



Peripheral threat detection in facial expressions by younger and older adults

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ARTICLE INFO

Keywords:

Threat detection
Aging
Peripheral vision
Facial expressions
Emotion

ABSTRACT

Everyday threat detection includes recognizing threat cues in facial expressions found in our peripheral visual field. The current study examined age differences in the detection of emotion in low and high intensity angry and fearful facial expressions presented in younger and older adults' parafoveal ($\pm 5^\circ$) and peripheral visual field ($\pm 10^\circ$, $\pm 15^\circ$). For both age groups, detection performance was better for higher than for lower intensity stimuli, and detection performance declined with greater peripheral distance. Although younger and older adults displayed a similar pattern of findings for angry facial expressions, younger adults appeared to be more sensitive to lower intensity fearful expressions across all viewing positions. These findings demonstrate that, although threat detection may be partly maintained into older age, neurophysiological changes may accompany aging that selectively reduce older adults' sensitivity to peripheral facial cues of fear.

1. Introduction

The ability to detect threatening stimuli in one's environment is important to survival throughout the entire lifespan. Aside from the occasional wild animal encountered outdoors, threats are likely to come in the form of other humans who intend to cause harm. People who are angry with us may express facial emotion warning us of their intentions. Likewise, the fearful expressions of others may help us hone in on threatening stimuli in our environment. Facial expressions of anger and fear signal negativity experienced by others and stimulate activity within our limbic system to highlight the importance of the danger we face and to promote defensive action (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Marsh, Ambady, & Kleck, 2005; Phelps, 2006; Whalen et al., 2001). This chain of behaviors is set in motion by the threat detection process. The current study evaluates how aging impacts the ability to detect threatening facial expressions appearing in the peripheral visual field.

1.1. Perceiving threat

Detecting threat in facial expressions requires accurate emotion perception. Past research has demonstrated that advancing age is associated with a decline in emotion recognition performance, especially for discrete emotions like anger and fear (Ruffman, Henry, Livingstone, & Phillips, 2008). However, fear recognition deficits may be limited to older age groups rather than showing a gradual decline across

adulthood (Isaacowitz et al., 2007; Mill, Allik, Realo, & Valk, 2009). Emotion recognition deficits have been observed in older adulthood when studies use cognitively demanding multiple-choice labeling response systems. With respect to simplified one-interval discrimination (e.g., emotion detection or recognition) and emotion matching tasks, age differences in emotion perception are small when they are observed and generally occur when the expressive intensity is low (Johnson & Whiting, 2013; Mienaltowski et al., 2013; Mienaltowski, Lemerise, Greer, & Burke, 2018; Orgeta, 2010). Ultimately then, older adults should be able to detect arousing negative emotions expressed by others in their environment. In the lab, negative facial emotion should be easily detected relative to neutral, emotionless facial stimuli.

Despite the modest age-related decline in emotion recognition, adults of all ages generally direct their attention toward emotional stimuli relative to neutral (Murphy & Isaacowitz, 2008). In fact, threat-related stimuli capture attention and enhance subsequent perceptual judgments. For instance, fearful facial stimuli can focus attention to enhance contrast sensitivity (Phelps, Ling, & Carrasco, 2006) or to improve the detection of temporal-based flicker (Bocanegra & Zeelenberg, 2011). Threat-related images capture attention when presented on a busy visual display, facilitating their detection. Ohman, Flykt, and Esteves (2001) found that fear-relevant, discrepant stimuli were located more quickly than fear non-relevant, discrepant stimuli in 3×3 visual arrays. Leclerc and Kensinger (2008) extended this work with an older adult sample and found that older adults were faster at locating both positive and negative discrepant images in the 3×3

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<https://doi.org/10.1016/j.visres.2019.09.002>

Received 1 September 2018; Received in revised form 20 August 2019; Accepted 16 September 2019

Available online 13 October 2019

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visual arrays relative to neutral images. For older adults, high arousal positive and negative discrepant images were more quickly located than low arousal positive and negative discrepant images. When replicating Ohman, Lundqvist, and Esteves (2001), Mather and Knight (2006) found that older adults, like younger adults, were faster at locating a discrepant angry schematic face in a 3×3 array of neutral schematic expressions than detecting a discrepant happy or sad schematic face. Taken together, these findings demonstrate that older adults, similar to younger adults, direct attention toward and detect threatening stimuli in their environment (Mienaltowski et al., 2013; Sklenar & Mienaltowski, 2019). Successfully performing these two processes should facilitate emotion detection for both younger and older adults when stimuli are presented in the peripheral visual field.

1.2. Peripheral detection

In the current study, we investigated how the detection of threat-related expressions in parafoveal and peripheral regions of the visual field changes with age. Younger adults successfully detect fearful facial expressions out to at least 30° of eccentricity into the left and right visual field (Rigoulot et al., 2011), albeit with declines in performance as distance from the center of the visual field increases. Moreover, expressions depicting emotion that rely on more salient cues (e.g., mouth for happiness) are better detected in the periphery than expressions where the cues are less distinctive (e.g., furrowed brow of anger) within the sample of face stimuli used (Calvo, Fernández-Martín, & Nummenmaa, 2014). In the current study, participants detected emotion presented on peripherally presented facial expressions. The face stimuli were blocked by emotion (anger/neutral and fearful/neutral) as well as by intensity (low versus high) to minimize the cue switching demands and to maximize the possible distinctiveness of the emotion cues available to the participants.

Recent models of peripheral vision propose that our representation of peripherally presented stimuli consists of a statistical summary of the information found within a pooling region within our peripheral visual field (Rosenholtz, Huang, & Ehinger, 2012). To the extent that aging impacts the inputs used to generate this statistical summary, our ability to detect or characterize peripheral stimuli may change as we grow older (Wolfe, Dobres, Rosenholtz, & Reimer, 2017). Advancing age is associated with declines in peripheral vision as well as other forms of visual processing critical to facial emotion detection. For example, one's useful field of view declines, especially when tasks require more complex decisions, present stimuli for short durations, and include noise in the stimulus arrays (Ball, Beard, Roenker, Miller, & Griggs, 1988; Scialfa, Kline, & Lyman, 1987; Sekuler & Ball, 1986). Contrast sensitivity also declines with age for high spatial frequency, peripherally presented stimuli but not for low spatial frequency, peripherally presented stimuli (Crassini, Brown, & Bowman, 1988). With age, visual processing may slow due to the speed with which information is sampled from the environment and integrated into the percept (Owsley, 2016), resulting in increased response times and less accurate peripheral stimulus detection. Additionally, age-related visual deficits seem to be more substantial for second-order stimuli that require more integration of processing across visual cortical regions (Faubert, 2002). With respect to face discrimination, it has been proposed that age-related deficits may be linked to reduced levels of signal to noise in the perceptual process due to dedifferentiation of visual regions that change to show less facial specificity (Habak, Wilkinson, & Wilson, 2008). Consequently, one might expect these age-related changes in visual processes reduce older adults' ability to detect many types of stimuli, including emotional faces, in their peripheral visual field.

Facial emotion recognition from static face images is dependent upon the participants' ability to perceive and use the facial cues available to make an accurate judgment (Ekman & Friesen, 2003). With peripheral stimulus presentation, visual crowding can reduce one's ability to detect those features that are diagnostic to judgments made in

psychophysical tasks (Martelli, Majaj, & Pelli, 2005). Specifically, feature crowding within a peripherally presented face dilutes the summary statistics gleaned from the image, obscuring key facial features important to the judgment (Balas, Nakano, & Rosenholtz, 2009). Although not examined with facial stimuli, older adults display greater crowding effects than do younger adults when detecting a Landolt C between two vertical, flanking bars at peripheral location in the visual field (Scialfa, Cordazzo, Bubric, & Lyon, 2013). To make up for the performance deficit, a larger stimulus may be needed for older adults than for younger adults to accurately detect the presence or absence of a specific feature in a peripherally presented stimulus. Should this translate to emotion detection, one might expect that stimuli depicting emotion cues (e.g., whites of eyes, bared teeth, etc.) over larger areas of visual space – or more expressive faces – may facilitate accurate emotion detection for both younger and older adults, whereas less expressive faces may disproportionately disrupt older adults' emotion detection performance.

The current study extends past work by looking at younger and older adults' ability to detect threat-related emotion cues on facial stimuli presented at parafoveal and peripheral locations. Participants were presented with neutral and low or high expressive intensity threat-related stimuli (i.e., angry or fearful expressions) at 5° , 10° , and 15° to the left or right of a central fixation point. Stimuli appeared randomly at one of the six locations and for a short duration to minimize the possibility that participants could shift their gaze away from the fixation cross toward the peripheral stimulus. Participants indicated if they observed a stimulus with a neutral or an emotional (angry/fearful) expression. By manipulating expressive intensity and peripheral location, it is possible to develop a clearer understanding of how aging interacts with stimulus characteristics to impact threat detection in facial expressions. Given past findings, one might expect both younger and older adults to show a decline in detection accuracy as the angle of eccentricity of stimulus location increases, perhaps with a greater decline for older participants given the confluence of changes in peripheral vision that accompany aging. Likewise, one might expect participants to show less detection accuracy for low than for high intensity stimuli. Entering into the study, we were uncertain as to whether the discrete emotion expressed by the target – angry or fearful – would also impact age differences in the pattern of detection accuracy, as past research with emotions presented centrally on the display has not consistently demonstrated differences with age.

2. Material and methods

2.1. Participants

A sample of 85 participants were recruited to participate, consisting of 43 younger adults and 42 older adults. Data from four younger and two older adults were excluded from analyses due to failure to follow instructions, resulting in a younger adult sample of $n = 39$ (ages 18–26, $M = 19.6$; 56.4% women) and an older adult sample of $n = 40$ (ages 62–79, $M = 70.7$; 50% women). The older adult sample was screened for dementia using a telephone version of the mini-mental status exam (Folstein, Folstein, & McHugh, 1975), and all met the necessary score of 17 out of 21 points ($M = 20.4$, $SD = 0.8$). Table 1 provides means and standard deviations for some basic characteristics of each sample's health and cognitive functioning. Participants were randomly assigned to one of two experimental conditions and either completed an anger detection task (18 younger/20 older) or a fear detection task (21 younger/20 older). No effects of task assignment and no interactions between age group and task assignment emerged in the sample characteristics included in Table 1. Participants provided informed consent before taking part in the study. All participants had normal or corrected-to-normal vision, and reported being in good subjective health. The younger adults were college students who earned course credit for their participation; 80% of the older adults had completed some college

Table 1
Characteristics of the younger and older adult samples.

Factor	Younger Adults Mean (SD)	Older Adults Mean (SD)	Age Group Comparison
Age	19.6 (1.9) years	70.7 (4.7) years	–
Perceptual Speed	26.2 (10.9)	24.8 (8.1)	$t(77) = 0.68, p = .50$
Verbal Ability	14.4 (4.3)	21.9 (6.2)	$t(77) = 6.25, p < .001, d = 1.41$
Depression Screen	36.6 (10.1)	28.0 (6.4)	$t(77) = 4.51, p < .001, d = 1.02$
Visual Acuity (in log Mar)	0.02 (0.25)	0.15 (0.23)	$t(77) = 2.50, p = .015, d = 0.54$
Subjective Health	3.5 (1.0)	3.7 (0.9)	$t(77) = 0.64, p = .52$
Health Problems	1.7 (0.11)	1.9 (1.0)	$t(77) = 0.67, p = .51$

Note: Participants completed the Finding A's test (0–125 possible) and the Advanced Vocabulary (0–36 possible) test to assess perceptual speed and verbal ability, respectively (Ekstrom, French, Harman, & Dermen, 1976). Each test is a timed test, and scores were calculated by summing the correct items attempted. The depression screen used was the Center for Epidemiological Studies Depression Scale (20 items; 20–60 possible; Cronbach's $\alpha = 0.90$); higher scores reflecting greater depressive symptomology (Radloff, 1977). Visual acuity was tested using a Precision Vision 2195 chart; participants stood 1 m away from chart. Participant health was assessed using two five-point rating scales. Participants rated their overall health (1 = poor to 5 = excellent) and how much health problems stood in their way (1 = not at all to 5 = a great deal).

or were college graduates and 20% had worked toward or earned a high school diploma. Older adults received a small stipend for participating in the study. This study's procedures and materials were approved by the human subjects review board of Western Kentucky University (IRB #17-130) to ensure compliance with the ethical treatment of human subjects, and written informed consent was obtained from each participant in advance of testing.

2.2. Materials

Participants completed one of two emotion detection tasks in which emotional or neutral stimuli appeared one at a time at three different distances to the left or right of a central fixation cross, centered along the horizontal axis at one of three possible angles of eccentricity (5°, 10°, or 15°). Stimuli were presented on an ASUS VG248QE 24-inch full HD 1920 × 1080 pixel resolution monitor with a 100 Hz refresh rate. Participants were seated 57.3 cm from the display (1 cm of display = 1° visual angle). The emotion detection tasks were created using fearful, angry, and neutral facial stimuli selected from the Chicago Face Database (Ma, Correll, & Wittenbrink, 2015) and the NimStim face set (Tottenham et al., 2009). For each task, four male and four female targets were selected (two Caucasian and two African-American targets per gender). Each target's emotional and neutral images were combined in equal proportions using Abrosoft Fantamorph 5 face morphing software to operationally define an intensity factor for the stimulus set. Each target was represented by three images: 100% intensity emotional expression, 50% intensity emotional expression, and neutral expression. An oval filter was next applied to each image to remove extraneous background information, restricting the facial area for each stimulus from the forehead to the chin, cutting off each target's ears, and minimizing hair features as much as possible (i.e., observe the target's eyebrows and eyelashes). The resulting stimuli were approximately 5.3°(w) × 7.6°(h). Sample images of fear and anger facial stimuli are depicted in Fig. 1 (Ma et al., 2015).

Participants completed either a task utilizing neutral and fearful expressions or a task utilizing neutral and angry expressions. In total, there were 768 trials per task, or 128 trials per location (2 sides of visual field × 3 distances), with 64 neutral trials and 64 emotional trials. The 64 emotional trials were further broken down into 32 high expressive intensity stimuli and 32 lower intensity stimuli. Overall, each target's emotional stimuli were repeated four times (8 targets × 4 repetitions = 32 trials). Trials were blocked by stimulus intensity and were counterbalanced such that some participants completed the low expressive intensity blocks first, whereas others completed the high expressive intensity blocks first. During a trial, a fixation cross appeared in the center of the display for 800 ms, after which a facial stimulus appeared on the display with a duration of 140 ms for younger adults and 200 ms for older adults (Fig. 2) randomly at one of the six locations.

Post face offset, participants had up to 1400 ms to categorize the stimulus as emotional (angry/fearful) or neutral using the number pad on the keyboard (1 = angry/fearful, 3 = neutral). The trials were presented at random so that, on any given trial, emotional and neutral trials were equally likely to appear. Anticipatory eye movements toward an expected stimulus position would also be an unsuccessful participant strategy because the stimulus location was randomized with the same number of presentations on each side of the fixation cross within each block of trials. The aforementioned stimulus duration was selected to minimize the possibility that the participants could move their eyes away from the central fixation cross toward the stimulus during a trial. Past research demonstrates that younger adults (ages 20–40) need approximately 250 ms ($SD \approx 40$ ms) to fixate on a new location, whereas older adults (ages 60–69) need approximately 342 ms ($SD \approx 64$ ms) to refixate (Carter, Obler, Woodward, & Albert, 1983). Different stimulus durations (i.e., just below 2 SD s from mean of age group) were used for the younger and older adult samples to reduce any benefit of eye movements toward the target facial stimuli while still affording members of each sample an opportunity to complete the task with reasonable accuracy. Participant responses were converted into hit rates and false alarm rates for each condition.

After the peripheral emotion detection task, participants completed two brief emotional judgment tasks with self-paced viewing durations and unconstrained eye movements. To ensure that both the younger and older adult samples perceived the angry and fearful face stimuli as emotionally expressive, participants (a) compared each target's face pair (50% versus 100%) to select which of the two images expressed the most intense emotion, and (b) viewed each emotional stimulus observed during the emotion detection task to rate the extent that each displayed the intended emotion (i.e., either fear or anger). In the former task, stimuli appeared side by side in the center of the display, and participants simply selected either the left or right stimulus. Comparison accuracy was calculated for each participant. In the other task, each emotional stimulus presented in the emotion detection task was presented in random order twice, and participants answered the following emotional salience question using a five-point rating scale (from none at all to a great deal): "To what extent does this image display fear (anger)?" Average salience ratings were calculated for each expressive intensity using 16 ratings (8 targets × 2 responses). The expectation was that emotional salience would be higher for the non-morphed than the morphed expressions.

2.3. Procedure

Prior to completing the emotion detection task, participants provided informed consent and completed a visual acuity test. During the emotion detection task, participants observed either angry and neutral or fearful and neutral stimuli presented at parafoveal and peripheral

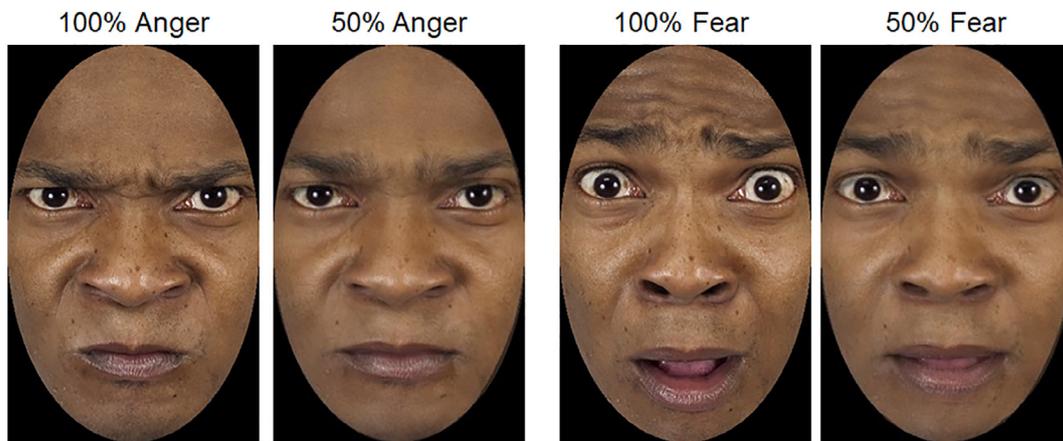


Fig. 1. Sample high (100%) and low (50%) intensity anger and fear expressions.

locations on the display, judging whether the stimulus expressed an emotion (i.e., choosing between “neutral” and either “angry” or “fearful” labels on each trial). Participants completed eight blocks of 96 trials each, with breaks in between each block. After the emotion detection task, participants completed the two self-paced emotion judgment tasks in which stimuli were presented on the display so that participants could compare the low and high intensity versions of the stimuli to choose the more intense expression and rate the individual stimuli on their expressivity. Next participants completed a brief cognitive battery, a depression screen and personality inventory, and a demographics form. At the end of the session, participants were debriefed, thanked, and compensated for their participation.

3. Results

Emotion detection performance (i.e., d' values) and response biases (i.e., C) were calculated using the participants’ hit and false alarm rates (Macmillan & Creelman, 2004). Both measures were evaluated using

mixed-model ANOVAs in which Age Group (2: younger/older) and Emotion Type (2: fear/anger) were between-subjects factors, whereas expressive Intensity (2: low/high), Distance from center of display (3: 5°/10°/15°), and Side of stimulus presentation (2: left/right) were within-subjects factors. Additional, mixed-model ANOVAs were performed to examine the impact of Age Group (2), Intensity (2), Distance (3), Side (2), Task (2: Angry/Neutral and Fearful/Neutral), and Emotion (2: Emotional Face/Neutral Face) on (a) the number of timeouts that took place during the experiment, and (b) the average response time for all trials (i.e., correct and incorrect) except for those in which timeouts occurred. Note that for these additional ANOVAs, neutral and emotional trials are disaggregated from one another, creating an additional within-subjects factor (i.e., Task and Emotion here versus Emotion Type for d' and C).

3.1. Emotion detection performance

The ANOVA performed on d' values revealed that main effects of

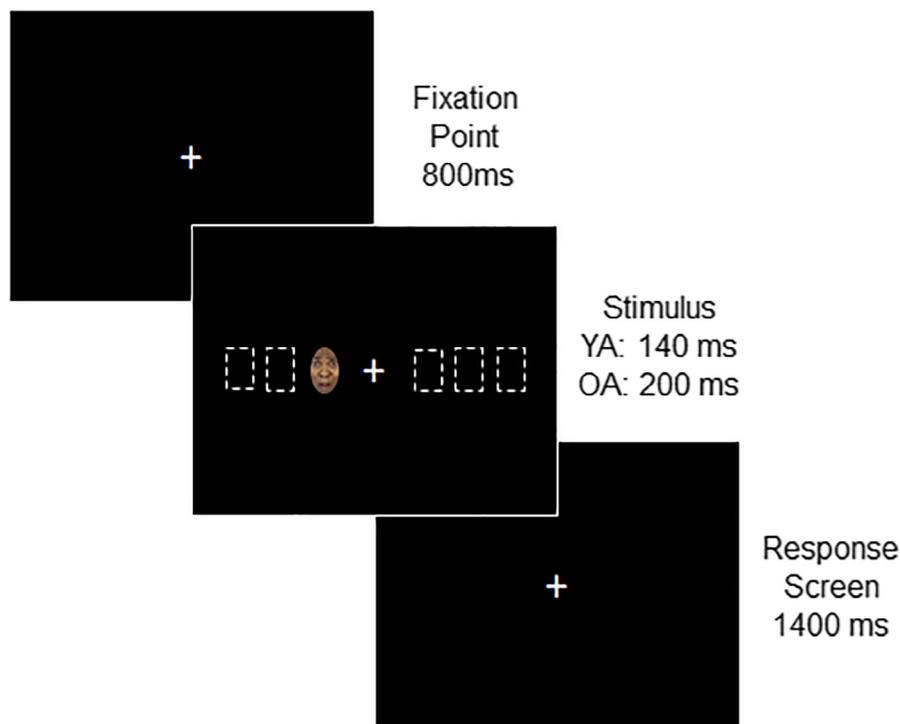


Fig. 2. Illustration of sequence of displays during a trial. Dotted white boxes did not appear on the display and are included to represent the six possible stimulus locations ($\pm 5^\circ$, $\pm 10^\circ$, and $\pm 15^\circ$ from the fixation cross).

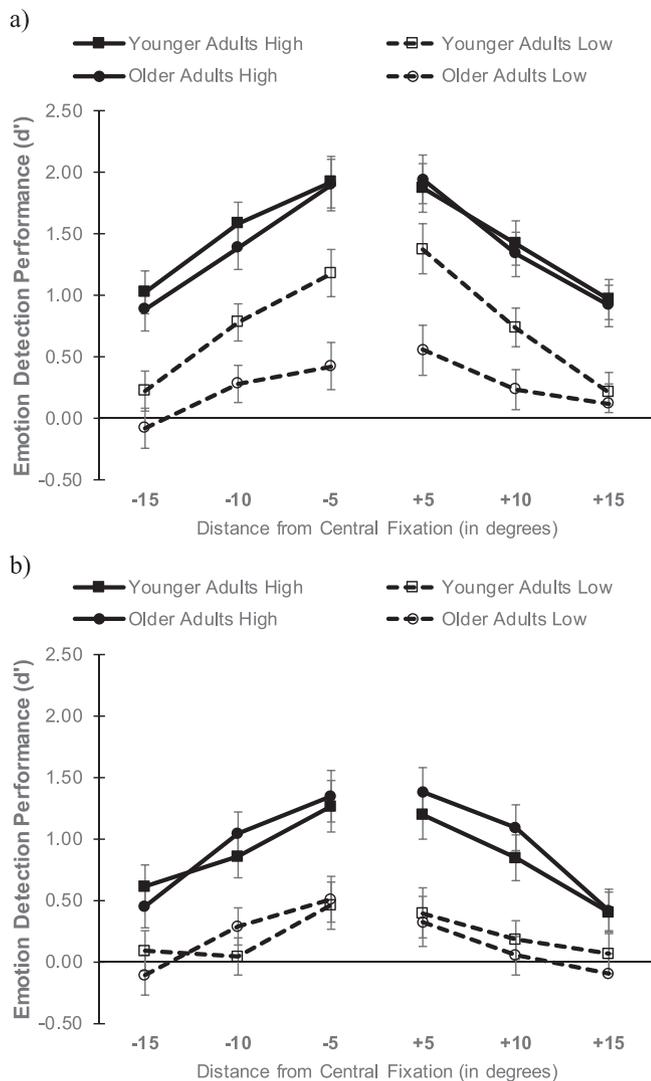


Fig. 3. Mean emotion detection performance for (a) the fear, and (b) the anger detection tasks, separated by age group. Error bars reflect ± 1 standard error.

emotion type, $F(1, 75) = 10.13$, $p = .002$, $\eta_p^2 = 0.119$, intensity, $F(1, 75) = 101.88$, $p < .001$, $\eta_p^2 = 0.576$, and distance, $F(2, 150) = 159.67$, $p < .001$, $\eta_p^2 = 0.680$, were qualified by a number of interactions: distance \times emotion type, $F(2, 150) = 4.09$, $p = .019$, $\eta_p^2 = 0.052$, intensity \times distance, $F(2, 150) = 8.38$, $p < .001$, $\eta_p^2 = 0.101$, distance \times age group \times emotion type, $F(2, 150) = 4.53$, $p = .012$, $\eta_p^2 = 0.057$, and intensity \times distance \times age group, $F(2, 150) = 3.28$, $p = .040$, $\eta_p^2 = 0.042$. No significant effects occurred with respect to the side of stimulus presentation. Means and standard errors for younger and older adults' emotion detection performance for the anger/neutral and fear/neutral tasks are presented in Fig. 3a and b, respectively. Stimulus locations in the left visual field are denoted with negative visual angles, whereas stimulus locations in the right visual field are denoted with positive visual angles. In order to decompose the three-way interactions, separate ANOVAs were performed for younger and older adults to examine the impact of emotion type, expressive intensity, and distance.

For younger adults, the ANOVA yielded significant main effects of emotion type, $F(1, 37) = 9.25$, $p = .004$, $\eta_p^2 = 0.200$, intensity, $F(1, 37) = 27.57$, $p < .001$, $\eta_p^2 = 0.427$, and distance, $F(2, 74) = 96.81$, $p < .001$, $\eta_p^2 = 0.723$, which were qualified by distance \times emotion type, $F(2, 74) = 9.41$, $p < .001$, $\eta_p^2 = 0.203$, and intensity \times distance \times emotion type interactions, $F(2, 74) = 3.71$, $p = .025$, $\eta_p^2 = 0.095$. Younger adults were better at emotion detection in the

fear task ($M = 1.11$, $SE = 0.13$) than in the anger task ($M = 0.54$, $SE = 0.14$). Separate ANOVAs were conducted for each emotion type to examine the impact of distance and intensity on detection performance. For the fear task, a main effect of distance, $F(2, 38) = 70.98$, $p < .001$, $\eta_p^2 = 0.789$, was followed up with Bonferroni-corrected post-hoc comparisons revealing significant incremental decline in performance at each further distance ($ps < 0.001$). A main effect of intensity, $F(1, 19) = 13.19$, $p = .002$, $\eta_p^2 = 0.410$, demonstrated that fear detection was better for high than for low expressive intensity stimuli. For the anger task, main effects of distance, $F(2, 36) = 29.56$, $p < .001$, $\eta_p^2 = 0.622$, and intensity, $F(1, 18) = 14.95$, $p = .001$, $\eta_p^2 = 0.454$, were qualified by a distance \times intensity interaction, $F(2, 36) = 5.02$, $p = .012$, $\eta_p^2 = 0.218$. Anger detection was always better at each distance for high than for low expressive intensity stimuli. Post-hoc Bonferroni corrected comparisons revealed significant incremental decline in anger detection at each further distance for high ($ps \leq .004$) intensity stimuli. For low intensity stimuli, these comparisons revealed that emotion detection was better at 5° than at 10° or 15° ($ps \leq .005$), but not different between 10° and 15°.

For older adults, the ANOVA examining the impact of emotion type, intensity, and distance on detection performance revealed significant main effects of intensity, $F(1, 38) = 94.39$, $p < .001$, $\eta_p^2 = 0.713$, and distance, $F(2, 76) = 68.08$, $p < .001$, $\eta_p^2 = 0.642$, which were qualified by an intensity \times distance interaction, $F(2, 76) = 9.43$, $p < .001$, $\eta_p^2 = 0.199$. Overall, older adults were better at detecting emotion in high than in low expressive intensity stimuli at each distance. Bonferroni-corrected post-hoc comparisons revealed significant incremental decline in performance at each further distance for both low ($ps \leq .009$) and high ($ps < .001$) intensity expressions. The intensity \times distance interaction emerged because the performance decline was greater for high ($\Delta d' = 0.98$) than for low ($\Delta d' = 0.49$) intensity expressions across the range of peripheral distances.

Both younger and older adults generally displayed incremental decline in emotion detection when the stimuli appeared at greater distances from the center of the display. Additionally, both age groups displayed better emotion detection for high than for low intensity stimuli. Although younger adults displayed better performance in the fear detection than in the anger detection task, older adults displayed no difference between tasks. Interestingly, despite having a somewhat longer stimulus duration, older adults struggled more than younger adults at detecting low intensity fear expressions at 5° and 10°, $t(38) = 2.57$, $p = .014$, $d = 0.81$, and $t(38) = 2.16$, $p = .037$, $d = 0.68$, respectively.

3.2. Response biases

The ANOVA performed on C values, which is a measure of response bias (Macmillan & Creelman, 2004), revealed that main effects of age group, $F(1, 75) = 6.55$, $p = .012$, $\eta_p^2 = 0.080$, emotion type, $F(1, 75) = 8.92$, $p = .004$, $\eta_p^2 = 0.106$, intensity, $F(1, 75) = 20.23$, $p < .001$, $\eta_p^2 = 0.212$, side, $F(1, 75) = 39.68$, $p < .001$, $\eta_p^2 = 0.346$, and distance, $F(2, 150) = 10.50$, $p < .001$, $\eta_p^2 = 0.123$, were qualified by a number of interactions: side \times distance, $F(2, 150) = 3.71$, $p = .027$, $\eta_p^2 = 0.047$, and side \times distance \times emotion type, $F(2, 150) = 4.77$, $p = .010$, $\eta_p^2 = 0.060$. C values greater than zero reflect a tendency to respond "neutral", whereas C values below zero reflect a tendency to respond "angry"/"afraid." In Fig. 4a and 4b, means and standard errors for C values for the anger/neutral and fear/neutral tasks are presented. Participants displayed a greater tendency to choose the neutral label over the emotion label in the low intensity blocks ($M = 0.42$, $SE = 0.05$) than in the high intensity blocks ($M = 0.19$, $SE = 0.04$) of the emotion detection task. On average, C values were closer to zero for stimuli presented in the left visual field ($M = 0.22$, $SE = 0.04$) than for stimuli presented in the right visual field ($M = 0.39$, $SE = 0.04$). Note that the side \times distance \times emotion type interaction emerged because C values declined from 5° to 15° for the

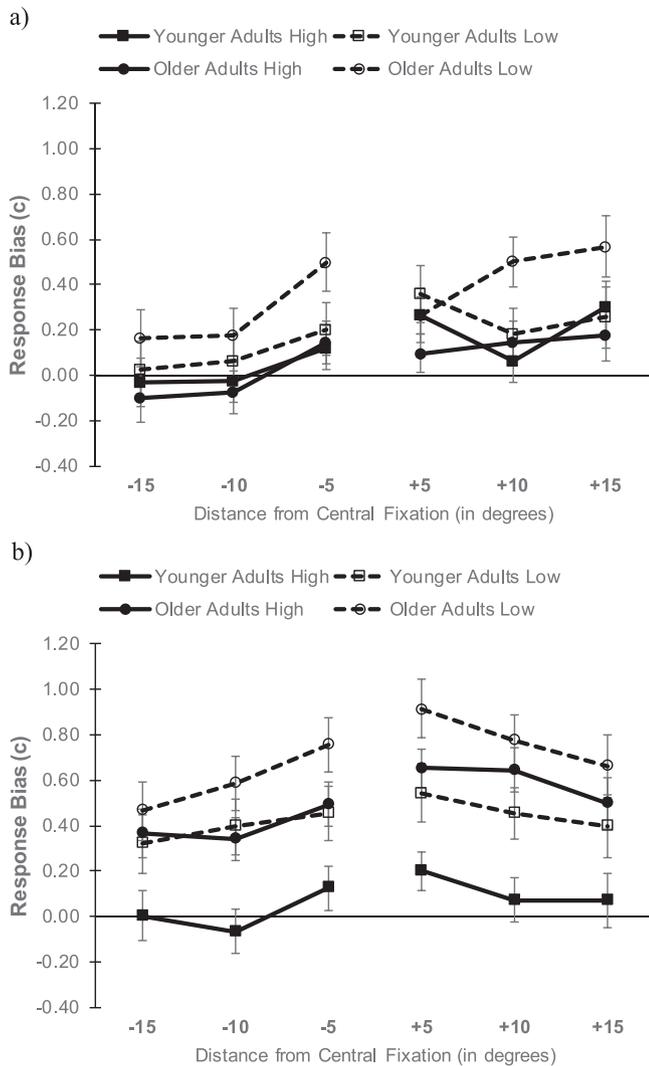


Fig. 4. Mean response biases for (a) the fear, and (b) the anger detection tasks, separated by age group. Error bars reflect ± 1 standard error.

angry task in both the left and right visual fields ($\Delta C = 0.17$; $ps \leq .02$; $-5^\circ M = 0.47, SE = 0.08$; $-15^\circ M = 0.29, SE = 0.07$; $+5^\circ M = 0.58, SE = 0.07$; $+15^\circ M = 0.41, SE = 0.08$) but, for the fear task, declined from 5° to 15° in the left visual field and not the right ($\Delta C = 0.17, p = .008$; $-5^\circ M = 0.19, SE = 0.06$; $-15^\circ M = 0.01, SE = 0.07$; $+5^\circ / +15^\circ M \approx 0.31, SE \approx 0.07$). In the right visual field, C was lower at 10° than 15° ($\Delta C = 0.10, p = .022$; $+10^\circ M = 0.22, SE = 0.07$).

3.3. Timeouts

The number of timeouts per condition were tabulated for each participant. Across experimental cells, the frequency of timeouts per condition ranged from 2.0% to 4.4% for younger adults and from 1.7% to 6.5% for older adults. The ANOVA performed on the frequency of timeouts revealed a main effect of distance, $F(2, 150) = 15.39, p < .001, \eta_p^2 = 0.170$, and distance \times age group, $F(2, 150) = 6.62, p = .002, \eta_p^2 = 0.081$, and emotion \times intensity, $F(1, 75) = 5.37, p = .023, \eta_p^2 = 0.067$, interactions. ANOVAs performed separately by age group to examine the impact of distance on timeout frequency failed to yield a main effect of distance for younger adults ($M = 1.9, SE = 0.4$), $F(2, 74) = 2.08, p = .132, \eta_p^2 = 0.053$, but did yield a main effect for older adults, $F(2, 76) = 13.89, p < .001, \eta_p^2 = 0.268$. Bonferroni-corrected post-hoc comparisons revealed a significant incremental increase in the frequency of timeouts ($ps \leq 0.005$) as

distance from the center of the visual field increased ($5^\circ M = 1.8, SE = 0.3$; $10^\circ M = 2.3, SE = 0.3$; $15^\circ M = 3.1, SE = 0.5$). The emotion \times intensity interaction emerged because there were moderately more timeouts when neutral expression trials were paired with low intensity emotional expressions (Emotion $M = 2.5, SE = 0.4$; Neutral $M = 2.6, SE = 0.4$) than with high intensity emotional expressions (Emotion $M = 1.9, SE = 0.3$; Neutral $M = 1.7, SE = 0.3$), presumably due to the smaller difference in the physical appearance of lower intensity emotional stimuli and neutral ones.

3.4. Average response time

The ANOVA performed on average response time revealed main effects of age group, $F(1, 75) = 43.08, p < .001, \eta_p^2 = 0.365$, distance, $F(2, 150) = 38.88, p < .001, \eta_p^2 = 0.341$, side, $F(1, 75) = 9.45, p = .003, \eta_p^2 = 0.112$, and interactions between distance \times age group, $F(2, 150) = 3.16, p = .045, \eta_p^2 = 0.040$, emotion \times age group, $F(1, 75) = 18.03, p < .001, \eta_p^2 = 0.194$, emotion \times side, $F(1, 75) = 5.76, p = .019, \eta_p^2 = 0.071$, and side \times task \times age group, $F(1, 75) = 4.55, p = .036, \eta_p^2 = 0.057$. Means and standard errors for younger and older adults' average response times for the low and high intensity trials of the fear/neutral task and the low and high intensity trials of the anger/neutral task are in Fig. 5a–d. Younger adults responded more quickly than older adults, irrespective of the location of the stimulus in the visual display. With increasing distance from the center of the visual field, response times increased for both age groups; however, there was a larger difference in response time for older adults ($\Delta RT = 43$ ms) than for younger adults ($\Delta RT = 26$ ms) between 5° and 15° . Younger adults required more time for neutral ($M = 666$ ms, $SE = 21$ ms) than emotional ($M = 655$ ms, $SE = 20$ ms) expressions, but older adults required more time for emotional ($M = 857$ ms, $SE = 20$ ms) than for neutral ($M = 838$ ms, $SE = 21$ ms) expressions. Response times were longer for stimuli appearing on the left side (Emotion $M = 759$ ms, $SE = 14$ ms; Neutral $M = 759$ ms, $SE = 14$ ms) of the display than the right (Emotion $M = 754$ ms, $SE = 14$ ms; Neutral $M = 744$ ms, $SE = 15$ ms), with a larger difference in side emerging when the stimuli were neutral expressions than when emotional.

To decompose the side \times task \times age group interaction, separate ANOVAs were performed on the response time for stimuli presented in the left and right visual field. For the left visual field, the ANOVA revealed a main effect of age group, $F(1, 75) = 47.38, p < .001, \eta_p^2 = 0.387$, and a task \times age interaction, $F(1, 75) = 4.24, p = .043, \eta_p^2 = 0.53$. Younger adults required more time for trials on the Fear/Neutral task ($M = 682$ ms, $SE = 28$ ms) than for trials on the Anger/Neutral task ($M = 644$ ms, $SE = 29$ ms), whereas older adults required more time for trials on the Anger/Neutral task ($M = 893$ ms, $SE = 29$ ms) than for trials on the Fear/Neutral task ($M = 817$ ms, $SE = 28$ ms). For the right visual field, the ANOVA revealed only a main effect of age group, $F(1, 75) = 38.15, p < .001, \eta_p^2 = 0.337$ (Young $M = 659$ ms, $SE = 21$ ms; Old $M = 840$ ms, $SE = 21$ ms).

3.5. Validation of stimuli

After the emotion detection task, participants (a) compared low and high intensity emotional expressions from the task indicating which stimulus was more intense for each target actor, and (b) rated how salient the emotion was in each emotion stimulus. A 2 (Emotion Type: fear/anger) \times 2 (Age Group: younger/older) between-subjects ANOVA conducted on the comparison accuracies yielded no significant effects (Fear: $M = 96.1\%, SE = 2.1\%$; Anger: $M = 95.7\%, SE = 2.2\%$). Additionally, a 2 (Expressive Intensity: high/low) \times 2 (Emotion Type: fear/anger) \times 2 (Age Group: younger/older) mixed-model ANOVA conducted on the emotional salience ratings yielded main effects of emotion type, $F(1, 75) = 9.38, p = .003, \eta_p^2 = 0.111$, and intensity, $F(1, 75) = 623.81, p < .001, \eta_p^2 = 0.893$. Participants offered slightly greater salience ratings (11% greater) for fearful stimuli ($M = 3.03$,

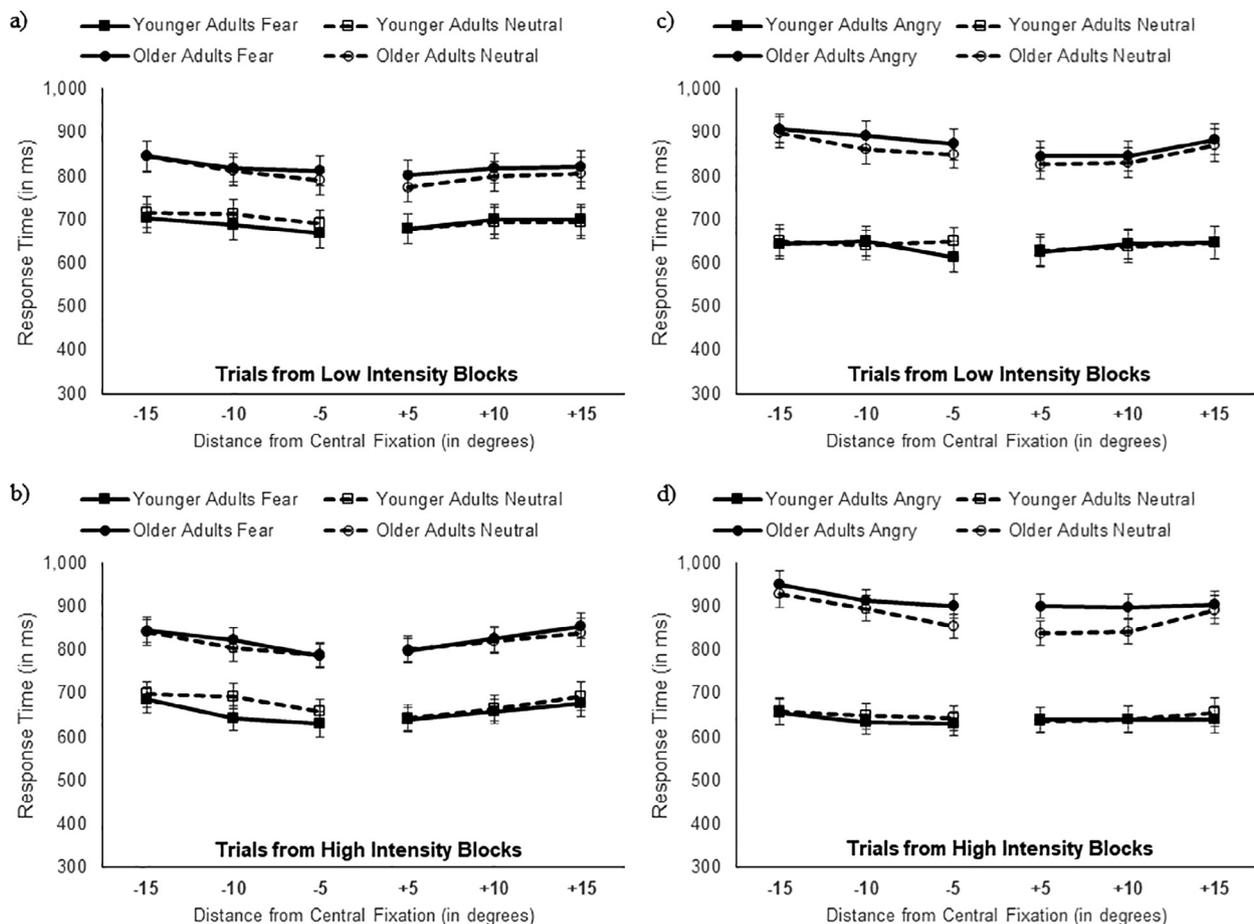


Fig. 5. Mean response times for blocks (a) in the fear/neutral task including low intensity fear expressions, (b) in the fear/neutral task including high intensity fear expressions, (c) in the anger/neutral task including low intensity anger expressions, (d) in the anger/neutral task including high intensity anger expressions. Error bars reflect ± 1 standard error.

$SE = 0.07$) than for angry stimuli ($M = 2.72$, $SE = 0.07$), and substantially greater salience ratings (60.2% greater) for higher expressive intensity stimuli ($M = 3.54$, $SE = 0.06$) than for the morphed lower intensity stimuli ($M = 2.21$, $SE = 0.05$). In sum, participants accurately reported which one of each target's stimulus pair was more intense and provided higher salience ratings for the original than for the morphed images. Participants also rated emotion as slightly more salient in stimuli expressing fear than in stimuli expressing anger.

4. Discussion

The purpose of this study was to extend previous research on age differences in visual search for emotional faces by investigating whether analogous age effects could be found for singly presented peripheral faces. High and low intensity facial expressions of fear and anger were presented to younger and older adults at 5°, 10°, and 15° to the left and right of fixation for a brief duration. Overall, both younger and older adults displayed better detection of fearful than of angry stimuli, better detection of emotion in high than in low intensity expressions, and an incremental decline in detection performance with each increase in distance away from the center of the visual field. Consistent with past research in which threat cues are foveally presented (e.g., Johnson & Whiting, 2013, who presented faces centrally at 5.5° w × 6.0° h), it is clear that members of both age groups are also capable of detecting threat cues in peripherally presented facial expressions. Moreover, for both younger and older adults, threat detection performance is superior when the emotion cues are highly salient.

There were two notable deviations in the performance of younger

and older adults, however. First, younger adults, despite having a shorter stimulus duration, displayed greater threat detection for low expressive intensity fear stimuli than did older adults. This finding is consistent with prior research in which younger adults were better than older adults at discriminating between fear and other negative emotions (Mienaltowski et al., 2013) and at detecting fear relative to anger if blocked with neutral faces (Johnson & Whiting, 2013) when stimuli were presented in the center of the display and at lower expressive intensities. This finding suggests that younger adults may be more sensitive to facial fear cues than are older adults and thus may have a lower threshold for fear cues during peripheral emotion detection. Second, although both age groups displayed poorer emotion detection for angry than for fearful expressions, older adults also displayed a significantly greater tendency to respond “neutral” than “angry” in the anger task than did younger adults. Because this study did not investigate the specific facial features underlying this bias (e.g., by manipulating the salience of visual cues for anger in the mouth region versus the eye region), it is impossible to know exactly why older adults' displayed this greater tendency toward responding with the neutral label. One possibility is that older adults have more difficulty integrating facial cues in the eye and mouth region to perceive anger in peripherally presented stimuli. Future research should include a systematic investigation of the impact of crowding between facial features (Martelli et al., 2005) and how they differ by discrete emotion, which may illuminate these differences between older and younger adults.

Although emotion detection accuracy is less when stimuli are presented in the peripheral visual field than when presented centrally (Bayle, Schoendorff, Hénaff, & Krolak-Salmon, 2011; Rigoulot et al.,

2011), peripherally presented fear expressions elicit greater activation than centrally presented ones in frontal cortical regions and the amygdala soon after stimulus onset, suggesting a top-down influence on emotion perception (Bayle, Hénaff, & Krolak-Salmon, 2009). It has been proposed that, in the presence of arousing negative stimuli, the amygdala communicates rapidly with anterior and posterior cortical regions via a low resolution magnocellular pathway-biased neuronal track (Adolphs, 2002; Im et al., 2017; Pessoa & Adolphs, 2010; Vuilleumier, 2005). Aging has been linked to degradation within this pathway as well as to higher levels of internal noise (Anderson & McDowell, 1997; Benedek, Horváth, Kéri, Braunitzer, & Janáky, 2017; Elliott & Werner, 2010; Langrová, Kuba, Kremláček, Kubová, & Vít, 2006; Steinman, Steinman, Trick, & Lehmkuhle, 1994; see Supplemental Information for exploratory analysis of cognitive functioning and emotion detection ability in the older adult sample). Both impediments could reduce top-down perceptual benefits (otherwise conferred to younger adults) for threat-related signals by disrupting the ability of the amygdala to modulate cortical regions that are important for processing threat and mobilizing a response. This possibility is consistent with older adults' deficits in detecting low intensity fearful expressions observed in the current study.

The observed findings are also partly consistent with prior research examining age differences in visually evoked potentials suggest that top-down processing of negative facial expressions of emotion may be blunted with age. Specifically, younger but not older adults display an enhanced frontocentral positivity to angry expressions early on after their onset (Hilimire, Mianaltowski, Blanchard-Fields, & Corballis, 2014), suggesting that prefrontal cortical regions may be less involved in early emotion processing for older adults. This possibility is consistent with older adults' increased tendency to respond "neutral" in the anger task observed in the current study. Likewise, older adults may be more likely to engage in cognitive control for negative stimuli, reducing emotion-induced perceptual gains that support emotion detection but nevertheless habituate over repeated exposure (Roalf, Pruis, Stevens, & Janowsky, 2011). Also, recent findings suggest that, relative to younger adults, older adults display a reduced amplitude visually-evoked parietal P1 to angry expressions and a reduced fronto-central N250 when decoding emotion in facial stimuli (Gonçalves et al., 2018; Houston, Pollock, Lien, & Allen, 2018). In sum, the perceptual gain normally conferred to stimulus processing may be diminished in the visual system of older adults, contributing to emotion recognition deficits. Certainly, future research is needed to more closely examine the interconnectivity of limbic regions of the brain and cortical regions responsible for prioritizing threat detection and for perceiving the actual threat (St. Jacques, Dolcos, & Cabeza, 2010; Tessitore et al., 2005). Additionally, systematic manipulations of facial stimuli that might differentially modulate retino-thalamo-cortical communication along magnocellular and parvocellular pathways (Im et al., 2017) of younger and older adults could help reveal the source of age-related deficits in threat processing including the role of the amygdala.

The current study is the first to examine age differences in peripheral facial emotion detection, but there are limitations in its design that are important to note. Although age differences in detection performance were observed for low intensity fearful expressions but not low intensity anger expressions, the mechanism accounting for this disparate outcome was not examined. One might speculate that age differences in low intensity fear detection emerged because fear cues in the eye region were less salient to older adults than to younger adults, given older adults' tendency to rely more on mouth- than eye-related cues in facial emotion recognition tasks (Wong, Cronin-Golomb, & Nearing, 2005). To better understand if younger and older adults differ in their ability to detect specific cues, future studies could ask participants' to simply detect facial features (e.g., furrowed brow, wide eyes, bared teeth, etc.) that contribute to one's perception of emotion in facial stimuli like those used in the current study (e.g., Martelli et al., 2005).

5. Conclusions

Extending prior research concerning the impact of aging on threat detection, the current study demonstrated that younger and older adults are both able to detect peripheral threat cues in facial expressions, but that lower intensity cues pose more of a challenge for older adult observers than younger adult observers. The age differences in threat detection may reflect an underlying change that emerges with increasing age in the interconnectivity between subcortical and cortical systems responsible for facilitating emotion perception. Given that peripheral threat detection occurs effectively for higher intensity expressions in old age, the perceptual pathways needed to communicate an emotion signal are likely intact but experience a quantitative reduction in function.

6. Author Note

This work was supported by funding awarded to B. N. G. by the Graduate School at Western Kentucky University, and by funding provided to A. M. by the Ogden College of Science and Engineering at Western Kentucky University.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.visres.2019.09.002>.

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