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Social feedback biases emerge during recall but not prediction and shift across the development of social anxiety

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Memory is a reconstructive process that can result in events being recalled as more positive or negative than they actually were. While positive recall biases may contribute to well-being, negative recall biases may promote internalizing symptoms, such as social anxiety. Adolescence is characterized by increased salience of peers and peak incidence of social anxiety. Symptoms often wax and wane before becoming more intractable during adulthood. Open questions remain regarding how and when biases for social feedback are expressed and how individual differences in biases may contribute to social anxiety across development. Two studies used a social feedback and cued response task to assess biases about being liked or disliked when retrieving memories vs. making predictions. Findings revealed a robust positivity bias about memories for social feedback, regardless of whether memories were true or false. Moreover, memory bias was associated with social anxiety in a developmentally sensitive way. Among adults (study 1), more severe symptoms of social anxiety were associated with a negativity bias. During the transition from adolescence to adulthood (study 2), age strengthened the positivity bias in those with less severe symptoms and strengthened the negativity bias in those with more severe symptoms. These patterns of bias were isolated to perceived memory retrieval and did not generalize to predictions about social feedback. These results provide initial support for a model by which schemas may infiltrate perceptions of memory for past, but not predictions of future, social events, shaping susceptibility for social anxiety, particularly during the transition into adulthood.

social evaluation | memory | social development | bias | social anxiety

Significance

Memory is malleable and reconstructive, and often leads to biased recall and predictions. Open questions remain regarding biases in the social domain. This has particular relevance for internalizing disorders like social anxiety, which become more intractable in adulthood. Across two studies, a positivity bias emerged for retrieving true and false social memories. However, more severe social anxiety symptoms yielded a negativity bias in retrieving memories but not making future predictions. During the transition to adulthood, age potentiated negativity and positivity biases in those with more or less severe social anxiety symptoms, respectively. Results provide initial support for a model by which schemas may shape social memories and suggest memory as a novel intervention target for preventing persistent social anxiety.

Biases in memory are common (1), and decades of research suggest one source of these biases are schemas (2, 3), internal knowledge structures that help people organize new information they encounter. While schemas can help organize our memories, they also leave people vulnerable to memory distortions (4–6) and false memories (7–11) which bias new information to be consistent with one's internal knowledge structures. Schema-related distortions often lead to inaccurately remembering events as more positive than they actually were, a phenomenon known as positivity bias (12–14). This rosy view of the past is beneficial for mental health in that it has been associated with optimism, resilience, and adaptive coping strategies (15, 16). However, positivity biases are not universal; prominent cognitive theories of social anxiety suggest that negatively biased memory for social experiences may contribute to symptoms (17, 18). Yet, few studies probe recall for peer-based feedback, which is at the core of social anxiety. Social anxiety disorder typically onsets during adolescence, and with prevalence rates reaching to 20 to 36% following the COVID-19 pandemic, it has become one of the most common symptoms of psychopathology among young people (19–21). Moreover, given that social anxiety symptoms exist on a continuum, its negative effects impact an even wider swath of the population, making it all the more essential to understand symptom-promoting mechanisms. Despite decades of research showing memory is influenced by schemas, biases linked to social anxiety are typically interpreted as emerging from bottom–up processes, like hyperattention and arousal to threat (22, 23). Given mounting evidence that schemas about social experiences begin to crystalize across adolescence (24, 25), biases may be stronger in socially anxious adults, who often have more treatment-resistant symptoms, compared to adolescents.

Alternative cognitive theories of social anxiety suggest that prediction biases, in addition to biased memory, contribute to symptoms (17, 26–28). Yet, it is unclear how biases in predictions, true memories, and false memories in the social domain relate to social anxiety. In this paper, we demonstrate the efficacy of an ecologically valid paradigm designed to test bias for true memories, false memories, and predictions about social feedback, and variability of bias in relation to social anxiety symptoms. We replicate promising results

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in a second study that isolates age-related differences in biases across adolescents and adults who vary in their level of social anxiety.

A great deal of prior research shows broad influence of schemas on both true and false memories (7–11) and on both episodic memory and predictions of future events (13, 29–31). However, much of this work has been in nonsocial domains, such as semantically related concepts [e.g., features within a categorical class of stimuli (32, 33)], or events that follow a generic script [e.g., taking a vacation (9, 34, 35)]. The few studies to test memory for social information, such as evaluative peer feedback, rely on autobiographical memory which are often unverifiable [e.g., describe an experience based on a cue word, such as "lonely" or "public speaking" (36, 37)], precluding the ability to discriminate between true and false memories. To address these issues, we developed the Recall After Feedback Task (RAFT), which provides an ecologically valid and verifiable means of concurrently testing memory and prediction biases following well-controlled positive and negative peer feedback.

Negative schemas have long been posited to be a central factor in the development and persistence of social anxiety (38–42). Although schema-related influence on true and false memory and prediction have not been assessed concurrently, in adults, social anxiety is associated with enhanced memory recall for negative compared to neutral or positive facial expressions (43–45), statements (46), and performance feedback (47–49). However, because social anxiety is associated with enhanced attention to threat (22, 23), measuring bias by contrasting memory for intrinsically threatening vs. nonthreatening stimuli precludes the ability to ascertain bias for perceptually identical memoranda. In the past, we have addressed this issue by testing recall for positive or negative feedback provided by purported peers, all of whom were depicted with smiling faces, and found that socially anxious adults recalled a higher number of peers who provided negative compared to positive feedback (50). However, this prior work did not allow us to probe whether these effects stem from biased encoding or schema-related distortions in recall. With the RAFT, we can disentangle these effects by exploring whether biases emerge only for the recall of actual events that occurred, reflecting biased encoding during feedback, or rather generalize across both true and false memory. Generalized effects would provide initial support for the idea that bias reflects schematic influences rather than encoding-based mechanisms. Further, this prior work did not allow us to probe prediction-related biases, another cognitive factor proposed to contribute to social anxiety symptoms (17, 26–28). While mixed evidence has emerged for such biases, the present study will concurrently test for relations between social anxiety symptoms and biases in memories for, and predictions about, social feedback.

To determine whether negativity biases contribute to the etiology of social anxiety, it is critical to investigate potential differences in the relation between symptom severity and biases in both adolescents and adults. While the incidence of social anxiety symptoms peaks in adolescence (51), persistence in early adulthood is associated with more intractable symptoms and comorbidity with depression (52–54). The adolescent peak in incidence coincides with heightened salience for social feedback (55–57) and a dramatic increase in the capacity to construct and utilize schemas (24, 25). Thus, negativity biases that are an outgrowth of schemas about social experiences may strengthen with age as beliefs solidify, thereby contributing to persistence of adult social anxiety symptoms. Moreover, in the context of poor memory for social interactions, increased reliance on schemas to "fill-in-the-gaps" may potentiate biases. Given that schemas typically bias memory and predictions, generalized negativity biases would suggest deeply entrenched schemas contribute to symptoms. Indeed, negative schemas that form across adolescence and remain stable in adulthood play a crucial role in the etiology and course of other forms of psychopathology (58–62). However, the complex influence that development may have on memory- and prediction-related processes have heretofore proven challenging to study in cross-sectional samples that vary in age (e.g., balancing complexity of words on a list, familiarity with positive and negatively valenced images or scenes to be equally suitable for youths and adults). The RAFT provides a flexible tool that circumvents many of these challenges.

Across two studies, we used the RAFT to test the specificity of biases in true and false memories for, and predictions about, social feedback. We hypothesized that, overall, positivity biases would emerge and generalize across memories and predictions regardless of actual feedback, but that symptoms of social anxiety would be associated with a generalized negativity bias. In study 2, we tested whether the strength of positivity and negativity biases varies as a function of social anxiety symptoms and whether the strength of these relations increases from adolescence to early adulthood, as schemas solidify.

Materials and Methods

General Procedure. For both studies, participants were told that they were participating in research on brain function during social evaluation and provided a digital photo of themselves that was purportedly uploaded to a study database. Participants were led to believe that once this photograph was uploaded, age-matched peers would receive a text message, and they had 5 min to view the photo and indicate whether they thought they would "like" or "dislike" the participant. Participants completed electroencephalography (EEG; study 1) or functional magnetic resonance imaging (fMRI; study 2) while encoding peer feedback during the Selection and Feedback Encoding phase of the RAFT (Fig. 1 *A* and *B*). After EEG or fMRI, participants then completed the surprise Cued Response phase of the RAFT (Fig. 1*C*) which probed recall for, and predictions about, peer feedback. This paper focuses on behavioral findings related to recall and predictions. Results related to neural response to social feedback are reported in other manuscripts (63–65).

Study 1 tested task effects and relations between bias and social anxiety symptoms in adults. Given previously established effects of social anxiety and age on memory for social feedback (50), and the fact that schemas for peer-based social experiences only begin to crystallize during midadolescence [~age 13 to 15 (24, 25)], study 2 aimed to replicate results from study 1 while exploring age-related associations between biases and social anxiety across early adolescence to mid-adulthood. All participants were English speaking, free of psychotropic medication use, and provided informed consent (adults), or assent with parental consent (adolescents), prior to participation. Procedures were approved by the Stony Brook University Institutional Review Board.

Participants. Study 1 participants were in emerging and mid-adulthood (18 to 38 y; N = 197; 64.5% female; M = 19.91 ± 2.52 y) with a range of social anxiety symptoms. Additional participants were excluded due to incomplete data (N = 3), technical errors (N = 1), or not following instructions (N = 4). Study 2 participants were composed of two samples that spanned the transition from early adolescence into midadulthood (66, 67). The first were those in early to midadolescence (11 to 15 y; N = 37; 48.6% female; M = 13.32 ± 1.20 y), and the second were those in emerging to mid-adulthood (18 to 35 y; N = 39; 61.5% female; M = 21.49 ± 4.11 y). Additional participants were excluded due to incomplete data (N = 6) or technical errors (N = 1). For analyses without specific age-related hypotheses, samples were collapsed to achieve greater statistical power (N = 76; 55.3% female; M = 17.51 ± 5.11 y).

RAFT.

Selection and feedback encoding. During the Selection phase of the RAFT (Fig. 1*A*), participants were presented with 60 pairs of purported peers who were age-matched to the participant. Pairs of purported peers were gender-matched (i.e., two male faces or two female faces). For half of the trials, participants were

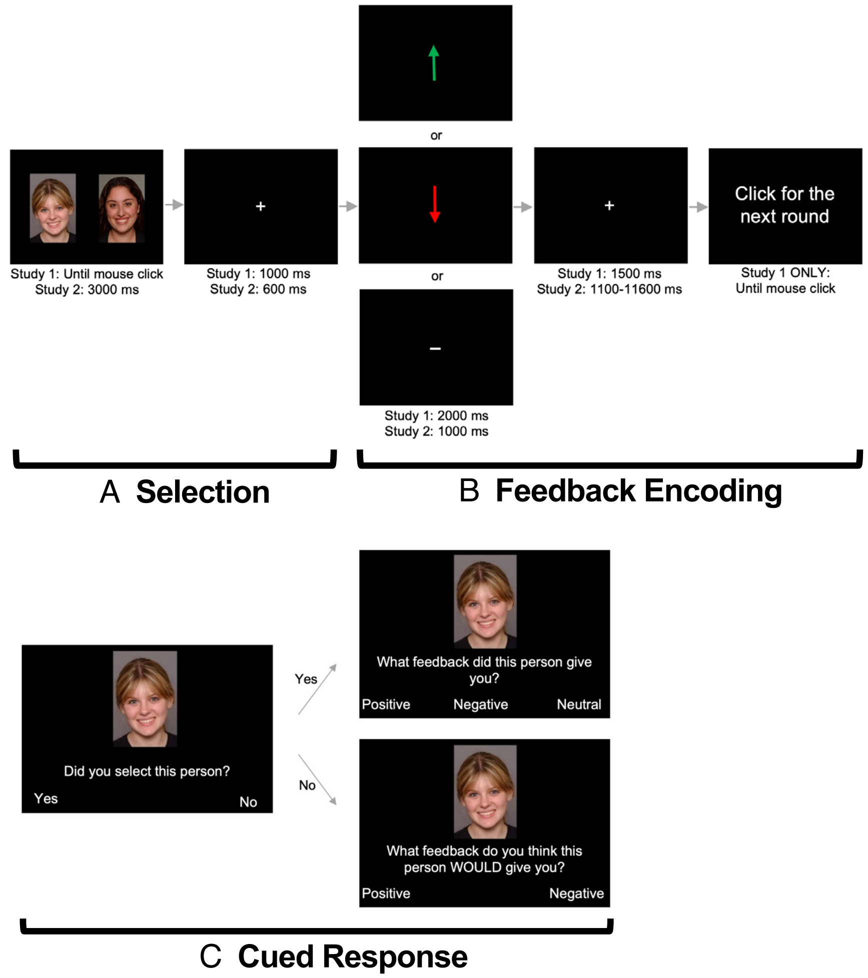

Fig. 1. Diagram of (*A*) Selection and (*B*) Feedback Encoding phases of the RAFT. Timing differences reflect optimization for different modalities (study 1: EEG; study 2: fMRI). Arrows reflect correctly selecting peer who liked (green; positive feedback) or disliked (red; negative feedback) the participant. The white horizontal dash (−) reflects an incorrect selection such that the person never rated the participant (neutral feedback). (*C*) Diagram of self-paced surprise Cued Response phase of RAFT for both studies.

instructed to select which peer in each pair liked them, and the other half to select which peer in each pair disliked them. Participants were told that there were three possible feedback scenarios for each trial: i) both peers said they would like/dislike the participant; ii) one peer said they would like/dislike the participant while the other did not make a rating in the time window allowed; or iii) neither peer rated the participant. Thus, feedback the participant received was only informative about the selected peer and not the unselected peer.

During the Feedback Encoding phase (Fig. 1*B*), participants received a green arrow pointing upward (↑) indicating correct selection of the purported peer who liked them (positive feedback), a red arrow pointing downward (↓) indicating correct selection of the purported peer who disliked them (negative feedback), or a white horizontal dash (—) indicating an incorrect selection such that the peer never rated them (neutral feedback). In actuality, feedback was preprogrammed such that participants received an equal amount of positive/negative or neutral feedback.

Purported peers were depicted by 120 smiling faces (60 females) compiled from multiple sources [National Institute of Mental Health's Child Emotional Faces picture set (68), and internet databases of noncopyrighted images]. Images were constrained to a standard size (study 1: 3.5″ × 4.5″; study 2: 2.75″ × 4″), cropped so that individuals were pictured from their shoulders up, and edited to have an identical solid gray background. Smiling faces were used because they are common in social reward tasks (50, 69, 70), are subject to less misinterpretation than neutral faces (18, 71), and to avoid introducing threat-related visual bias that might impact memory, particularly in relation to social anxiety.

The Selection and Feedback Encoding phases of the RAFT were administered using Presentation software (72) for study 1 and E-Prime software (73) for study 2. This aspect of the task has been described previously (63–65). Timing varied slightly across studies due to differences in data acquisition modalities.

Cued response. After completing Selection and Feedback Encoding phases, participants completed the surprise Cued Response phase (Fig. 1*C*), where they made either memory- or prediction-based decisions about feedback. Data related to this aspect of the task have never been described. Participants were shown each of the 120 peer photos from the Selection and Feedback Encoding phase of the experiment. For each peer, participants answered two questions. The first question tested memory for social interactions. Specifically, participants were asked whether they selected, and thus received feedback from, each peer (Yes or No). The second question tested valence-related bias, independent of whether memory for social interactions was true or false. For trials where participants recalled receiving feedback from the peer, participants were then asked to recall whether the peer gave them positive (like), negative (dislike), or neutral (did not rate) feedback. For trials where participants did not recall receiving feedback from the peer, they were asked to predict whether they thought the peer would have provided positive or negative feedback. For both studies, the Cued Response phase was self-paced and administered using E-Prime software (73).

Social Anxiety and Depression Symptoms. Anxiety and depression are often comorbid (74) and have each been associated with negativity bias (75, 76). However, they have also shown unique associations with brain function during the Feedback phase of the RAFT (63–65). To test the specificity of effects related to social anxiety, depression was also measured and then controlled for in all analyses.

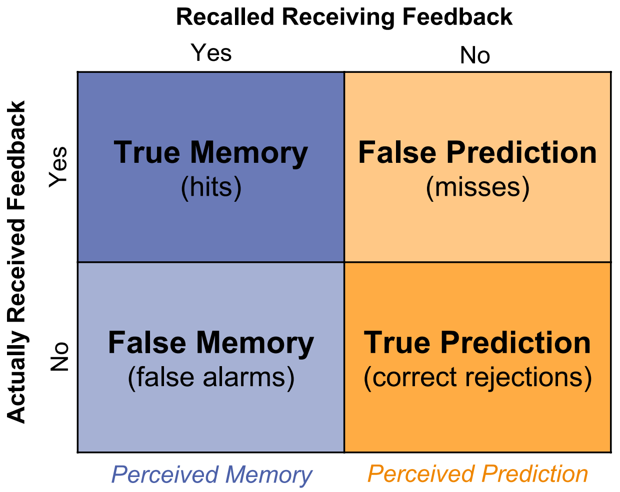

Fig. 2. Trial types based on responses to the first question of the cued response phase. Perceived memory trials (shown in blue) reflect instances where participants believed they had chosen a peer and retained a memory of feedback to recall. Based on whether the participant actually received feedback, these trials were further divided into true memories (i.e., hits) or false memories (i.e., false alarms). Similarly, perceived prediction trials (shown in orange) reflect instances where participants believed that they had not selected the peer and must predict what that peer's feedback would have been. These trials were further divided into true predictions (i.e., correct rejections) and false predictions (i.e., misses). The terms true and false characterize the memory and prediction based on the presence or absence of actual feedback receipt and are shown here in darker and lighter hues, respectively.

In studies 1 and 2, adult symptoms were assessed via the Inventory of Depression and Anxiety Symptoms–Expanded Version social anxiety (6 items; Cronbach's α study 1 = 0.86; study 2 = 0.84) and general depression subscales (20 items; Cronbach's α study 1 = 0.89; study 2 = 0.90) (77, 78). In study 2, adolescent symptoms were assessed via the Screen for Child Anxiety Related Disorders social anxiety subscale (7 items; Cronbach's α = 0.88) (79) and the Children's Depression Inventory (27 items; Cronbach's α = 0.88) (80). Given differences in study 2 scoring between adolescent and adult measures, each subscale was z-scored before collapsing across the sample.

Analytic Methods. All analyses were conducted using R (81).

Does bias generalize across memories and predictions, regardless of actual feedback? The first question during the Cued Response phase probed memory for social interactions and yielded four trial types (Fig. 2). Perceived memory trials, or those where participants believed they had chosen a peer and retained a memory of feedback to recall, were then categorized as true memories (i.e., hits–they did actually receive feedback from that peer) or false memories (i.e., false alarms–they did not actually receive feedback from that peer). Similarly, perceived prediction trials, or those where participants believed that they had not selected the peer and must predict what that peer's feedback would have been, were categorized as true predictions (i.e., correct rejections–they did not actually receive feedback from that peer) and false predictions (i.e., misses–they did actually receive feedback from that peer). The terms "true" and "false" characterize the memory and prediction based on the presence or absence of actual feedback receipt. For example, a "true prediction" signifies a prediction that is not informed by actual feedback from a peer, and thus reflects an uninfluenced prediction from the participant. In contrast, a "false prediction" pertains to instances where feedback was actually provided (but not recalled), and may be implicitly influenced by the feedback received during the trial, even in the absence of explicit recall.

The second question of the Cued Response Phase was used to quantify bias for social feedback. For each of the four response types (true and false memories and predictions), a bias score was calculated that reflected the number of peers a participant recalled as giving them (or predicted would give them) positive feedback, divided by the total number of peers the participant recalled as giving them (or predicted would give them) either positive or negative feedback.

Thus, scores nearing 1 or 0 respectively reflected a strong positivity or negativity bias whereas a score of 0.5 reflected the recall or prediction of an equal amount of positive and negative feedback. Despite the fact that 50% of all trials provided neutral feedback, participants recalled relatively few instances of neutral feedback (study 1: 14.0% ± 8.5%; study 2: 10.0% ± 7.5%). Thus, this condition was omitted from analyses.

To test the presence of bias, a one-sample t test was performed to determine whether scores for each of the four trial types differed from 0.5. A $P < 0.0125$ was needed to achieve significance after Bonferroni correction for multiple comparisons. To test whether biases generalized across true and false memories and predictions, pairwise Pearson's correlations were performed among all four bias scores. For study 1, one participant had insufficient variability to calculate a bias score for false memory trials and was thus omitted from false memory-specific analyses.

Further analyses were performed to gain preliminary insight into the extent to which other cognitive mechanisms may contribute to bias. For instance, in the presence of poor memory for social interactions more generally, there may be greater reliance on schemas to fill-in-the-gaps for recall of feedback valence. This would result in a stronger correlation between bias for true and false memories. To test for the presence of this effect, d' was calculated to quantify the accuracy of memory for social interactions using the "d′" command from the "psycho" R package (82):

$$d' = Z\left(\frac{hits}{hits + misses}\right) - Z\left(\frac{false\ \ alarms}{false\ \ alarms + correct\ \ rejections}\right).$$

A d' value of 0 would indicate that memory for social interactions was equal to chance, and larger positive numbers would indicate more accurate memory for social interactions. Linear regression models and the Johnson–Neyman technique were then used to determine whether d' moderated the association between bias scores for true and false memories or predictions.

Does bias vary depending on social anxiety and age? Across both studies, linear regression was used to test the relation between social anxiety symptoms and bias. To test the specificity of effects, depression was included as a regressor of no interest. For results that were discrepant across studies, appropriate independent samples tests were performed to determine whether the magnitude of effects differed. In study 2, age was added to the linear regression model to test the age by social anxiety interaction on bias. All main and interaction effects were specified in both models. Two adolescents were omitted from this analysis due to missing depression scores.

Results

Does Bias Generalize across Memories and Predictions, Regardless of Actual Feedback? Bias scores across trial types are depicted in Fig. 3*A* (study 1) and Fig. 3*B* (study 2). For both studies, a positivity bias emerged for perceived memories, regardless of whether the memories were true (hits; study 1: 0.65 ± 0.22; $t(196) = 9.42$, $P < 0.001$, Cohen's d = 0.67; study 2: 0.61 ± 0.18; $t(75) = 5.01$, $P < 0.001$, Cohen's d = 0.57) or false (false alarms; study 1: 0.63 ± 0.24; $t(195) = 7.76$, $P < 0.001$, Cohen's d = 0.55; study 2: 0.62 ± 0.21; $t(75) = 4.86$, $P < 0.001$, Cohen's d = 0.56). No biases emerged for perceived predictions, regardless of whether the predictions were true (correct rejections; study 1: 0.51 ± 0.20; $t(196) = 0.62$, $P = 0.534$, Cohen's d = 0.04; study 2: 0.52 ± 0.17; $t(75) = 1.10$, $P = 0.275$, Cohen's d = 0.13) or false (misses; study 1: 0.52 ± 0.20; $t(196) = 1.27$, $P = 0.205$, Cohen's d = 0.09; study 2: 0.51 ± 0.20; $t(75) = 0.54$, $P = 0.593$, Cohen's d = 0.06). This provides support that biases track with perceived experiences, regardless of actual feedback events, and that positivity biases are specific to perceived memories.

Further, as described in Table 1 (study 1) and Table 1B (study 2), biases evoked by true and false memories were positively correlated (study 1: $r(194) = 0.57$, $P < 0.001$; study 2: $r(74) = 0.65$, $P < 0.001$), as were biases for true and false predictions (study 1: $r(195) = 0.82$, $P < 0.001$; study 2: $r(74) = 0.78$, $P < 0.001$). For study 1, small

$$bias\ \ score = \frac{\text{number of peers recalled (or predicted) as giving positive feedback}}{\text{number of peers recalled (or predicted) as giving positive + negative feedback}}.$$

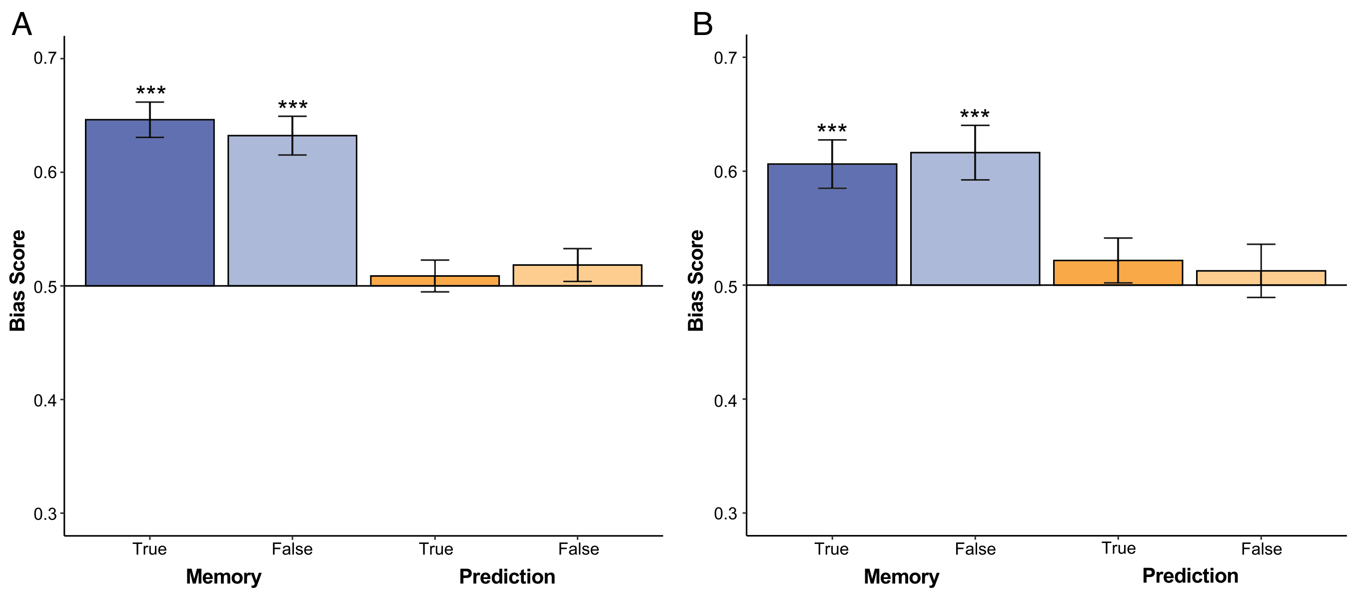

Fig. 3. Bias scores across trial types for (*A*) study 1 and (*B*) study 2. Error bars represent SE. *** indicates $P < 0.001$.

but significant negative correlations also emerged between true memory and true prediction bias ($r(195) = -0.19$, $P = 0.006$), as well as between true memory and false prediction bias ($r(195) = -0.17$, $P = 0.014$).

Linear regression demonstrated that memory for social interactions (d') moderated the association between true and false memory bias (study 1: $\beta = -0.15$, SE = 0.05, $t(192) = 2.73$, $P = 0.007$; study 2: $\beta = -0.26$, SE = 0.08, $t(72) = 3.34$, $P = 0.001$). A Johnson–Neyman analysis showed that the association between true and false memory bias decreased as d' increased, and was no longer significant for study 1 when $d' \geq 1.38$ and for study 2 when $d' \geq 0.79$. To facilitate visualization, participants were split into low and high d' groups based on a mean split within each study, and relations between true and false memory bias for each group were plotted in Fig. 4*A* (study 1) and Fig. 4*B* (study 2). d' did not moderate the relation between true and false prediction bias (study 1: $\beta = -0.05$, SE = 0.04, $t(193) = 1.18$, $P = 0.241$; study 2: $\beta = -0.03$, SE = 0.08, $t(72) = 0.31$, $P = 0.758$).

Table 1. Correlations between bias scores for (A) study 1 and (B) study 2

A

Trial type	True memory	False memory	True prediction
True memory bias			
False memory bias	0.57***		
	[0.47, 0.66]		
True prediction bias	−0.19**	−0.09	
	[−0.32, −0.06]	[−0.22, 0.05]	
False prediction bias	−0.17*	−0.10	0.82***
	[-0.31, -0.04]	[−0.24, 0.04]	[0.76, 0.86]

B

Trial type	True memory	False memory	True prediction
True memory bias			
False memory bias	0.65***		
	[0.50, 0.76]		
True prediction bias	−0.11	0.00	
	[−0.33, 0.12]	[−0.23, 0.23]	
False prediction bias	−0.19	−0.06	0.78***
	[−0.40, 0.04]	[−0.28, 0.17]	[0.68, 0.86]

Values in square brackets indicate the 95% CI for each correlation. * indicates $P < 0.05$; ** indicates $P < 0.01$; *** indicates $P < 0.001$.

Does Bias Vary Depending on Social Anxiety? Because of the large positive correlation between true and false memory biases, and to minimize the number of statistical tests, we combined true and false memory trials to generate a perceived memory bias score for subsequent analyses. To do this, we used the same bias calculation as described in the formula above, but combined true and false memory trials together (Fig. 2, blue cells). In study 1, linear regression showed that after controlling for depression and its potential interactive effects, more severe social anxiety symptoms were associated with a greater negativity bias for perceived memories of social feedback ($\beta = -0.25$, SE = 0.10, $t(193) = 2.55$, $P = 0.012$; Fig. 5*A*). This association did not emerge for study 2 ($\beta = -0.16$, SE = 0.14, $t(70) = 1.17$, $P = 0.246$; Fig. 5*B*). A two-sample Z-test revealed no difference in the standardized coefficients (effect size) for study 2 vs. study 1 ($Z = 0.53$, $P = 0.596$). There were no associations between symptoms and bias for perceived predictions across either study (study 1: $\beta = -0.19$, SE = 0.10, $t(193) = 1.90$, $P = 0.059$; study 2: $\beta = 0.06$, SE = 0.14, $t(70) = 0.41$, $P = 0.684$).

Does Bias Vary Depending on Social Anxiety and Age? In study 2, linear regression demonstrated that social anxiety moderated the association between age and bias for perceived memories ($\beta = -0.34$, SE = 0.16, $t(66) = 2.21$, $P = 0.030$). Specifically, for individuals with few social anxiety symptoms, increasing age was associated with a more pronounced positivity bias. However, for individuals with more severe social anxiety symptoms, increasing age was associated with a more pronounced negativity bias (Fig. 6). This association did not emerge for bias for perceived predictions ($\beta = 0.27$, SE = 0.16, $t(66) = 1.71$, $P = 0.092$).

Discussion

Across two studies, we introduced the ecologically valid RAFT, which quantifies bias in memory for, and predictions about, social feedback. This task also allowed us to assess whether social memory

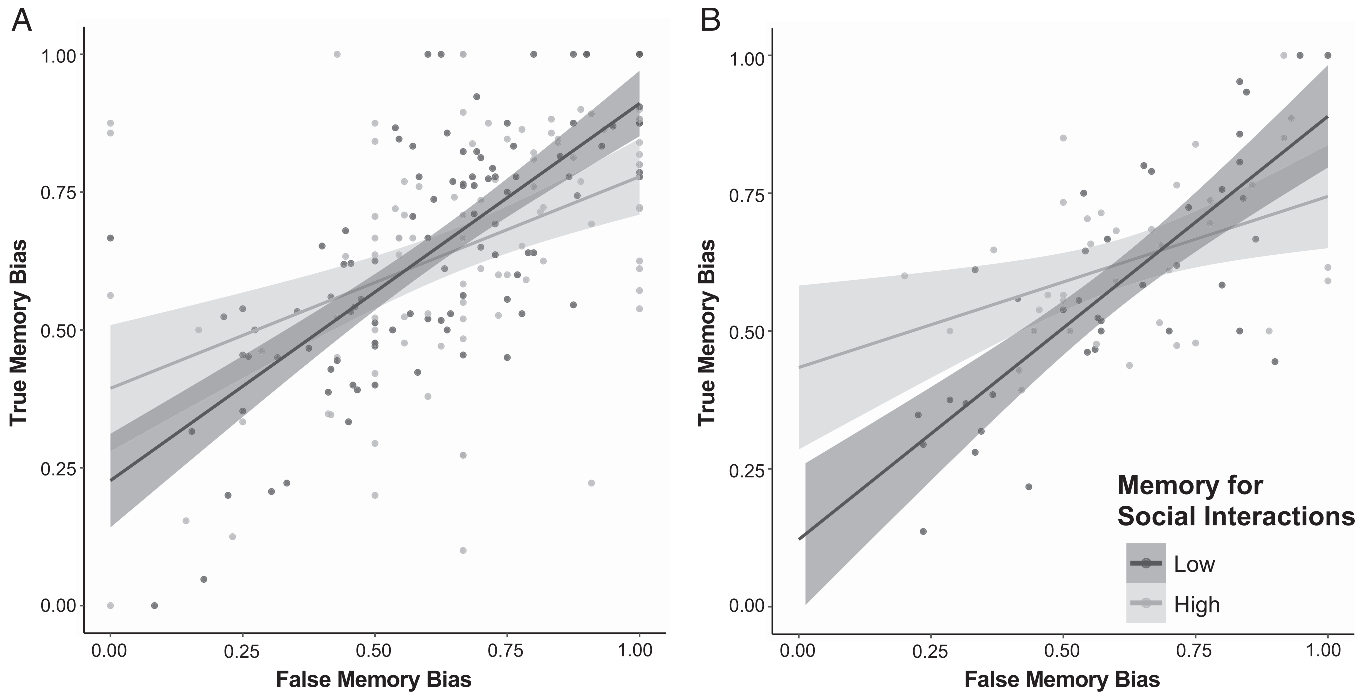

Fig. 4. Correlations between bias for true and false memories were stronger among those with poor memory (low *d′*) for social interactions in (*A*) study 1 and (*B*) study 2. A mean split on *d′* (study 1 = 0.49; study 2 = 0.32) was plotted to facilitate visualization, but all analyses were performed with a continuous measure. Those in the low (study 1 N = 39; study 2 N = 100) and high *d′* groups (study 1 N = 37; study 2 N = 96) were characterized as low or high in memory for social interactions, respectively.

biases in social anxiety are an outgrowth of biased encoding or may instead result from an overreliance on negative social schemas. Using this task, we performed a study to test the generalization of biases across true and false memories and predictions in the domain of social evaluation. Results revealed the specificity of effects for perceived memories of social feedback, regardless of the actual feedback, thus demonstrating bias generalized across true and false memories. Further, we speculate that schemas may contribute to positivity bias among those with few social anxiety symptoms and negativity bias among those with more severe symptoms. Additionally, these relations were potentiated with age, as social schemas become more firmly instantiated throughout adolescence into adulthood. Together, we propose that these findings provide an account of how schemas about social interactions may bias episodic memory and that these biases may be associated with social anxiety in a developmentally sensitive manner.

While the RAFT evoked an overall positivity bias, effects were specific to perceived memories (i.e., true and false memories) rather than predictions about the future. The robust correlation between bias scores for true and false memories helps disambiguate

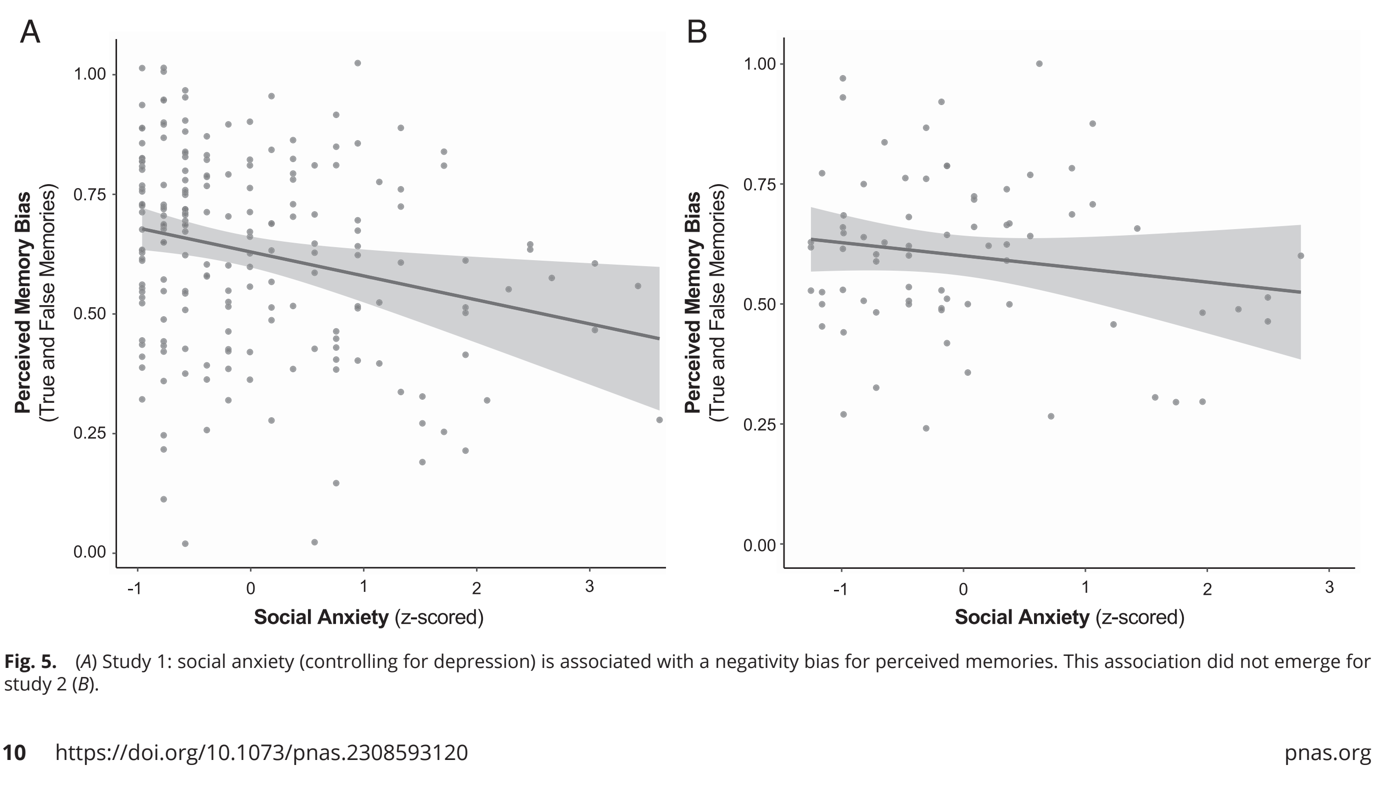

Fig. 5. (*A*) Study 1: social anxiety (controlling for depression) is associated with a negativity bias for perceived memories. This association did not emerge for study 2 (*B*).

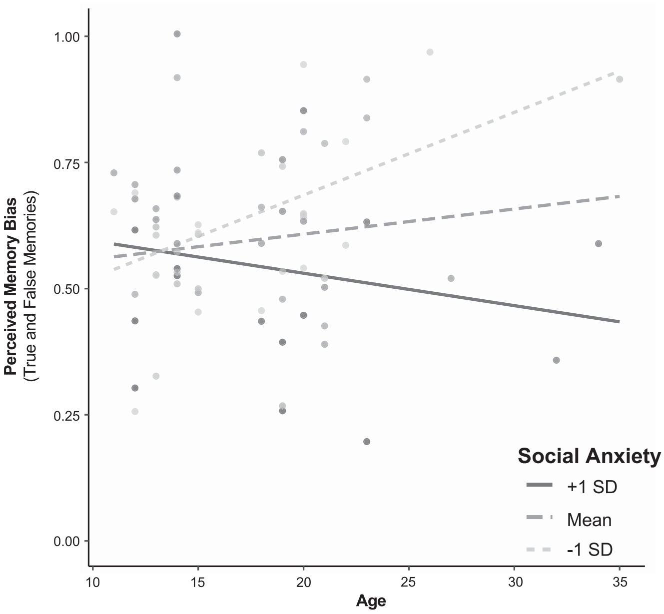

Fig. 6. For study 2, social anxiety (controlling for depression) moderates the relation between age and perceived memory bias.

between at least two potential mechanisms supporting bias. One stems from valence-based enhancements that influence memory encoding (e.g., if one is superior at encoding positive rather than negative or neutral feedback, then recall will contain more positive feedback). The other stems from differences in schema-based enhancements that influence recall. Bias for true memories, which underwent encoding, and false memories, which were never encoded, exhibited remarkably similar patterns of memory bias. This provides support for our proposed model of schema-based influence on memory recall. This interpretation aligns with established theoretical frameworks in the field, emphasizing the dynamic interplay between schemas, memory, and retrieval mechanisms (7–11). Future work using neuroimaging-based methods, which could isolate these processes as they are unfolding, is needed to more fully test this proposed model.

The fact that positivity biases did not extend to predictions is surprising and unexpected in light of previous research in nonsocial domains demonstrating that memory recall plays a critical role in the construction of future predictions (83). Specifically, behavioral, neuroimaging, and lesion-based studies suggest that mechanisms engaged during memory retrieval are also engaged during the prediction of future events, such that prediction emerges from the construction of unexperienced events founded in memory for actual events (84). Prior work has found that the modulatory influences of schemas similarly influence both memory retrieval and memory prediction. However, most of this work has not been conducted in the context of peer interactions (85). Thus, an open question remains in the current results as to why social schemas influenced perceived memories but not predictions. One potential explanation is that predictions about social events may rely on cognitive mechanisms outside of episodic memory networks, such as those centered on feedback-learning systems, which are supported by cortico-striatal circuits, and typically do not rely on event-specific details of the past (86). Alternatively, making predictions about peer feedback may hinge upon more reflective cognitive mechanisms, such as those engaged with counterfactual thinking (87), which may down-regulate the influence of schemas on prediction. Follow-up studies are needed to test these alternative hypotheses.

Despite the discrepancy between retrieval and prediction, bias did generalize across true and false memories to a remarkably high degree. This provides strong evidence that biases are linked to the perceived memory of feedback events, rather than actual feedback events. More broadly, we speculate that our results show that social schemas may differentially influence memory-related operations when individuals are in a retrieval mode vs. a prediction mode. These results are therefore consistent with extensive prior work demonstrating the influence of schemas on both true and false memories (7–11) and extend evidence for these effects to the social domain.

Our results also demonstrate the correlation between bias for true and false memories was stronger among those with poor memory for social interactions. This suggests that when one's memory for social events is hazy (e.g., when one does not recall everyone they interacted with at a party), they may rely more on other cognitive mechanisms, such as schemas, to fill-in-the-gaps that inform their recollection of event outcomes (e.g., whether interactions with specific party-goers were positive or negative). This parallels a large body of prior work showing that systemic biases due to schemas are expressed more when there is poor memory for events (88–93). Because memory is reconstructive and rarely exact, such gaps are ubiquitous. Given the extensive amount of face-to-face and online social feedback encountered on a daily basis, our results suggest bias potentially introduced by schemas may have a profound impact on a broad swath of memories in the social domain.

We also found that social anxiety was associated with negativity bias, particularly among adults. Specifically, in study 1, among those in emerging and mid-adulthood, more severe symptoms of social anxiety were associated with greater negativity bias for perceived memories of social feedback. Yet, the basic relation between social anxiety and memory bias was not observed in study 2. It is plausible that this may be due to diminished power given the smaller sample size. This possibility is supported by the fact that while the relation between social anxiety and memory bias was not significant in study 2, the size of effects across studies did not differ. However, our theoretical claim that schema reliance may be an adolescent-emergent phenomenon (94) predicts there would be no main effect of social anxiety on negativity bias when youth are included in the study sample. Indeed, as hypothesized, we demonstrated that biases were potentiated across adolescence into adulthood. Specifically, with age, negative memory biases became more pronounced among those with more severe social anxiety, whereas positive memory biases became more pronounced among those with low levels of social anxiety. These findings are consistent with work by our group and others demonstrating that social schemas undergo dramatic construction and solidification across the transition to adulthood (24, 25) and that individuals rely more heavily on schemas to process incoming information across age (95–97). A study that replicates the current research in a larger cross-sectional sample is needed to more definitively test this theoretical claim.

The double dissociation in the direction of bias across age, more positive vs. negative among those with low vs. high social anxiety, provides further support for the idea that memory can be protective or punitive in the context of mental health across development (28). Indeed, in normative populations, positivity biases increase across adulthood and are associated with greater well-being (98, 99). In those with social anxiety, negative schemas about the social world may contribute to the intractable nature of symptoms in adulthood. Overall, our findings provide critical additional context as to how the development of schemas across age might contribute to increased social positivity bias in most people, while also potentiating social negativity biases in socially anxious individuals. Longitudinal research is needed to confirm these relations.

Taken together, our results are consistent with prominent cognitive theories of social anxiety that suggest that negative memory bias for social experiences contributes to symptoms (17, 18). Despite the prominence of these theories, few studies of social anxiety-related memory test effects in the social domain. Moreover, those that do often probe unverifiable autobiographical events. Thus, the RAFT provides a much-needed tool for testing relations between social anxiety and social memory biases. Although social anxiety symptoms are frequently associated with attention biases to threat (22, 23), and often comorbid with depressive symptoms (74), which also demonstrate negative memory biases (75), our results are not likely explained by these factors. Specifically, participants received positive and negative feedback from smiling purported peers. Thus, stimuli across conditions embodied similar initial levels of threat, which guards against attention bias as an alternative explanation for results. Further, positive and negative feedback both reflected a "correct" outcome and are thus balanced in the degree to which error-related threat was engaged during encoding. Another strength of the paradigm is that it disentangles the reward associated with being correct about the type of feedback from the affective response that may be elicited by the valence of the feedback. We also demonstrated the clinical specificity of effects such that negative memory bias was associated with the severity of social anxiety symptoms, even after controlling for co-occurring symptoms of depression. Taken together, our findings suggest that negativity bias for perceived memories may be related to negative social schemas that contribute to social anxiety symptoms. Moreover, results hint at the idea that novel treatments targeting veridical memory for social interactions (d'), which moderated the relationship between true and false memory bias, could protect individuals with social anxiety from the negative consequences of schema-based processing.

By examining memory biases in the social domain, the present studies offer a crucial extension to the literature showing that memory is a reconstructive process which may introduce biases toward events consistent with schemas, specifically during recall. The RAFT enables bias to be quantified as a distinct construct from memory for social interactions, thereby allowing differences in bias for true and false memories and predictions to be considered separately. Ultimately, results demonstrated that perceived recall vs. prediction is more prone to positivity biases following social feedback, a bias that is especially potent in individuals with poor memory for social interactions. Importantly, findings suggest that while social anxiety symptoms are indeed associated with a negativity bias for perceived memories, age plays a crucial role in the expression of these biases over development. This supports the idea that positivity biases may be protective, whereas negativity biases may play a role in the etiology and/or maintenance of social anxiety symptoms, and help explain why it is particularly difficult to treat symptoms in adults. Taken together, these findings provide a much-needed alternative model for understanding the mechanisms underlying social anxiety, in which schemas infiltrate perceptions of memory for past, but not predictions of future, social events as social schemas solidify in adolescence. This model has the potential to lay the foundation for new intervention strategies that prevent the persistence of social anxiety into adulthood by using cognitive strategies that target memory processes.

Results from this work have broad implications given that clinically significant and subthreshold symptoms of social anxiety impact the lives of a large portion of the population. However, there are several ways that this work may generate new avenues of research that reach far beyond the domain of social anxiety. First, both social- and memory-related problems are transdiagnostic symptoms that cut across numerous forms of psychopathology. Results highlight how novel, memory-related mechanisms may promote the development or persistence of (mal)adaptive patterns of social cognition. For example, negative self-referential memory bias in the presence of early childhood trauma predicts poor mental health outcomes (100). It is plausible that social memory bias may be an important contributor to such outcomes. Moreover, the RAFT could be used to test social influence on bias in individuals with primary memory impairment symptoms. Despite the fact that psychosocial problems are significant secondary symptoms in those with dementia and mild cognitive impairment (101–103), well-controlled studies that test biased recall for social events in these populations are few and far between. Second, while longitudinal research is needed to test the brain-based mechanisms implicated in schema formation and its possible causal role in the expression of memory bias, the RAFT provides an experimental framework for cross-sectional studies of memory- and prediction-related processes at numerous stages of development. This opens the door to a wide range of new programs of research across the lifespan in the domain of social memory and beyond. Finally, results suggest that systematic memory bias likely occurs in a range of situations that involve the reconstruction of social events. This may include narrow events, such as eyewitness testimony, or a broader construal of events, such as those that ultimately shape the very way that humans see themselves and their place in the world. Thus, the present work may stimulate critical new lines of inquiry in disparate fields, ranging from basic memory research, clinically focused investigation, theoretically motivated study of the self and social cognition, to application-based public policy.

Data, Materials, and Software Availability. Anonymized data and analysis code have been deposited in Open Science Framework at (104).

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