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REVIEW

Emotional information processing in young and older adults: meta-analysis reveals faces elicit distinct biases

Neda Nasrollahi[1,2] · Tim Jowett[1,3] · Liana Machado[1,2]

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Abstract

Although a number of empirical studies have found support for distinct emotional information processing biases in young versus older adults, it remains unclear whether these biases are driven by differential processing of positive or negative emotional information (or both) and whether they are moderated by stimulus type, in particular face versus non-face, the former of which is known to be subject to distinct processing. To address these gaps in the literature, our analyses included 2237 younger (mean age = 21.61 years) and 2136 older (mean age = 70.58 years) adults from 73 data sets, 19 involving face stimuli and 54 involving non-face stimuli (objects or scenes). Our findings indicated a significant overall age-related positivity effect (Hedge's $g = 0.35$) when comparing positive and negative stimuli, but consideration of emotionally neutral stimuli revealed significant age differences in emotional processing for negative stimuli only, with younger adults showing a stronger negativity bias. Furthermore, compared to emotionally neutral stimuli, both younger and older adults showed evidence of biases toward non-face positive and negative stimuli and toward positive but not negative face stimuli. Thus, although the present meta-analysis found evidence of an overall age-related positivity effect consistent with a shift toward positivity with aging, a different picture emerged when comparing emotional against neutral stimuli, and consideration of stimulus type revealed a distinct pattern for face stimuli, which may reflect the biological and social significance of facial expressions.

Keywords Meta-analysis · Aging · Faces · Non-faces · Positivity · Negativity

Introduction

Despite healthy aging being accompanied by declines in many physical and cognitive domains, older adults nevertheless show a tendency for a more positive mood profile relative to young adults (Machado et al. 2019). Furthermore, a large body of research indicates that older adults show a preference toward positive over negative stimuli relative to younger adults (Reed and Carstensen 2012). This preference, also known as the age-related positivity effect, can be explained by the Socio-emotional Selectivity Theory (SST), which posits that personal goals and individual motivations change across the life span. When the time horizon is perceived as long and nebulous, as it is in youth, future-oriented goals related to gathering information and exploring are prioritized over emotional gratification. However, when older adults perceive their time is limited, they become motivated to focus on present-oriented goals related to emotional satisfaction and well-being compared to goals associated with long-term rewards (Carstensen et al. 1999). Based on this framework, older adults' motivation to achieve and maintain a positive affective state is reflected in their attentional preference toward, and memory for, positive compared to negative information (Reed and Carstensen 2012). Since directing information processing toward goal-oriented emotional stimuli requires cognitive resources, the positivity bias in older adults largely occurs only when there is sufficient access to cognitive resources (Reed and Carstensen 2012; Sasse et al. 2014).

In contrast to older adults, there is a well-documented negativity bias in younger adults in terms of emotional

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✉ Neda Nasrollahi
nasne646@student.otago.ac.nz; nedanasrolahi@gmail.com

1 Department of Psychology and Brain Health Research Centre, University of Otago, William James Building, 275 Leith Walk, Dunedin 9016, New Zealand

2 Brain Research New Zealand, Auckland, New Zealand

3 Department of Mathematics and Statistics, University of Otago, Dunedin, New Zealand

information processing, such that younger adults attend to negative stimuli more than positive stimuli, which is evolutionarily adaptive as it helps them avoid danger and consequently increases their chance of survival (for a review, see Baumeister et al. 2001; Vaish et al. 2008). It has been suggested that these emotional processing biases are dynamic across the lifespan, with negativity bias in younger adults shifting toward positivity bias as people age (Kauschke et al. 2019). In line with this, the age-related positivity effect, which is a relative difference between older and younger adults in processing of positive over negative emotional stimuli, can be driven by older adults showing stronger processing of positive (Demeyer et al. 2017; Sasse et al. 2014) or weaker processing of negative stimuli (Goeleven et al. 2010) or by younger adults showing stronger processing of negative stimuli (Charles et al. 2003; Tomaszczyk and Fernandes 2014).

Although a number of alternative explanations have been put forward to account for the age-related shift toward positivity, these have largely been debunked through subsequent experimental works. For example, the Dynamic Integration Theory suggests that older adults compensate for cognitive declines with an optimization strategy involving automatic processing of positive information due to it being easier to process than negative information (Labouvie-Vief 2003). Another alternative explanation for the age-related shift toward positivity is the Aging Brain Model, which posits that degeneration of the arousal-sensitive brain circuits, including the amygdala, results in attenuated responses to negative information (Cacioppo et al. 2011a, b). However, there is some evidence against these theoretical frameworks; for instance, if the age-related positivity bias is associated with cognitive declines, emotional bias toward positive information should be stronger in individuals with poorer cognitive control. However, previous studies have found stronger positivity biases in individuals with high compared to low levels of cognitive control (Mather and Knight 2005; Sasse et al. 2014). Moreover, some evidence shows that the age-related shift toward positivity reverses when cognitive resources are diminished either experimentally as a result of task-related cognitive demands (Knight et al. 2007) or in association with Alzheimer's disease (Fleming et al. 2003). Overall, these findings rule out cognitive/brain decline as an explanation for the age-related shift in emotional biases toward positivity and provide more support for the SST and availability of cognitive resources as a necessary requirement for emotional biases.

Findings from initial research on age differences in the processing of emotional information are in line with the SST. For instance, in a study by Mather and Carstensen (2003) older adults showed an attentional bias toward positive and against negative stimuli, as evidenced in a dot-probe task by faster reaction times to a dot at the location of a recently viewed positive face and slower reaction times to a dot at the location of a negative face, whereas younger adults showed no attentional bias. Further support for an age-related shift toward positivity can be found in research investigating the effect of emotion on memory. For example, Charles et al. (2003) demonstrated that, compared to younger adults, older adults exhibited better memory for positive compared to negative objects or scenes, as evidenced by recall of a greater number of positive compared with negative objects or scenes. Since these initial studies were published, the age-related positivity effect has frequently been observed (Demeyer et al. 2017; Ebner and Johnson 2010; Goeleven et al. 2010; Madill and Murray 2017; Mather and Carstensen 2005; Sasse et al. 2014; Scheibe and Carstensen 2010).

The age-related positivity effect establishes age differences in emotional processing, however, it does not address whether the differences are driven by differential processing of positive or negative emotional information (or both). A meta-analysis by Murphy and Isaacowitz (2008) considered emotional processing relative to neutral stimuli in samples comprised mostly of younger adults and found processing biases toward both positive and negative stimuli. It should be noted, however, that the majority of studies included in their meta-analysis (roughly 85%) did not include older adults, which precluded a direct investigation of age differences in emotional information processing and thus limited any insight regarding age-related shifts toward positivity. In contrast to Murphy and Isaacowitz (2008), a recent meta-analysis by Reed et al. (2014) reported an age-related bias toward positive over negative stimuli. However, their meta-analysis did not include measures of neutral information processing, which prevented insight regarding whether the age-related positivity bias resulted from shifts toward positive or against negative stimuli. Thus, a direct comparison between younger and older adults, with inclusion of neutral stimuli as a control condition, is needed to clarify the nature of age-related differences in emotional processing biases.

Furthermore, previous meta-analyses did not address potentially important variations in stimulus type. Some past studies investigating emotional processing biases utilized non-face stimuli whereas others utilized face stimuli, yet it is now well known that face stimuli are a special class of stimuli subject to distinct processing (Liu et al. 2002; Palermo and Rhodes 2007). It is therefore likely that these different stimulus types affect emotional processing differently (Madill and Murray 2017). Evidence in support of this notion comes from a number of previous studies. For instance, Lee and Knight (2009) found evidence in older but not younger adults of a bias against negative face stimuli, however there was no evidence of emotional bias for non-face pictures. Similarly, other studies observed an age-related positivity bias using emotional face stimuli (Ebner and Johnson 2010; Goeleven et al. 2010), however

Madill and Murray (2017) found evidence that non-face pictures may be less subject to an age-related shift toward positivity. At the neural level, fMRI research has shown that expressive faces elicit greater activation in the superior temporal gyrus, insula and anterior cingulate than emotional non-face pictures (Britton et al. 2006). Due to the biological and social relevance specific to faces, it has been suggested that compared to non-face stimuli, faces are processed more automatically, placing less demand on cognitive resources such as inhibitory control (Machado et al. 2011; Wronka and Walentowska 2011, 2012). In contrast, evidence suggests that more cognitive resources are required for processing non-face stimuli. For example, emotional non-face pictures are associated with slower reaction times than expressive faces, which suggests higher cognitive demands for processing non-face pictures (Britton et al. 2006). Given that goal-oriented emotional processing biases require cognitive resources (Knight et al. 2007; Mather and Knight 2005; Reed and Carstensen 2012; Sasse et al. 2014), which are known to be more limited in older adults (Machado 2021; Reuter-Lorenz et al. 2013) and less taxed by face processing, it is important to consider face and non-face stimuli separately and not assume that they evoke similar emotional processing biases. This highlights face versus non-face as a potential moderator of age differences in emotional information processing.

The current meta-analyses aimed to elucidate the nature of emotional processing biases in young versus older adults by considering biases toward emotional stimuli relative to neutral stimuli. We also aimed to clarify the diverse findings pertaining to age-related differences in the processing of emotional information by taking into account stimulus type (face vs. non-face), which may influence results. This was achieved by including face versus non-face stimuli as a moderator in a subgroup analysis. Based on the theories and experimental findings reviewed, we hypothesized that older adults would show emotional biases toward positive and against negative stimuli compared to neutral stimuli, and younger adults would show an emotional bias toward negative compared to neutral stimuli. Support for this hypothesis would provide further evidence in favour of SST. Given that faces capture attention more automatically than emotional non-face stimuli, it can be assumed that fewer cognitive resources are required to process face stimuli. Thus, in consideration of the availability of cognitive resources as a requirement for goal-directed emotional processing biases and declines in cognitive resources that occur with adult aging, we hypothesized that emotional biases would be greater for face compared to non-face stimuli in older adults, which would be reflected in stronger biases toward positive and against negative face compared to non-face stimuli.

Method

Literature search

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Page et al. 2021) to conduct a comprehensive systematic review. Three research databases, Scopus, PsycINFO and PubMed, were searched in June 2021 for studies published from 1970 through to June 2021. We used the following keywords: (*"positivity effect"* OR *"negativity bias"* OR *"positivity bias"* OR *"emotion*"* OR *"valence"*) AND (*"attention"* OR "*memory*" OR "*cognition*" OR "*cognitive processing*" OR "*processing*" OR "*visual search*" OR "*dot probe*" OR "*visual scanning*" OR "*eye tracking*") AND ("*reaction time*" OR "*recognition*" OR "*recall*" OR "*time perception*" OR "*response*") AND ("*facial expression*" OR "*face**" OR "*image*" OR "*object*" OR "*scene*" OR "*picture*" OR "*visual perception*" OR "*face perception*" OR "*stimuli*" OR "*visual stimulation*") AND ("*aging*" OR "*ageing*" OR "*older adult*" OR "*elderly*" OR "*retired*") as they are the most common terms used in the literature (see Supplementary Material for a full electronic search strategy). We removed duplicate articles after transferring to Endnote all the articles found in the first step of the systematic review. All abstracts were then examined to select articles relevant to the current systematic review according to the following criteria.

Inclusion criteria

We only included studies that compared two non-clinical age groups (younger adults vs. older adults), with the mean age of the older adult sample being 60 or older, and the mean age of the younger adult sample being 40 or younger. In addition, a study's design needed to include a measure for the processing of positive, negative and neutral emotional stimuli. To reduce potential confounders related to stimulus complexity and enhance comparability between studies, non-face stimuli were restricted to pictures of objects or scenes, which are commonly used as comparisons against face stimuli (e.g., Lee and Knight 2009; Mavratzakis et al. 2016). The stimuli in included studies had to be faces or non-faces (objects or scenes); if both were presented in the same study, results were separated based on stimulus type. Furthermore, included studies had to report direct measures of attention to, and/or memory of, emotional stimuli. Considering that attention and memory tasks have used a wide variety of measures, we attempted to reduce heterogeneity by only including studies with the following measured variables: reaction time to emotional stimuli, correct identification of previously seen emotional stimuli (hits, as a measure of recognition memory), and number of emotional stimuli correctly recalled (free recall, as a measure of recall memory). We only included studies that reported the mean and the standard deviation, standard error or confidence intervals; in the latter two cases, we converted the statistics into standard deviations before conducting the meta-analyses as standard deviations were required to calculate effect sizes.

Exclusion criteria

Studies were excluded if they contained only one age group. Samples that were manipulated experimentally by mood shift induction were excluded to remove potentially misleading results related to interaction effects of emotional processing with the mood manipulation. Studies that used categories of non-face stimuli other than objects or scenes (e.g., words) were excluded to reduce the heterogeneity between studies. We excluded studies that used measures of attentional processing other than reaction time to reduce potential confounders which may influence the results. In addition, studies that used flanker tasks in their design were excluded due to the potential for processing of emotional flankers to obfuscate the effects of the emotional target stimuli, as these paradigms do not allow the effects of the flankers and the effects of the targets to be disentangled. We also excluded studies that reported only attentional bias scores (and not reaction times). We excluded unpublished works, Master's theses and doctoral dissertations, as well as studies that were written in languages other than English. Figure 1 depicts the systematic review process. We assessed the full-text of 234 articles for eligibility, of which 197 were eliminated for failing to meet our inclusion criteria and the remaining 37 articles were included in the current meta-analyses. One article that met our inclusion criteria was identified via hand-searching.

Data extraction

We coded for the following variables in each included data set: primary author, publication year, sample size, mean age, stimulus type (face or non-face), measure (reaction time, hits and free recall) and valence of the stimuli (positive, negative or neutral).

Quality assessment of studies

The quality of included studies was assessed using a checklist of 11 quality indicators adopted from Buckley et al. (2009). This checklist assesses quality of studies using some indicators such as clarity of the research question and appropriateness of the study design, analysis and conclusions. A study should meet a minimum of seven out of these

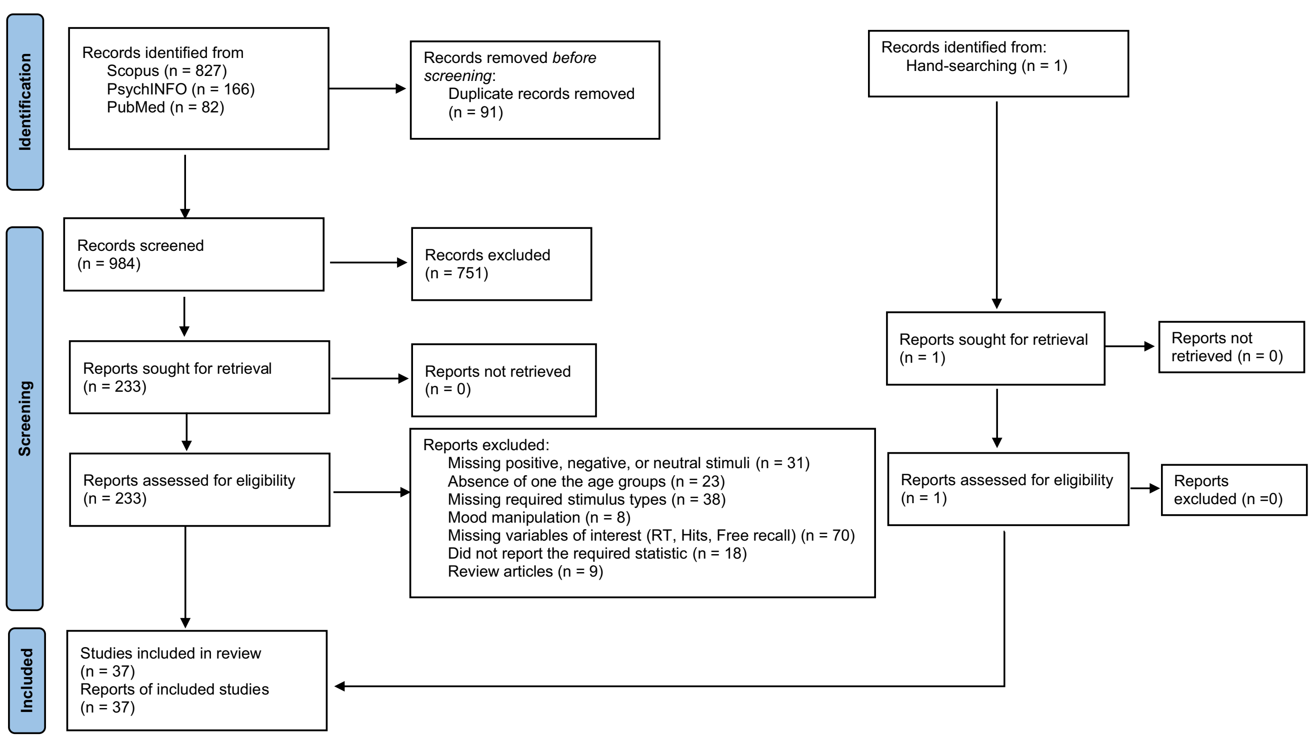

Fig. 1 Systematic review flow diagram. Adapted from "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews" by Page et al. (2021)

11 indicators to be considered as a higher quality study (see Supplementary Table S1).

Meta-analysis approach

We used Comprehensive Meta-Analysis software (version 3.0) to calculate Hedges' g, also known as the corrected effect size. We used Hedges' g as an index of standardized mean differences (Card 2012) as Cohen's d is a biased estimation of population effect sizes and is more likely to underestimate effect sizes in studies with smaller samples. We decided on a random effects model for the meta-analyses due to the population variability in effect sizes (Card 2012).

In the first instance, in keeping with the operational definition of the age-related positivity effect as a relative preference for positive over negative information in older compared to younger adults, we calculated effect sizes for processing of positive versus negative stimuli (initial meta-analysis). To avoid potential inflation of effect size estimations due to the repeated measures design of this study (Dunlap et al. 1996), we used the following formula as suggested by Borenstein et al. (2009): Hedges' $g_{\text{bias}} = [(M_{\text{Positive}} - M_{\text{Negative}})/\text{SD}_{\text{Dif}}] * [2\,(1-r)]^{1/2}$, where $\text{SD}_{\text{Dif}} = [\text{SD}^2_{\text{Positive}} + \text{SD}^2_{\text{Negative}} - (2r * \text{SD}_{\text{Positive}} * \text{SD}_{\text{Negative}})]^{1/2}$. A correlation of $r = 0.4$ (positive to negative stimuli) derived from Charles et al. (2003) as reported in Reed et al. (2014) was used in the formula. The positivity effect size (Hedges' g_{PE}) was then computed as the difference in positivity bias score between older (Hedges' g_{biasO}) and younger adults (Hedges' g_{biasY}). Hedges' g_{PE} = Hedges' g_{biasO} – Hedges' g_{biasY}.

To meet the aims of the current study, in the main meta-analysis, we calculated separate effect sizes for processing positive and negative stimuli compared to neutral stimuli using the following formula (adapted from the formula used for the initial meta-analysis):

$$\text{Hedges}'g = \left[\left(M_{\text{Emotional}} - M_{\text{Neutral}}\right) / \text{SD}_{\text{Dif}}\right] * [2(1-r)]^{1/2},$$

$$\text{where } \text{SD}_{\text{Dif}} = \left[\text{SD}^2_{\text{Emotional}} + \text{SD}^2_{\text{Neutral}} - (2r * \text{SD}_{\text{Emotional}} * \text{SD}_{\text{Neutral}})\right]^{1/2}.$$

Since the correlation between positive and neutral, as well as negative and neutral, stimuli is required to calculate effect sizes, we estimated these correlations by converting mean difference (d) to a correlation (r) using the following formula as suggested by Borenstein et al. (2009): $r = d/(d^2 + a)^{1/2}$, where a is a correction factor for cases of unequal sample sizes ($n_1 \neq n_2$) defined as $a = (n_1 + n_2)^2/n_1 n_2$. Consistent with a past meta-analysis (Reed et al. 2014), we used d from Charles et al. (2003) as reported in Murphy and Isaacowitz (2008, see Table 2).

For studies with memory measures, we assigned a positive sign to effect sizes when the number of items remembered for emotional stimuli was higher than for neutral stimuli, and a negative sign when the number of items remembered for neutral stimuli was higher than for emotional stimuli. For studies with attention measures, we assigned a positive sign to effect sizes when responses to emotional stimuli were faster than responses to neutral stimuli, and a negative sign when responses to neutral stimuli were faster than responses to emotional stimuli. The interpretation of effect sizes in the current meta-analyses is based on recommendations in Cohen (1988): a small effect ~ 0.2, a medium effect ~ 0.5 and a large effect ~ 0.8.

Heterogeneity and subgroup analysis

We evaluated the heterogeneity of effect sizes by calculating Q. A significant Q indicates that the heterogeneity in effect sizes is due to the variability between data sets and cannot be explained by chance. We then used the I^2 index to investigate the amount of heterogeneity between studies, which can be interpreted as the percentage of variability among effect sizes. $I^2 = 25\%$ reflects a small amount of heterogeneity, $I^2 = 50\%$ reflects a medium amount of heterogeneity, and $I^2 = 75\%$ reflects a large amount of heterogeneity (based on the suggestions made by Huedo-Medina et al. 2006). To consider the cause of the heterogeneity, we also conducted a subgroup analysis to investigate the influence of stimulus type as a potential moderator of the magnitude of effect sizes. As all studies included in the current meta-analyses provided data for three emotion conditions (positive, negative and neutral), the correlation between these emotion conditions (positive-neutral and negative-neutral) should be taken into account when comparing mean effect sizes within groups to increase efficiency and accuracy. Furthermore, a multilevel model was required because data were obtained from multiple measures nested within individual data sets. Thus, we followed the guidelines provided by Berkey et al. (1998) and Konstantopoulos (2011) and conducted a multivariate/multilevel random-effects regression model in *R* (R Core Team 2018; Viechtbauer 2010) using the metafor package (rma.mv function) to compare mean effect sizes within and between groups in the main and subgroup analyses.

Publication bias

To evaluate publication bias, we used funnel plots and Egger's regression intercept (Card 2012). The risk for publication bias is that published literature might not be representative of the studies that have been conducted on a topic, as studies that do not have statistically significant results, or that have a statistically significant effect that contradicts the expected outcome, are less likely to be published.

Results

The descriptive data from the samples are shown in Supplementary Table S2. In total, 73 data sets that used either face stimuli ($n = 19$) or non-face stimuli (objects or scenes; $n = 54$) were taken from 37 published studies. The current meta-analyses included 2237 younger (mean age = 21.61 years) and 2136 older (mean age = 70.58 years) adults. Overall, 86.5% of the studies included in the current meta-analyses met seven or more quality indicators, and thus were deemed to be of high quality. Effect sizes for processing of positive and negative stimuli in comparison to neutral stimuli in each age group are shown in Supplementary Table S3; note that positive effect size values indicate a bias in favor of emotional stimuli, and negative effect size values indicate a bias against emotional stimuli.

Initial meta-analysis

The initial meta-analysis (see Table 1), which considered effect sizes for processing positive versus negative information, showed a small-to-medium but significant age-related positivity effect ($g = 0.35$, $Z = 2.41$, $p = 0.016$). Note, however, that neither age group showed a significant bias toward one emotion over the other (older adults: $g = 0.29$, $Z = 1.36$, $p = 0.174$; younger adults: $g = -0.08$, $Z = -0.41$, $p = 0.679$). The heterogeneity tests were significant and indicated a high level of variance in the effect sizes (see Q and I^2 results in Table 1). A visual inspection of the standard funnel plot for assessing publication bias showed a symmetrical scattering of data sets (see Fig. 2). Additionally, Egger's regression method indicated no significant publication bias ($t = 0.10$, $p = 0.917$).

Main meta-analysis

The main meta-analysis (see Table 2), which considered effect sizes for processing positive and negative stimuli compared to neutral stimuli, revealed that older adults showed a medium-to-large significant effect for processing positive compared to neutral stimuli ($Z = 3.41$, $p < 0.001$) and a small non-significant effect for processing negative compared to neutral stimuli ($Z = 1.40$, $p = 0.163$). The difference between positivity and negativity bias was highly significant ($Z = -4.06$, $p < 0.001$), indicating a bias toward positivity over negativity in older adults. Younger adults showed medium-sized significant effects for processing of both positive stimuli ($Z = 4.02$, $p < 0.001$) and negative stimuli ($Z = 0.22$, $p = 0.034$) compared to neutral stimuli, and there was no significant difference between the positivity and negativity biases ($Z = -0.43$, $p = 0.668$).

Comparisons of the effect sizes between the two age groups showed that younger and older adults differed significantly in the processing of negative emotional relative to neutral stimuli ($Z = 5.11$, $p < 0.001$). However, there was no significant difference between younger and older adults in the processing of positive emotional relative to neutral stimuli ($Z = 1.06$, $p = 0.290$). Tests for heterogeneity were significant for both positivity and negativity bias in both age groups and indicated a quite high level of variance in the effect sizes (see Q and I^2 results in Table 2). These high levels of heterogeneity between studies made it possible to conduct a subgroup analysis.

Subgroup analysis

To investigate stimulus type (face vs. non-face) as a potential moderator in the processing of emotional information, a subgroup analysis was conducted using the data from the main meta-analysis (see Table 3). The between-stimulus-type heterogeneity tests were significant in both age groups for negative stimuli ($p < 0.05$) but not for positive stimuli ($p > 0.2$), indicating that stimulus type could explain the variance in the effect sizes for processing of negative but not positive stimuli.

The result of the multivariate/multilevel regression model used to compare mean effect sizes revealed a significant Stimulus Type × Emotion Condition × Age Group interaction ($\beta = -0.27$, $Z = -2.17$, $p = 0.029$), which indicated that the Stimulus Type × Emotion Condition interaction differed

Table 1 Initial Meta-analysis: effect sizes for processing of positive versus negative stimuli by age group and the age-related positivity effect

		N	Effect Size	95% CI	Q_W	I^2
Older	Positive–Negative	73	0.29	[−0.13, 0.70]	681.63***	97.18
Younger	Positive–Negative	73	−0.08	[−0.44, 0.29]	758.44***	96.54
Age-related positivity effect	Positive–Negative	73	0.35*	[0.07, 0.63]	429.31***	87.55

N = number of data sets included in the meta-analysis. Effect Size = Hedges' g. CI = Confidence Interval. Q_W = within-group heterogeneity test (significant results indicate that heterogeneity among effect sizes is due to the variability between studies and is not explained by sample error). I^2 = percentage of variability among effect sizes (note that $I^2 > 75\%$ indicates a large amount of heterogeneity). *$p < .05$, ***$p < .001$

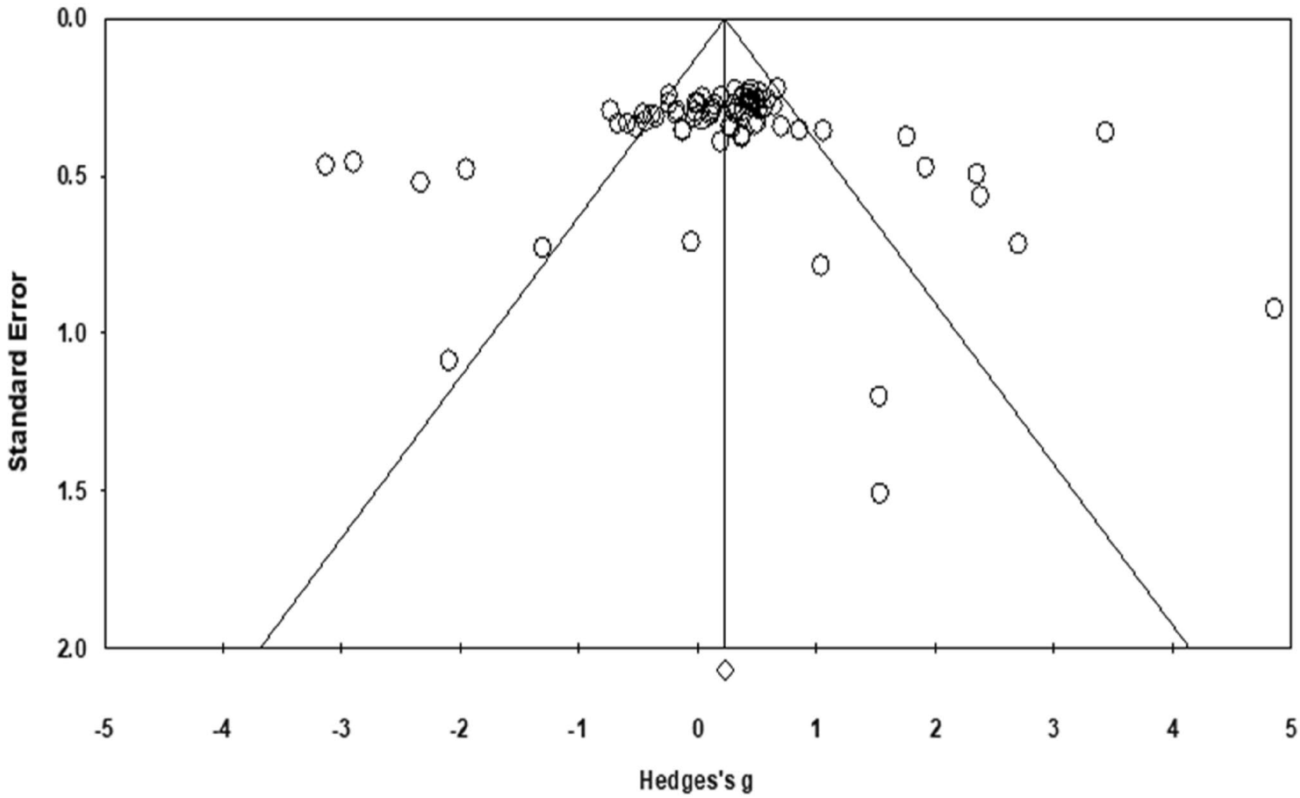

Fig. 2 *Funnel Plot for the Analysis of Publication Bias. Note* Funnel plot showing a symmetrical scattering of the 73 data sets included in the meta-analyses, which indicates no publication bias. Additionally, Egger's regression method found no significant publication bias ($p = .917$). The y-axis is standard error, and the x-axis is the effect size (Hedges' g) for the age-related positivity effect (positive–negative)

Table 2 Main meta-analysis: effect sizes for processing of positive and negative stimuli compared to neutral stimuli by age group

		N	Sample Size	Effect Size	95% CI	Q_W	I^2
Older	Positive–Neutral	73	2136	0.64***	[0.27, 1.01]	701.65***	89.74
	Negative–Neutral	73	2136	0.26	[−0.11, 0.63]	519.83***	86.15
Younger	Positive–Neutral	73	2237	0.54***	[0.28, 0.80]	507.46***	85.81
	Negative–Neutral	73	2237	0.47*	[0.04, 0.90]	802.76***	91.03

N = number of data sets included in the meta-analysis. Effect Size = Hedges'*g*. CI = Confidence Interval. Q_W = within-group heterogeneity test (significant results indicate that heterogeneity among effect sizes is due to the variability between studies and is not explained by sample error). I^2 = percentage of variability among effect sizes (note that $I^2 > 75\%$ indicates a large amount of heterogeneity). *$p < .05$, ***$p < .001$

Table 3 Subgroup analysis of stimulus type

	Face			Non-Face			Q_B
	N	Effect Size	95% CI	*N*	Effect Size	95% CI	
Older	19	1.12$^+$	[−0.01, 2.24]	54	0.47**	[0.12, 0.81]	1.34
	19	−0.48$^+$	[−1.04, 0.08]	54	0.59**	[0.19, 0.99]	8.63*
Younger	19	0.56$^+$	[0.04, 1.15]	54	0.49***	[0.20, 0.79]	0.00
	19	−0.38	[−1.00, 0.25]	54	0.86***	[0.36,1.36]	5.25*

N = number of data sets included in the moderator analysis. Effect Size = Hedges'*g*. CI = Confidence Interval. Q_B = between-stimulus-type heterogeneity test (significant results indicate that heterogeneity among effect sizes is due to the variability between stimulus types and is not explained by sample error). $^+p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$

between the age groups. Post-hoc comparisons showed that the two age groups statistically differed only for negativity bias for non-face stimuli ($Z = -2.55$, $p = 0.044$). To compare effect sizes at each level of stimulus type (face or non-face) across each level of emotion condition (positive or negative compared to neutral stimuli), we ran a series of contrast tests within each age group. The findings in older adults revealed that the processing of negative face stimuli differed significantly from the processing of negative non-face stimuli ($Z = 3.56$, $p = 0.001$), in that older adults showed medium-sized biases against negative face but toward negative non-face stimuli, although the former only reached marginal significance (see Table 3). Regarding findings in older adults for positive stimuli, the effect size was more than two times larger for face than non-face stimuli, but the conditions did not statistically differ ($Z = -1.74$, $p = 0.122$). Similar to older adults, younger adults showed a significant difference between negative face and non-face stimuli ($Z = 3.83$, $p < 0.001$), but no difference between positive face and non-face stimuli ($Z = -0.58$, $p = 0.564$).

Discussion

The aim of the present meta-analyses was to provide a clearer understanding of emotional processing biases in young and older adults. Specifically, we sought to examine whether age differences in emotional processing biases are driven by differential processing of positive or negative emotional information (or both), and to consider the potential influence of stimulus type (face vs. non-face) on emotional information processing, given evidence in the literature that faces are known to be subject to distinct processing biases. To achieve this, we first conducted an initial meta-analysis that enabled comparison with the literature on the age-related positivity effect by calculating effect sizes for processing of positive versus negative stimuli. Then, in the main meta-analysis, we calculated separate effect sizes for processing of positive and negative stimuli against emotionally neutral stimuli, followed by a subgroup analysis that investigated the influence of stimulus type (face versus non-face) as a potential moderator of the magnitude of effect sizes, given evidence in the literature that faces are processed differently than non-face stimuli.

The result of our initial meta-analysis (see Table 1) showed a significant age-related positivity effect that was in line with Reed et al. (2014). However, unlike Reed et al. (2014), who found that the age-related positivity effect was driven by similar levels of positivity bias in older adults and negativity bias in younger adults, in the current meta-analysis, the age-related positivity effect was driven mostly by positivity bias in older adults, although neither the positivity bias in older adults nor the negativity bias in younger adults reached significance. Nevertheless, the overall pattern is in line with the theoretical framework of the age-related positivity effect and SST.

Comparison of emotional stimuli against neutral stimuli in the main meta-analysis revealed biases toward positive stimuli in both age groups (see Table 2), which is consistent with Murphy and Isaacowitz (2008). Although the pattern of results showed a bias toward positivity over negativity in older adults, as indicated by a significantly larger effect size for positive versus neutral emotional stimuli, the effect size for positivity bias in younger adults (0.54) was not a lot smaller than in older adults (0.64). However, in contrast with Murphy and Isaacowitz (2008), the negativity bias was significantly larger in younger than older adults (0.47 vs. 0.26). Thus, overall, the results of this meta-analysis indicate that age differences in processing of emotional relative to neutral stimuli are consistent with SST but mostly characterized by stronger processing of negative stimuli in younger adults.

One explanation for the inconsistency between the results of our initial meta-analysis, which indicated age differences largely reflect greater positivity bias in older adults, and the main meta-analysis, which indicated age differences largely reflect greater negativity bias in younger adults, relates to the neutral stimuli included in the latter. Although the intention was to select emotionally neutral stimuli, which implies no more positive than negative, the pattern of results in the main versus initial meta-analysis indicates that the “neutral” stimuli were not evaluated as emotionally neutral but rather as more negative than positive. This is evidenced in older adults by the positive-neutral effect size being 0.38 larger than the negative-neutral effect size (see Table 2) despite the positive–negative effect size being 0.29 (see Table 1), and evidenced in younger adults by the positive-neutral effect size being 0.07 larger than the negative-neutral effect size (see Table 2) but the positive–negative effect size being −0.08 (see Table 1). This outcome fits with past reports of stimuli intended to be emotionally neutral not being evaluated as neutral but rather as more positive or more negative (Kauschke et al. 2019; Lee et al. 2008).

To the best of our knowledge, the subgroup analysis comparing face versus non-face stimuli marks the first in the literature investigating age differences in the processing of emotional information by stimulus type (see Table 3). The results revealed that both younger and older adults showed medium-to-large biases toward non-face emotional stimuli (positive and negative) and toward positive (albeit only trend level) but not negative face stimuli. Regarding age differences, the three-way interaction between age group, emotional condition and stimulus type was statistically significant, and follow-up analyses showed that young adults exhibited a stronger bias toward negative non-face stimuli than older adults. Additionally, the three-way interaction appears to be driven in part by the effect size for positivity bias being more than twice as large for faces than for non-face stimuli in older, but not young, adults. Collectively, these patterns are consistent with the SST and availability of cognitive resources as a requirement for goal-directed emotional processing biases (Knight et al. 2007; Mather and Knight 2005; Reed and Carstensen 2012; Sasse et al. 2014). We propose that less demand on cognitive resources to process face stimuli resulted in the large effect size for positivity bias for face stimuli in older adults (in relation to cognitive resources being more limited in older adults). Regarding processing of negative face stimuli, older adults showed a medium effect size for bias against negative face stimuli, which is generally consistent with past studies (Lee and Knight 2009; Mather and Carstensen 2003).

Although the present meta-analyses provide new insight into the conditions under which age differences in emotional information processing may emerge, it should be noted that we only included studies that assessed emotional information processing using pictures of faces and non-face objects and scenes. There is evidence that age differences in processing of emotional information differ in relation to other types of stimuli. For example, the pattern of results in a study by Leclerc and Kensinger (2011) showed the age-related positivity effect for words, but not for non-face pictures. Thus, future meta-analyses should investigate studies that used other classes of stimuli such as words. Another limitation is that we only included studies that reported reaction times to emotional stimuli as a measure of attentional processing. To reduce the heterogeneity between studies, we did not include studies that reported measures of attentional processing other than reaction time, such as fixation duration in eye tracking or attentional bias scores in dot-probe paradigms. Although limiting variance unrelated to the hypotheses under investigation is advantageous, there is evidence that the magnitude of emotional biases depends on how attentional processing is measured. For example, Isaacowitz et al. (2006) demonstrated that older adults showed significant bias toward happy faces and away from sad faces when a visual search eye tracking task was used, whereas older adults' positivity bias only reached trend level during a dot-probe task. Thus, consideration of attentional paradigm and other measures of attentional processing as a potential moderator of emotional information processing in future meta-analytic investigations may provide a useful addition to the literature. In addition, the sample size for faces was smaller than for non-face stimuli, which may have contributed to the lack of statistically significant effect sizes for face stimuli.

Furthermore, it may be worth noting that most of the studies included in the present meta-analyses used sad and angry negative facial expressions. Yet evidence indicates that, compared to younger adults, older adults have more difficulty recognizing these negative emotions (Ruffman et al. 2008). As such, future studies should consider type of negative emotion (e.g., sad, angry, disgust, fear) as a potential moderator of age differences in emotional information processing. Another limitation is that some emotional scenes used in the studies analyzed here depicted photographs of people, such as babies, children or families. In light of the current finding that emotional bias differs for face versus non-face stimuli, this may have been a confounding factor as emotional information processing may have been influenced by the facial expressions of the people in the scenes. Thus, we recommend that future studies investigating non-face stimuli exclude images that depict people. Additionally, we did not include middle-aged adults in the current meta-analytic review. Future studies should include this age group, for which data are currently very limited, to provide better understanding of developmental changes in emotional information processing. Another limitation of the current meta-analysis relates to exclusion of unpublished works and doctoral dissertations (i.e., grey literature). Although we conducted a comprehensive systematic search in three databases, inclusion of grey literature may further elucidate age differences in emotional information processing. Finally, although it is recommended that the quality of studies should be assessed by two reviewers, it was not possible to add a second reviewer in the current meta-analytic review.

In conclusion, the initial meta-analysis found evidence of an overall age-related positivity effect driven mostly by a positivity bias in older adults. The main meta-analysis, which considered emotional processing relative to emotionally neutral stimuli, showed an age difference for processing of emotionally negative stimuli only, with younger adults showing a stronger negativity bias, consistent with the literature. Moreover, consideration of stimulus type (face vs. non-face) revealed that the pattern of emotional processing biases differed by age group in relation to stimulus type and a distinct pattern evident in both age groups emerged for negative face stimuli that may relate to the social and biological significance of facial expressions (Frith 2009). Taken together, the results reported here provide further support for SST as a theoretical framework for age differences in emotional information processing and suggest that when targeting older populations with messaging (e.g., marketing or health related), it may be important to use positive framing as this may be more effective at attracting their attention due to their bias toward positive information. Given the pattern of results of the present meta-analysis, and considering that only a few experimental studies have investigated age differences in emotional information processing relative to neutral stimuli as a function of stimulus type in the same experiment with the same participants (Isaacowitz et al. 2007; Lee and Knight 2009), more research is needed to provide a comprehensive picture of age differences in emotional biases in relation to different types of emotional stimuli.

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Data availability Data will be available from the corresponding author upon request.

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