), though any age differences that emerged were expected to be in the direction of positive attentional selection being relatively more beneficial for older adults.

Study 1

Method

Participants—Participants were included in analyses if their gaze fixation was tracked for 75% or more of the time¹. The final sample consisted of thirty-five younger adults (ages 17-23, $M_{age} = 19.15$, 57% female; 6% Hispanic, 12% African American, 39% Asian/Asian American, 46% Caucasian) and 34 older adults (ages 60-91, $M_{age} = 72.27$, 59% female; 6%

Hispanic, 7% African American, 90% Caucasian). Younger adults were recruited from Introductory to Psychology courses at Northeastern University and were compensated with credit toward a psychology course, and older adults were recruited from the Boston community and were compensated \$10/hour. Younger ($M=3.67$, $SD=.99$) and older ($M=3.58$, $SD=.89$) adults did not differ on self-reported health, $t(62)=-.37$, $p=.72$. Younger adults ($M=23.24$, $SD=9.26$) had a higher depression score than older adults ($M=16.58$, $SD=7.09$), $t(62)=3.22$, $p=.002$, as measured by the CES-D scale (Radloff, 1977). All older participants passed the Mini-Mental State Exam (Newkirk et al., 2004), which was administered by phone during recruitment.

Stimuli & Measures—The “affective environment” is a medium-sized room with a desk containing three computer screens presenting videos and articles, and wall hangings varying in affective valence. Following Rovenpor et al. (2013), the affective environment included a greater proportion of negative stimuli (5 videos, 5 websites, 4 wall pictures) compared to positive and neutral stimuli (2 videos, 2 websites, 2 wall pictures each of positive and neutral). This was meant to represent the greater representation of negative information in real-world media (e.g., news programs) and to provide an adequate amount of potentially emotion-eliciting material to choose from. A full list of stimuli can be found in Appendix A.

Stimuli were chosen from a set that had been rated by younger ($N=11$, $M_{age} = 23.55$, $SD = 3.64$) and older ($N=9$, $M_{age} = 71.33$, $SD=5.47$) adults. Both thumbnails and stimuli were rated on valence and arousal. To test age and valence differences, 2 (age) $\times$ 3 (valence) mixed ANOVAs were conducted. Negative thumbnails and stimuli were rated as significantly lower in valence than neutral, and positive thumbnails and stimuli were rated as significantly higher in valence than neutral. Both negative and positive thumbnails and stimuli were rated as more arousing than neutral stimuli. For thumbnails (but not stimuli), negative items were rated as more arousing than positive ones. Collapsing across valence, older adults rated thumbnails as more positive ($p=.02$) and less relevant ($p=.002$), but no different in arousal, than younger adults. They rated stimuli as more positive ($p=.03$), but no different in arousal, than younger adults. The age difference in valence was qualified by an age $\times$ valence interaction: Older adults rated neutral stimuli ($M=6.37$, $SD=.70$) as more positive in valence than younger adults ($M=5.30$, $SD=.46$), $t(18)=-4.15$, $p=.001$, but did not differ on positive or negative. Full descriptive and inferential statistics can be found in online supplemental material.

Eye movements were recorded at a temporal resolution of 30 Hz and an accuracy of 0.5-1.0° visual angle using an ASL (Applied Science Laboratories, Bedford, MA) MobileEye XG eye-tracker. Fixations were defined as holding a point of gaze for 100 ms each. LookZones (LZs, labeled as positive, negative, and neutral) were drawn around the computer screens and wall hangings, and were mapped onto a video file of the affective environment using ASL Results+ software. Because LookZones were drawn on the computer screens, time spent in LookZones thus included both selection time (time spent viewing menus) as well as time spent interacting with stimuli². Analyses were conducted using the percentage of time

¹Ninety-four participants were originally recruited for this study. Due to technical problems related to eye tracking and/or the mood rating process, 25 participants did not have sufficient data to include in analyses (10 YA, 15 OA).

participants fixated on positive, negative, and neutral LookZones, as well as outside of all LookZones.

Self-report mood ratings, on a scale from 0 (completely unpleasant) to 100 (completely pleasant), were collected every 3 minutes on paper. The 15-minute eye tracking files were parsed into 3 minute intervals, each corresponding to one mood rating, and fixation percentages were computed within each interval.

Procedure—Participants were told, “Once we have the eye-tracking device ready, you will be in this room alone for 15 minutes. There is a selection of materials that you will be able to interact with. There are websites on the computers that contain video clips and news articles. There are also pictures on the wall that you can look at. All of the pictures on the wall are real and from news stories, and all of the website news clips and news articles are real as well. During the 15 minutes you have in the room you will have the freedom to choose from any of these materials in whatever order you want, and for however long you want.”

Participants then entered the affective environment with the researcher. In order to familiarize them with the procedure, they were given time to practice navigating an example website menu to ensure adequate computer-use ability. As they practiced, the researcher gave them additional instructions about how to navigate articles and videos, and answered any questions.

Participants were then fitted with the eye tracking glasses and their gaze was calibrated with the mobile eye tracker for points on all three computers. Participants then rated their mood, which served as a baseline mood rating. The experimenter briefly reminded the participant of the instructions and left the room for 15 minutes.

Analyses—Within participants, each 3-minute interval was associated with separate percentages of time spent looking at negative, neutral, and positive material, as well as percentage of time fixating outside of LookZones. Separate percentages for time spent looking at videos, articles, and wall hangings were also calculated. Mood was reported at the end of each interval. All fixation statistics are reported as percentages. Seventy-nine blocks were excluded due to problems with eye data (35 were missing eye data, 6 had problems calculating fixation, and 38 recorded 0% fixations inside of LZs; remaining blocks = 266). Mood ratings were missing from 9 of the remaining blocks. Partial data were used when available.

Multi-level modeling using restricted maximum likelihood estimation was conducted using HLM 7 (Raudenbush, Bryk, & Congdon, 2013) to analyze relationships between age, fixation, and mood. Mood and fixation were treated as continuous Level 1 variables. When fixation percentages were used as predictors, they were entered grand-mean-centered. To improve estimation, all continuous predictors were initially modeled as random, and non-significant random effects ($p > .10$) were dropped from the model. Age group was entered

²Although participants had not yet chosen a specific item, the material viewed during selection time matched the valence of the screen, so they were looking at negative, neutral, or positive content.

uncentered as a fixed Level 2 variable, with 1=YA and 0=OA. In follow-up analyses, baseline mood was entered as a grand-mean centered covariate. Descriptive statistics are presented in Table 1. Complete multi-level models can be found in Appendix B. Non-multilevel analyses were conducted using SPSS 19.

Results

Overall fixation—A repeated-measures ANOVA showed that fixations varied by valence of material, $F(3,198)=8.65, p<.001$. Participants spent the least amount of time viewing negative material ($M=16.59, SD=15.15$), compared to positive ($M=24.30, SD=16.25$), $t(66)=-2.43, p=.005$, and neutral ($M=24.95, SD=17.29$), $t(66)=-1.87, p=.01$, which did not differ, $t(66)=.19, p=.85$. People spent more time looking outside of LookZones compared to other material ($M=34.29, SD=20.67$), $p's < .02$. When age was added to the ANOVA model, the effect of age was not significant, $F(1,65)=.13, p=.72$, and there was no age $\times$ valence interaction, $F(3,195)=1.74, p=.16$.

Are There Age differences in Attentional Selection?—We examined whether time spent looking at negative, neutral, and positive material (attentional selection), as well as whether time spent looking outside of LookZones, differed by age. Estimates of fixed effects of multi-level models are presented in Table 2. Younger and older adults did not differ in negative fixation, ($\gamma = 3.78, SE=3.51$), $t(264)=1.08, p=.28$, in neutral fixation, ($\gamma=-3.50, SE=3.61$), $t(264)=-.97, p=.33$, in positive fixation, ($\gamma=4.95, SE=3.65$), $t(264)=1.36, p=.18$, or in time spent looking outside of LookZones, ($\gamma = -6.34, SE=5.06$), $t(65)=-1.25, p=.22$ (see Figure 1).

Are There Age Differences in the Extent to Which Attentional Selection Predicts Mood?—First, we examined whether there were overall age differences in mood. An independent t-test showed that younger ($M=67.73, SD=18.00$) and older ($M=74.29, SD=21.09$) participants did not differ in baseline mood, $t(62)=-1.34, p=.19$. In MLM analyses, younger and older adults did not differ in mood across the five blocks ($\gamma = -5.03, SE=4.77$), $t(63)=-1.05, p=.30$. Thus, age was not related to mood during the 15 minutes participants were in the affective environment. When baseline mood was entered to predict mood ratings over the 15 minutes, it was significantly related ($\gamma = .62, SE=.11$), $t(62)=5.82, p<.001$, and age was not ($\gamma=-2.10, SE=3.89$), $t(62)=-.54, p=.59$.

Next, we examined whether fixation predicted mood, examining each valence separately. Fixation in negative LZs was associated with more negative mood ($\gamma=-.26, SE=.06$), $t(64)=-4.35, p<.001$. Fixation in positive LZs was associated with more positive mood ($\gamma = .20, SE=.05$), $t(64)=4.42, p<.001$. Fixation in neutral LZs was related to more positive mood ($\gamma = .08, SE=.04$), $t(189)=2.28, p=.02$. When controlling for baseline mood, negative ($p<.001$), neutral ($p=.008$), and positive ($p<.001$), fixation remained significant. Baseline mood was significant in all cases ($p's < .001$); and did not interact with fixation ($p's > .55$).

We then examined whether age and attentional selection interacted to predict mood (see Figure 2). The main effect of age was not significant in any of the four analyses ($p's > .16$). The main effects of positive fixation ($\gamma=.21, SE=.07$), $t(63)=2.89, p=.005$, negative fixation

($\gamma = -.21$, $SE = .10$), $t(63) = -2.08$, $p = .04$, and neutral fixation ($\gamma = .13$, $SE = .06$), $t(188) = 2.31$, $p = .02$), remained significant. The age $\times$ fixation interactions were not significant for negative fixation ($\gamma = -.09$, $SE = .12$), $t(63) = -.73$, $p = .47$, neutral fixation ($\gamma = -.10$, $SE = .07$), $t(188) = -1.32$, $p = .19$, positive fixation ($\gamma = -.004$, $SE = .07$), $t(63) = -.05$, $p = .96$. These effects remained the same when controlling for baseline mood.

Analysis by Media Type—There was no age difference in fixation to pictures, $p = .57$ or websites, $p = .13$. Older people spent less time fixating on videos than younger adults, ($\gamma = -.12$, $SE = .04$), $t(166) = -2.06$, $p = .044$. When controlling for media type, the valence fixation results reported above did not change: There were no significant age differences in fixation to valenced stimuli.

Greater fixation on pictures was associated with better mood ($\gamma = .20$, $SE = .08$), $t(166) = 2.40$, $p = .02$, as was greater fixation on videos ($\gamma = .11$, $SE = .04$), $t(166) = 3.03$, $p = .003$. Greater fixation on websites was associated with lower mood ($\gamma = -.12$, $SE = .04$), $t(165) = -2.97$, $p = .003$. When controlling for media type (all entered simultaneously), fixation to positive and negative material remained significantly related to mood (p 's $< .001$), though fixation to neutral material was no longer significantly related to mood ($p = .17$). In all cases, media type predictors were not significant (p 's $> .27$). This suggests that it is valence, rather than media type, that is driving effects on mood.

Discussion

Study 1 revealed an age-related pattern quite different than what is generally found in the study of attentional deployment. Whereas studies of attentional deployment tend to find older adults displaying a more positive looking pattern (Isaacowitz, 2012), age differences disappeared when participants could more actively choose what stimuli they looked at. Moreover, whereas positive looking patterns have been found to predict better moods for older but not younger adults (Isaacowitz, 2012), giving participants a more active role in choosing the stimuli they were exposed to revealed no age differences in looking-mood relationships. In both age groups, selecting positive stimuli led to better moods, and selecting negative stimuli led to worse moods. These findings suggest that attentional selection may not show age differences, thus calling into question the generality of age differences in emotion regulation strategies when looking to more complex contexts that contain an array of potentially emotion-eliciting material.

Though the findings of this first mobile eye tracking study of aging and attentional selection are suggestive, there are nonetheless some limitations with this initial study. First, the location of valenced stimuli on screens was not counterbalanced and stimuli were presented in the same order for every participant. Despite the lack of counterbalancing, almost all ($n = 66$) participants made selections from all three monitors, suggesting that the majority of participants from both age groups used the full range of choices. Nonetheless, this was an issue that we could address in a follow-up. Second, the first study used only an extreme age design. Although this is a common practice in the study of adult development and aging, it is advantageous to consider middle-aged individuals as well (Freund & Isaacowitz, 2013), especially given recent findings suggesting that middle-aged individuals may show

positivity effects in stationary eye tracking of similar magnitude to older adults (Isaacowitz & Harris, in press). Third, a number of blocks were excluded because of problems with eye tracking reliability. Because use of mobile tracking to assess attentional selection is new, it is important to replicate the findings. Therefore, Study 2 replicated the basic design of Study 1, but also included middle-aged participants and counterbalanced the valence of the three screens in the AE.

Study 2

Method

Participants—Participants were included in analyses if their gaze was tracked for at least 75% of the time³. The final sample consisted of 20 younger adults (ages 18-25, $M_{age}=20.00$, 70% female; 5% Hispanic, 45% Asian/Asian American, 15% African American, 40% Caucasian), 21 middle-aged adults (ages 35-59, $M_{age} = 48.40$, 52% female; 5% American Indian, 28% African American, 62% Caucasian), and 21 older adults (ages 60-88, $M_{age} = 69.48$, 56% female; 100% Caucasian). Younger adults were recruited from introduction to psychology courses at Northeastern University, and middle-aged and older adults were recruited from the Boston community through newspaper ads and Craigslist ads. The three age groups did not differ on self-reported health ($M_{YA}=3.85$, $SD=.67$; $M_{MA}=3.90$, $SD=.83$; $M_{OA}=3.67$, $SD=1.03$), $F(2,56)=.41$, $p=.67$. They also did not differ in depression as measured by the CES-D ($M_{YA}=20.65$, $SD=8.20$; $M_{MA}=16.76$, $SD=1.60$; $M_{OA}=16.50$, $SD=6.37$), $F(2,56)=1.96$, $p=.15$. All older participants passed the Mini-Mental State Exam (Newkirk et al., 2004), which was administered by phone during recruitment.

Stimuli, Measures, and Procedure—The same Affective Environment room, stimuli, measures, and procedures were used in order to effectively replicate Study 1. In order to eliminate potential issues of location effects, the three computer screens were counterbalanced in valence across participants. The images on the wall remained in the same position for each participant.

Analyses—Within participants, each 3-minute interval was associated with one mood rating and separate percentages for time spent looking at negative, neutral, and positive material, as well as for time spent looking outside of all LookZones. Separate percentages for time spent looking at videos, articles, and wall hangings were also calculated. Twenty-two blocks were excluded due to problems with eye data (9 were missing eye data, 13 had problems calculating fixation, 3 had 0% fixation within LookZones; remaining blocks=286). Mood ratings were missing from 24 of the remaining blocks. Partial data were used when available.

Treatment of fixation and mood data in multi-level modeling analyses were the same as for Study 1. In these analyses, OAs served as the reference group and were coded as 0; separate dummy codes were entered for YAs and MAs. Descriptive statistics are presented in Table 3. Complete multi-level models can be found in Appendix B.

³A total of 91 participants were recruited for this study. Due to technical problems related to eye tracking and/or the mood rating process, 29 participants did not have sufficient data to include in analyses (13 YA, 9 MA, 7 OA).

Results

Overall fixation—Fixation varied by valence, $F(3, 183)=14.36, p<.001$. People spent the most time viewing positive ($M=30.29, SD=18.80$) and negative ($M=36.24, SD=21.81$), which did not differ, $t(62)=1.31, p=.19$, but were significantly higher than neutral ($M=19.62, SD=17.34$), p 's $< .005$. Percent fixating outside of LookZones ($M=13.92, SD=13.83$) was marginally less than percent viewing neutral material, $t(62)=1.83, p=.07$. When age was added to the ANOVA model, the effect of age was not significant, $F(1,59)=.12, p=.89$, and there was no age $\times$ valence interaction, $F(3,177)=1.07, p=.16$.

Are There Age Differences in Attentional Selection?—Estimated fixed effects in multilevel modeling analysis are presented in Table 4. We examined whether time spent looking at negative, neutral, and positive material, and time spent looking outside of LZs, differed by age (see Figure 3). Consistent with Study 1, there were no differences between YAs and OAs in negative fixations ($\gamma = 2.23, SE=6.51$), $t(59)=.34, p=.73$, neutral fixations ($\gamma = 6.64, SE=4.19$), $t(59)=1.58, p=.12$, or positive fixations ($\gamma = -1.30, SE=5.88$), $t(59)=-.22, p=.83$. In this study, older adults fixated more outside of LZs ($\gamma = -7.85, SE=3.01$), $t(59)=-2.38, p=.02$. MAs and OAs did not differ in fixations in negative ($\gamma = -5.73, SE=6.57$), $t(59)=-.87, p=.39$, positive ($\gamma = -3.87, SE=5.80$), $t(59)=-.67, p=.51$, or outside areas ($\gamma = -1.24, SE=4.65$), $t(59)=-.27, p=.79$. Middle-aged adults did, however, fixate more in neutral LZs than OAs ($\gamma = 10.24, SE=5.10$), $t(59)=2.01, p=.049$.

Are There Age Differences in the Extent to Which Attentional Selection Predicts Mood?—First, we examined whether there were age differences in mood. A one-way ANOVA showed that there was a significant age difference in baseline mood, $F(2,57)=4.79, p=.01$. Contrasts showed that older adults ($M=85.90, SD=17.51$) had a significantly higher baseline mood than younger adults ($M=66.40, SD=19.15$), $t(57)=-3.08, p=.003$, and a marginally higher baseline mood than middle-aged adults ($M=74.70, SD=22.94$), $t(57)=-1.77, p=.08$.

As in Study 1, over the course of the 15 minutes, there were no age differences in mood. OAs did not differ from YAs ($\gamma = -7.05, SE=5.94$), $t(58)=-1.19, p=.24$, or from MAs ($\gamma = 5.16, SE=5.92$), $t(58)=.87, p=.39$. When baseline mood was entered into the model, it was significantly related to mood over the course of the 15 minutes ($\gamma = .52, SE=.10$), $t(55)=5.14, p<.001$. Controlling for baseline mood, there were no significant differences between OAs and either YAs ($p=.95$) or MAs ($p=.21$).

Next, we examined whether attentional selection predicted mood, examining each valence separately. As in Study 1, fixation in negative LZs was associated with lower mood ($\gamma = -.30, SE=.04$), $t(60)=-7.42, p<.001$, fixation in positive LZs was associated with better mood ($\gamma = .22, SE=.04$), $t(60)=5.37, p<.001$, and fixation in neutral LZs was associated with better mood ($\gamma = .14, SE=.05$), $t(60)=-3.16, p=.002$. The same pattern was found when baseline mood was entered into the models.

We then examined whether age and attentional selection interacted to predict mood (see Figure 4). There were no age differences in any of the analyses (YAs vs. OAs, p 's $> .16$, MAs vs. OAs, p 's $> .29$). Fixation in negative and in positive LZs were significantly related

to mood (p 's $< .001$), but fixation in neutral LZs was no longer related to mood, ($\gamma = .12$, $SE = .11$), $t(58) = 1.13$, $p = .26$). None of the interactions between age and fixation were significant (p 's $> .17$). This pattern remained the same when controlling for baseline mood.

Analysis by Media Type—Younger and middle-aged participants did not differ from older adults in fixation to pictures (p 's $> .10$). Both younger adults ($\gamma = 24.47$, $SE = 6.85$, $t = 3.57$, $p < .001$) and middle-aged adults ($\gamma = 13.64$, $SE = 6.74$, $t = 2.02$, $p = .048$) spent significantly more time fixating on videos than older adults. Younger adults ($\gamma = -13.82$, $SE = 6.70$) fixated less on websites than older adults, $t(59) = -2.06$, $p = .04$, but middle-aged ($\gamma = -7.05$, $SE = 6.59$) and older adults did not differ, $t(59) = -1.07$, $p = .29$. When controlling for media type, the valence fixation results reported above did not change: The only significant age difference in fixation was between middle-aged and older adults in neutral fixation.

Fixating on pictures was not related to mood ($\gamma = -.28$, $SE = .18$), $t(60) = -1.54$, $p = .13$, nor was fixating on websites ($\gamma = -.06$, $SE = .05$), $t(60) = -1.39$, $p = .17$. Fixating on videos was marginally related to more positive mood ($\gamma = .09$, $SE = .05$), $t(60) = 1.84$, $p = .07$. When controlling for fixation on videos, the valence results above did not change: Fixation to positive, neutral, and negative areas continued to be related to mood (p 's $> .02$). Fixation to videos became non-significant when controlling for neutral and negative fixations, suggesting that valence is driving the effect of fixation on mood, rather than stimulus type. When both fixation to positive and fixation to videos were entered to predict mood, both were significant, suggesting independent effects.

Discussion

Study 2 was designed to replicate the findings of age-similarity in attentional selection from Study 1, while also addressing some methodological limitations of Study 1, such as the lack of middle-aged individuals and the lack of counterbalancing of choice stimuli. Study 2 therefore included middle-aged individuals and fully counterbalanced the distribution of valence choices in the three screen choices across participants. Findings largely replicated those of Study 1. No age differences emerged in positive or negative attentional selections, and no age differences emerged in how these selections predicted subsequent mood. Middle-aged individuals attended somewhat more to neutral stimuli and had somewhat better moods, but the overall pattern of age similarity seemed generally maintained.

General Discussion

Using mobile eye tracking, two studies investigated age differences in attentional selection of positive, negative, and neutral stimuli, as well as age differences in the extent to which attentional selection was related to mood. Previous studies of attentional deployment using stationary eye tracking had consistently found that older adults look more at positive and less at negative stimuli, and that these more positive fixation patterns predict better mood, at least for older adults with good attentional functioning (see Isaacowitz, 2012 for a summary). Younger adults often seem to benefit mood-wise from engaging more with negative stimuli. Stationary eye tracking studies that show more positive looking patterns in older adults have been interpreted as reflecting “age-related positivity effects” in attention. Findings that such positive looking patterns predict better mood for some older people is

broadly consistent with the premise that age-related positivity effects reflect emotional goals (Reed & Carstensen, 2012). Thus, stationary eye tracking provides evidence concerning preferences and adaptiveness of age-related positive looking, at least when stimuli are experimentally controlled.

Mobile eye tracking told a different story about aging and fixation to emotional stimuli, and how such fixation relates to mood in real-time. Here, across two studies, the pattern was one of no significant age differences. Though the specific pattern of fixation varied across studies (participants looked least at negative in Study 1, but most at positive and negative in Study 2), the age groups did not differ in these patterns. In Study 1, younger and older adults generally selected to fixate similarly on positive and negative options. Participants in both age groups seemed to avoid negative material, but this may be because of the location of the computer containing that material. In Study 2, when valence order was counterbalanced, all three age groups showed similar patterns that were also consistent with the age-similarity in choices reported by Rovenpor et al. (2013).

Moreover, there were also no age differences in how attentional selection was related to mood. Individuals of all age groups who fixated on more positive stimuli reported better moods in that interval, whereas individuals of all age groups who fixated more on negative stimuli reported worse moods in that interval. When given greater choice about what to interact with, then, positive looking does not discriminate by age; adults across a wide range of ages show similar patterns of looking, and these patterns are related in similar ways to subsequent moods.

There are related methodological and conceptual reasons why the pattern of age effects may differ between stationary and mobile eye tracking. Conceptually, age-related positivity effects may not characterize attentional patterns in cases where individuals have discretion over their environment. Studies of attentional deployment using stationary tracking assess fixation to one stream of valenced stimuli. Attentional deployment is assumed to take place when an individual looks more at mood-enhancing or less at mood-threatening stimuli. In the current study of attentional selection using mobile tracking, we assessed fixation directed at stimuli selected by the participant; attentional selection is assumed to take place when an individual chooses to look at positive rather than negative stimuli. Having the ability to choose from a multitude of various stimuli, as we often can do in everyday life, apparently changes the parameters of emotion regulation-relevant attentional patterns. This suggests limitations to the usual paradigm of studying emotion regulation with only one stream of valenced information; the way individuals behave when confronted with the more realistic situation of a choice of many stimuli may not mimic how they behave when the experimenter has made that selection for them.

Additionally, the more proactive nature of attentional selection (vs. attentional deployment) may allow older adults with weaker attentional control abilities to manage their moods (see also Charles, 2010; Urry & Gross, 2010). We have found in previous studies that older adults with poorer executive control of attention may display positivity effects in their fixation in stationary eye tracking (a “preference”) but do not show any mood regulation benefit for doing so (no “effectiveness”: see Isaacowitz, 2012). It may be that older adults

who are not able to benefit from shifting attention within stimuli that are not freely chosen are actually able to benefit from shifting attention among stimuli that are freely chosen.

One possible alternative explanation for the lack of age differences is that the affective environment is a new situation that encourages people of all ages to adopt information-gathering goals. Part of the rationale for the design of the affective environment is that participants are introduced to an environment that has the potential to elicit emotions. An important question is how they interact with that environment. Even within a novel situation, there was the possibility that people would have different emotional or non-emotional goals. In line with theorized age-related positivity effects, older adults may seek out positive information and avoid negative situation, whereas younger adults may seek out salient (e.g., any emotional) information. The findings here suggest that when exposed to a new environment that has the potential to elicit emotions, younger, middle-aged, and older adults engage with that environment in similar ways.

A related critique is that older adults may have been experiencing greater anxiety due to the computer-administrated nature of the task, compared to younger and middle-aged adults, and this may have influenced their choices. The mobile eye tracking and choice procedures were new to all age groups, though all were given the chance to acclimate to the equipment before proceeding with the task. Moreover, there was no evidence that older adults were experiencing greater anxiety; in Study 1, there were no age differences in baseline mood, and in Study 2, older adults reported more positive moods before beginning the task.

We must make two important caveats regarding this research. First, we cannot definitively infer that attentional selection caused changes in mood, given the correlational nature of the data. Future research could possibly rule out the influence of extraneous variables when examining age differences (or similarity) by manipulating gaze patterns and testing their effects on mood across different age groups. In the current research, we did establish covariation as well as the temporal precedence of fixation before mood, in a more naturalistic setting by allowing participants to direct their attention toward stimuli of their own choosing.

Second, the results here revealed a lack of age differences in gaze patterns, and a lack of age differences in how gaze patterns affect mood, when stimuli are freely chosen from an array of possibilities. This finding, replicated across two studies, represents a departure from past research using more fixed stimuli that have found age differences, and is therefore of interest. Finding no age differences, however, is not the same as finding age equivalence, and therefore additional research is needed to make a stronger claim.

This work represents a first step toward the wider use of mobile eye tracking to study emotion regulation across the adult lifespan. A key limitation of both studies is that current analyses also do not consider fixations within a selected stimulus, though this will be possible with software currently under development. In other words, we cannot currently distinguish attentional selection from specific attentional deployment within the selected target. So, for example, younger and older adults may choose to fixate broadly on valenced stimuli, but they may then proceed to fixate on different parts, or clips, of the selected

stimuli. This possibility will need to be tested once more nuanced analysis of fixations is technologically possible.

Another limitation is that the current results cannot determine whether differences between stationary and mobile eye tracking emerge because participants *have choices* in mobile tracking, or because of *the nature of the choices* made in mobile eye tracking. In other words, it may be the case either that the differences arise from the specific choices made or from the general fact of having a choice. We are currently running a follow-up study in which participants watch the selections made by an age-matched peer to evaluate their effects in the absence of choice. This is especially relevant given the large literature on the importance of perceived control in the aging process (e.g., Lachman, 2006).

Even given these limitations, the study of attentional selection with mobile eye tracking has the potential to give quite new and different perspectives on age similarities in emotion regulation in environments that may better approximate real-world regulation than have existing lab paradigms. Already, it suggests that the nature of the context influences whether age groups do or do not differ in how they interact with material varying in valence.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Appendix

Appendix A

Affective Environment Stimuli

	Positive Content	Neutral Content	Negative Content
Videos	Funny news clips Making a difference	The importance of vitamin D Medical shoe phone	Marines killed in Iraq Special report on domestic violence Oklahoma city bombing: 15 years later Mexico's drug war Oil spill wildlife devastation
Websites	Hearts and souls: A heart- warming story American love stories: So close, yet so far away	MBTA maps and schedules Campus map	Holocaust: Stories of sadness Aftermath of Gulf oil spill Devastation of earthquake in Haiti Violence in Iraq Remembering the horror of Hurricane Katrina
Wall Pictures	Still in love after 80 years Radical kindness: Banker gives away all of his money	Japanese man calculates pi to 5 trillion digits on homemade computer Kazakhstan: Home of the apple	Serial "slasher" gets more than 400 years in prison Acid attack leaves woman scarred UN officials say 500 were victims of Congo rapes Ohio man held his family hostage, raped own child

Appendix B: Multilevel Equations

Study 1

Age Differences in Fixation

$$\begin{aligned} (1) - (4) \quad \text{Fixation} &= \beta_{0j} + r_{ij} \\ \beta_{0j} &= \gamma_{00} + \gamma_{01} (Y A_j) + u_{0j} \end{aligned}$$

Age Differences in Mood

$$\begin{aligned} (5) \quad \text{Mood} &= \beta_{0j} + r_{ij} \\ \beta_{0j} &= \gamma_{00} + \gamma_{01} (Y A_j) + u_{0j} \end{aligned}$$

Main Effect of Fixation on Mood

$$\begin{aligned} (6) - (8) \quad \text{Mood} &= \beta_{0j} + \beta_{1j} (\text{Fixation}_j) + r_{ij} \\ \beta_{0j} &= \gamma_{00} + u_{0j} \\ \beta_{1j} &= \gamma_{10} + u_{1j} \end{aligned}$$

Age × Fixation Interaction Effects on Mood

$$\begin{aligned} (9) - (11) \quad \text{Mood} &= \beta_{0j} + \beta_{1j} (\text{Fixation}_j) + r_{ij} \\ \beta_{0j} &= \gamma_{00} + \gamma_{01} (Y A_j) + u_{0j} \\ \beta_{1j} &= \gamma_{10} + \gamma_{11} (Y A_j) + u_{1j} \end{aligned}$$

Study 2

Age Differences in Fixation

$$\begin{aligned} (1) - (4) \quad \text{Fixation} &= \beta_{0j} + r_{ij} \\ \beta_{0j} &= \gamma_{00} + \gamma_{01} (Y A_j) + \gamma_{02} (M A_j) + u_{0j} \end{aligned}$$

Age Differences in Mood

$$\begin{aligned} (5) \quad \text{Mood} &= \beta_{0j} + r_{ij} \\ \beta_{0j} &= \gamma_{00} + \gamma_{01} (Y A_j) + \gamma_{02} (M A_j) + u_{0j} \end{aligned}$$

Main Effect of Fixation on Mood

$$\begin{aligned} (6) - (8) \quad \text{Mood} &= \beta_{0j} + \beta_{1j} (\text{Fixation}_j) + r_{ij} \\ \beta_{0j} &= \gamma_{00} + u_{0j} \\ \beta_{1j} &= \gamma_{10} + u_{1j} \end{aligned}$$

Age × Fixation Interaction Effects on Mood

$$\begin{aligned}
 (9) - (11) \quad \text{Mood} &= \beta_{0j} + \beta_{1j} (\text{Fixation}_j) + r_{ij} \\
 \beta_{0j} &= \gamma_{00} + \gamma_{01} (Y A_j) + \gamma_{02} (M A_j) + u_{0j} \\
 \beta_{1j} &= \gamma_{10} + \gamma_{11} (Y A_j) + \gamma_{12} (M A_j) + u_{1j}
 \end{aligned}$$

Note. Fixation was modeled separately for negative, neutral, positive, and outside fixations. Nonsignificant error terms ($p > .10$) were dropped from models.

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Figure 1.
Mean fixation of younger and older adults in LookZones.

Figure 2. Relationship between mood and fixation in negative, neutral, and positive LookZones for younger and older adults. Estimated values are plotted at 1 SD below (Less) and above (More) the grand mean of fixation for each valence.

Figure 3.
Mean fixation of younger, middle-aged, and older adults in LookZones * $p < .05$.

Figure 4. Relationship between mood and fixation in negative, neutral, and positive LookZones for younger, middle-aged, and older adults. Estimated values are plotted at 1 SD below (Less) and above (More) the grand mean of fixation for each valence.

Table 1

Descriptive Statistics, Study 1

Variable	N	M	SD	Min.	Max.
Level 1					
Negative Fixation	266	17.21	27.89	0.00	98.81
Neutral Fixation	266	24.64	29.73	0.00	99.79
Positive Fixation	266	24.77	32.46	0.00	100.00
Fixation Outside LookZones	266	33.52	31.82	0.00	99.77
Mood	255	64.57	25.21	0.00	100.00
Level 2					
Baseline Mood	65	70.89	20.00	30.00	100.00

Table 2

Fixed Effects in Multi-Level Modeling, Study 1

Eq.	Fixed Effect	Coefficient (SE)	t(df)	p
Dependent Variable: Percent Fixation in Negative LookZones				
(1)	Intercept γ_{00}	15.25 (1.94)	7.86 (264)	<.001
	YA γ_{01}	3.78 (3.51)	1.08 (264)	.282
Dependent Variable: Percent Fixation in Neutral LookZones				
(2)	Intercept γ_{00}	26.45 (2.63)	10.07 (264)	<.001
	YA γ_{01}	-3.50 (3.61)	-.97 (264)	.333
Dependent Variable: Percent Fixation in Positive LookZones				
(3)	Intercept γ_{00}	22.20 (2.20)	10.11 (264)	<.001
	YA γ_{01}	4.95 (3.65)	1.36 (264)	.176
Dependent Variable: Percent Fixation Outside of LookZones				
(4)	Intercept γ_{00}	37.14 (3.26)	11.41 (65)	<.001
	YA γ_{01}	-6.34 (5.06)	-1.25 (65)	.215
Dependent Variable: Mood				
(5)	Intercept γ_{00}	68.25 (4.10)	16.66 (63)	<.001
	YA γ_{01}	-5.03 (4.77)	-1.05 (63)	.296
(6)	Intercept γ_{00}	65.43 (2.34)	27.90 (64)	<.001
	Negative Fix. γ_{10}	-.26 (.06)	-4.35 (64)	<.001
(7)	Intercept γ_{00}	65.57 (2.34)	27.99 (64)	<.001
	Neutral Fix. γ_{10}	.08 (.04)	2.28 (189)	.024
(8)	Intercept γ_{00}	65.81 (2.35)	28.00 (64)	<.001
	Positive Fix. γ_{10}	.20 (.05)	4.42 (64)	<.001
(9)	Intercept γ_{00}	67.95 (4.04)	16.80 (63)	<.001
	YA γ_{01}	-4.73 (4.78)	-.99 (63)	.326
	Negative Fix. γ_{10}	-.21 (.10)	-2.08 (63)	.041
	YA $\times$ Negative Fix. γ_{11}	-.09 (.12)	-.73 (63)	.469
(10)	Intercept γ_{00}	67.93 (4.06)	16.74 (63)	<.001
	YA γ_{01}	-4.69 (4.74)	-.99 (63)	.326
	Neutral Fix. γ_{10}	.13 (.06)	2.31 (188)	.022
	YA $\times$ Neutral Fix. γ_{11}	-.10 (.07)	-1.32 (188)	.189
(11)	Intercept γ_{00}	69.32 (3.95)	17.54 (63)	<.001
	YA γ_{01}	-6.67 (4.70)	-1.42 (63)	.161
	Pos. Fix. γ_{10}	.21 (.07)	2.89 (63)	.005
	YA $\times$ Positive Fix. γ_{11}	-.00 (.09)	-.05 (63)	.957

Notes. Eq. = Equation; Fix. = Fixation. Young adults (YAs) were coded as 1 and older adults (OAs) were coded as 0. When entered as predictors, fixation variables were entered grand mean-centered. Age was entered uncentered.

Table 3

Descriptive Statistics, Study 2

Variable	N	M	SD	Min.	Max.
Level 1					
Negative Fixation	285	35.87	37.90	0.00	100.00
Neutral Fixation	285	19.90	31.14	0.00	100.00
Positive Fixation	285	30.90	36.91	0.00	100.00
Fixation Outside Lookzones	285	13.39	17.60	0.00	91.83
Mood	261	64.21	27.19	0.00	100.00
Level 2					
Baseline Mood	60	75.67	21.24	25.00	100.00

Table 4

Fixed Effects in Multi-Level Modeling, Study 2

Eq.	Fixed Effect	Coefficient (SE)	t(df)	p
Dependent Variable: Percent Fixation in Negative LookZones				
(1)	Intercept γ_{00}	37.28 (4.18)	8.92 (59)	<.001
	YA γ_{01}	2.23 (6.51)	.34 (59)	.733
	MA γ_{02}	-5.73 (6.57)	-.87 (59)	.387
Dependent Variable: Percent Fixation in Neutral LookZones				
(2)	Intercept γ_{00}	14.17 (1.98)	7.15 (59)	<.001
	YA γ_{01}	6.64 (4.19)	1.58 (59)	.119
	MA γ_{02}	10.24 (5.10)	2.01 (59)	.049
Dependent Variable: Percent Fixation in Positive LookZones				
(3)	Intercept γ_{00}	32.53 (4.20)	7.74 (59)	<.001
	YA γ_{01}	-1.30 (5.88)	-.22 (59)	.826
	MA γ_{02}	-3.87 (5.80)	-.67 (59)	.507
Dependent Variable: Percent Fixation Outside of LookZones				
(4)	Intercept γ_{00}	16.73 (2.91)	5.75 (59)	<.001
	YA γ_{01}	-7.85 (3.01)	-2.38 (59)	.021
	MA γ_{02}	-1.24 (4.65)	-.27 (59)	.791
Dependent Variable: Mood				
(5)	Intercept γ_{00}	64.23 (4.23)	15.18 (58)	<.001
	YA γ_{01}	-7.05 (6.11)	-1.15 (58)	.253
	MA γ_{02}	5.16 (6.05)	.85 (58)	.397
(6)	Intercept γ_{00}	63.91 (2.38)	27.89 (60)	<.001
	Negative Fix. γ_{10}	-.30 (.04)	-7.42 (60)	<.001
(7)	Intercept γ_{00}	63.59 (2.47)	25.69 (60)	<.001
	Neutral Fix. γ_{10}	.14 (.05)	3.16 (60)	.002
(8)	Intercept γ_{00}	64.13 (2.50)	25.64 (60)	<.001
	Positive Fix. γ_{10}	.22 (.04)	5.37 (60)	<.001
(9)	Intercept γ_{00}	65.12 (3.81)	17.09 (58)	<.001
	YA γ_{01}	-6.65 (5.67)	-1.17 (58)	.246
	MA γ_{02}	2.46 (5.66)	.44 (58)	.665
	Negative Fix. γ_{10}	-.32 (.07)	-4.60 (58)	<.001
	YA*Negative Fix. γ_{11}	.06 (.10)	.57 (58)	.573
	MA*Negative Fix. γ_{12}	.01 (.10)	.05 (58)	.959
(10)	Intercept γ_{00}	65.02 (4.11)	15.82 (58)	<.001
	YA γ_{01}	-8.11 (5.83)	-1.39 (58)	.169
	MA γ_{02}	3.29 (6.00)	.55 (58)	.586
	Neutral Fix. γ_{10}	.12 (.11)	1.13 (58)	.262

Eq.	Fixed Effect	Coefficient (SE)	t(df)	p
	YA*Neutral Fix. γ_{11}	.01 (.14)	.07 (58)	.944
	MA*Neutral Fix. γ_{12}	.05 (.12)	.42 (58)	.679
(11)	Intercept γ_{00}	64.19 (4.17)	15.40 (58)	<.001
	YA γ_{01}	-6.61 (5.91)	-1.12 (58)	.268
	MA γ_{02}	6.15 (5.79)	1.06 (58)	.293
	Positive Fix. γ_{10}	.25 (.07)	3.46 (58)	.001
	YA*Positive Fix. γ_{11}	-.06 (.10)	-.60 (58)	.550
	MA*Positive Fix. γ_{12}	-.05 (.10)	-.53 (58)	.602

Notes. Eq. = Equation; Fix. = Fixation. Age Group was dummy coded such that in D1, YA=1 and in D2, MA=1, with OA=0 in all cases. When entered as predictors, fixation variables were entered grand mean-centered. Age was entered uncentered.