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The limited roles of cognitive capabilities and future time perspective in contributing to positivity effects

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Abstract

When compared to younger adults, older adults tend to favor positive over negative information in attention and memory. This is known as the *positivity effect.* Although this is a robust phenomenon, there is still debate about how it relates to individual differences in cognitive capabilities and future time perspective (FTP). To address this, we investigated how measures of fluid cognitive capabilities and FTP related to positivity effects within the domains of episodic memory, visual attention, and autobiographical memory. Cognitive capabilities were assessed using the National Institute of Health Toolbox Cognition battery, and included assessments of executive function, working memory, episodic memory, and processing speed. FTP was assessed via the Carstensen and Lang (1996) scale. Within our final sample (N = 196), we replicated positivity effects in all three task domains, which were all driven by age differences in how people responded to negative (but not positive) information. However, there was limited evidence that the magnitude of these age-related reductions in negativity varied as a function of individual differences in older adults' cognitive capabilities or FTP. Furthermore, when FTP did emerge as a predictor, the pattern was not in line with expectations based upon socioemotional selectivity theory. Thus, the positivity effect may be less reliant on cognitive capabilities and self-reported FTP than is often assumed. Given that there was also very little consistency in the extent to which participants displayed positivity effects across the task domains, these results also raise the possibility that there may be multiple mechanisms underlying positivity effects.

Key words: aging, emotional valence, executive function, fluid cognition, individual differences, future time perspective

1. Introduction

When compared to younger adults (YAs), older adults (OAs) tend to focus relatively less on negative information and/ or relatively more on positive information (e.g., Charles, Mather, & Carstensen, 2003; Kennedy, Mather, & Carstensen, 2004). This is known as the age-related *positivity effect* (for reviews, see Carstensen & DeLiema, 2018; Mather & Carstensen, 2005; Reed & Carstensen, 2012). Although some studies have failed to replicate this phenomenon (e.g., Comblain, D'Argembeau, Van der Linden, Aldenhoff, 2004; Fung, Isaacowitz, Lu, Wadlinger, Goren, & Wilson, 2008; Grühn, Smith, & Baltes, 2005; Leclerc & Kensinger, 2008; Kensinger, Brierley, Medford, Growdon, & Corkin, 2002), a meta-analysis of 100 empirical studies found that it reliably occurs when participants' information processing is unconstrained (see Reed, Chan, & Mikels, 2014). However, there is still debate about the positivity effect's underlying mechanisms. Is it a purposeful outcome associated with successful aging that requires high cognitive capabilities to achieve? Or is it an unintended consequence of age-related cognitive declines? To further evaluate this, this study examined the relationships between various aspects of fluid cognitive capabilities and positivity effects in multiple domains.

1.1 The positivity effect is related to future time perspective

The positivity effect is typically explained by drawing upon socioemotional selectivity theory (SST), which is a lifespan theory of motivation (Carstensen, 1992, 2006). According to SST, goals are always set in time-based contexts. Because chronological age tends to correlate with perceptions of time (Lewin, 1939; see also Cate & John, 2007; Kotter-Grühn & Smith, 2011; Lang & Carstensen, 2002), this results in age-differences in goal hierarchies. YAs are theorized to perceive time as expansive; they should therefore prioritize future-oriented goals, such as exploration and learning new information. In contrast, OAs are theorized to perceive time as limited; they should therefore strive to maximize their current emotional well-being and avoid wasting time on unpleasant or unfulfilling pursuits. Consistent with this, when people are asked to imagine a limited time horizon, they report more emotional-meaningfulness-related goals (Chu, Grühn, & Holland, 2018).

1.2 The positivity effect requires high cognitive capabilities

One way that emotional well-being could be maximized is by preferentially attending to, and remembering positive over negative information, and hence displaying a positivity effect (see Reed & Carstensen, 2012). However, because this is thought to involve motivated goal-pursuit, accomplishing this task is often theorized to require executive control and working memory resources (Kryla-Lighthall & Mather, 2009; Mather & Carstensen, 2005; Mather & Knight, 2005). According to this cognitive control model of the positivity effect, older adults whose cognitive control capabilities are lowest, and who therefore have more difficulty carrying out goal-directed behavior, should show the smallest positivity effects.

This prediction is echoed in the strength and vulnerability integration (SAVI) model of well-being across adulthood (Charles, 2010; see also Charles & Luong, 2013). Building upon SST, the SAVI model posits that even though perceptions of time plays a key role in motivating people to pursue positive and/or avoid negative affective experiences, having this goal does not necessarily mean that it will be achievable. This instead depends upon the extent to which OAs have experienced age-related strengths (such as increased emotion regulation skills) and age-related weaknesses (such as physiological and cognitive declines). Of relevance to this study, the SAVI model proposes that OAs' ability to pursue positive and/or avoid negative emotions depends upon their cognitive capabilities. As age-related cognitive declines increase, the likelihood of observing the positivity effect should decrease.

Supporting these predictions, some studies have found that the positivity effect is greater amongst participants with high levels of cognitive control. In episodic memory recall, one study found that the positivity effect was greater amongst participants with above-average composite cognition scores (Mather & Knight, 2005), and in another it was greater amongst older-old adults with lower Stroop performance interference (Sakaki, Raw, Findlay, & Thottam, 2019). Likewise, another study found greater visual attention towards positive information for OAs who were better able to flexibly exert top-down control during a singleton distraction paradigm (Sasse, Gamer, Büchel, & Brassen, 2014). These behavioral results are supported by neuroimaging findings. For example, amongst OAs, those whose memory recognition performance was relatively higher for positive than negative information also had greater coupling between the amygdala and medial prefrontal cortex, which suggests a greater involvement of higher order cognitive processes (Sakaki, Nga, & Mather, 2013). Furthermore, other evidence shows that the positivity effect is larger amongst healthy OAs as compared to those with diagnosed cognitive impairments (Fleming, Kim, Doo, Maguire, & Potkin, 2003; Sava, Krolak-Salmon, Delphin-Combe, Cloarec, & Chainay, 2017). For example, in one study, the positivity effect in delayed recall test was present for healthy OAs (aged 65-78) and very-old OAs (aged 79-94), but was absent in OAs with Alzheimer's disease (Kalenzaga, Lamidey, Ergis, Clarys, & Piolino, 2016).

Further support for the conclusion that the positivity effect requires cognitive control comes from studies that have used divided attention manipulations as a means of decreasing participants' available cognitive resources to perform the task. In these studies, the positivity effect has often been eliminated when attention has been divided. This has been true in episodic memory recall (Mather & Knight, 2005; Exp 3; see also Joubert, Davidson, & Chainay, 2018;

Mantantzis, Maylor, & Schlaghecken, 2018) and also in attention (Kennedy, Huang, & Mather, 2019; Knight, Seymour, Gaunt, Baker, Nesmith, & Mather, 2007).

1.3 The positivity effect is a byproduct of low cognitive capabilities

Although the positivity effect is typically explained through the lens of socioemotional selectivity theory, one alternate account comes from dynamic integration theory (Labouvie-Vief, 2003, 2009; Labouvie-Vief, Diehl, Jain, & Zhang, 2007; Labouvie-Vief & Medler, 2002). This theory posits that people have two modes of processing emotional information: affect optimization and affect complexity. Affect optimization reflects an emphasis on promoting well-being by increasing positive affect and/or by decreasing negative affect. In contrast, affect complexity reflects an emphasis on personal growth, in which people elaborate upon, and amplify, affect. Ideally, these two modes of processing are dynamically integrated. However, affect complexity is thought to be a resource demanding process that involves processing and creating complex representations of emotions that may be contradictory in valence. Because of this, people with low cognitive capabilities should be less able to use affect complexity, and should instead default to affect optimization (as it is less cognitively demanding). Given that affect optimization involves increasing positive affect and/or decreasing negative affect, dynamic integration theory therefore predicts that positivity in attention and memory should be greatest for people with *low* cognitive capabilities. Because of age-related cognitive declines (see Salthouse, 2010), when comparing YAs and OAs this results in an age-related positivity effect. However, within each age group, dynamic integration theory also proposes that individuals with relatively lower cognitive capabilities should show greater positivity than those with higher cognitive capabilities.

In contrast to the studies reviewed earlier, there is also research supporting the hypothesis that positivity effects are most likely to occur for those with low cognitive capabilities. For example, Bohn, Kwong See, and Fung (2016) found that the relative positivity in recall and recognition was greater for people with probable Alzheimer's disease than it was for healthy OAs. Similar conclusions have also been reported by Leal, Noche, Murray, and Yassa (2016), who found that positivity in memory performance was limited to OAs with subclinical levels of memory impairment. In addition, other research with both YAs and OAs has shown that slower response times are associated with more positive valence ratings (Neta & Tong, 2006) and divided attention manipulations can sometimes increase the positivity of OAs' attributions (Zebrowitz, Boshyan, Ward, Gutchess, & Hadjikhani, 2017). Likewise, amongst OAs, those with higher cognitive abilities actually show stronger negativity biases in their neural responses (Foster, Davis, & Kisley, 2013).

1.4 Overview of the current study

The primary goal of this study was to further test whether individual differences in cognitive capabilities modulate the magnitude of the positivity effect. Although prior studies have yielded mixed results, this could be because of methodological issues. For example, Bohn et al (2016) operationalized the positivity effect as the number of positive images recalled divided by the total number of pictures recalled. Although composite indices of the positivity effect are often used (e.g., Barber et al., 2016; Löckenhoff & Carstensen, 2007), this approach may overestimate the magnitude of the positivity effect amongst people with AD (who on average recalled only a single item). Composite indices of positivity are also problematic when they are only assessed in OA participants (e.g., Leal, et al., 2016; Petrican, Moscovitch, & Schimmack, 2008). These studies delineate factors affecting OAs' relative propensity to focus on positive versus negative information. However, because these same relationships might also emerge for YAs, conclusions about how these factors relate to the age-related positivity effect (i.e., an age X valence interaction) are tenuous.

An additional issue in previous studies examining the link between cognitive capabilities and the positivity effect is that sample sizes in past studies have often been small. This issue has been pervasive in psychology and is not limited to research on this topic (see Button, Ioannidis, Mokrysz, Nosek, Flint, Robinson, & Munafò, 2013; Marszalek, Barber, Kohlhart, & Cooper, 2011). However, low statistical power can lead to both false negative and false positive results.

More generally, an additional limitation of prior studies is that the positivity effect has generally not been tested in multiple domains simultaneously and the measures of cognitive capabilities used in prior studies have been idiosyncratic. Because of this, it is unclear how distinct aspects of cognitive abilities are linked to positivity effects, and whether this varies across positivity effect task domains. To address these limitations, the current study recruited a large sample of community-dwelling YA and OA participants and investigated the role of cognitive capabilities in contributing to the positivity effect across the domains of episodic memory recall, visual attention preferences, and autobiographical memory. We also used a battery of standardized tasks to assess executive function, working memory, episodic memory, and processing speed. We examined how positivity effects related to individual differences in each these cognitive abilities and also to a composite measure of fluid cognitive abilities. This approach sheds light onto whether positivity effects are related to certain components of fluid cognition but not others, and whether these relationships vary across task domains.

1.5 Secondary Aim: Evaluating the role of future time perspective (FTP)

As a second aim we also considered the role of future time perspective (FTP) in contributing to positivity effects. As previously noted, the positivity effect is most frequently interpreted through the lens of SST (Carstensen, 2006). According to this view, OAs tend to have a limited FTP, which leads them to pursue positive emotional goals, and hence display positivity effects (see Reed & Carstensen, 2012). Thus, FTP rather than chronological age is proposed to be the mechanism underlying age-related positivity effects. Consistent with this, positivity effects in decision making are related to self-reported FTP (Löckenhoff & Carstensen, 2007), and experimental manipulations of FTP can affect the magnitude of positivity effects in a variety of task domains (e.g., Barber et al., 2016; Cypryańska et al., 2014; Fung & Carstensen, 2003; Kellough & Knight, 2012; see also DeWall & Baumeister, 2007; Neta, Tong, & Henley, 2018; Strough, Parker, & Bruine de Bruin, 2019). However, there have also been findings that have failed to support this account. Some prior studies have found no significant relationship between self-reported FTP and positivity effects (e.g., Bohn et al., 2016; Kalokerinos, von Hippel, Henry, & Trivers, 2014; Kan, Garrison, Drummey, Emmert, & Rogers, 2018), and experimental manipulations of FTP have not always altered the magnitude of the positivity effect (Demeyer & De Raedt, 2013; 2014).

One potential reason for these mixed results comes from the SAVI model of well-being across adulthood (Charles, 2010; Charles & Luong, 2013). According to this theory, as people get older their FTP becomes more limited. Although this motivates OAs to pursue positive and/or avoid negative information, their ability to do this depends upon their cognitive capabilities; the link between FTP and positivity effects should therefore be reduced as age-related cognitive declines increase. To test this, in the current study we examined whether OAs’

FTP related to their propensity to focus on positive versus negative information in each task, and also tested whether this link depended upon the OAs' cognitive capabilities.

2. Method

2.1 Power Analyses

In a prior meta-analysis, the positivity effect had an average effect size of d = .482 when processing was unconstrained (Reed et al., 2014). A power analysis conducted in GPower 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) determined that a sample of at least 36 participants would provide 80% power to replicate this age by valence interaction in each task domain (given f = .241, an alpha of .05, and a correlation of .50 between the repeated measures).

However, our primary aims were to examine whether the positivity effect relates to cognitive capabilities or to OAs' FTP. As described in the Results below, we evaluated this by testing for interactions between age group, valence, and cognitive capabilities. Within the sample of OAs we also tested for interactions between valence, FTP, and cognitive capabilities. Significant interactions were further explored by evaluating correlations between cognitive capabilities, FTP, and performance in each age group. An additional power analysis showed that a sample size of at least 84 participants in each age group would provide us with 80% power to observe medium-sized correlations of .30 or larger (when using an alpha of .05). To account for potential data exclusions, we aimed to recruit a sample of at least 100 OAs and 100 YAs.

2.2 Participants

Participants were 104 OAs who ranged in age from 59 to 85 and 102 YAs who ranged in age from 18 to 34. The OAs were recruited from a database of individuals who had previously expressed interest in volunteering for research studies related to aging issues and also from advertisements at a senior living facility. The YAs were students at San Francisco State

University (SFSU). OAs received payment of $40 (USD) for their participation. YAs had the option of receiving cash payment or credit towards their psychology course requirements. To ensure that participants had a broad range of cognitive capabilities, our only inclusion criteria were age, English-language fluency, normal or corrected-to-normal color vision, and no diagnosed cognitive impairment at the time of testing. All study procedures were approved by the Institutional Review Board at SFSU. See Table 1 for additional participant characteristics as a function of age.

2.3 Stimuli and Tasks

2.3.1 Emotional Picture Memory Task. Stimuli for this task were 90 images from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001). Of these, 80 were critical items and 10 were neutral buffer items to control for primacy and recency effects during the recall test. Of the 80 critical images, 40 were positive and 40 were negative in valence, as defined by the IAPS norms.[1] The positive and negative images did not significantly differ from one another in normative arousal ratings. Within each valence category, half of the images were social (i.e., featured people), and half were not (i.e., did not contain people).

During the task, participants were shown all 90 images in the same randomized order, for 5 seconds each. Prior to viewing them, participants were instructed to look at them as if they were watching television. Immediately afterwards, participants were given a surprise free recall test. As in prior positivity effect studies (e.g., Barber et al., 2016; Barber, Seliger, Yeh, & Tan, 2019; Bohn et al., 2016; Mather & Knight, 2005; Kalokerinos et al., 2014; Kwon, Scheibe,

[1] IAPS numbers for the positive images: 1610, 1441, 1440, 5779, 5220, 5982, 7350, 7480, 1630, 1410, 2091, 2260, 2000, 2550, 2540, 2650, 8120, 1340, 1659, 2055.2, 5260, 7270, 8501, 8170, 7451, 1650, 5450, 5700, 7650, 7405, 5460, 5621, 5629, 4626, 8180, 8300, 8370, 8470, 8490, 4640
IAPS numbers for the negative images: 1280, 9395, 9101, 9290, 1275, 9280, 9561, 9000, 9471, 9830, 2490, 2590, 2750, 3300, 9584, 2205, 9415, 2455, 6010, 2276, 9600, 9909, 1300, 1050, 1202, 1931, 9623, 9300, 9187, 9911, 9414, 2661, 2345.1, 9423, 9810, 9921, 6550, 2717, 6250, 9403
IAPS numbers for neutral buffer images: 7035, 7080, 7010, 7052, 7002, 7055, 7211, 7012, 7006, 7950

Samanez-Larkin, Tsai, & Carstensen, 2009) they were asked to write brief descriptions of each recalled image. Participants received up to 15 minutes to complete this task. Free recall was self-paced and completion times were recorded. An image was scored as correctly recalled if the participant provided a description that a coder could clearly match to one of the studied images. To ensure reliability of these ratings, this was repeated by a second coder for a randomly selected set of 20 YA and 20 OA participants. There was over 93% agreement between the two coders. For recall scores as a function of age group and image valence, see Table 2.

2.3.2 Dot-Probe Attention Task. This dot-probe task was previously used by Mather and Carstensen (2003). The critical stimuli for this task consisted of 30 pairs of photographs of faces. Within each pair, one photograph depicted a target person with a neutral facial expression and the other depicted the same target person with an emotional facial expression: 10 posed to be happy, 10 posed to be sad, and 10 posed to be angry.[2] Half of the faces were of males and half were of females.

During the dot-probe task, each trial began with a center fixation point for 500 ms followed by one of the photograph pairs, with faces displayed on the left and right side of the screen for 1,000 ms. After this, a small gray dot appeared on either the left or right, centered in the location of one of the previously displayed faces. Participants were instructed to respond as quickly and accurately to the location of this dot. The dot remained on the screen until the participant made a response. In total, participants responded to 120 critical trials. Each of the 30 pairs of photographs was shown 4 times. This allowed for full counterbalancing of the side of the

[2] We included both sad and angry faces as prior studies have yielded contradictory conclusions about whether OAs' tendency to look away from negative faces is limited to angry expressions (e.g., Isaacowitz, Wadlinger, Goren, & Wilson, 2006; Orgeta, 2011), or also occurs for sad expressions (e.g., Mather & Carstensen, 2003). In addition, some studies have found that age differences during this task are limited to the negative faces (e.g., Orgeta, 2011; Steenhaut, Demeyer, Rossi, & De Raedt, 2019), but others have also found age differences in response to the positive faces (e.g., Isaacowitz et al., 2006; see also Mather & Carstensen, 2003).

screen that depicted the emotional face and the location of the dot relative to the face version. For response times as a function of age group and face valence, see Table 2.

2.3.3 Autobiographical Memory (AM) Task. Stimuli for this task consisted of 8 positive words (*angel, abundance, brave, charm, confident, lucky, merry, mountain*) and 8 negative words (*hungry, lonely, mistake, nervous, panic, tense, upset, weary*) from the Affective Norms for English Words database (ANEW; Bradley & Lang, 1999). In pilot test data from Durbin, Barber, Brown, and Mather (2019) there was no significant differences in how YAs and OAs perceived the self-relevance or age-stereotypicality of these words.

AMs were elicited using a cue-word technique (see Crovitz & Schiffman, 1974). Participants saw the cue words one at a time in a random order, and were asked to generate an AM in response to each. They were instructed that the AM did not have to be important or interesting and that it could come from any point in time. However, the memory did have to be specific, meaning it occurred at a particular place and time. The memory could last several hours or minutes, but no more than a day. Participants received one minute to view the cue word and write a brief description of their generated AM. We later coded for participants' success rates in generating AMs as a function of the cue's valence. When participants generated an AM then rated the valence of that memory on a scale of 1 (very negative) to 7 (very positive) and estimated the date the memory occurred. Internal consistency of these ratings was acceptable (Cronbach's alpha = .73). For valence ratings as a function of age group, see Table 2.

2.3.4 Tasks Assessing Cognitive Capabilities. Individual differences in cognitive capabilities were assessed using the National Institute of Health (NIH) Toolbox Cognition Battery (http://www.nihtoolbox.com). This is a collection of seven neuropsychological test instruments assessing the cognitive subdomains of working memory, episodic memory, processing speed, executive function, and language. In this study, we focused on the first four of these, as they each represent an aspect of fluid cognitive capabilities.

Within this assessment battery, working memory abilities are assessed via performance on the List Sorting Working Memory Test. Episodic memory abilities are assessed via performance on the Picture Sequence Memory Test. Processing speed is assessed via performance on the Pattern Comparison Processing Speed Test. Executive function is assessed via performance on two measures: (1) the Dimensional Change Card Sort Test, which measures the set-shifting component of executive function, and (2) the Flanker Inhibitory Control and Attention Test, which measures the ability to inhibit visual attention to irrelevant aspects of the task. We used the average performance on these two tests as our executive function measure.

The test instruments were administered on an iPad and took approximately 30 to 45 minutes to complete. The majority of the instruments are adaptive in nature, such that they get harder when participants make correct responses. In addition to providing scores on each instruments, the NIH Toolbox Cognition Battery also provides composite scores reflecting crystallized and fluid cognitive capabilities. Age-adjusted scores are presented in Table 3 as a function of age group. These scores are calculated by comparing each participant's performance to those in the NIH nationally-representative norming sample within the same age-band. These scores have a normative mean of 100 and a standard deviation of 15 (e.g., scores of 115 or 85 indicate scores 1 *SD* above and 1 *SD* below the national average of similarly-aged individuals). Although age-adjusted scores are used in all analyses, we present unadjusted scale scores in Table 3 to document age-differences in overall levels of cognitive functioning. For additional details about these assessments, see Weintraub et al. (2013) and Heaton, et al. (2014).

2.4 Procedure

Participants completed an online survey followed by an in-person study session. Implied consent was obtained prior to completing the online questionnaires. Written informed consent was obtained prior to completing the in-person study session. The online survey consisted of a series of questionnaires administered through Qualtrics, and included the 36-item Health Survey (Hays, Sherbourne, & Mazel, 1993) and the 10-item Carstensen and Lang (1996) Future Time Perspective (FTP) Scale. Five OA and four YA participants did not complete this online survey. For the comprehensive list of items included in the online survey, see Appendix A.

Participants later completed an in-person study session either at SFSU or in their own homes, which lasted approximately 1.5 to 2 hours. At the beginning of this session, participants completed the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988) and the 15-item Geriatric Depression Scale (GDS-15; Sheikh & Yesavage, 1986). Participants were also asked to provide a saliva sample for genotype analyses and their resting blood pressure was recorded. However, these measures will not be discussed further. Participants next completed three tasks designed to assess for positivity effects. First they completed the emotional picture memory task. This task was always administered first in order to increase the likelihood that encoding was incidental (see Reed et al., 2014), which we reasoned may be less likely if it was preceded by other cognitive assessments. This was followed by the dot-probe attention task and the AM task. Participants then received a break before completing the NIH Toolbox Cognition Battery. At the end of the session, they were thanked and debriefed.

3. Results

Ten participants were removed from these analyses. During the emotional picture memory task, one OA did not recall any pictures. During the dot-probe task, data did not properly record for one YA and two OAs. One OA did not complete the AM task. One YA and four OAs did not complete the full set of NIH Toolbox Cognition Battery instruments. This left a final sample size of 196 participants in the following analyses. Within these analyses we used an alpha of .05 and report effect sizes for significant findings.

3.1 Age Group Differences in Health, Mood, and Depression

YAs and OAs differed in terms of health, current mood, and levels of depression. Independent *t* test analyses showed that compared to the OAs, the YAs self-reported significantly higher physical functioning, $t(186) = 2.10$, $p = .038$, $d = .31$, but significantly lower general health, $t(186) = -2.66$, $p = .009$, $d = .39$, social functioning, $t(186) = -6.18$, $p < .001$, $d = .90$, and emotional well-being, $t(186) = -6.89$, $p < .001$, $d = 1.01$. YAs also had significantly lower positive mood scores, $t(194) = -4.63$, $p < .001$, $d = .66$, significantly higher negative mood scores, $t(194) = 4.40$, $p < .001$, $d = .63$, and significantly higher depression scores, $t(194) = 4.74$, $p < .001$, $d = .68$. In fact, 25% of the YAs scored above a cutoff of 5 on the GDS-15 measure of depression (see D'Ath, Katona, Mullan, Evans, & Katona, 1994; Marc, Raue, & Bruce, 2008) compared to only 7% of the OAs. To ensure that age group differences in depression were not artificially leading to positivity effects, in all subsequent analyses depression scores are included as a covariate.[3]

3.2 Replicating Positivity Effects

3.2.1 The Positivity Effect vs. Age-Related Positivity Biases. The *positivity effect* occurs when there is a relative difference between YAs and OAs in the processing of positive as opposed to negative information (see Reed & Carstensen, 2012). This is operationalized as a

[3] In exploratory analyses, we also tested whether depression scores moderated the magnitude of observed positivity effects. To do so, we repeated the analyses described in Section 3.2 and included the interaction between age group and depression scores as a covariate. Doing so did not alter any of the reported results and there was no evidence that the magnitude of the observed positivity effects varied based upon depression scores (i.e., all *ps* $\geq .072$ for the three-way interactions between depression scores, age group, and picture valence).

significant interaction between age group (YA vs. OA) and information valence (positive versus negative) for attention and memory outcomes. We tested for this interaction in each task. In addition, during the AM test, participants rated the valence of their AM memories. We also tested for an age-related *positivity bias* during this AM task. This was operationalized as a main effect of age group, such that OAs were expected to rate their generated AMs as being relatively more positive as compared to YAs (e.g., Gallo, Korthauer, McDonough, Teshale, & Johnson, 2011; Rubin & Schulkind, 1997).

3.2.2 Emotional Picture Memory Task. We conducted a 2 (Age Group: YA vs. OA) X 2 (Picture Valence: Negative vs. Positive) General Linear Model (GLM) on the number of critical pictures recalled (buffer pictures were excluded). In addition to depression scores, we also included recall time as a covariate.[4] Within this analysis, there was a significant main effect of age group, $F(1, 192) = 7.45$, $p = .007$, $\eta_p^2 = .04$, and a significant interaction between age group and picture valence, $F(1, 192) = 12.23$, $p = .001$, $\eta_p^2 = .06$ (see Table 2). This interaction is indicative of a positivity effect.

We next examined whether this interaction was driven by age-related declines in memory for negative pictures, age-related improvements in memory for positive pictures, or both. To do so, we conducted follow-up single factor (Age Group) GLMs on the number of pictures recalled from each valence category. Results showed that OAs recalled significantly fewer negative pictures than did YAs, $F(1, 192) = 15.45$, $p < .001$, $\eta_p^2 = .07$ (adjusted *M*s: YAs = 9.95, OAs = 9.65). In contrast, there was no significant main effect of age group for the recall of positive pictures, $F(1, 192) = 0.24$, $p = .876$ (adjusted *M*s: YAs = 6.10, OAs = 7.69).

[4] YAs spent significantly less time completing the free recall test (*M* = 5 min 55 s) than did the OAs (*M* = 8 min 38 s). Due to experimenter error completion times were not recorded for four participants; we imputed the average recall time from other participants in their age group for analyses.

3.2.3 Dot-Probe Attention Task. A positivity effect during the dot probe task would be evidenced by an interaction in response time (RT) between age group and face valence. Before testing for this, we removed RTs associated with incorrect responses, RTs faster than 200 ms, and responses more than three standard deviations faster or slower than each participant's own average RT. We then conducted a 2 (Age Group: YA vs. OA) X 2 (Face Valence: Negative (sad or angry) vs Positive) GLM on log-transformed RTs with depression scores as a covariate. Within this analysis, there was a significant main effect of age group, $F(1, 193) = 96.52$, $p < .001$, $\eta_p^2 = .33$, which reflected the fact that YAs had faster RTs than OAs. There was also a significant interaction between age group and face valence, $F(1, 193) = 6.62$, $p = .011$, $\eta_p^2 = .03$ (see Table 2), which is indicative of a positivity effect.

To determine whether this pattern reflected age differences in attention away from negative faces or towards positive faces, we conducted follow-up analyses for the sad-neutral, angry-neutral, and happy-neutral face pairs. Looking first at the sad-neutral face pairs, a follow-up 2 (Face Valence) X 2 (Age Group) GLM on log-transformed RTs with depression scores as a covariate showed a significant main effect of age group, $F(1, 193) = 95.74$, $p < .001$, $\eta_p^2 = .33$, and a significant interaction between age group and face valence, $F(1, 193) = 5.29$, $p = .023$, $\eta_p^2 = .03$. Within the sad-neutral face pairs, the YAs log-transformed RTs did not significantly differ as a function of face valence, $F(1, 98) = 0.37$, $p = .543$, but OAs were significantly faster to respond when the dot appeared behind the neutral-expression face as opposed to the sad-expression face, $F(1, 94) = 7.79$, $p = .006$, $\eta_p^2 = .08$. In contrast, the interaction between age group and face valence, which is indicative of a positivity effect, was not statistically significant for either the angry-neutral face pairs, $F(1, 193) = 3.43$, $p = .065$, or the happy-neutral face pairs, $F(1, 193) = 0.73$, $p = .395$.

3.2.4 Autobiographical Memory (AM) Task. Our primary outcome for the AM task was the proportion of cues for which participants were able to successfully generate an AM. We operationalized success as occurring when participants wrote either an event-specific or general AM. In contrast, failures occurred when participants wrote nothing or only wrote single words. A positivity effect during this task would be evidenced as an interaction between age group and cue valence in the proportion of cues associated with successful AM generation. To test for this, we conducted a 2 (Age Group: YA vs. OA) X 2 (Cue Valence: Negative vs. Positive) GLM on the proportion of cues associated with successful AM generation and included depression scores as a covariate. Within this analysis there was a significant main effect of age group, $F(1, 193) = 4.56$, $p = .034$, $\eta_p^2 = .02$, as well as a significant interaction between age group and cue valence, $F(1, 193) = 14.40$, $p < .001$, $\eta_p^2 = .07$, which is indicative of a positivity effect. Follow-up analyses showed that in response to negative cue words, YAs had a higher success rate (97%) in generating AMs than did OAs (92%), $F(1, 193) = 13.21$, $p < .001$, $\eta_p^2 = .06$. In contrast, in response to positive cue words YAs and OAs had similar success rates (96%) in generating AMs, $F(1, 193) = 0.08$, $p = .775$ (see Table 2). However, these effects should be interpreted cautiously as there were ceiling effects in AM generation success rates, particularly in response to the positive cue words.

When an AM was successfully generated, participants next rated its valence. We next examined whether these valence ratings varied based upon age. We did this using a single factor (Age Group: YA vs. OA) GLM on the AM valence ratings (collapsing across cue valence). We included depression scores as a covariate and excluded trials where no AM was generated. Within this analysis there was no evidence of an age-related positivity bias. The predicted main effect of age group was not significant, $F(1, 193) = 0.07$, $p = .796$ (see Table 2).

3.3 Age Group Differences in Cognitive Capabilities

Cognitive capabilities were assessed using the NIH Toolbox Cognition Battery. Shown in Table 3, the unadjusted scale scores replicate well-established findings (e.g., Horn & Cattell, 1967) that YAs had higher overall levels of fluid cognitive functioning than did OAs, $F(1, 193) = 177.23$, $p < .001$, $\eta_p^2 = .48$. YAs also had higher unadjusted scale scores than OAs on each of the fluid cognition assessments (see Table 2). Although not the focus of this study, YAs also had lower unadjusted crystallized cognition scores as measured via vocabulary tests than did OAs, $F(1, 193) = 177.15$, $p < .001$, $\eta_p^2 = .48$ (see Verhaeghen, 2003).

Although the prior analyses document age differences in cognitive functioning, in subsequent analyses we used age-adjusted scale scores. These take into account expected developmental changes in cognitive capabilities and allow for a direct comparison of YAs and OAs whose cognitive capabilities are better (or worse) than would be expected given their age. As shown in Table 2, on average the YAs in this study had age-adjusted composite fluid cognition scores that were below the normative mean for their age ($M = 95.88$, $SD = 15.87$) whereas OAs had composite fluid cognition scores above the normative mean for their age ($M = 102.30$, $SD = 12.87$). Similar patterns were seen on each of the fluid cognition assessments (see Table 2). Within each assessment there was also sufficient variability in the scores to discriminate between individuals in subsequent analyses. For OAs the age-adjusted composite fluid cognition scores ranged from 72 to 138, with 43% of our sample scoring below the expected mean of 100. Likewise, for YAs the age-adjusted composite fluid cognition scores ranged from 56 to 129, with 54% of the sample scoring below the expected mean of 100.

3.4 The Role of Cognitive Capabilities in Positivity Effects

3.4.1 Analytic Plan for Testing the Role of Cognitive Capabilities. We next examined whether age-normed cognitive capability scores modulated the magnitude of the previously-reported positivity effects (i.e., the age group X valence interactions) in each task. To do so, we repeated the GLM analyses described in Section 3.2 but included age-adjusted cognitive capabilities, and their interactions with age group and valence, as covariates. Separate analyses were conducted for each age-adjusted cognitive capability measure (composite fluid cognition, executive function scores, working memory scores, episodic memory scores, and processing speed scores)[5] and our key outcomes of interest were the three-way interactions between age group, valence, and cognitive capability scores.[6]

3.4.2 Emotional Picture Memory Task. During the emotional picture memory task, our prior analyses revealed a positivity effect such that OAs recalled significantly fewer negative pictures than did YAs, but there was no significant age-difference in recall of positive pictures. The magnitude of this positivity effect varied based upon age-adjusted working memory scores, $F(1, 190) = 4.85$, $p = .029$, $\eta_p^2 = .03$. Follow-up partial correlational analyses (controlling for recall time and depression scores) showed that amongst YAs, increases in age-adjusted working memory scores were positively correlated with recall of negative pictures ($r = .20$, $p = .044$), but were not significantly related to recall of positive pictures ($r = -.04$, $p = .706$); these correlations were significantly different in magnitude, $z = 1.93$, $p = .027$. In contrast, amongst OAs, age-adjusted working memory scores were not significantly related to recall of either negative pictures ($r = .02$, $p = .851$) or positive pictures ($r = .13$, $p = .223$). When considered together, this

[5] In exploratory analyses, we also examined the role of crystallized cognitive capabilities. Our composite measure of age-normed crystallized cognition did not significantly moderate any of the observed positivity effects. It also did not moderate the positivity bias in AM valence ratings.

[6] These interactions indicate heterogeneity of regression slopes. Although this is usually viewed as an obstacle that precludes the use of ANCOVA, in this context their discovery indicates that individuals demonstrated differential positivity effects based upon their cognitive capabilities.

pattern provides preliminary evidence that the positivity effect in episodic picture recall is more likely to occur when participants (particularly YA participants) have higher working memory capabilities than would be expected given their age.[7] No similar pattern emerged for any of the other cognitive capability measures (i.e., all *ps* ≥ .136 for the three-way interactions with age group and picture valence).

3.4.3 Dot-Probe Attention Task. During the dot-probe attention task, our prior analyses revealed a positivity effect, which was evidenced as a significant interaction between age group and face valence (positive versus negative) on log-transformed RTs (with depression scores as a covariate). However, there was no evidence that the magnitude of this positivity effect varied based upon cognitive capabilities. In follow-up analyses none of the three-way interactions between cognitive capability measures, age group, and face valence were significant (all *ps* ≥ .239).

3.4.4 Autobiographical Memory (AM) Task. During the AM test, our prior analyses revealed a positivity effect in AM generation success: OAs were less successful than YAs in generating AMs in response to the negative cue words, but there was no significant age-difference in AM generation success in response to the positive cue words. The magnitude of this positivity effect did not significantly vary based upon cognitive capabilities. In follow-up analyses there were no significant three-way interactions between cognitive capability measures, age group, and cue valence (all *ps* ≥ .090).

[7] We also conducted follow-up analyses on participants whose working memory scores were better versus worse than expected given their age. This was done using separate 2 (Age Group: YA vs. OA) X 2 (Picture Valence: Sad versus Neutral) GLMs analyses on the number of critical pictures recalled with the covariates of recall time and depression. Amongst participants with age-adjusted working memory scores above 100, we found evidence of a positivity effect; the interaction between age group and picture valence was significant, $F(1, 108) = 17.71$, $p < .001$, $\eta_p^2 = .14$. In contrast, amongst participants with age-adjusted working memory scores below 100, we found no evidence of a positivity effect; the interaction between age group and picture valence was not significant, $F(1, 80) = 0.74$, $p = .393$.

Within this task we also examined for positivity biases in valence ratings (i.e., rating the generated AMs as more positive). Although our prior analyses revealed no evidence of age-differences in these valence ratings, we tested whether the presence of this expected effect may depend upon participants' cognitive capabilities. To do so, we conducted a series of single factor (Age Group) GLMs on the AM valence ratings (collapsing across cue valence) and included depression scores, cognitive capabilities, and the interaction between cognitive capabilities with age group as covariates. Separate analyses were conducted for each age-adjusted cognitive capability measure. Within these analyses, we found a significant interaction between age group and age-adjusted executive function scores, $F(1, 191) = 9.89$, $p = .002$, $\eta_p^2 = .05$. Follow-up partial correlational analyses (controlling for depression scores) showed that amongst OAs, increases in age-adjusted executive function scores were associated with more positive AM valence ratings ($r = .33$, $p = .001$). In contrast, amongst YAs, age-adjusted executive function scores were not significantly associated with AM valence ratings ($r = -.09$, $p = .358$). Thus, an age-related positivity bias in AM valence ratings is more likely to occur when participants (particularly the OA participants) have higher executive function capabilities than would be expected given their age.[8] No similar pattern emerged for any of the other cognitive capability measures (i.e., all *ps* ≥ .112 for the two-way interactions with age group).

3.5 FTP and OAs' Processing of Emotional Information

[8] We also conducted follow-up analyses on participants whose executive function scores were better versus worse than expected given their age. This was done using separate single factor (Age Group: YA vs. OA) GLMs analyses on AM valence ratings (collapsing across cue valence) and included depression as a covariate. Amongst participants with age-adjusted executive function scores below 100, there was an age-related negativity bias such that OAs provided significantly more negative valence ratings than the YAs, $F(1, 113) = 4.22$, $p = .042$, $\eta_p^2 = .04$. In contrast, amongst participants with age-adjusted executive function scores above 100, there was a numeric trend for the OAs to provide more positive valence ratings than the YAs, $F(1, 74) = 2.37$, $p = .128$. When further limiting the sample to participants with age-adjusted scores above 104 (i.e., at least 0.3 *SD* above what would be expected for their age), OAs valence ratings were significantly more positive than were YAs, $F(1, 54) = 6.22$, $p = .016$, $\eta_p^2 = .09$.

As shown in Table 1, on the Carstensen and Lang (1996) FTP scale, YAs saw the future as more expansive/ less limited than OAs, $F(1, 185) = 157.15$, $p < .001$, $\eta_p^2 = .46$.[9] However, there was also variability within each age group: FTP scores ranged from 2 to 7 for the YAs and from 1.4 to 6.4 for the OAs.

3.5.1 Analytic Plan for Testing the Roles of FTP and Cognitive Capabilities. We next examined the contributing roles of chronological age and FTP in predicting OAs' processing of positive versus negative stimuli. For each task, we conducted two sets of analyses. The first was a series of single factor (Valence) GLM analyses with the covariates of depression scores, chronological age, and FTP. For the emotional picture memory task, we also included the covariate of recall time. Analyses were limited to the OA participants. Our key outcomes of interest were: (1) the two-way interactions between chronological age and valence, which would indicate age differences across OA in the magnitude of positivity effects, and (2) two-way interactions between FTP and valence, which would indicate that the magnitude of the positivity effect is related to OAs' FTP.

Our second set of analyses then evaluated whether the contributions of FTP to positivity effects varied based upon cognitive capabilities. To do so, we repeated the prior analyses including the covariates of age-adjusted cognitive capabilities and the interactions between FTP and cognitive capabilities. Separate analyses were run for each cognitive capability measure. Our

[9] We chose to use this scale as it is one of the most commonly-used measures of FTP and is often linked to socioemotional selectivity theory. However, in the pre-session online survey, participants also completed the Brothers et al. (2014) Multidimensional FTP scale. On this scale, YAs saw the future as more open, $F(1, 185) = 32.55$, $p < .001$, $\eta_p^2 = .15$, less limited, $F(1, 185) = 16.17$, $p < .001$, $\eta_p^2 = .08$, and as more ambiguous, $F(1, 185) = 16.17$, $p < .001$, $\eta_p^2 = .08$, than did OAs. Participants were also asked to report their perceived remaining life expectancy Of participants who responded to this question, YAs expected to live an additional 59.06 years whereas OAs expected to live an additional 17.77 years, and this difference was significant, $F(1, 171) = 459.19$, $p < .001$, $\eta_p^2 = .729$. There was again variability within each age group with expected life expectancies ranging from 5 to 100 for the YAs and from 5 to 40 for the OAs. Repeating the analyses reported here with these alternate measures of FTP yielded largely similar conclusions. Additional details are available from the authors upon request.

outcome of interest from the second analyses were three-way interactions between FTP, valence, and cognitive capability score; these would indicate that the link between OAs' FTP and the magnitude of the positivity effect varies based upon cognitive capabilities. OAs who did not complete the pre-session survey (and who therefore did not complete the FTP questionnaire) were excluded from these analyses.

3.5.3 Emotional Picture Memory Task. Within the first set of analyses, the interaction between age and picture valence was significant, $F(1, 87) = 5.02$, $p = .028$, $\eta_p^2 = .05$. Amongst the OA participants, increased age was associated with a decreased propensity to recall negative pictures, $r = -.27$, $p = .008$, but was not significantly associated with recall of positive pictures, $r = -.11$, $p = .275$. However, there was no significant interaction between FTP and picture valence, $F(1, 87) = 2.75$, $p = .101$.

We next tested whether the link between FTP and the positivity of recall varied based upon OAs' cognitive capabilities. Within these analyses, there was a significant interaction between picture valence, FTP, and age-adjusted executive function scores, $F(1, 85) = 4.79$, $p = .031$, $\eta_p^2 = .05$, but not with any of the other cognitive capability measures (i.e., ps $\geq .096$ for interactions between picture valence, FTP, and the other cognitive capability measures). To better understand the interaction we conducted follow-up analyses on participants whose executive function scores were better versus worse than expected given their age (i.e., age-adjusted scores higher versus lower than 100). Amongst OAs whose executive functions were better than expected, partial correlations (controlling for depression scores, recall time, and age) showed that lower FTP scores were associated with significantly greater recall of negative pictures, $r = -.36$, $p = .014$, but were not significantly related to recall of positive pictures, $r = -.19$, $p = .213$. In contrast, amongst OAs whose executive functions were worse than expected there were no significant relationships between FTP and recall of either negative pictures, r = -.23, p = .165, or positive pictures, r = -.09, p = .579. This pattern is inconsistent with predictions based upon SST and SAVI: OAs with a limited FTP preferentially recalled negative pictures, although this relationship was limited to those OAs whose executive function scores were better than expected given their age.

3.5.4 Dot-Probe Attention Task. For the dot-probe attention task, there was no evidence that OAs log-transformed RTs to positive versus negative faces varied based upon age, $F(1, 88) < 0.01$, $p > .999$, or FTP, $F(1, 88) = 2.00$, $p = .161$. These conclusions did not change when including cognitive capabilities in the analyses; there were no significant interactions between FTP, cognitive capabilities, and face valence (all ps ≥ .158).

3.5.5 Autobiographical Memory (AM) Task. For the AM task, there was no evidence that cue valence influenced OAs' success in generating AMs in response to the cues as a function of their age, $F(1, 88) = 0.67$, $p = .414$, or as a function of their FTP, $F(1, 88) = 0.05$, $p = .833$. There were also no significant three-way interactions between FTP, cognitive capabilities, and cue valence (all ps ≥ .387).

A different pattern emerged for positivity biases in OAs' AM valence ratings. In a GLM analysis with OAs' depression scores, age, and FTP scores as covariates, there was no significant effect of age, $F(1, 88) = 0.36$, $p = .551$, but there was a significant effect of FTP, $F(1, 88) = 4.52$, $p = .036$, $\eta_p^2 = .05$. Amongst OAs, higher FTP scores were associated with significantly more positive AM valence ratings. This effect did not vary based upon cognitive capabilities. In subsequent analyses adding age-adjusted cognitive capability scores and their interactions with FTP to the model, there were no significant interactions between FTP and cognitive capabilities (all ps ≥ .566).

3.6 Relationships Amongst Positivity Effect Measures

In the prior analyses, the positivity effects were inconsistently related to measures of cognitive capabilities, FTP, and age. This raises the question of how strongly positivity effects themselves are related to one another. In order to test this, we next created positivity index scores. During the Emotional Picture Memory Task**,** we determined the relative positivity of each participants' recall. This was defined as the number of positive pictures recalled divided by the total number of critical pictures recalled. Higher scores indicate relatively higher positivity. During the Dot Probe Attention Task, we created attentional bias scores by subtracting the RT of trials when the dot appeared behind the emotional face from the RT of trials when the dot appeared behind the neutral face. This was done separately for the angry-neutral, sad-neutral, and positive-neutral trials. A positive score indicates longer response times for the neutral faces, and thus a bias towards the emotional faces.[10] During the AM Task, we determined the relative efficacy of positive versus negative cues in leading to successful generation of AMs. This was defined as the number of positive cues that led to an AM being generated minus the number of negative cues that led to an AM being generated. From the AM test, we also included the positivity of AM valence ratings.

Within each age group, we next examined the partial correlations (controlling for depression scores) amongst these positivity indices. As shown in Table 4, there were relatively few significant relationships amongst these positivity effect measures. For YAs, higher positivity bias scores during the episodic memory task were related to marginally more positive valence ratings during the AM memory task (p = .050). For YAs, there was stability in

[10] One OA participant had extreme attentional biases, with values more than 7 *SD* below the means of all other OAs. This participant was excluded from these analyses.

positivity/negative preferences during the dot-probe task. YAs who had a propensity to look away from negative faces also tended to look towards positive faces.

Amongst OAs there was only one case where greater positivity on one measure related to greater positivity on another measure: OAs who tended to look towards the happy faces during the dot-probe task tended to give more positive valence ratings during the AM memory task. In contrast to this, during the dot probe task OAs who showed a positivity biases (by looking towards the happy faces) tended to also show negativity biases when shown the sad-neutral face pairs.

4. Discussion

As people get older, they preferentially process positively-valenced over negatively-valenced information (Carstensen & Mikels, 2005). In this study we replicated aspects of this age-related *positivity effect* (age X valence interaction) in three different cognitive tasks. In an episodic memory task, OAs recalled fewer negative pictures than YAs, but there were no age differences in memory for positive pictures. In a dot-probe task assessing visual attention, OAs (but not YAs) responded faster if the dot was presented on the same side of the screen as a neutral-expression face as compared to a sad-expression face. However, this positivity effect was limited to the sad-neutral face pairs and did not significantly emerge for the angry-neutral or happy-neutral face pairs. Finally, in an AM task, OAs were less likely than YAs to generate an AM in response to negative cue words, but there were no age differences in the likelihood of generating AMs in response to the positive cue words. However, once the memories were generated, there was no overall age difference in *positivity biases* of the valence ratings. OAs and YAs rated the valence of their generated AMs similarly.

Thus, age differences in this study only emerged in response to the negative information, and may be more aptly characterized as age-related reductions in negativity rather than age-related increases in positivity. This is similar to prior results showing age-stability in the processing of positive information (e.g., Charles et al., 2003; Sakaki et al., 2019; Schlagman et al. 2006), and manipulations that alter the magnitude of positivity effects often do so by exerting larger influences on the processing of negative, rather than positive, information (e.g., Barber et al., 2018; Mather & Knight; Exp. 3; Mather, Knight, & McCaffrey, 2005). However, we note that there have also been other studies documenting age-related improvements in attention and memory for positive information (e.g., Mather & Carstensen, 2003; Mather & Knight, 2005; Exp 1) and more research is needed to determine how and when preferences away from negative information relate to preferences towards positive information.

4.1 The Role of Cognitive Capabilities in Positivity Effects

In addition to replicating positivity effects, we also examined whether or not they related to individual differences in cognitive capabilities. There are theoretical debates and empirical inconsistencies about whether positivity effects require substantial amounts of cognitive capabilities. Whereas the cognitive control account (e.g., Kryla-Lighthall & Mather, 2009) and the SAVI model (Charles, 2010) both predict that positivity effects should be greatest for OAs with *high* cognitive control capabilities, the dynamic integration theory (e.g., Labouvie-Vief et al., 2010) predicts that positivity effects should be greatest for people with *low* cognitive capabilities. Results from prior studies addressing this question have yielded mixed results. There are some studies finding that positivity effects are greatest in individuals with high cognitive control capabilities (Mather & Knight, 2005), disappear when attention is divided (e.g., Joubert et al., 2018; Mantantzis et al., 2018; Mather & Knight, 2005; Knight et al., 2007), and that participants with Alzheimer's disease have negativity biases (Fleming et al., 2003). However, other studies find that participants with Alzheimer's disease or subclinical memory impairments have enhanced positivity effects compared to healthy older adults (Bohn et al., 2016; Leal et al., 2016).

In the current study, we found limited evidence that the positivity effect varies as a function of cognitive capabilities. Cognitive capabilities did not significantly moderate age differences in attentional preferences during the dot-probe task, and did not significantly moderate age differences in the efficacy of positive versus negative cues in eliciting AMs. The only place where we observed a role of cognitive capabilities was within the domain of episodic memory. Here, the positivity effect was more pronounced amongst participants with higher age-adjusted working memory scores (i.e., there was an age X picture valence X working memory score interaction). However, this three-way interaction was almost entirely driven by the YAs; as their working memory scores increased, so too did the negativity of their recall. No similar patterns emerged for the OAs. This pattern does not support the cognitive control account of the positivity effect (Kryla-Lighthall & Mather, 2009), which proposes that as OAs' cognitive capabilities decrease the positivity of their performance should also decrease. It is also not entirely consistent with dynamic integration theory (Labouvie-Vief, 2003, 2009), which predicts that within each age group those with lower cognitive capabilities should show greater positivity than those with higher cognitive capabilities. Although this pattern emerged for the YAs, it was absent for the OAs.

Although OAs' cognitive capabilities were never related to the magnitude of their positivity effects, they were related to their positivity biases. OAs with higher executive function scores rated their generated AMs more positively. In addition to identifying a role of cognitive capabilities in affecting emotional processing, this also highlights the importance of distinguishing between age-related positivity effects (i.e., age X valence interactions in attention and memory) and positivity preferences and biases (e.g., main effects of age in ratings). Although positivity biases are often referred to in the literature as “positivity effects”, these may be related, but distinct, phenomena. For example, our results suggest that they can be moderated by different factors.

These findings also add to a growing body of literature documenting no significant relationships between fluid cognitive capabilities and positivity effects. For example, the relative positivity of recall does not always differ between healthy older adults and those with mild cognitive impairment or dementia (e.g., Gorenc-Mahmutaj et al., 2015; Werheid, McDonald, Simmons-Stern, Ally, & Budson, 2011) and sometimes divided attention manipulations fail to affect the magnitude of the positivity effect in visual attention (Allard & Isaacowitz, 2008; 2019; Sakaki et al., 2013). Furthermore, one prior study found that after controlling for age, scores on working memory and verbal fluency tests were not significantly related positivity indices in memory recall (Löckenhoff & Carstensen, 2007). Likewise, another study found that controlling for vocabulary scores and for Digit Symbol Substitution test performance did not alter the magnitude of the positivity effect in recognition (Kwon et al., 2009).

The fact that positivity effects were not related to individual differences in OAs’ cognitive capabilities could suggest that age-related positivity often occur in a relatively automatic fashion. This is consistent with some prior research suggesting that positivity effects may reflect mnemonic processes rather than motivational factors (e.g., Baraly, Morand, Fusca, Davidson, & Hot, 2019; Werheid et al., 2010). For example, Spaniol Voss, and Grady (2008) found that OAs experience greater familiarity for positive items than do YAs. Given that familiarity is often viewed as a rapid and automatic process that places few demands on cognitive resources (e.g., Jacoby, 1991; Yonelinas & Jacoby, 1994, 1996), this may explain why positivity effects in this study were not consistently related to cognitive capabilities.

Our findings are also consistent with some views of emotion processing. According to dual-process models (see Chaiken & Trope, 1999), information processing is comprised of both controlled and automatic components. Controlled processes require attentional resources and are driven by explicit goals. In contrast, automatic processes operate outside of conscious awareness or intention and arise from sensory inputs activating knowledge structures and goals. Building upon this distinction, Mauss, Bunge, and Gross (2007) have proposed that there are also controlled and automatic emotion regulation processes. Controlled (or deliberate) emotion regulation occurs when people make a conscious decision to change some aspect of their emotions; this is often an effortful process. In contrast, automatic emotion regulation occurs when there is a goal-driven change in emotions but it occurs without a conscious decision or deliberate effort to do so. Automatic emotion regulation may arise because of overlearned habits, regulatory strategies, or sociocultural norms, and can be adaptive in producing higher levels of happiness and well-being (Mauss, et al., 2007).

One possibility is that positivity effects are often the outcome of automatic emotion regulation processes, which do not require conscious deliberation or goal-setting. This hypothesis is consistent with prior research suggesting that emotion regulation is less cognitively costly for older adults as compared to younger adults (Scheibe & Blanchard-Fields, 2009). It is also consistent with prior research showing that positivity effects can emerge in cognitive domains that reflect more automatic processing. For example, involuntary memories are those that spontaneously come to mind during everyday life without a conscious intent to retrieve them. Even though they represent an automatic retrieval process, research shows that positivity effects and biases still emerge; OAs' involuntary memories are more positive in content than are YAs, and OAs rate their involuntary memories as more positive in valence than do YAs (Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009; Schlagman, Schulz, & Kvavilashvili, 2006). Further support for the notion that positivity effects can occur in a more automatic manner comes from research showing that there are age-related reductions in sensitivity to negatively-valenced stimuli in early sensory processing stages (Gong, Fung, Zeng, & Tse, in press; Hilimire, Mienaltowski, Blanchard-Fields, & Corballis, 2014; Kennedy et al., 2019; Mienaltowski, Corballis, Blanchard-Fields, Parks, & Hillmire, 2011; see also Thomas & Hasher, 2006). In fact, Johnson and Whiting (2013) found that that positivity effects were greater when the processing was relatively automatic (i.e., presentation of stimuli at 60 ms) rather than controlled (i.e., presentation of stimuli at 2,000 ms).

It is also possible that there are domain differences in the extent to which positivity effects are automatic. For example, Foster et al. (2013) postulated that in early processing stages positivity effects are automatic and arise because of age-related decreases in sensitivity to negative information, but in later processing stages positivity effects are more cognitively effortful and reflect deliberate emotion regulation processes. More recently, Gronchi, Righi, Pierguidi, Giovannelli, Murasecco, and Viggiano (2018) proposed an alternate dual-process model of the positivity effect in visual attention such that OAs' biases towards positive information are automatic whereas their biases away from negative information represent a controlled process. Although our results are not clearly consistent with either of these accounts, future research is needed that measures cognitive capabilities and also manipulates the demands of different tasks to favor automatic versus controlled emotion regulation processing. In doing so, the perceived difficulty of the tasks should also be assessed. This would allow for a more systematic examination of whether there are domain differences in the extent to which positivity effects are automatic or cognitively effortful.

Future studies are also needed that link measures of the positivity effect and measures of cognitive capabilities with positive affective outcomes. As noted by Isaacowitz and Blanchard-Fields (2012), researchers often assume that positivity effects in cognition lead to increases in positive emotion in old age. However, the likelihood of this down-stream emotional benefit occurring may depend upon individuals' cognitive capabilities. For instance, in a visual attention study, Isaacowitz, Toner, and Neupert (2009) found that in response to a negative mood induction, OAs showed preferential gazes toward positive emotional faces. This was in turn associated with stable (rather than declining) mood states, but only for OAs with the highest levels of executive control (see also Noh, Lohani, & Isaacowitz, 2011; for a review see Isaacowitz, 2012). One limitation to the current study is that we did not investigate these downstream effects. Although OAs' fluid cognitive capabilities may not be related to the propensity to display positivity effects, they may be linked to downstream emotional benefits.

4.2 The Role of FTP in Positivity Effects

As a second aim, we also investigated the role of self-reported FTP, and its interactions with cognitive capabilities, in modulating positivity effects. According to SST, when people see the future as limited, emotional goals are prioritized (e.g., Carstensen, 2006). Because OAs typically have a more limited FTP than YAs (e.g., Lang & Carstensen, 2002), this leads to age-related positivity effects (see Reed & Carstensen, 2012). Thus, SST views chronological age as simply a proxy for FTP. In this study, we tested this by examining how OAs' FTP related to their emotional processing preferences. In doing so, we also considered the role of cognitive capabilities. This is because the SAVI model of well-being across adulthood (Charles, 2010; Charles & Luong, 2013) proposes that whereas a limited FTP motivates OAs to prioritize emotional well-being and positivity, their ability to implement these goals will depend upon their age-related strengths and vulnerabilities. In particular, the link between OAs' limited FTP and the positivity of their emotional processing should be less robust as cognitive declines increase.

Our results did not support these predictions. In this study, OAs with a limited FTP and high executive function capabilities recalled significantly more negative pictures during the episodic picture memory task. OAs with a limited FTP also gave more negative AM valence ratings. These findings are similar to other studies showing that a limited FTP predicts greater negative affect, greater depressive symptoms, lower life-satisfaction, lower self-reported health, and lower positive affect (Grühn, Sharifian, & Chu, 2016). A limited FTP is also associated with a greater preoccupation with negative events (Strough, Bruine de Bruin, Parker, Lemaster, Pichayayothin, & Delaney, 2016), and lower morale (Kozik, Hoppmann, & Gerstorf, 2015).

Although these findings do not support the SST explanation of positivity effects, they could also suggest a need to reexamine how "future time perspective" is measured. SST conceptualizes time perspective as "the subjective sense of remaining time until death" (Carstensen, 2006; page 1913). However, items on the commonly-used Carstensen and Lang (1996) FTP scale focus on perceptions of future opportunities and obstacles. These perceptions likely reflect not only perceptions of future time left to live, but also factors such as self-efficacy and optimism; this may obscure the links between self-reported FTP and positivity effects. This problem is not limited to the Carstensen and Lang FTP scale; for example, asking participants to estimate their perceived time left to live may also be affected by similar variables. This may explain why manipulations of time horizons have more consistently been related to positivity effects than have self-reported measures of FTP.

In further examining the links between self-reported FTP and positivity effects, research is also needed that considers FTP as a multi-dimensional construct (e.g., Barber & Strickland-Hughes, 2019; Brothers et al., 2014; Cate & John, 2007; Kuppelweiser & Sarstedt, 2014; Rohr, John, Fung, & Lang, 2017), with both global and domain-specific components (e.g., Andre, van Vianen, Peetsma, & Oort, 2018; Zacher & Frese, 2009). Although our exploratory analyses yielded relatively similar findings for a variety of FTP measures (see Footnote 9), it is possible that some aspects of FTP are more clearly tied to positivity effects than others.

Future research is also needed that more closely examines the purported link between FTP, motivational goals, and positivity effects. According to SST, a limited FTP increases the importance of goals related to optimizing emotional well-being and deepening relationships (Carstensen, 2006). However, motivational goals do not necessarily equate to changes in performance. In general, OAs are more selective in when they are willing to expend effort and engage in deliberative processing (see Hess, 2014), and may not always engage in the effortful aspects that lead to positivity effects. Furthermore, when OAs expend effort to maximize emotional well-being, this may not always manifest as avoidance of negative information / pursuit of positive information. This goal may instead be evident as an increased tendency to interpret experiences positively (i.e., as a positivity bias). It may also result in increased attention to negative information that is perceived to have personal or interpersonal value. Consistent with this, the positivity effect in attention (Fung, Lu, & Isaacowitz, 2019) and episodic picture memory (Hess, Popham, Dennis, & Emery, 2013; Tomaszcyk, Fernandes, & MacLeod, 2008) is eliminated for stimuli with social or personal relevance.

4.3 Relationships amongst positivity effect measures

The fact that individual differences in FTP and cognitive capabilities did not consistently relate to positivity effects is perhaps not surprising given that our three positivity measures themselves were also inconsistently related to one another. Although positivity effects across different domains are theorized to rely upon the same mechanisms, this assumption has not been systematically tested. The vast majority of prior studies have limited their examination of positivity effects to a single task or domain. Furthermore, when multiple domains have been assessed, the relationships between positivity effects across the domains has not been reported. One exception to this comes from Isaacowitz, Wadlinger, Goren, and Wilson (2006) who measured the positivity effect using both response times and eye-tracking visual fixations within a dot probe task. Although positivity effects were obtained with both outcomes, the correlations between the measures of positivity were low for both YA and OA participants (correlations of $-.18 \leq r \leq .28$). This may also explain why positivity effects in episodic memory emerge even when co-varying out potential positivity effects in attention (i.e., viewing times; Kwon et al., 2009). Our findings extend this by also documenting low consistency amongst positivity effects in three domains. Even though the positivity effect was a robust age difference, in the current study there was very little consistency in which participants were the most likely to display it in each domain.

On the one hand, this could be due to the relatively flexible operational definition of the positivity effect. For example, positivity effects can be evidenced by OAs showing greater positivity in attention/memory as compared to YAs, but in other cases positivity effects can be evidenced by OAs showing reduced negativity in attention/memory as compared to YAs. In the current study, all results were driven by reductions in negativity rather than age-related increases in positivity. However, the preference towards positive information and the preference away from negative information may be distinct components that rely upon different mechanisms. Alternately, this low convergent validity could reflect poor psychometric properties of positivity effect tasks. For example, dot-probe tasks (such as the one used in the current study) have been criticized for having low test-retest reliability (Schmukle, 2005). Although this task is commonly-used in the positivity effect literature, it may be less amenable to the study of individual differences.

4.3 Limitations

There are additional limitations to the current study that should also be addressed in future studies. For instance, our OA participants were still community-dwelling and we did not include people with diagnosed cognitive impairments. Although we still observed a large range of scores on each of our fluid cognition measures, it is possible that individual differences amongst cognitively-intact OAs are only minimally related to changes in the magnitude of the positivity effect. Relatedly, because the NIH Toolbox Cognition Battery is only designed for use with adults up to the age of 85, we limited our sample of OAs to only those under this age. It is possible that different patterns would be observed if we had included older-old adults. Our convenience samples also overrepresented women, and there was a fairly substantial difference in the ethnic identities of the YA and OA participants. Although a prior study found that these participant factors did not modulate the magnitude of the positivity effect in episodic memory (Charles et al., 2003), in future studies these issues should be further examined.

It should also be noted that because our aim was to minimize Type II errors, we did not correct for multiple comparisons in our analytic plan (i.e., we did not control for Type I errors). Even with this liberal criterion, we found very few significant relationships between cognitive capabilities and FTP in predicting positivity effects. However, the significant results that are reported should be interpreted cautiously before being replicated.

Finally, although a strength of this study is that we included measures of multiple types of fluid cognitive capabilities, a weakness is that we did not differentiate between subtypes of executive function abilities. Given that this was the only cognitive domain that related to OAs' positivity biases, in future studies it will be important to more systematically investigate the unique contributions of executive function subcomponents (such as shifting, updating, and inhibition; Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000).

5. Conclusions

Overall, the present study suggests that even though the positivity effect is a robust phenomenon, amongst cognitively-intact participants it is not very reliant on individual differences in fluid cognitive capabilities or self-reported FTP. Furthermore, the pattern of these relationships varied across our three task domains. Given that for OAs the positivity effects themselves were also unrelated to one another, this also raises the intriguing possibility that the factors leading to the positivity effect may to some extent be domain specific.

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Appendix A

A full list of all the questionnaire items included in the prescreen survey.

- Emotion Regulation Questionnaire (Gross & John, 2003)
- Beliefs about Well-Being Scale (McMahan & Estes, 2011)
- Attitudes Toward Emotions Scale (Harmon-Jones, Harmon-Jones, Amodio, & Gable, 2011)
- Satisfaction with Life Scale (Diener, Emmons, Larsen, & Griffin, 1985)
- Single-Item Self-Esteem Scale (Robins, Hendin, & Trzesniewski, 2001)
- Future Time Perspective Scale (Carstensen & Lang, 1996)
- Multidimensional Future Time Perspective Scale (Brothers, Chui, & Diehl, 2014)
- Life Progress Scale: Based upon Cottle’s (1976) Future Extension Line Test, participants used a sliding bar to report how far they had progressed in life
- Age group Identification and Discrimination Scale (Garstka, Branscombe, & Hummert, 1997)
- Essentialist Beliefs about Aging questions (Weiss & Grah, 2014)
- Attitudes Toward Own Aging Scale (subscale from the Philadelphia Center Morale Scale; Lawton, 1975)
- Short Form Health Survey (SF-36; Hays, Sherbourne, & Mazel, 1993)
- 12 Item Social and Economic Conservatism Scale (Everett, 2013)
- Ten Item Personality Measure (Gosling, Rentfrow, & Swann, 2003)
- Demographics form developed for this study
    - Questions assessing age, year of birth, gender, educational attainment, ethnicity and race, retirement status and primary occupation, quality of life, subjective age, subjective life expectancy, political partisan affiliation and conservatism, and current medications.

Table 1. ***Participant Characteristics as a function of Age Group in the Final Sample***

	Younger adults (n = 100)	**Older adults (n = 96)**
Age [a]	21.94 (3.40)	72.81 (5.83)
Gender	30 male 70 female	25 male 71 female
Ethnicity	38 Hispanic 57 Non-Hispanic 4 Decline to state	1 Hispanic 94 Non-Hispanic 1 Decline to state
Race	3 African American 24 Caucasian 28 Asian 1 Pacific Islander / Native Hawaiian 21 Other race not listed 11 Biracial / Multiracial 11 Decline to state	1 African American 83 Caucasian 10 Asian 1 Pacific Islander / Native Hawaiian 1 Other race not listed 0 Biracial / Multiracial 0 Decline to state
Education (total years) [a]	14.87 (1.70)	17.00 (1.96)
Future Time Perspective [a, b]	5.11 (1.10)	3.53 (1.16)
Future as Open [a, c]	4.11 (0.78)	3.86 (0.82)
Future as Limited [a, c]	3.14 (1.11)	3.47 (0.86)
Future as Ambiguous [a, c]	2.88 (1.02)	2.45 (0.91)
General Health [a, d]	62.32 (23.36)	70.74 (19.89)
Physical Functioning [a, d]	85.40 (22.89)	79.28 (16.49)
Social Functioning [a, d]	61.98 (25.64)	83.97 (23.02)
Emotional Well-being [a, d]	58.88 (19.13)	76.85 (16.48)
Positive Mood [a, e]	2.92 (0.80)	3.42 (0.68)
Negative Mood [a, e]	1.40 (0.42)	1.16 (0.31)
Depression [a, f]	3.75 (3.01)	1.80 (2.73)

Note: Of the 206 participants, 10 were excluded from analyses (see Results) and are not included here. Within this final sample, four OAs and three YAs did not complete the online pre-session survey (see Procedure) and are therefore missing health, education, and future time perspective measure data. Numbers in parentheses indicate standard deviations.

[a] Independent samples *t*-tests revealed a significant age-difference ($p < .05$) on this measure.
[b] Future time perspective was assessed using the Carstensen and Lang (1996) Future Time Perspective Scale. Questions are answered on a 1 (very untrue) to 7 (very true) scale and the average response is reported here. Higher scores indicate a more expansive future time perspective.

[c] Future as Open, Future as Limited, and Future as Ambiguous was assessed using the Brothers, Chui, Diehl, and Pruchno (2014) Multidimensional Future Time Perspective Questionnaire. The average response to each subscale is reported here on a 1 to 5 scale (1 = strongly disagree, 5 = strongly agree).
[d] General Health, Physical Function, Social Function, and Emotional Well-being were assessed using the 36-Item Health Survey (Hays, Sherbourne, & Mazel, 1993). Scores on each subscale can range from 0 to 100, with higher values indicating better functioning and well-being.
[e] Positive and negative mood in the present moment were assessed using the PANAS (Watson, Clark, & Tellegen, 1988). The average response to each subscale is reported on a 1 to 5 scale (1 = very slightly or not at all, 5 = extremely).
[f] Depression was assessed using the GDS-15 (Sheikh & Yesavage, 1986). The average total score is reported here. Scores can range from 0 to 15, with higher values indicating higher levels of depression.

Table 2. ***Mean (and SD) Task Performance as a function of Age Group in the Final Sample***

	Younger adults (n = 100)	Older adults (n = 96)
Emotional Picture Memory Task		
# Positive pictures recalled *	6.10 (3.53)	7.69 (4.09)
# Negative pictures recalled	9.95 (4.76)	9.65 (4.90)
Relative positivity of recall *	0.38 (0.15)	0.44 (0.15)
Dot Probe Attention Task		
Angry-Neutral Face Pairs		
RTs when dot behind angry face *	564 (128)	793 (194)
RTs when dot behind neutral face *	564 (131)	785 (198)
Attentional bias towards angry faces	5 (34)	-2 (44)
Sad-Neutral Face Pairs		
RTs when dot behind sad face *	560 (130)	803 (220)
RTs when dot behind neutral face *	569 (130)	781 (200)
Attentional bias towards sad faces *	2 (40)	-22 (85)
Happy-Neutral Face Pairs		
RTs when dot behind happy face *	569 (131)	798 (210)
RTs when dot behind neutral face *	563 (131)	792 (203)
Attentional bias towards happy faces	-7 (28)	-6 (57)
Autobiographical Memory (AM) Task		
Proportion positive cues where AM generated	0.96 (0.08)	0.96 (0.07)
Proportion negative cues where AM generated *	0.97 (0.06)	0.92 (0.11)
Ratings for AMs	4.27 (0.75)	4.39 (0.72)

Note: For each measure, we conducted an independent samples *t*-test comparing the YAs and OAs. Outcomes where a significant age difference ($p < .05$) occurred are noted with an asterisk.

Table 3. ***Mean (and SD) NIH Cognition Toolbox Task Performance as a function of Age Group in the Final Sample***

	Younger adults (n = 100)	Older adults (n = 96)
NIH Toolbox Cognition scores		
Picture Sequence Memory Test	112.63 (14.32)	92.93 (10.81)
List Sorting Working Memory Test	105.39 (9.96)	97.90 (11.07)
Pattern Comparison Processing Speed Test	115.45 (18.61)	89.15 (14.45)
Dimension Change Cart Sort Test	107.21 (8.38)	99.31 (8.15)
Flanker Inhibitory Control & Attention Test	101.65 (7.52)	92.84 (5.80)
Composite Executive Function Score	104.43 (7.12)	96.08 (5.83)
Composite Fluid Capabilities	110.54 (10.68)	90.94 (8.81)
Oral Reading Recognition Test	108.83 (7.10)	114.85 (4.66)
Picture Vocabulary Test	100.86 (8.76)	119.61 (7.84)
Composite Crystallized Capabilities	104.82 (7.24)	118.03 (6.11)
Age-adjusted NIH Toolbox Cognition scores		
Picture Sequence Memory Test	104.27 (16.11)	98.99 (12.87)
List Sorting Working Memory Test	97.30 (13.16)	107.14 (14.30)
Pattern Comparison Processing Speed Test	103.88 (21.64)	99.71 (18.97)
Dimension Change Cart Sort Test	96.02 (17.67)	108.99 (16.57)
Flanker Inhibitory Control & Attention Test	85.63 (13.48)	93.56 (9.46)
Composite Executive Function Score	90.83 (14.13)	101.28 (11.11)
Composite Fluid Capabilities	95.88 (15.87)	102.30 (12.87)
Oral Reading Recognition Test	111.32 (16.64)	119.46 (10.70)
Picture Vocabulary Test	101.45 (14.39)	117.03 (9.82)
Composite Crystallized Capabilities	106.88 (14.48)	119.82 (10.20)

Note: For each measure, we conducted an independent samples *t*-test comparing the YAs and OAs. On almost all measures there was a significant age difference ($p < .05$). However, the one exception to this was age-adjusted pattern comparison processing speed scores, $t(194) = 1.43$, $p = .154$.

Table 4. ***Partial correlations (controlling for depression scores) between measures of the positivity effect a function of age group***

YOUNGER ADULTS (N = 100)	**1**	**2**	**3**	**4**	**5**	**6**
1. Relative positivity of recall	**--**					
2. Attentional bias towards sad faces during dot probe	-.132	--				
3. Attentional bias towards angry faces during dot probe	-.016	**.470****	--			
4. Attentional bias towards happy faces during dot probe	.177	**-.394****	**-.210***	--		
5. Advantage of positive over negative cues in leading to AM generation	-.056	.104	-.137	-.103	**--**	
6. AM valence ratings	**.198***	-.094	-.056	.005	-.067	**--**
OLDER ADULTS (N = 95) [a]	**1**	**2**	**3**	**4**	**5**	**6**
1. Relative positivity of recall	**--**					
2. Attentional bias towards sad faces during dot probe	.076	--				
3. Attentional bias towards angry faces during dot probe	-.046	**.209***	--			
4. Attentional bias towards happy faces during dot probe	-.075	**.240***	.099	--		
5. Advantage of positive over negative cues in leading to AM generation	.091	-.078	-.014	-.040	**--**	
6. AM valence ratings	.104	.105	.131	**.219***	.182	**--**

*Note: * indicates $p \leq .05$, ** indicates $p < .01$*

[a] *One OA was an extreme outlier in attentional bias scores during the dot probe task (see Results) and was not included in these analyses.*