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# Validating a mobile eye tracking measure of integrated attention bias and interpretation bias in youth

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## Abstract

**Introduction:** This study sought to validate a real-world speech task designed to assess attention and interpretation bias in an integrated and ecologically valid manner.

**Methods:** Thirty adolescent girls gave a speech in front of an emotionally ambiguous judge and a positive judge while wearing mobile eye tracking glasses to assess how long they looked at each judge (i.e., attention bias). They also reported their interpretations of the ambiguous judge and distress associated with the task (i.e., interpretation bias).

**Results:** These task-based measures correlated with self-report of interpretation bias and mother-report of attentional control, demonstrating convergent validity. They did not correlate with frustration or high intensity pleasure, indicating discriminant validity. Task-based measures of interpretation bias also showed predictive and incremental validity in relation to child distress during the speech.

**Discussion:** This proof-of-concept study demonstrates the initial validity of a novel task designed to assess attention and interpretation bias as they manifest in real-world social interactions.

Anxiety disorders are highly prevalent in youth, with meta-analytic prevalence estimates at approximately 10% (Costello, Egger, Copeland, Erkanli, & Angold, 2011). These disorders are accompanied by significant impairment across family, educational, and social domains (Muroff & Ross, 2011; Mychailyszyn, Mendez, & Kendall, 2010; Whiteside, 2009). Further, anxiety disorders in youth elevate risk for the subsequent onset of comorbid disorders, particularly depression and substance use (Woodward & Fergusson, 2001). There is

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Informed consent: Informed consent was obtained from all individual participants included in the study.

emerging evidence that risk for these subsequent disorders may be especially elevated in those with social anxiety disorder, an anxiety disorder characterized by intense fear of social embarrassment and gross avoidance (Beesdo et al., 2007; Buckner et al., 2008). A better understanding of the factors that put youth at risk for this and other anxiety disorders is essential to improving our current prevention and intervention approaches.

Cognitive theories of anxiety hypothesize that both the onset and maintenance of these disorders are intimately linked with information processing biases (Beck, Emery, & Greenberg, 1985; Williams, Watts, MacLeod, & Mathews, 1988). A significant branch of the robust field of anxiety disorders etiology research focuses on the role of two information processing biases: attention bias (AB) and interpretation bias (IB; Mathews & MacLeod, 1994). AB is the tendency to preferentially attend to threat versus non-threat stimuli, while IB is the tendency to interpret ambiguous information in a threatening manner. There is a considerable literature linking both clinical and high trait anxiety in youth with an AB to threat (Abend et al., 2017; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Roy et al., 2008). This research typically groups together the major anxiety disorders of childhood, but recent work has demonstrated an AB in social anxiety disorder specifically (Schmidtendorf, Wiedau, Asbrand, Tuschen-Caffier, & Heinrichs, 2018), and suggests that the AB seen in generally anxious child samples might be specific to social anxiety and school phobia (Abend et al., 2017). A fairly consistent link has also been demonstrated between IB and both clinical and high trait anxiety in youth (Creswell & O'Connor, 2011; Hadwin, Frost, French, & Richards, 1997; Muris & Field, 2008), with a recent meta-analysis suggesting a medium, positive association (Stuijfzand, Creswell, Field, Pearcey, & Dodd, 2018). This connection has been found in socially anxious youth specifically (Muris, Merckelbach, & Damsma, 2000), with some evidence of content specificity; that is, socially anxious youth have a negative IB for ambiguous social situations but not for ambiguous non-social situations (Miers, Blöte, Bögels, & Westenberg, 2008).

Although the findings showcasing AB and IB as risk factors for childhood anxiety are relatively consistent, concerns have surfaced about the reliability and validity of the ways in which these constructs are measured. The dot-probe task is the most widely-used measure of AB. In this task, participants are presented with pairs of facial expressions, one neutral and the other negative (e.g., disgust, anger, fear). Each pair is then replaced with a probe located in the previous position of either the neutral or negative face. The participant is to press a key to indicate the location or content of these probes. If one's attention is drawn to the negative faces (i.e., they have an AB), they will be faster to respond to probes that replace negative faces compared to those that replace neutral faces. Despite the ubiquitous nature of the dot-probe task within the AB literature, recent work has shown the split-half and test-retest reliability of this reaction time measure to be poor (Brown et al., 2014), and has also revealed poor convergent and concurrent validity (Bockstaele et al., 2019). Conversely, eye tracking indices collected during the task appear to be more reliable than reaction time measures (Price et al., 2015). A recent meta-analysis of eye tracking studies of attention bias in youth demonstrated greater attentional avoidance of threat in anxious compared to non-anxious youth; however, there was some evidence that this was the case only in children, not adolescents (Lisk, Vaswani, Linetzky, Bar-Haim, & Lau, 2019). Despite the psychometric advantages of eye tracking, this screen-based methodology occurs in the absence of real-

world interaction, telling us little about how attention to threat operates in ecologically valid contexts and how attention and behavior interact with one another (Morales, Fu, & Pérez-Edgar, 2016).

Mobile eye tracking is a novel methodology that enables the assessment of attentional patterns as they unfold in real-world settings. This is critically important because emerging work suggests that attention is deployed differently in screen-based vs. real-world settings. For example, Kretch and Adolph (2015) found that in contrast to screen-based studies, where both infants and adults preferentially attend to people during free viewing, only infants – not adults – were biased to look at people during free viewing in a real-world setting. In addition, Laidlaw, Foulsham, Kuhn, and Kingstone (2011) showed that adults initiated fewer fixations to an experimenter who was sitting in the room with them compared to those who were presented with a videotaped experimenter, suggesting that attention may be deployed differently when there is the potential for social interaction.

There are additional reasons to question the ecological validity of the dot-probe task. First, the static facial expressions used in the task differ drastically from the evolving facial expressions experienced over the course of a social interaction. Second, the dot-probe task draws one's attention towards the previous location of threat and non-threat stimuli, which are presented for relatively short periods of time. Such manipulation is not present in the real world, where individuals are free to look at whichever stimuli they choose, for as long as they choose (Morales et al., 2016). Third, cognitive theories suggest that explicitly threatening stimuli arouse anxiety in most individuals; what sets apart those with anxiety is their exaggerated responses to ambiguous stimuli (Mogg & Bradley, 1998). Therefore, the threatening faces typically used in the dot-probe may not be optimal in differentiating anxious from non-anxious individuals.

There are also concerns about the self-report measures used in the assessment of IB. These measures commonly consist of hypothetical ambiguous scenarios, with participants indicating how they would feel and think in each one (Barrett, Rapee, Dadds, & Ryan, 1996; Creswell & O'Connor, 2006). Given that cognitive models suggest that IB is a relatively automatic feature of the information processing apparatus (Beck et al., 1985; Williams et al., 1988), it is unclear how responses given following the reflection inherent in these measures relates to the actual emotion experienced and interpretations made when one is confronted with real-world ambiguity.

The present study aimed to pilot and initially validate a novel task designed to address concerns regarding the measurement of AB and IB. We employed mobile eye tracking and self-report to assess AB and IB as they unfolded in the context of an ecologically valid stressor. There is evidence that these information processing biases are related to one another (White, Suway, Pine, Bar-Haim, & Fox, 2011), so we sought to measure them in concert. We hypothesized that with regard to our novel, task-based measures of AB and IB, we would find evidence of 1) convergent validity (with mother-reported attentional control and child-reported interpretation bias), 2) discriminant validity (with mother-reported frustration and high intensity pleasure), and 3) predictive validity (with child-reported social anxiety and both child- and mother-reported task-induced distress). We also predicted that our task-based

measures of AB and IB would show 4) incremental validity in the prediction of social anxiety and distress, over and above child- and mother-report measures. Finally, we hypothesized 5) a relationship between our novel measures of AB and IB.

## Methods

### Participants

Participants were 32 adolescent girls (ages 11-16, *M*= 14.19, *SD*= 1.57) recruited from the community. We focused on girls as there is evidence that both social anxiety symptoms and IB are more prevalent in adolescent girls than boys (Miers et al., 2008; Ranta et al., 2007), and AB may be more common in women than men (Waters, Nitz, Craske, & Johnson, 2007). Girls were 80% Caucasian, 16.7% Black, and 3.3% Biracial. Exclusion criteria included serious health problems; psychoactive or cardiovascular medications; history of autism spectrum disorder, bipolar disorder, neurological disorder, or psychosis; active substance abuse; ocular conditions that would impede eye tracking measurement; and inability to clearly see a person a short distance away without prescription glasses.

### Measures

**Speech Task.—**This task was designed as a real-world combination of an ambiguous scenario and the dot-probe task, intending to illustrate both how adolescents attend to and interpret an in vivo, ambiguous social stimulus. Girls were instructed to give a two-minute speech on why they should be chosen for a reality television show. They were given two minutes to prepare with their mothers beforehand and their mothers were seated behind them during the speech. Two female, young adult judges were seated equidistant (eight feet) from participants during the speech. These judges were study confederates trained to act in predetermined ways. The positive judge smiled and nodded her head at designated intervals, while the ambiguous judge maintained a neutral facial expression, shuffled her feet, and spent time looking away (see Table S1 in the Supplement for a detailed description). The judges' seat positions (left or right) were counterbalanced. After completing the speech and questions described below, girls were given scripted positive feedback from both judges in order to minimize potential discomfort.

**Task-Based Measures of Interpretation Bias:** Three indices of IB were modeled after our self-report measure of IB, the Ambiguous Scenarios Questionnaire (Barrett et al., 1996; Creswell & O'Connor, 2006; see below). See Table 1 for descriptive statistics of these and all other study measures.

***Distress Predictions:*** Prior to the speech, girls rated on a 1 (not at all) - 7 (extremely) scale how stressed they thought they were going to be when giving the speech.

***Distress Attributed to Ambiguous Judge:*** Immediately following the speech, girls rated how stressed the ambiguous judge made them feel on a 0 (not at all) - 10 (very, very) scale.

***Threatening Interpretations of Ambiguous Judge:*** Girls were asked "What do you think this judge thought about your speech?" Responses were coded by the first author as either

threatening (dummy coded as 1; e.g., “I think she thought that I did bad and wasn’t impressed with me”) or non-threatening (dummy coded as 0; e.g., “It was hard to tell what she was thinking since she kept her face neutral”). Inter-rater reliability with a trained graduate student was excellent: $\kappa = .93$.

**Task-Based Measures of Attention Bias:** Tobii Pro Glasses 2 (Tobii Technology, Inc., Falls Church, VA) tracked girls’ attention toward the judges during the speech task. These mobile eye tracking glasses are similar to reading glasses but have a high-definition camera that captures the participant’s visual field. They feature four eye tracking sensors with a sampling rate of 50 Hz, as well as infrared illuminators that brighten the eye and support the sensors. Advanced image processing algorithms were used to estimate the eye’s position and gaze point using Tobii’s standard software. A series of accuracy tests indicate that the average difference between a target location and the measured gaze location is 0.62° (Tobii, 2017).

Eye tracking data were processed using Tobii Pro Glasses Analyzer, with a customized filter classifying eye movements. Fixations were defined as a consecutive chain of raw data points below the velocity threshold of 30°/second that lasted for at least 100ms. The Tobii real-world mapping function automatically mapped fixations to areas of interest (AOIs) using proprietary algorithms that account for parallax error and slippage. Specifically, an AOI was created around the entire face and body of each judge, and Tobii identified whether or not the participant fixated on either judge at each sampling point. To do so, the automated mapping procedure superimposed raw gaze data from the video captured by the glasses camera onto a still photo of the judges, which was created using a representative frame from the girl’s glasses camera. To ensure accuracy, a research assistant verified frame-by-frame whether the data automatically mapped onto the snapshot matched the data captured by the eye tracking sensors and glasses camera. Discrepancies (e.g., due to the participant moving her head) were manually corrected (see Figure S1 in the Supplement). Our measures of AB were total fixation duration (TFD) on each judge and a bias score, TFD on the ambiguous judge minus TFD on the positive judge (positive scores indicating a greater bias for the ambiguous judge).

Eye tracking data were missing for two girls who lacked adequate eye tracking calibration (see Supplement). These data were found to be missing completely at random and were estimated using maximum likelihood estimation. Girls who were missing more than 60% of gaze data (i.e., gaze coordinates could not be estimated by Tobii) were excluded from analysis ($n = 2$), leaving a sample of 30 girls. Scores that were more than three times the interquartile range (IQR) above or below the median were identified as outliers and Winsorized (i.e., rescaled) by being reassigned to the maximum or minimum valid value (i.e., 3*IQR +/− the median).

It should be noted that AB as measured in the speech task has previously been shown to be related to adolescent depressive symptoms in this sample (Woody et al., 2019). This paper advances these previous findings by examining the psychometric properties of the speech task and extending the work to both IB and anxiety.

## Self-Report Measure of Interpretation Bias

***Ambiguous Scenarios Questionnaire*** (ASQ; Barrett et al., 1996; Creswell & O'Connor, 2006). Girls were presented with 12 ambiguous scenarios. Six of the scenarios were social (e.g., "You see a group of children from another class playing a great game. When you walk over to join in they are laughing,") while the other 6 were non-social (e.g. "You are lying in bed at night when you hear a big crash in the house.") Girls were asked to rate how distressed they would be in each scenario (from 0 to 10), with scores summed for a total distress score (0-120). Internal consistency was good ($\alpha$= 0.87). Girls also provided their interpretation of each scenario, with responses coded by trained research assistants as threatening or non-threatening. Threatening interpretations were summed for a total threat score out of 12. A randomly selected 28% of ASQs were double-coded; $\kappa$ ranged from 0.73-1.0, indicating substantial to perfect agreement.

## Mother-Report Measure of Attention Bias

***Early Adolescent Temperament Questionnaire-Revised*** (EATQ-R; Ellis & Rothbart, 2001). Due to constraints of the larger study in which the current investigation was embedded, dot-probe data were only available on a subset of girls that was too small to analyze. Instead, attentional control was used as a correlate of AB because the latter may be at least partially explained by the poor attentional control typically found in anxious individuals (Derryberry & Reed, 2002). We used the Attention subscale of the EATQ-R, which measures the capacity to focus and shift attention when desired. Internal consistency was acceptable ($\alpha$= 0.78). The EATQ-R is a 62-item questionnaire with 11 subscales corresponding to dimensions of temperament in early adolescence. Items are rated on a five-point scale and subscales are computed as the average response.

## Mother-Report Discriminant Validity Measures

Two additional subscales of the EATQ-R served as measures of discriminant validity: Frustration and High Intensity Pleasure. Frustration measures negative affect related to the interruption of tasks or the blocking of goals and High Intensity Pleasure measures pleasure derived from high intensity activities or novel pursuits. Neither construct has a theoretical connection to AB or IB. Internal consistency was good for Frustration ($\alpha$= 0.83) and acceptable for the High Intensity Pleasure subscale ($\alpha$= 0.73).

## Child-and Mother-report Predictive Validity Measures

***Screen for Child Anxiety Related Disorders*** (SCARED; Birmaher, Brent, Chiappetta, Bridge, Monga, & Baugher, 1999) is a 41-item self-report inventory rated on a three-point scale. Due to the social nature of the speech task and the potential specificity between AB/IB and social anxiety (Abend et al., 2017; Miers et al., 2008), child-report on the social anxiety disorder subscale was used (internal consistency was excellent; $\alpha$= 0.91).

***Distress Impressions***. Following the speech, both girls and mothers rated on a 1 (not at all) to 7 (extremely) scale how stressed they thought the girl was during her speech.

### Procedure

Mothers provided informed consent and permission, and girls provided assent to be in the study. Participants wore the eye tracking glasses and completed a calibration procedure. Next, as part of a larger series of interaction tasks not described here, girls completed the speech task while seated across from the judges. Finally, girls and mothers completed study questionnaires. Study procedures were approved by the University of Pittsburgh's Institutional Review Board.

### Data Analysis Plan

Correlations were used to assess convergent, discriminant, and predictive validity, and the relationship between task-based measures of AB and IB. Hierarchical regressions were used to assess the incremental validity of our task-based measures of AB and IB over and above more commonly used measures. Due to our small sample size, we limited the predictors in each model by including only the measure that was most highly correlated with each outcome, with the caveat that it had to have at least a medium effect size ($r \geq 0.3$). If no such measure existed, that step was skipped. In the first step we entered ASQ measures, in the second step the task-based measures of IB, in the third step attentional control, and in the final step task-based measures of AB. Hypotheses requiring multiple tests were controlled for using the false discovery rate (Benjamini & Hochberg, 1995).

## Results

### Convergent and Discriminant Validity

**AB—**All results with regards to convergent, discriminant, and predictive validity are depicted in Table 2. With regards to AB, total time spent fixating on the ambiguous judge was negatively correlated with attentional control. Conversely, there were no significant correlations between any of the task-based measures of AB and either frustration or high intensity pleasure on the EATQ-R.

**IB—**With regard to IB, 1) children's predicted distress before the speech task was positively correlated with threatening interpretations of ambiguous situations on the ASQ and 2) distress attributed to the ambiguous judge was positively correlated with distress in response to ambiguous situations on the ASQ. Conversely, none of the task-based measures of IB were significantly correlated with either frustration or high intensity pleasure on the EATQ-R.

### Predictive Validity

**AB—**As shown in Table 2, none of the task-based measures of AB were associated with any of the three outcome measures: social anxiety on the SCARED, child-reported distress during the speech, and mother-reported distress during the speech.

**IB—**Both children's predicted distress before the speech and distress attributed to the ambiguous judge were positively correlated with child and mother impressions of distress during the speech.

### Incremental Validity

Table 3 depicts the hierarchical regression predicting social anxiety on the SCARED. Threatening interpretations on the ASQ was a significant predictor in the first step, but it became non-significant in subsequent steps. The addition of predicted distress before the speech did not add a significant percentage of variance explained, nor did the addition of TFD bias score; however, the three predictors combined predicted 29% of the variance in SCARED social anxiety.

Table 4 shows the results of the hierarchical regression predicting child-report of distress during the speech. Because none of the AB measures were moderately correlated with this outcome, and two of the task-based measures of IB were strongly correlated with it, both of the latter were included. Again, threatening interpretations on the ASQ was a significant predictor in step 1, but became non-significant in the next step. Both child-predicted distress before the task and distress attributed to the ambiguous judge were significant, independent predictors. The final model accounted for 58% of the variance in child-reported distress during the speech.

Table 5 depicts the hierarchical regression predicting mother-report of distress during the speech. Child-predicted distress before the speech was a significant, positive predictor, whereas mother-reported attentional control was a significant, negative predictor. Total fixation time on the ambiguous judge was not related to mother-reported distress. The final model accounted for 62% out of the variance in this outcome.

### Relationship between task-based measures of AB and IB

Table 2 demonstrates that there were no noteworthy associations among the task-based measures of AB and IB.

## Discussion

AB and IB are typically regarded as individual difference variables that confer risk for anxiety, but there are methodological and psychometric concerns about the measures typically used to assess them. This study provides preliminary evidence of the convergent, discriminant, predictive, and incremental validity of a novel, ecologically valid task designed to assess these biases in an integrated manner. The most consistent evidence was found for convergent and discriminant validity. After controlling for multiple comparisons, IB assessed with regard to a live stressor was associated with IB measured via a reflective, self-report measure (the ASQ), while AB toward a live, potentially threatening judge was related to poorer mother-rated attentional control. None of the task-based measures of AB or IB were related to the theoretically distinct constructs of frustration or high intensity pleasure. These findings suggest that our novel, lab-based task is not only an ecologically valid assessment of these information processing biases, but a psychometrically sound one as well. This is an important step forward in the information processing bias literature as we now have the technology to assesses these constructs as they unfold in real-time, rather than via retrospective report or in response to static stimuli.

In terms of predictive validity, we found evidence that our distress-related IB constructs (predicted distress before the speech and distress attributed to the ambiguous judge) were related to both mother and child impressions of distress during the speech. Distress-related IB constructs also predicted additional variance in these outcomes, over and above routinely used self- and mother-report measures of IB and AB. Interestingly, our threat-related metric of IB, whether girls interpreted the ambiguous judge as threatening or not, did not show evidence of any of the assessed forms of validity. This corresponds with work showing a stronger link between child anxiety and predicted affective response to ambiguity than child anxiety and threat-related measures (Dodd, Stuijfzand, Morris, & Hudson, 2015). Youth likely experience a cascade of cognitive and affective responses when processing real-world ambiguity; however, when asked in the immediate aftermath, they may report the final interpretation chosen, providing a more tempered response than their in vivo interpretation. Conversely, their anticipated distress before the task is unable to be filtered. Future work might periodically assess affect and cognition over the course of the task and model interactional effects over time. We may find that distress and interpretations vary across the course of the task as a function of emotion regulation strategies employed, such as cognitive restructuring of the stressor or ruminative thoughts in relation to perceived performance.

Despite findings supporting the convergent and discriminant validity of our mobile eye tracking measure of AB (in particular, total fixation time on the ambiguous judge), we failed to find evidence for the predictive or incremental validity of this measure. This is in contrast to developmental work suggesting that assessing toddlers' threat-related attention in a live context may lead to better prediction of social inhibition than behavior alone (Kiel & Buss, 2011). This discrepancy may be explained by changes in AB across development. A recent meta-analysis of AB in anxious youth suggests that there may be avoidance of threat in childhood, no AB in either direction in adolescence, and an attention bias toward threat in adulthood (Lisk et al., 2019). Our adolescent sample may have fallen in the interim phase, before AB switches from avoidance to vigilance. Future longitudinal work will be critical to elucidating this trajectory. Alternatively, it may be that in live contexts, where the task does not place any constraints on viewing behavior, other eye tracking metrics are more pertinent to distress and anxiety. We limited our investigation to the eye tracking metric most typically assessed in the AB literature (maintenance of attention on threat), largely due to our small sample size, but vigilance towards threat and difficulty disengaging from threat are also theoretically consistent with AB (Cisler & Koster, 2010). Future work, therefore, may explore metrics such as latency of first fixation and average fixation duration on the ambiguous vs. positive judge. Frequency of gaze may be an additional metric of interest as its relation to a stranger has been shown to differentiate behaviorally inhibited children from those who are not (Fu, Nelson, Borge, Buss, & Perez-Edgar, in press), and gaze frequency toward the ambiguous judge in the current sample has been associated with depressive symptoms (Woody et al., 2019).

This study had some unexpected findings as well. Predicted distress during the speech was not related to distress on the ASQ or self-reported social anxiety symptoms. We note, however, that these correlations were roughly on the order of medium effect sizes, and may prove to be significant in larger samples. Also, we did not find evidence that AB and IB were related to one another when measured in a task designed to integrate them. This is in

contrast to stationary eye-tracking work with adolescents showing that attentional deployment to peer cues predicts IB (Haller et al., 2017). We may also have been under-powered to find this effect, or it may be that there are important intervening affective and cognitive responses that help to explain how attention to ambiguity relates to its ultimate interpretation.

This study has several limitations. First, enthusiasm is tempered by the small sample size. While we acknowledge that it will be critical to replicate this work in larger samples, we are encouraged by the overall pattern of findings, which provides preliminary evidence of various forms of validity across a range of measures. Despite the sample size, this novel study is an important addition to the burgeoning mobile eye tracking literature. Second, the study was conducted within a community sample of girls and anxiety levels were therefore truncated. Future studies should evaluate this task with youth with sub-clinical and clinical levels of social anxiety. Third, we did not have adequate dot-probe data in the current sample and substituted attentional control as a correlate of AB. And we used parent-report of attention control when adolescents may be better reporters of these abilities. Directly comparing our task-based measures of AB with AB measured via the dot-probe will be an important future direction. Fourth, two of our outcome measures (mother and child impressions of distress during the speech) overlapped with some of our task-based measures of IB due to shared method variance. It will be important to incorporate behavioral observation of child distress in future work. Fifth, we used total amount of time spent fixating on each judge as our measure of AB, which precludes investigation of how attention might have changed during various parts of the task (e.g., when the ambiguous judge looked around the room). A more fine-grained analysis of how attentional processes interact with behavioral inputs is an important next step.

## Conclusions

This is a critical proof-of-concept study which provides preliminary evidence of the validity of a speech task designed to assesses AB and IB in an integrated manner. It assesses these constructs in real-time during an in vivo stressor relevant to real-world functioning, using mobile eye tracking technology. This methodology opens up the possibility of future work outside of the lab in even more ecologically valid contexts and with potentially difficult to reach populations. Capturing the emotional evocativeness of social situations is essential in the context of social anxiety, and a more nuanced understanding of how information processing biases are instantiated in these interactions may have important implications for interventions designed to target them.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## References

Abend R, Voogd L. de, Salemink E, Wiers RW, Pérez-Edgar K, Fitzgerald A, … Bar-Haim Y (2017). Association between attention bias to threat and anxiety symptoms in children and adolescents. Depression and Anxiety, 35(3), 229–238. 10.1002/da.22706 [PubMed: 29212134]

Bar-Haim Y, Lamy D, Pergamin L, Bakermans-Kranenburg MJ, & van IJzendoorn MH (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. Psychological Bulletin, 133(1), 1–24. 10.1037/0033-2909.133.1.1 [PubMed: 17201568]

Barrett PM, Rapee RM, Dadds MM, & Ryan SM (1996). Family enhancement of cognitive style in anxious and aggressive children. Journal of Abnormal Child Psychology, 24(2), 187–203. 10.1007/BF01441484 [PubMed: 8743244]

Beck AT, Emery G, & Greenberg RL (1985). Anxiety disorders and phobias: A cognitive approach. New York, NY: Basic.

Beesdo K, Bittner A, Pine DS, Stein MB, Höfler M, Lieb R, & Wittchen H-U (2007). Incidence of Social Anxiety Disorder and the Consistent Risk for Secondary Depression in the First Three Decades of Life. Archives of General Psychiatry, 64(8), 903–912. 10.1001/archpsyc.64.8.903 [PubMed: 17679635]

Benjamini Y, & Hochberg Y (1995). Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. Journal of the Royal Statistical Society. Series B (Methodological), 57(1), 289–300. Retrieved from JSTOR.

Bockstaele BV, Lamens L, Salemink E, Wiers RW, Bögels SM, & Nikolaou K (2019). Reliability and validity of measures of attentional bias towards threat in unselected student samples: Seek, but will you find? Cognition and Emotion, 0(0), 1–12. 10.1080/02699931.2019.1609423

Brown HM, Eley TC, Broeren S, MacLeod C, Rinck M, Hadwin JA, & Lester KJ (2014). Psychometric properties of reaction time based experimental paradigms measuring anxiety-related information-processing biases in children. Journal of Anxiety Disorders, 28(1), 97–107. 10.1016/j.janxdis.2013.11.004 [PubMed: 24486916]

Buckner JD, Schmidt NB, Lang AR, Small JW, Schlauch RC, & Lewinsohn PM (2008). Specificity of social anxiety disorder as a risk factor for alcohol and cannabis dependence. Journal of Psychiatric Research, 42(3), 230–239. 10.1016/j.jpsychires.2007.01.002 [PubMed: 17320907]

Cisler JM, & Koster EHW (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. Clinical Psychology Review, 30(2), 203–216. 10.1016/j.cpr.2009.11.003 [PubMed: 20005616]

Costello EJ, Egger HL, Copeland W, Erkanli A, & Angold A (2011). The Developmental Epidemiology of Anxiety Disorders: Phenomenology, Prevalance, and Comorbidity In Anxiety Disorders in Children and Adolescents (pp. 56–75). Cambridge, UK: Cambridge University Press.

Creswell C, & O'Connor TG (2006). Anxious cognitions in children: An exploration of associations and mediators. British Journal of Developmental Psychology, 24(4), 761–766. 10.1348/026151005X70418

Creswell C, & O'Connor TG (2011). Interpretation Bias and Anxiety in Childhood: Stability, Specificity and Longitudinal Associations. Behavioural and Cognitive Psychotherapy, 39(02), 191–204. 10.1017/S1352465810000494 [PubMed: 20875165]

Derryberry D, & Reed MA (2002). Anxiety-related attentional biases and their regulation by attentional control. Journal of Abnormal Psychology, 111(2), 225–236. 10.1037/0021-843X.111.2.225 [PubMed: 12003445]

Dodd HF, Stuijfzand S, Morris T, & Hudson JL (2015). Child Anxiety and the Processing of Ambiguity. Cognitive Therapy and Research, 39(5), 669–677. 10.1007/s10608-015-9689-1

Everaert J, Podina IR, & Koster EHW (2017). A comprehensive meta-analysis of interpretation biases in depression. Clinical Psychology Review, 58, 33–48. 10.1016/j.cpr.2017.09.005 [PubMed: 28974339]

Fu X, Nelson EE, Borge M, Buss KA, & Perez-Edgar K (2019). Stationary and Ambulatory Attention Patterns are Differentially Associated with Early Temperamental Risk for Socioemotional Problems: Preliminary Evidence from a Multimodal Eye-tracking Investigation. Development and Psychopathology, 1–18.

Hadwin J, Frost S, French CC, & Richards A (1997). Cognitive processing and trait anxiety in typically developing children: Evidence for an interpretation bias. Journal of Abnormal Psychology, 106(3), 486–490. 10.1037/0021-843X.106.3.486 [PubMed: 9241952]

Haller SPW, Doherty BR, Duta M, Kadosh KC, Lau JYF, & Scerif G (2017). Attention allocation and social worries predict interpretations of peer-related social cues in adolescents. Developmental Cognitive Neuroscience, 25, 105–112. 10.1016/j.dcn.2017.03.004 [PubMed: 28416273]

Kiel EJ, & Buss KA (2011). Toddlers' Duration of Attention Toward Putative Threat. Infancy, 16(2), 198–210. 10.1111/j.1532-7078.2010.00036.x [PubMed: 21373365]

Kretch KS, & Adolph KE (2015). Active vision in passive locomotion: Real-world free viewing in infants and adults. Developmental Science, 18(5), 736–750. 10.1111/desc.12251 [PubMed: 25438618]

Laidlaw KEW, Foulsham T, Kuhn G, & Kingstone A (2011). Potential social interactions are important to social attention. Proceedings of the National Academy of Sciences, 108(14), 5548–5553. 10.1073/pnas.1017022108

Lisk S, Vaswani A, Linetzky M, Bar-Haim Y, & Lau JYF (2019). 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, 0(0). 10.1016/j.jaac.2019.06.006

Mathews A, & MacLeod C (1994). Cognitive Approaches to Emotion and Emotional Disorders. Annual Review of Psychology, 45(1), 25–50. 10.1146/annurev.ps.45.020194.000325

Miers AC, Blöte, Anke W, Bögels SM, & Westenberg PM (2008). Interpretation bias and social anxiety in adolescents. Journal of Anxiety Disorders, 22(8), 1462–1471. 10.1016/j.janxdis.2008.02.010 [PubMed: 18420374]

Mogg K, & Bradley BP (1998). A cognitive-motivational analysis of anxiety. Behaviour Research and Therapy, 36(9), 809–848. 10.1016/S0005-7967(98)00063-1 [PubMed: 9701859]

Morales S, Fu X, & Pérez-Edgar KE (2016). A developmental neuroscience perspective on affect-biased attention. Developmental Cognitive Neuroscience, 21, 26–41. 10.1016/j.dcn.2016.08.001 [PubMed: 27606972]

Muris P, & Field AP (2008). Distorted cognition and pathological anxiety in children and adolescents. Cognition and Emotion, 22(3), 395–421. 10.1080/02699930701843450

Muris P, Merckelbach H, & Damsma E (2000). Threat Perception Bias in Nonreferred, Socially Anxious Children. Journal of Clinical Child Psychology, 29(3), 348–359. 10.1207/S15374424JCCP2903_6 [PubMed: 10969419]

Muroff J, & Ross A (2011). Social Disability and Impairment in Childhood Anxiety In Handbook of Child and Adolescent Anxiety Disorders (pp. 457–478). 10.1007/978-1-4419-7784-7_31

Mychailyszyn MP, Mendez JL, & Kendall PC (2010). School Functioning in Youth With and Without Anxiety Disorders: Comparisons by Diagnosis and Comorbidity. School Psychology Review, 39(1), 106–121.

Platt B, Murphy SE, & Lau JYF (2015). The association between negative attention biases and symptoms of depression in a community sample of adolescents. PeerJ, 3, e1372 10.7717/peerj.1372 [PubMed: 26539335]

Price RB, Kuckertz JM, Siegle GJ, Ladouceur CD, Silk JS, Ryan ND, … Amir N (2015). Empirical Recommendations for Improving the Stability of the Dot-Probe Task in Clinical Research. Psychological Assessment, 27(2), 365–376. 10.1037/pas0000036 [PubMed: 25419646]

Ranta K, Kaltiala-Heino R, Koivisto A-M, Tuomisto MT, Pelkonen M, & Marttunen M (2007). Age and gender differences in social anxiety symptoms during adolescence: The Social Phobia Inventory (SPIN) as a measure. Psychiatry Research, 153(3), 261–270. 10.1016/j.psychres.2006.12.006 [PubMed: 17707088]

Roy AK, Vasa RA, Bruck M, Mogg K, Bradley BP, Sweeney M, … Pine DS (2008). Attention Bias Toward Threat in Pediatric Anxiety Disorders. Journal of the American Academy of Child &

Adolescent Psychiatry, 47(10), 1189–1196. 10.1097/CHI.0b013e3181825ace [PubMed: 18698266]

Schmidtendorf S, Wiedau S, Asbrand J, Tuschen-Caffier B, & Heinrichs N (2018). Attentional Bias in Children with Social Anxiety Disorder. Cognitive Therapy and Research, 42(3), 273–288. 10.1007/s10608-017-9880-7

Stuijfzand S, Creswell C, Field AP, Pearcey S, & Dodd H (2018). Research Review: Is anxiety associated with negative interpretations of ambiguity in children and adolescents? A systematic review and meta-analysis. Journal of Child Psychology and Psychiatry, and Allied Disciplines, 59(11), 1127–1142. 10.1111/jcpp.12822

Waters AM, Nitz AB, Craske MG, & Johnson C (2007). The effects of anxiety upon attention allocation to affective stimuli. Behaviour Research and Therapy, 45(4), 763–774. 10.1016/j.brat.2006.07.002 [PubMed: 16956578]

White LK, Suway JG, Pine DS, Bar-Haim Y, & Fox NA (2011). Cascading Effects: The Influence of Attention Bias to Threat on the Interpretation of Ambiguous Information. Behaviour Research and Therapy, 49(4), 244–251. 10.1016/j.brat.2011.01.004 [PubMed: 21353663]

Whiteside SP (2009). Adapting the Sheehan Disability Scale to Assess Child and Parent Impairment Related to Childhood Anxiety Disorders. Journal of Clinical Child & Adolescent Psychology, 38(5), 721–730. 10.1080/15374410903103551 [PubMed: 20183656]

Williams JMG, Watts FN, MacLeod C, & Mathews A (1988). Cognitive psychology and emotional disorders. Oxford, England: John Wiley & Sons.

Woodward LJ, & Fergusson DM (2001). Life Course Outcomes of Young People With Anxiety Disorders in Adolescence. Journal of the American Academy of Child & Adolescent Psychiatry, 40(9), 1086–1093. 10.1097/00004583-200109000-00018 [PubMed: 11556633]

Woody ML, Rosen D, Allen KB, Price RB, Hutchinson E, Amole MC, & Silk JS (2019). Looking for the negative: Depressive symptoms in adolescent girls are associated with sustained attention to a potentially critical judge during in vivo social evaluation. Journal of Experimental Child Psychology, 179, 90–102. 10.1016/j.jecp.2018.10.011 [PubMed: 30476697]

**Table 1.**

Descriptive statistics of study measures

| | |
|---|---|
| **Distress Predictions** | 4.10 (1.52) |
| **Ambiguous Judge Distress** | 5.70 (2.90) |
| **Threatening Interpretation of Ambiguous Judge, %** | 66.7 |
| **ASQ Distress** | 48.03 (23.34) |
| **ASQ Threat** | 4.02 (2.03) |
| **Ambiguous Judge TFD** | 4.12 (3.90) |
| **Positive Judge TFD** | 7.28 (9.30) |
| **TFD Bias Score** | −3.16 (7.64) |
| **EATQ-R Attention** | 3.50 (.84) |
| **Frustration** | 2.97 (.89) |
| **High Intensity Pleasure** | 3.35 (.73) |
| **Social Anxiety** | 4.54 (3.99) |
| **Speech Distress-Child** | 4.57 (1.59) |
| **Speech Distress-Mom** | 4.57 (1.33) |

*Note.* Data presented as mean (SD) unless otherwise noted. ASQ= Ambiguous Scenarios Questionnaire, TFD= total fixation duration, EATQ-R= Early Adolescent Temperament Questionnaire-Revised.

**Table 2.**

Correlations depicting validity of and relationships between the task-based measures of attention and interpretation bias

| | Task-based IB | | | CV IB | | Task-based AB | | | CV AB | Discriminant Validity | | Predictive Validity | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Measure** | **1.** | **2.** | **3.** | **4.** | **5.** | **6.** | **7.** | **8.** | **9.** | **10.** | **11.** | **12.** | **13.** |
| **1. Distress Predictions** | - | | | | | | | | | | | | |
| **2. Ambiguous Judge Distress** | .42* | - | | | | | | | | | | | |
| **3. Ambiguous Judge Threat** | .19 | .47* | - | | | | | | | | | | |
| **4. ASQ Distress** | .28 | .47* | .15 | - | | | | | | | | | |
| **5. ASQ Threat** | .44* | .21 | .26 | .43* | - | | | | | | | | |
| **6. Ambiguous Judge TFD** | .12 | −.05 | −.21 | −.08 | −.23 | - | | | | | | | |
| **7. Positive Judge TFD** | .06 | −.07 | −.29 | .20 | −.09 | .60*** | - | | | | | | |
| **8. TFD Bias Score** | −.01 | .06 | .25 | −.28 | −.01 | −.22 | .91*** | - | | | | | |
| **9. EATQ-R Attention** | −.20 | −.08 | .03 | −.01 | .09 | −.47* | −.26 | .08 | - | | | | |
| **10. Frustration** | .00 | .04 | .29 | −.16 | .20 | .11 | .04 | .01 | −.30 | - | | | |
| **11. High Intensity Pleasure** | −.18 | −.10 | .13 | .04 | .24 | .08 | .03 | .01 | .35 | .06 | - | | |
| **12. Social Anxiety** | .34 | .23 | .30 | .27 | .39 | −.00 | −.27 | .32 | −.01 | −.11 | −.07 | - | |
| **13. Speech Distress-Child** | .65*** | .63*** | .39 | .16 | .39 | .10 | −.02 | .07 | −.23 | .22 | −.07 | .49** | - |
| **14. Speech Distress-Mom** | .71*** | .47* | .25 | .11 | .18 | .30 | .20 | −.09 | −.47* | .11 | −.07 | .33 | .77*** |

*Note.* CV = Convergent validity, IB = interpretation bias, AB = attention bias, ASQ= Ambiguous Scenarios Questionnaire, TFD= total fixation duration, EATQ-R= Early Adolescent Temperament Questionnaire-Revised

* $p < .05$

** $p < .01$

*** $p < .001$

p-values were corrected for multiple comparisons using the false discovery rate

**Table 3.**

Hierarchical regression predicting SCARED social anxiety

| | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***B*** | ***SE B*** | **β** | ***B*** | ***SE B*** | **β** | ***B*** | ***SE B*** | **β** |
| **ASQ Threat** | .76 | .34 | .39* | .58 | .38 | .30 | .59 | .36 | .30 |
| **Distress Predictions** | | | | .54 | .51 | .21 | .54 | .48 | .21 |
| **TFD Bias Score** | | | | | | | .17 | .09 | .33 |

*Note.* ASQ= Ambiguous Scenarios Questionnaire, TFD= total fixation duration; Step 1: $\Delta R^2$= .15, $p$=.03; Step 2: $\Delta R^2$= .03, $p$=.30; Step 3: $\Delta R^2$= .11, $p$=.06

*$p < .05$

**Table 4.**

Hierarchical regression predicting child-reported speech distress

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | ***B*** | ***SE B*** | **β** | ***B*** | ***SE B*** | **β** |
| **ASQ Threat** | .31 | .14 | .39* | .10 | .11 | .12 |
| **Distress Predictions** | | | | .43 | .16 | .41* |
| **Ambiguous Judge Distress** | | | | .24 | .08 | .43** |

*Note*. ASQ= Ambiguous Scenarios Questionnaire; Step 1: $\Delta R^2 = .15$, $p = .03$; Step 2: $\Delta R^2 = .43$, $p < .001$

* $p < .05$

** $p < .01$

*** $p < .001$

**Table 5.**

Hierarchical regression predicting mother-reported speech distress

| | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***B*** | ***SE B*** | **β** | ***B*** | ***SE B*** | **β** | ***B*** | ***SE B*** | **β** |
| **Distress Predictions** | .62 | .12 | .71*** | .56 | .11 | .64*** | .56 | .11 | .64*** |
| **Attention** | | | | −.55 | .19 | −.35** | −.50 | .22 | −.32* |
| **Ambiguous Judge TFD** | | | | | | | .02 | .05 | .07 |

*Note*. TFD = total fixation duration; Step 1: $\Delta R^2 = .50$, $p < .001$; Step 2: $\Delta R^2 = .12$, $p < .01$; Step 3: $\Delta R^2 = .00$, $p = .62$

* $p < .05$

** $p < .01$

*** $p < .001$