

ATTENTIONAL ORIENTING TO ANGRY FACES

Social threat processing in adults and children: faster orienting to, but shorter dwell time on,
angry faces during visual search

Research Highlights

- Children and adults are *slower* to select angry faces when measured by time to mouse-click but *faster* to detect angry faces when measured by time to first eye fixation.
- Use of eye-tracking addresses some limitations of prior visual search tasks with children that rely on behavioral responses alone.
- Results suggest shorter time to first fixation, but subsequently, shorter duration of dwell on social threat in children and adults.

Abstract

Attention to emotional signals conveyed by others is critical for glean information about potential social partners and the larger social context. Children appear to detect social threat (e.g., angry faces) faster than non-threatening social signals (e.g., neutral faces). However, methods that rely on behavioral responses alone are limited in identifying different attentional processes involved in threat detection or responding. To address this question, we used a visual search paradigm to assess behavioral (i.e., reaction time to select a target image) and attentional (i.e., eye-tracking fixations, saccadic shifts, and dwell time) responses in children (ages 7-10 years old, $N=42$) and adults (ages 18-23 years old, $N=46$). In doing so, we compared behavioral responding and attentional detection and engagement with threatening (i.e., angry and fearful faces) and non-threatening (i.e., happy faces) social signals. Overall, children and adults were faster to detect social threats (i.e., angry faces), but spent a smaller proportion of time dwelling on them and had slower behavioral responses. Findings underscore the importance of combining different measures to parse differences between processing versus responding to social signals across development.

Keywords: visual search; threat detection; social threat; emotion; eye-tracking

To enable successful social interactions, we learn to attend to relevant signals from other people. Facial cues to emotion are frequent and robust signals of other people's internal states or their behavioral intentions (Clément & Dukes, 2017). Facial cues to emotion also convey information about the environment, including signaling an impending physical threat (Walle et al., 2017). We are responsive to such signals and adjust behavior accordingly, including avoiding individuals conveying anger or using fear signals to stop a risky activity (Sorce et al., 1985; Clément & Dukes, 2017).

Fast detection of threats is particularly important from an evolutionary perspective (Hansen & Hansen, 1988). Rapid *social* threat detection has been described in the “face in the crowd” effect, which suggests faster detection of angry versus happy faces (Hansen & Hansen, 1988; Öhman et al., 2001). The effect emerges early in life (Fu & Pérez-Edgar, 2019) and has been reliably observed in adults and children using visual search tasks, where a target image (e.g., angry face) is situated among “distractors” (e.g., neutral or happy faces) within a visual array of faces (Frischen et al., 2008). Bias to attend to emotional faces (both happy and angry) is demonstrated in the first four years of life (Burris et al., 2017), while bias to detect negative emotional stimuli increases in the first two years of life alongside engagement with negative emotional stimuli (Reider et al., 2022). For example, children and adults consistently click on angry faces more quickly than happy, neutral, and sad faces when presented within visual arrays of 4-12 faces (Frischen et al., 2008; LoBue, 2009, 2014; LoBue & Larson, 2010; LoBue & Pérez-Edgar, 2014; Öhman et al., 2001). Faster social threat detection has been linked to symptoms of internalizing psychopathology among children at risk for developing anxiety disorders (LoBue & Pérez-Edgar, 2014) and among adults with post-traumatic stress disorder (Armstrong et al., 2013), and is thought to shape trajectories of risk for disorder through self-

reinforcing feedback loops (Morales et al., 2016). However, to fully investigate how children and adults attend and respond to social threat signals from others, attentional processes need to be disambiguated from behavioral responses.

In adults, distinctions between attentional processes include detecting (also referred to as “alerting”), directing attention to (sometimes termed “orienting”), and engaging (also referred to as “executive attention”) (Posner & Rothbart, 2007). Social threat signals have been investigated by pairing behavioral responding with eye-tracking, a continuous (Hermans et al., 1999) and ecologically valid (Armstrong & Olatunji, 2012) approach for identifying different attentional processes in responding to threat signals (Frischen et al., 2008). The captured processes reflect biologically distinguishable networks underlying different aspects of attention (Posner & Rothbart, 2007). In addition to a behavioral response (i.e., button/key press), *threat detection* is inferred from time to the first fixation to the target stimulus, *threat orientation* (i.e., frequency of attending to a threat cue) can be characterized by saccadic shifts, and *threat engagement* can be inferred from dwell time (i.e., proportion of time on average a participant fixates on the target versus other stimuli) (Castelhano et al., 2008; Lisk et al., 2020; Malcolm & Henderson, 2009).

Differentiating these processes is critical in research with children, who can take longer to prepare and execute a motor response after detecting threat (Dudeney et al., 2015). Delayed behavioral response times could mask actual threat detection or give children longer to reallocate attention. Additionally, attentional processes such as saccadic shifts reflect (and may contribute to) the development of emotion regulation and coping (Burriss et al., 2019; Posner & Rothbart, 2007). Much of the prior research with children using visual search paradigms with faces, however, has relied on touchscreen tasks that provide a single, indirect index (i.e., selection time) of threat detection, orientation, and engagement (Armstrong & Olatunji, 2012). In one exception

using a passive viewing task, children and adults show faster initial detection of angry faces (Lagattuta & Kramer, 2017). However, participants reallocated their attention if instructed to look at happy faces, and adults were more successful in this directed attentional shift. In other examples, researchers that distinguished between first fixation (location and latency) as a measure of threat detection and dwell time as a measure of threat engagement in visual search tasks find that adults show more avoidance of negative images as measured with dwell time (and not first fixation) (Shechner et al., 2017) and anxious youth show heightened threat detection in initial fixations (Shechner et al., 2013). More studies are needed to differentiate between multiple attentional processes and behavioral responses to social threat to provide greater insight into how children attend to emotional signals in their social environments.

To address this knowledge gap, we combine behavioral and attentional (i.e., eye-tracking) assessments and compared response patterns across children and adults. We used an established visual search paradigm in which participants located a target image within a visual array of distractor images (LoBue, 2009; LoBue & DeLoache, 2008; LoBue & Pérez-Edgar, 2014). In our child sample, we focused on late-childhood because the prioritization of negative social information decreases between mid-childhood and adulthood (Lagattuta & Kramer, 2017). First, to situate our findings alongside prior studies using behavioral measures, we examined *behavioral response time* for identifying social threat (i.e., mouse click). We hypothesized that children and adults would be faster to select socially threatening stimuli (i.e., angry and fearful faces) via mouse click, particularly from a small set size. Second, we used eye-tracking to assess *attentional detection* of social threat, indexed by how long it took participants to fixate on the target stimulus. We hypothesized that participants would be faster to detect threat-relevant stimuli, specifically angry and fearful faces, and specifically from a small set size. Third, we

evaluated how long it took participants to behaviorally make their selection after they had attentionally detected the target stimulus (i.e., “selection time”). Finally, we assessed saccadic shifts and “average dwell time,” which was defined as the proportion of time fixations were on the target stimulus (relative to distractors) to characterize orienting to and engagement with social threat. We did not make any *a priori* hypotheses, with the possibility that participants could orient to or engage with threatening stimuli more *or* less often.

Method

Participants

Participants were 42 children (21 female, 19 male; $M_{age}=9.14$ years, $SD_{age}=1.08$ years; 3 Asian, 17 Black or African American, 12 Hispanic or Latinx, 8 “Other”, 11 White; 2 participants were missing demographic information) and 46 adults (25 female, 19 male; $M_{age}=19.63$ years, $SD_{age}=1.23$ years; 1 American Indian or Alaska Native, 17 Asian, 3 Black or African American, 9 Hispanic or Latinx, 1 Native Hawaiian or Pacific Islander, 6 “Other”, 16 White). The sample size had been predetermined for the [masked] study, but was reduced because of COVID-19 pandemic-related disruption to data collection. Thus, we conducted a *post hoc* power analysis using the pwr package (general linear model $u=3$, $v=85$, $f^2=.15$, $sig.level=.05$) (Champely, 2020). This test revealed 86% power to detect a medium effect size. Children were recruited from two cities in the Northeastern United States for a multi-site study ([site masked], $n=20$; [site masked], $n=22$) through community advertising (e.g., flyers). Adults were a part of the [name masked] study conducted at [site masked] and consisted of undergraduate students at [institution masked] recruited through SONA (<https://www.sona-systems.com/>) and other adults recruited from the community. Eligibility criteria for adults were (1) over 18 years old, (2) fluent English speaker; and (3) normal/corrected-to-normal vision to see computer screen. Children met

the same criteria (with the exception of age). A further 11 participants were excluded for stopping the task (n=4 children; n=5 adults), having 0% accuracy (n=0 children; n=1 adult), and timing out on >50% of trials (n=1 child; n=0 adults).

Design and Stimuli

Participants were presented with 4, 8, or 12 images randomly placed in a 5 x 5 matrix on the screen (number of images on screen referred to as “set size”; **Figure 1**). We varied set size to understand behavior and attentional processes under different levels of task complexity and assess “pop out” effects (i.e., no increase in reaction time with set size; Becker & Rheem, 2020; Hampton et al., 1989). One image was the “target” image (happy, fearful, or angry face) and the other images were “distractor” images (neutral faces). Participants completed 24 trials with happy targets (8 of each set size) and 12 trials with each angry and fearful faces (4 of each set size). We reduced the number of trials for angry and fearful faces to equate the number of trials with positive stimuli (i.e., happy faces) and threat-relevant stimuli (i.e., angry, fearful faces). Images were obtained, with permission, from the NIMH Child Emotional Faces Picture Set (NIMH-ChEFS) (Egger et al., 2011). Participants also completed a separate, non-face version of the task in which the targets were frogs and snakes and the distractor images were flowers (full reporting in **Supplemental Materials**). All images were presented in grayscale following a fixation cross.

Procedure

Data were collected as part of a multi-site study with a 3-hour laboratory visit that included computer tasks paired with eye-tracking, parent (or adult) questionnaires, and parent demographic interview. Adult participants and parents provided informed written consent and children provided verbal assent. Families were compensated \$120. Undergraduate students

received course credit and community participants received \$20. All procedures were approved by the Institutional Review Boards at [masked] and [masked]. Participants completed the trials in a randomized, intermixed order. The instructions were, “Your job is to find the picture that looks different from all the others.” Participants saw one example set of faces to illustrate one expression differing from the distractors and received the instructions, “On this page, you would click on the happy face because it’s different from the other faces.” Participants selected their response using a standard clickable mouse. If participants did not respond within 5000ms, the trial timed out.

Eye-Tracking

Eye-tracking was recorded using the SR Research Eyelink 1000 Plus and data were preprocessed using DataViewer. Participants sat with their chin in an adjustable chin-rest that was centered and positioned 60cm from the computer monitor. The experimenter adjusted the corneal reflection and pupil threshold and then completed calibration and validation. Calibration was rechecked (and repeated if necessary) every sixteen trials. Each square in the matrix (**Figure 1**) was defined as a region of interest. Example scan paths for representative participants and trials are on OSF (https://osf.io/khuws/?view_only=ed847c1e3e1a403fb3762341326d92c3).

Analytic Strategy

First, we conducted trial-level exclusions. Fifteen percent of trials were excluded for timing out (i.e., no mouse click within 5000ms), <1% of trials were excluded because the reaction time to the first fixation to the target was <200ms (indicating the participant fixated on the target likely by chance when the trial began), <1% of trials were excluded because the first fixation to any location was >500ms (indicating the participant was not attentive), and <1% of trials were excluded because the mouse selection reaction time was <500ms (indicating too fast

of a selection). Second, to explore the main study questions we used linear mixed-effects models regressing our dependent variables of interest on the interaction between age group (centered: children=-.5, adults=.5), set size (8-set size as referent), and target emotion (angry face as referent). We included all lower-order effects (i.e., main effects and 2-way interactions). We included a by-participant random intercept (by-participant random slopes removed because of singular fit). Site ([masked]=- .5, [masked]=.5) was included as a covariate. Our dependent variables were: (1) *Behavioral response time*: time (in ms) from the start of the trial for participants to respond using a mouse click; (2) *Attentional detection*: time (in ms) from the start of the trial for participants to first fixate on the target; (3) “*Selection time*”: time difference (in ms) between attentional detection and behavioral response time. (4) *Saccadic shifts*: number of times (within a trial) that participants looked away from the target (note: this measure inherently also captures number of times participants looked to the target). For this analysis, we also controlled for trial time (in ms, mean-centered); and (5) *Average dwell time*: average time (within a trial) participants fixated on the target relative to distractor images (note: this number is the *proportion* of average dwell times on target relative to the distractors).

The de-identified dataset and analysis script are on Open Science Framework (https://osf.io/khuws/?view_only=ed847c1e3e1a403fb3762341326d92c3); the experimental task is available on request. Analysis tools reported in **Supplemental Materials**.

Results

Across trials, adults demonstrated higher accuracy than children ($b=.06$, $t=2.37$, $p=.02$), though average accuracy was 90% or above for all set sizes for both age groups. (**Supplemental Materials Figure S1**). For subsequent analyses, we only included correct trials.

Aim 1: Behavioral response time (mouse-click)

Adults showed faster behavioral response times (i.e., correctly selecting target via a mouse click) than children ($X^2(1)=49.62, p<.001$; means and standard deviations of measures are reported in **Supplemental Materials Table S1**). All participants showed faster behavioral response times for smaller set sizes ($X^2(2)=5325.49, p<.001$), with this effect more pronounced among children (age group by set size interaction, $X^2(2)=100.01, p<.001$). In contrast to hypotheses, participants were slower to respond to target angry faces compared to happy ($b=-429.54, p<.001$) or fearful faces ($b=-492.73, p<.001$; omnibus: $X^2(2)=1744.68, p<.001$). This effect was more pronounced among adults than children (target emotion by age group interaction, $X^2(4)=369.58, p<.001$) and for smaller set sizes (target emotion and set size interaction, $X^2(2)=93.43, p<.001$). A three-way interaction between age group, set size, and target emotion revealed that slower responding to angry faces was more pronounced with set sizes of four or eight images among adults versus children ($X^2(4)=78.93, p<.001$; **Figure 2**; pairwise comparisons including slopes in **Table 1**). Comparisons between happy and fearful faces were less consistent, but generally, participants were faster to respond to happy faces (**Table 1**). Finally, because using a mouse could be confounded by other relevant child characteristics, we conducted a *post hoc* analysis showing that neither child age ($r=-.12, p=.26$) or attentional difficulties (measured with the CBCL attention-problems subscale; $r=-.008, p=.99$) were correlated with response time.

Aim 2: Attentional detection of social threat (eye-tracking)

Overall, time to initial target fixation assessed using eye-tracking (our measure of attentional detection) was moderately correlated with behavioral response time assessed using a mouse-click ($r=.52, p<.001$). Consistent with behavioral response time, time to initial target fixation was faster for adults ($X^2(1)=24.09, p<.001$) and smaller set sizes overall ($X^2(2)=723.64,$

$p < .001$). Unlike the behavioral response time, but consistent with hypotheses, we found a main effect of target emotion ($X^2(2)=10.78, p=.005$), with children and adults faster to detect angry faces compared to happy ($b=-138.00, p<.001$) and fearful ($b=-133.63, p=.001$) faces. There was no difference in the detection of happy and fearful faces ($b=-4.37, p=.99$). There was a two-way interaction between set size and target emotion ($X^2(4)=56.40, p<.001$), such that faster attentional detection of angry faces was more pronounced for the 12-image set size, providing some evidence for “pop out”. Moreover, there was a three-way interaction with age ($X^2(4)=11.82, p=.02$), such that faster attentional detection of angry faces was evident with 8- or 12 images for children but only with 12 images for adults (**Figure 3**; pairwise comparisons in **Table 2**). The effect of site, and interactions between age group and set size, age group and trial type, and set size and trial type were not significant ($ps > .30$). Together, results demonstrated faster detection of angry faces, particularly in more complex displays.

The “selection time” findings aligned with the behavioral response time findings. That is, despite being faster overall to *detect* angry faces (via time to first eye-tracking fixation) compared to happy or fearful faces, participants were then slower to enact a mouse click response ($X^2(2)=352.55, p<.001$) when compared to fearful ($b=480.40, p<.001$) and happy ($b=547.00, p<.001$) faces. Participants had slower selection times for fearful faces than happy faces ($b=66.50, p=.04$). The effect of age group was also significant ($X^2(1)=23.06, p<.001$) with adults making selections faster than children. Other covariates were not significant ($ps > .1$).

Aim 3: Orienting to and engaging with social threat

Next, we examined saccadic shifts (i.e., the number of times within a trial that participants looked towards and then away again from the target). We included time as a covariate since longer trials allowed for more saccadic shifts. Although there was an overall

effect of target emotion ($X^2(2)=6.21, p=.045$), this effect was qualified by an interaction with set size ($X^2(4)=21.83, p<.001$; **Figure 4**). Specifically, there were more saccadic shifts for angry versus fearful ($b=0.31, p=.002$) and happy ($b=0.40, p<.001$) faces, but only for the 4-image set size. All other pairwise comparisons were not significant. Additional effects of age group, set size, and reaction time (included as a covariate) are available in **Table S2**. No other effects were significant. Thus, there were more saccadic shifts for angry faces, but only when there were fewer faces to look at overall.

Finally, we examined *average dwell time*, calculated as the average duration of each dwell within a trial to the target relative to the distractor. An average dwell time above .5 indicates that participant dwell time was longer for the target region relative to the distractors and a lower proportion indicates that participant dwell time was longer for the distractor regions relative to the target. As before, although there was a main effect of target emotion ($X^2(2)=47.29, p<.001$), this effect was qualified by an interaction with set size ($X^2(4)=24.08, p<.001$; **Figure 5**). Specifically, participants had shorter average dwell time on angry faces (relative to distractors) than fearful faces ($b=-0.04, p<.001$) and happy faces ($b=-0.06, p<.001$) in the 4-image set size. Participants also had a lower average dwell time on the target when the trial contained fearful faces as compared to happy faces in the 4-image set size ($b=-0.03, p=.004$). Finally, participants had a lower average dwell time to the target when trials contained angry faces versus happy faces ($b=-0.03, p<.007$ in the 12-image set size (all other pairwise contrasts were not significant; **Supplemental Materials Table S3** for full model output). In **Supplemental Materials**, we report results for the proportion of cumulative dwell time. Results are consistent with average dwell time results and suggest that, in addition to shorter dwell lengths to angry faces, the sum total of the time spent fixating on angry faces was also shorter.

Discussion

We used behavioral response time and eye-tracking to characterize attention and response to social threat in children in adults. We find evidence for faster attentional detection of social threats, consistent with previous research (Frischen et al., 2008; LoBue, 2009, 2014; LoBue & Larson, 2010; LoBue & Pérez-Edgar, 2014; Öhman et al., 2001). However, faster attentional detection of angry faces was masked by slower behavioral response time as measured with a mouse click. In dissecting the discordant findings between attentional detection and behavioral response time, we found more saccadic shifts and less time (on average and cumulatively) spent fixating on angry faces (as represented by lower proportion of dwell times to the target vs. distractors). These findings provide insight into how participants allocate attention. That is, participants looked to angry faces quicker, spent less time fixating on those faces and took longer to identify them as the “odd one out” compared to happy or fearful targets. More frequent visits to the angry face (as evidenced by saccadic shifts) than happy or fearful faces may indicate an unwillingness to hold fixation on angry faces or difficulty in distinguishing the facial features from the neutral distractors. These competing hypotheses cannot be tested with the present data and necessitate further investigation in future studies. However, since there was a unique pattern for angry faces when considering these different metrics in combination, our findings suggest that social threat modulates attentional processes during the task, which could reflect relationships between anger and heightened uncertainty (Anderson et al., 2019; Pittig et al., 2014). Responses to fearful faces were sometimes—but not often—distinct from happy faces. Fearful faces are important signals for cuing environmental threats (Clément & Dukes, 2017) and are attended to by social partners (Sorce et al., 1985), however, they may be considered a more indirect signal of social threat compared to angry faces, which are also perceptually prioritized

when gaze is directed toward the perceiver (Adams Jr. & Kleck, 2005). Many investigations use touchscreen tasks instead of mouse clicks, with some evidence that touchscreen tasks capture similar behavioral responses as mouse responses (LoBue, 2014), though our results show more alignment between *eye-tracking* and touchscreen tasks.

By varying the set size, we examined attentional processes when visual displays differed in complexity. Thus we explored whether density of social signals that a perceiver has to process affected social threat detection, orienting, and engagement (Frischen et al., 2008) and whether smaller set sizes allowed for opportunities for participants to intentionally allocate their attention (i.e., “executive attention” (Posner & Rothbart, 2007)). The tension between attentional detection versus engagement is consistent with other investigations, showing that perceivers can shift their focus to more positive social signals following an initial rapid orientation to social threat (Lagattuta & Kramer, 2017) and that detection and orienting can disassociate in the context of threat (Shechner et al., 2013, 2017).

Findings should be considered alongside several limitations. First, the sample size was smaller than intended due to COVID-19-related disruptions to in-person data collection. Second, although we used validated stimuli, the set included static and posed facial configurations of emotion. Emotions unfold dynamically and are sensitive to other features of contexts (Barrett et al., 2019), thus future research should consider increasing the ecological validity of the social context being investigated. For example, visual search paradigms with behavioral responding and eye-tracking (in particular mobile eye-tracking) in real-world social environments could further our understanding of social threat detection in daily life, including through use of virtual reality to simulate ecologically valid visual displays (Hadnett-Hunter et al., 2022; Olk et al., 2018). Finally, we were not powered to investigate individual differences in social threat

attention and behavioral responding, which likely have important consequences for social development (Fu & Pérez-Edgar, 2019), the formation of friendships and relationships (Pavlou et al., 2016), and development and maintenance of psychopathology (Armstrong et al., 2013; Jenness et al., 2021; Lisk et al., 2020; LoBue & Pérez-Edgar, 2014).

Conclusion

We used an experimental task to disentangle how children and adults process and respond to social threat signals. Children and adults detected direct social threats (i.e., angry faces) quickly, but subsequently showed slower behavioral response times. Social threat detection, orienting, engagement, and behavioral response were modulated by set size, indicating that mechanisms may be sensitive to the complexity of the social context. Responding to emotional signals is a key skill underlying social functioning and capturing detection and engagement with social can help elucidate potential mechanisms of social development.

References

- Adams Jr., R. B., & Kleck, R. E. (2005). Effects of Direct and Averted Gaze on the Perception of Facially Communicated Emotion. *Emotion, 5*, 3–11. <https://doi.org/10.1037/1528-3542.5.1.3>
- Anderson, E. C., Carleton, R. N., Diefenbach, M., & Han, P. K. J. (2019). The Relationship Between Uncertainty and Affect. *Frontiers in Psychology, 10*. <https://www.frontiersin.org/articles/10.3389/fpsyg.2019.02504>
- Armstrong, T., Bilsky, S. A., Zhao, M., & Olatunji, B. O. (2013). Dwelling on Potential Threat Cues: An Eye Movement Marker for Combat-Related Ptsd. *Depression and Anxiety, 30*(5), 497–502. <https://doi.org/10.1002/da.22115>
- Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review, 32*(8), 704–723. <https://doi.org/10.1016/j.cpr.2012.09.004>
- Barrett, L. F., Adolphs, R., Marsella, S., Martinez, A. M., & Pollak, S. D. (2019). Emotional Expressions Reconsidered: Challenges to Inferring Emotion From Human Facial Movements. *Psychological Science in the Public Interest, 20*(1), 1–68. <https://doi.org/10.1177/1529100619832930>
- Becker, D. V., & Rheem, H. (2020). Searching for a face in the crowd: Pitfalls and unexplored possibilities. *Attention, Perception, & Psychophysics, 82*(2), 626–636. <https://doi.org/10.3758/s13414-020-01975-7>
- Burris, J. L., Barry-Anwar, R. A., & Rivera, S. M. (20170522). An eye tracking investigation of attentional biases towards affect in young children. *Developmental Psychology, 53*(8), 1418. <https://doi.org/10.1037/dev0000345>

- Burris, J. L., Buss, K., LoBue, V., Pérez-Edgar, K., & Field, A. P. (2019). Biased attention to threat and anxiety: On taking a developmental approach. *Journal of Experimental Psychopathology*, *10*(3), 204380871986071. <https://doi.org/10.1177/2043808719860717>
- Castelhano, M. S., Pollatsek, A., & Cave, K. R. (2008). Typicality aids search for an unspecified target, but only in identification and not in attentional guidance. *Psychonomic Bulletin & Review*, *15*(4), 795–801. <https://doi.org/10.3758/PBR.15.4.795>
- Clément, F., & Dukes, D. (2017). Social Appraisal and Social Referencing: Two Components of Affective Social Learning. *Emotion Review*, *9*(3), 253–261. <https://doi.org/10.1177/1754073916661634>
- Dudeny, J., Sharpe, L., & Hunt, C. (2015). Attentional bias towards threatening stimuli in children with anxiety: A meta-analysis. *Clinical Psychology Review*, *40*, 66–75. <https://doi.org/10.1016/j.cpr.2015.05.007>
- Egger, H. L., Pine, D. S., Nelson, E., Leibenluft, E., Ernst, M., Towbin, K. E., & Angold, A. (2011). The NIMH Child Emotional Faces Picture Set (NIMH-ChEFS): A new set of children's facial emotion stimuli. *International Journal of Methods in Psychiatric Research*, *20*(3), 145–156. <https://doi.org/10.1002/mpr.343>
- Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological Bulletin*, *134*(5), 662–676. <https://doi.org/10.1037/0033-2909.134.5.662>
- Fu, X., & Pérez-Edgar, K. (2019). Threat-related attention bias in socioemotional development: A critical review and methodological considerations. *Developmental Review*, *51*, 31–57. <https://doi.org/10.1016/j.dr.2018.11.002>

- Hadnett-Hunter, J., O'Neill, E., & Proulx, M. J. (2022). Contributed Session II: Visual Search in Virtual Reality (VSVR): A visual search toolbox for virtual reality. *Journal of Vision*, 22(3), 19. <https://doi.org/10.1167/jov.22.3.19>
- Hampton, C., Purcell, D. G., Bersine, L., Hansen, C. H., & Hansen, R. D. (1989). Probing “pop-out”: Another look at the face-in-the-crowd effect. *Bulletin of the Psychonomic Society*, 27(6), 563–566. <https://doi.org/10.3758/BF03334670>
- Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology*, 54, 917–924. <https://doi.org/10.1037/0022-3514.54.6.917>
- Hermans, D., Vansteenwegen, D., & Eelen, P. (1999). Eye Movement Registration as a Continuous Index of Attention Deployment: Data from a Group of Spider Anxious Students. *Cognition & Emotion*, 13(4), 419–434. <https://doi.org/10.1080/026999399379249>
- Jenness, J. L., Lambert, H. K., Bitrán, D., Blossom, J. B., Nook, E. C., Sasse, S. F., Somerville, L. H., & McLaughlin, K. A. (2021). Developmental Variation in the Associations of Attention Bias to Emotion with Internalizing and Externalizing Psychopathology. *Research on Child and Adolescent Psychopathology*. <https://doi.org/10.1007/s10802-020-00751-3>
- Lagattuta, K. H., & Kramer, H. J. (2017). Try to Look on the Bright Side: Children and Adults Can (Sometimes) Override Their Tendency to Prioritize Negative Faces. *Journal of Experimental Psychology. General*, 146(1), 89–101. <https://doi.org/10.1037/xge0000247>
- Lisk, S., Vaswani, A., Linetzky, M., Bar-Haim, Y., & Lau, J. Y. F. (2020). Systematic Review and Meta-Analysis: Eye-Tracking of Attention to Threat in Child and Adolescent

- Anxiety. *Journal of the American Academy of Child & Adolescent Psychiatry*, 59(1), 88-99.e1. <https://doi.org/10.1016/j.jaac.2019.06.006>
- LoBue, V. (2009). More than just another face in the crowd: Superior detection of threatening facial expressions in children and adults. *Developmental Science*, 12(2), 305–313. <https://doi.org/10.1111/j.1467-7687.2008.00767.x>
- LoBue, V. (2014). Measuring Attentional Biases for Threat in Children and Adults. *Journal of Visualized Experiments*, 92. <https://doi.org/10.3791/52190>
- LoBue, V., & DeLoache, J. S. (2008). Detecting the Snake in the Grass: Attention to Fear-Relevant Stimuli by Adults and Young Children. *Psychological Science*, 19(3), 284–289. <https://doi.org/10.1111/j.1467-9280.2008.02081.x>
- LoBue, V., & Larson, C. L. (2010). What makes an angry face look so ... angry? Examining visual attention to the shape of threat in children and adults. *Visual Cognition*, 18(8), 1165–1178. <https://doi.org/10.1080/13506281003783675>
- LoBue, V., & Pérez-Edgar, K. (2014). Sensitivity to social and non-social threats in temperamentally shy children at-risk for anxiety. *Developmental Science*, 17(2), 239–247. <https://doi.org/10.1111/desc.12110>
- Malcolm, G. L., & Henderson, J. M. (2009). The effects of target template specificity on visual search in real-world scenes: Evidence from eye movements. *Journal of Vision*, 9(11), 8. <https://doi.org/10.1167/9.11.8>
- Morales, S., Fu, X., & Pérez-Edgar, K. E. (2016). A developmental neuroscience perspective on affect-biased attention. *Developmental Cognitive Neuroscience*, 21, 26–41. <https://doi.org/10.1016/j.dcn.2016.08.001>

- Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*, 381–396. <https://doi.org/10.1037/0022-3514.80.3.381>
- Olk, B., Dinu, A., Zielinski, D. J., & Kopper, R. (2018). Measuring visual search and distraction in immersive virtual reality. *Royal Society Open Science, 5*(5), 172331. <https://doi.org/10.1098/rsos.172331>
- Pavlou, K., Benson, V., & Hadwin, J. A. (2016). Exploring Links between Neuroticism and Psychoticism Personality Traits, Attentional Biases to Threat and Friendship Quality in 9–11-year-olds. *Journal of Experimental Psychopathology, 7*(3), 437–450. <https://doi.org/10.5127/jep.055316>
- Pittig, A., Pawlikowski, M., Craske, M. G., & Alpers, G. W. (2014). Avoidant decision making in social anxiety: The interaction of angry faces and emotional responses. *Frontiers in Psychology, 5*. <https://www.frontiersin.org/articles/10.3389/fpsyg.2014.01050>
- Posner, M. I., & Rothbart, M. K. (2007). Research on Attention Networks as a Model for the Integration of Psychological Science. *Annual Review of Psychology, 58*(1), 1–23. <https://doi.org/10.1146/annurev.psych.58.110405.085516>
- Reider, L. B., Bierstedt, L., Burris, J. L., Vallorani, A., Gunther, K. E., Buss, K. A., Pérez-Edgar, K., Field, A. P., & LoBue, V. (2022). Developmental patterns of affective attention across the first 2 years of life. *Child Development, 93*(6), e607–e621. <https://doi.org/10.1111/cdev.13831>
- Shechner, T., Jarcho, J. M., Britton, J. C., Leibenluft, E., Pine, D. S., & Nelson, E. E. (2013). Attention Bias of Anxious Youth During Extended Exposure of Emotional Face Pairs:

An Eye-Tracking Study. *Depression & Anxiety (1091-4269)*, 30(1), 14–21.

<https://doi.org/10.1002/da.21986>

Shechner, T., Jarcho, J. M., Wong, S., Leibenluft, E., Pine, D. S., & Nelson, E. E. (2017).

Threats, rewards, and attention deployment in anxious youth and adults: An eye tracking study. *Biological Psychology*, 122, 121–129.

<https://doi.org/10.1016/j.biopsycho.2015.10.004>

Sorce, J. F., Emde, R. N., Campos, J., & Klinnert, M. D. (n.d.). *Maternal Emotional Signaling: Its Effect on the Visual Cliff Behavior of 1-Year-Olds*. 6.

Walle, E. A., Reschke, P. J., & Knothe, J. M. (2017). Social Referencing: Defining and Delineating a Basic Process of Emotion. *Emotion Review*, 9(3), 245–252.

<https://doi.org/10.1177/1754073916669594>

Tables

Table 1*Pairwise comparison for behavioral response times (mouse click) to social threat*

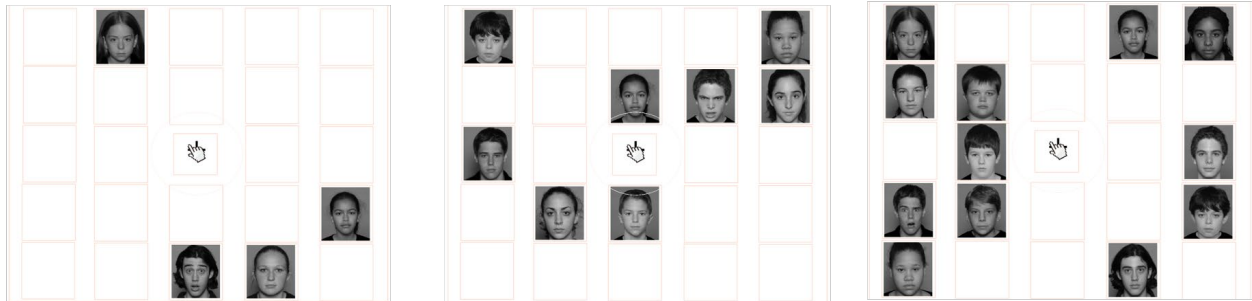
	<i>Set Size</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Adults					
Anger-Fear	4	908.88	37.10	24.53	<.001
Anger-Happy	4	807.81	31.10	25.95	<.001
Fear-Happy	4	-101.07	34.80	-2.90	0.01
Anger-Fear	8	565.62	32.10	17.61	<.001
Anger-Happy	8	705.66	27.80	25.34	<.001
Fear-Happy	8	140.04	28.60	4.89	<.001
Anger-Fear	12	246.56	31.00	7.94	<.001
Anger-Happy	12	247.11	27.00	9.15	<.001
Fear-Happy	12	0.55	26.70	0.02	1.00
Children					
Anger-Fear	4	549.53	35.70	15.38	<.001
Anger-Happy	4	692.94	31.20	22.21	<.001
Fear-Happy	4	143.41	31.50	4.56	<.001
Anger-Fear	8	293.47	34.20	8.59	<.001
Anger-Happy	8	279.79	30.10	9.30	<.001
Fear-Happy	8	-13.68	28.10	-0.49	0.88
Anger-Fear	12	91.35	35.20	2.59	0.03
Anger-Happy	12	224.76	30.80	7.30	<.001
Fear-Happy	12	133.40	29.70	4.49	<.001

Table 2*Pairwise comparisons for attentional detection of social threat*

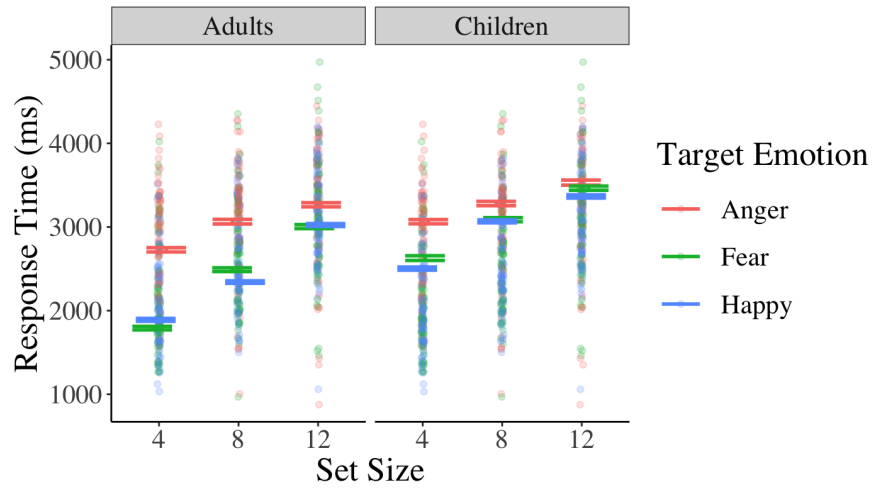
	<i>Set Size</i>	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Adults					
Anger-Fear	4	153.70	85.70	1.80	0.17
Anger-Happy	4	118.20	74.70	1.58	0.25
Fear-Happy	4	-35.60	72.20	-0.49	0.87
Anger-Fear	8	28.00	86.50	0.32	0.94
Anger-Happy	8	56.80	75.40	0.75	0.73
Fear-Happy	8	28.80	72.60	0.40	0.92
Anger-Fear	12	-510.90	97.40	-5.25	<.001
Anger-Happy	12	-559.10	88.10	-6.35	<.001
Fear-Happy	12	-48.20	77.70	-0.62	0.81
Children					
Anger-Fear	4	166.50	87.20	1.91	0.14
Anger-Happy	4	149.30	77.00	1.94	0.13
Fear-Happy	4	-17.30	70.10	-0.25	0.97
Anger-Fear	8	-251.90	91.60	-2.75	0.02
Anger-Happy	8	-266.30	80.80	-3.29	0.00
Fear-Happy	8	-14.30	72.60	-0.20	0.98
Anger-Fear	12	-387.20	102.60	-3.77	0.00
Anger-Happy	12	-326.80	89.30	-3.66	0.00
Fear-Happy	12	60.40	84.70	0.71	0.76

Figures

Figure 1

Experimental Task Display

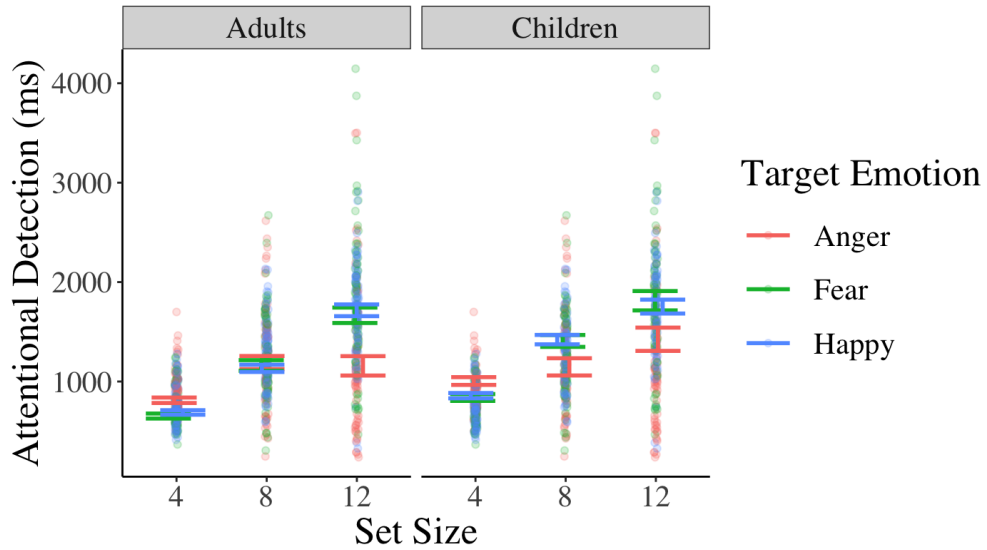
Note. Four, eight, or twelve images were randomly placed in a 5 x 5 matrix and presented in randomized order throughout the task. Images were 177x195 on a 1920x1070 monitor. Facial images were from the NIMH Child Emotional Faces Picture Set (NIMH-ChEFS) (Egger et al., 2011) and obtained with permission. Outlines of the boxes were not visible to participants.

Figure 2

Note. Error bars reflect standard error and data points are individual averages by target emotion and set size.

Figure 3

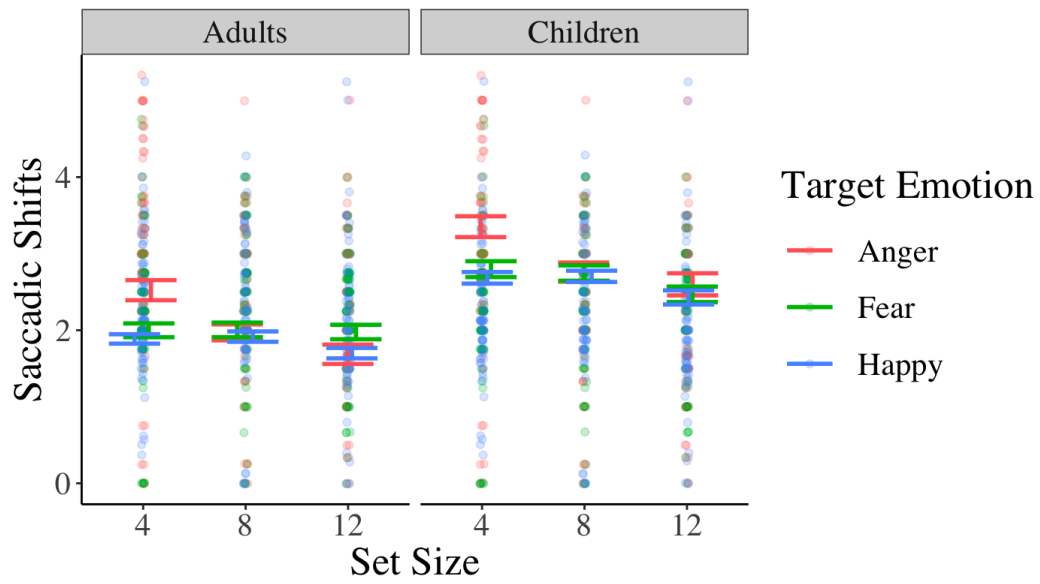
Faster attentional detection of angry faces in more complex displays



Note. Error bars reflect standard error and data points are individual averages by target emotion and set size.

Figure 4

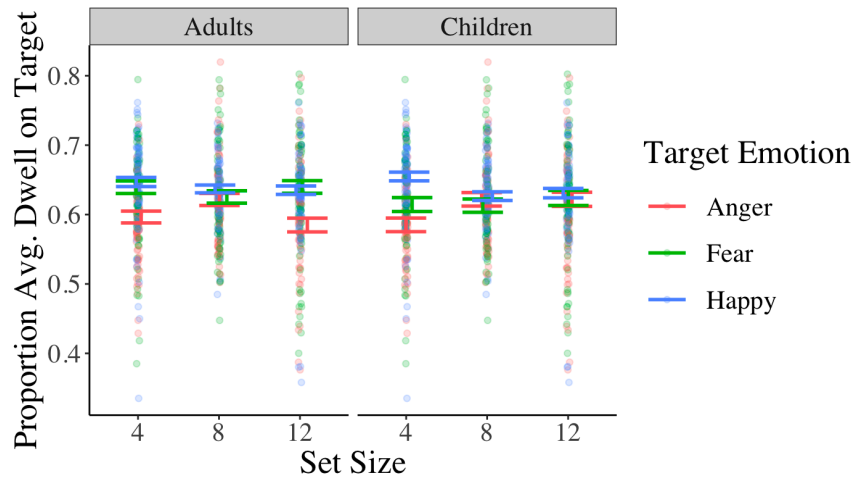
More saccadic shifts for angry faces in less complex displays



Note. Error bars reflect standard error and data points are individual averages by target emotion and set size.

Figure 5

Smaller proportion of average dwell time on angry faces (relative to distractors) in less complex displays



Note. Error bars reflect standard error and data points are individual averages by target emotion and set size.