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Smiles may go unseen in generalized social anxiety disorder: Evidence from binocular rivalry for reduced visual consciousness of positive facial expressions

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ABSTRACT

Research has demonstrated increased attention to negative social cues and reduced attention to positive social cues in generalized social anxiety disorder (GSAD), but little is known about whether GSAD also involves differences in lower levels of visual processing. This study explored visual experience in GSAD compared to participants with generalized anxiety disorder (GAD) and healthy controls using binocular rivalry. Participants were presented with dissimilar images to each eye, and the two images competed for perceptual dominance. Consistent with the hypothesis that GSAD involves a reduced visual salience for positive social cues, we found that smiling faces were dominant for significantly shorter durations in GSAD compared to GAD and controls. Contrasting with our hypothesis of greater visual salience of negative social cues, we found no difference in negative stimuli salience. These findings are consistent with the broader view that a perceiver's affective state directly influences the content of visual consciousness.

1. Introduction

People with generalized social anxiety disorder (GSAD) experience pervasive anxiety in social and performance situations, resulting in significant distress, functional impairment, and avoidance of these situations (Kessler, 2003; Lochner et al., 2003; Ruscio et al., 2008; Stein & Stein, 2008). This disorder is characterized by a misinterpretation of social cues, such that people with GSAD have a heightened attention to negative social information and an increased sensitivity to negative evaluation from others (Rosenberg, Roth Ledley, & Heimberg, 2010). Recent research examining selective attention has further demonstrated that socially anxious individuals are not only biased to attend to negative social information (Pineles & Mineka, 2005) but may also automatically direct their attention away from positive social information (Chen, Clarke, MacLeod, & Guastella, 2012; Taylor, Bomyea, & Amir, 2010).

While differences in attention allocation are important, recent research suggests an even more fundamental bias in visual processing. Recent work shows that affect (including anxiety) profoundly influences perception at very early stages of processing – possibly before changes in overt attention occur (for review, see Barrett & Bar, 2009). For instance, participants with high (compared to low) fear of heights perceived the balconies they were standing on to be higher (Teachman, Stefanucci, Clerkin, Cody, & Proffitt, 2008). Additionally, participants with high levels of spider phobia (versus low phobia) perceived relatively faster motion of a spider (but not a rabbit) crawling toward them (Riskind, Kelly, Moore, Harman, & Gaines, 1992). These findings are difficult to explain through cognitive control or selective attentional mechanisms. This emerging evidence suggests that anxiety disorders may involve fundamental changes in visual processing beyond attention, and that GSAD in particular may be associated with disorder specific differences in visual perceptual processing and awareness. Consistent with this hypothesis, brain areas associated with emotional face processing (left amygdala, insula, and bilateral superior temporal sulcus) showed increased activation in social anxiety participants when viewing faces (Gentili et al., 2008). Additionally, task irrelevant threatening faces captured low-level visual processing resources (as measured by steady-state visual evoked scalp potentials) at the cost of processing task relevant stimuli, such as Gabor patches (Wieser, McTeague, & Keil, 2012). Individuals with GSAD also

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judge faces differently, such that patients with GSAD categorized overtly presented 'neutral' faces as expressing contempt while non-anxious controls categorized them as displaying happiness (Heuer, Lange, Isaac, Rinck, & Becker, 2010). This last finding could be due to differences in later judgments – not perception. That is, all participants might perceptually see the faces in the same way, but GSAD participants make a biased decision that some 'neutral' faces show contempt. On the other hand, the perceptual system might actually represent 'neutral' faces differently for participants with GSAD, which leads to downstream differences in judgments. Untangling these two related processes is difficult, and we will return to this question later. However they come about, these differences in visual processing and/or judgment might enhance or sustain GSAD symptoms in a feed forward fashion. For example, individuals with GSAD might be more likely to see and categorize a supervisor's ambiguous expression as negative, leading them to falsely believe that they are failing at work. This could result in heightened anxiety and avoidance that further worsen both performance and symptoms, hallmarks of GSAD.

The aim of the present study was to explore two potential hypotheses about perceptual biases in patients with GSAD (described above). Specifically, we explored whether negative social stimuli are more visually salient (hyper-negativity) and whether positive social stimuli are less visually salient (hypo-positivity) in GSAD. To examine visual saliency in GSAD, we utilized a phenomenon known as binocular rivalry (for review, see Blake, 2001). Binocular rivalry occurs when perceptually dissimilar images are presented to different eyes (e.g., a face to one eye and a house to the other eye) and the two percepts compete for perceptual dominance. Visual input from one eye is consciously experienced (i.e., subjectively seen) while the other is suppressed from visual awareness and remains subjectively unseen. After a period of a few seconds, the suppressed image eventually becomes dominant and the formerly dominant image becomes suppressed so that over time, people experience the two percepts alternating back and forth. Because the visual stimulation does not change, but the visual experience does, binocular rivalry is an excellent tool to study visual saliency by examining what types of perceptual inputs are selected by the brain for conscious experience.

Binocular rivalry is a good method to test our hypotheses because it is thought to be relatively independent of voluntary and controlled attention – particularly compared to the processing of other types of bi-stable images (such as the Necker cube; Meng & Tong, 2004). Here we used binocular rivalry instead of an attention task (such as dot-probe) because it is a relatively novel technique for clinical populations, and it allowed us to examine which percepts are preferentially selected by the visual systems of socially anxious individuals in a way that is not completely determined by controlled attention and is unlikely due to biased judgments since no explicit evaluation is taking place.

A hallmark of binocular rivalry is that perceivers cannot voluntarily shift their conscious perception between images simply by shifting their attention from one image to another; this paradigm thus differs from controlled attention tasks. Much of the original research has focused on how stimulus based features (such as luminance and contrast) influence rivalry resolution (for review, see Blake, 2001). Nonetheless, some perceiver-based influences on binocular rivalry have been documented. For example, when skilled observers intentionally attend to one image in a rivalry paradigm, dominance durations can increase (Chong, Tadin, & Blake, 2005) and visualizing objects with imagery can influence which percept dominates in consciousness (Pearson, Clifford, & Tong, 2008). The outcome of binocular rivalry is thus determined by some combination of perceiver based and stimulus driven factors at early and late levels of visual processing (for review, see Tong, Meng, & Blake, 2006). Furthermore, recent research has demonstrated that the affective state of the perceiver influences conscious experience during binocular rivalry, lending support to the hypothesis that affective states associated with GSAD might also be associated with changes in the visual experience of social information. In healthy participants, smiling faces dominated in consciousness relatively longer when perceivers were in a pleasant state, whereas scowling faces dominated for relatively longer when perceivers were in an unpleasant state (Anderson, Siegel, & Barrett, 2011). This means that the moment-by-moment affective state of the perceiver influences which ocular input is suppressed by the visual system. What the perceivers consciously see depends on the affective state of the perceiver and the valance of the stimulus in the world. Moreover, some clinically relevant individual differences have been shown to influence rivalry. Non-clinical anxiety increases the alternation rate between images (Nagamine et al., 2007), and self-reported state and trait anxiety levels are correlated with increased perception of negative faces and decreased perception of smiling expressions as the first percept (Gray, Adams, & Garner, 2009).

Very few studies have explored conscious experience in clinical populations using binocular rivalry. A recent study reported that posed, stereotypical sad faces are more visually salient and happy faces less visually salient for patients with major depressive disorder (MDD); individuals with MDD suppressed frowning faces for shorter durations and smiling faces for longer durations compared to healthy controls (Sterzer, Hilgenfeldt, Freudenberg, Bermpohl, & Adli, 2011), which is consistent with the hyper-negativity and hypo-positivity hypothesis. Also consistent with the hyper-negativity hypothesis is a recent study that reported participants diagnosed with GSAD are more likely to consciously see posed, stereotypical fear as compared to neutral faces as the initial percept in binocular rivalry conditions (i.e., fear faces appear as the first conscious percept more frequently than do neutral faces; Singer, Eapen, Grillon, Ungerleider, & Hendler, 2012). Interestingly, GSAD participants (compared to healthy controls) perceived neutral faces longer over the duration of a 40 s trial, but there was no overall difference between how long groups perceived fearful faces.

In the present study, we tested whether visual processing is disordered in GSAD. Specifically, we tested the hyper-negativity hypothesis: for individuals with GSAD, negative social stimuli (scowling faces) would be more visually salient (and would dominate more) compared to neutral faces under conditions of binocular rivalry. We also tested the hypo-positivity hypothesis: positive social stimuli (smiling faces) would be less visually salient (and would dominate less). Based on previous findings that non-clinical anxiety increases the alternation rate between images (Nagamine et al., 2007), we also examined whether differences in anxiety levels would be correlated with differences in alternation rate. Additionally, this study explored whether individual differences in currently experienced affect (e.g. positive/negative affect, self-rated anxiety, or perceived stress) were related to visual salience during binocular rivalry. We compared individuals with GSAD to individuals with generalized anxiety disorder (GAD), as an anxious psychopathology control, and non-psychiatrically-ill controls. GAD is a general anxiety and worry based disorder; although some social concerns can be present, GAD is not a phobic, fear based condition and does not specifically focus on social evaluative concerns. Participants with GAD were thus used as another control to test whether anxiety in general leads to hyper-negativity/hypo-positivity in social affective visual saliency, or whether GSAD in particular is related to these changes.

Table 1
Sample demographics & affective individual difference scores.

	Primary diagnosis (N)		
	Control (73)	GSAD (56)	GAD (36)
Mean age (std. error)	40.68 (1.53)	34.8 (1.68)*	40.53 (2.46)
Gender, % male (*N*)	42.5 (31)	62.5 (35)	50.0 (18)
Race, % Caucasian (*N*)	63.0 (46)	80.4 (45)	86.1 (31)
Ethnicity, % non-Hispanic (*N*)	95.9 (70)	91.1 (51)	91.7 (33)
PANAS negative affect	2.17 (0.60)	7.18 (1.01)***	9.43 (1.60)
PANAS positive affect	30.54 (1.51)	19.69 (1.61)***	20.20 (1.65)***
Perceived stress scale	9.77 (0.75)	21.20 (0.86)***	23.49 (1.07)***
STAI state anxiety	29.00 (1.04)	42.25 (1.48)***	44.31 (2.40)***
STAI trait anxiety	30.31 (0.82)	51.42 (1.45)***	54.32 (1.43)***
MADRS	2.31 (2.81)	10.72 (6.9)***	15.44 (6.33)***
LSAS+	–	86.81 (2.27)	–

Note: standard errors given in parentheses.
** $p < 0.01$ for 2-tailed *t*-tests compared to control participants.
* $p < 0.05$, for 2-tailed *t*-tests compared to control participants.
*** $p < 0.001$ for 2-tailed *t*-tests compared to control participants.
+ LSAS data was only collected for GSAD participants. Some participants did not complete questionnaires, so *n* for control participants ranges from 70 to 73, $n = 55–56$ for GSAD, and $n = 34–35$ GAD in this table.

2. Materials and methods

2.1. Participants

All participants were recruited to Massachusetts General Hospital through referral from other studies at the Center for Anxiety and Traumatic Stress Disorders or local media advertising from November 2007 to May 2010. In total, 56 participants diagnosed with GSAD (mean age = 34.8; SE = 1.68), 36 with GAD (mean age = 40.53; SE = 2.46) and 73 healthy controls (mean age = 40.68; SE = 1.53) completed the study (84 males; see Table 1 for demographic information). Psychiatric diagnoses were determined by clinical interviewers certified in administering the Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbon, & Williams, 1994) which has been demonstrated to exhibit strong between-rater consistency (Ventura, Liberman, Green, Shaner, & Mintz, 1998). Exclusions for GSAD and GAD participants included lifetime history of psychosis, bipolar disorder, mental disorder due to a medical condition or substance, current eating disorders, and alcohol or substance use disorders within the past 6 months. Control participants could have no current or lifetime DSM-IV Axis I disorders, with the exception of specific phobia and a past history of alcohol or substance use disorders in remission for at least 12 months. Overall, at least one current mood or anxiety disorder was present for 36% of patients with primary GAD ($n = 36$), and 36% of those with primary GSAD ($n = 56$), with no significant difference between groups [Chi-square (1 df) = 0.0015, $p = 0.97$]. A total of 28% of those with primary GAD had secondary SAD comorbidity, while 16% of those with primary SAD had secondary GAD comorbidity. The Institutional Review Board approved study procedures and all participants provided written informed consent. Participants received $30 for participating supported by departmental funds (NMS & MHP).

2.2. Materials and procedure

Instructions and stimuli were presented using E-Prime Version 1.0 (Schneider, Eschman, & Zuccolotto, 2002). Participants sat with their head fixed with a chin rest. On each trial, participants were presented with a photograph of a face and a photograph of a house under binocular rivalry conditions. Red faces were overlaid on green houses, and vice versa (counterbalanced), to create composite images (Tong, Nakayama, Vaughan, & Kanwisher, 1998; see Fig. 1). When viewed with red/green anaglyphic glasses, the face was presented to one eye and the house to the other eye. A frame was placed around each stimulus to facilitate fusion of the two images. Six different face identities were used (each paired with a different house) and each identity was presented depicting a smiling, scowling, and neutral expression. Each face-house pair was shown once with the face in red and once with the face in green for a total of 36 trials. Participants switched the anaphylactic glasses after 18 trials so that for 50% of the trials the green image was seen by the right eye, and for the other 50% it was seen by the left eye.

Each trial began with a 1-second fixation cross (+) immediately followed by the 10-second face-house pair presentation. There was a 4-second interval between each trial. Participants were instructed to focus on the central fixation point and to press and hold the '*L*'

Fig. 1. Example of binocular rivalry stimuli.

key when they perceived a house, the '*A*' key when they perceived another object, or both keys simultaneously if they saw both a house and another object or a blend of the two. These instructions were used so explicit evaluation was not part of the task, so any observed differences are unlikely due to biases in judgments. Response keys were counterbalanced across participants. Participants were instructed to keep their fingers on the keys at all times during the task and were given a practice block of 12 trials at the beginning of the experiment (with rivaling fruit and houses).

To measure individual differences in current affective experience, participants completed the following self-report scales: Positive and Negative Affect Schedule – Revised (PANAS-X; Watson, Clark, & Tellegen, 1988), State and Trait Anxiety Inventory (STAI; Spielberger, 1973), and the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983). The PANAS-X is an 88 item scale that measures participants' affect with item responses from 0 to 6. The scale contains the two original higher order scales (positive affect and negative affect). Scores for each subscale are summed, with higher scores indicating a stronger presence of that specific trait. The PANAS-X has also been shown to have strong internal consistency for the positive and negative affect scales, adequate to strong convergent and discriminant validity (Watson & Clark, 1994), with excellent internal consistency (Cronbach's alpha of .92 for Positive Affect and .89 for Negative Affect in our sample). The STAI is a 40 item measure with items rated from 1 to 4; half the items represent state anxiety ("right now") and half trait anxiety ("generally"). Total scores range from 20 to 80, with higher scores indicating greater anxiety. The STAI has also been shown to have strong construct and concurrent validity (Spielberger, 1989), reliability (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and excellent internal consistency (Cronbach's alpha of .96 for STAI: State and .94 for STAI: Trait in our sample). The PSS is a 10 item measure of perceived stress with items rated from 0 to 4. Total scores range from 0 to 40, with higher scores indicating greater perceived stress. The PSS has also been shown to have substantial validity, adequate internal and test–retest reliability (Cohen et al., 1983), and excellent internal consistency (Cronbach's alpha of .92 in our sample).

In addition to these three self-report scales, clinicians completed the Liebowitz Social Anxiety Scale (LSAS; Heimberg et al., 1999) for all GSAD patients to assess social anxiety symptom severity. The LSAS is a 24 item scale with fear or anxiety, as well as avoidance rated from 0 to 3 for each item. Total scores range from 0 to 144, with higher scores indicating greater social anxiety. The LSAS has additionally been shown to have strong convergent validity, adequate discriminant validity, and be highly reliable (Heimberg et al., 1999) also demonstrating good internal consistency (Cronbach's alpha of .87 in our sample). A standard clinician rated continuous measure of depression symptoms with minimal overlap with anxiety symptoms, the Montgomery–Asberg Depression Rating Scale (MADRS; Montgomery & Asberg, 1979), was also administered. The MADRS is a 10 item scale with items rated from 0 to 6. Total scores range from 0 to 60, with higher scores indicating more severe depression. The MADRS has also been shown to have adequate validity, high inter-rater reliability (Montgomery & Asberg, 1979), and good internal consistency (Cronbach's alpha of .87 in our sample).

2.3. Data reduction

Based on previous research, we measured visual awareness using the duration of individual dominance/suppression phases. We calculated the mean duration that each individual reported seeing faces in visual awareness across binocular rivalry trials (mean face dominance duration; Anderson, Siegel, Bliss-Moreau, & Barrett, 2011; Zhou, Jiang, He, & Chen, 2010). We also computed a similar index to compute the duration during which houses were seen (mean face suppression duration). Additionally, we calculated the cumulative proportion of time a face, house, or blend was seen (by summing each percept of that type on a trial), alternation rate (number of percepts per trial; Nagamine et al., 2007), and the first percept seen (Gray et al., 2009). To compare our effects with those reported by Singer et al., we also computed an 'initial bias score' for scowling/smiling faces and a face predominance score that was equivalent to that used by Singer et al. (2012; see Table 2 notes for calculation details). Percepts occurring at the end of each trial were

Table 2
Perception measures.

		Primary diagnosis		
		Control	GSAD	GAD
Face dominance duration (ms)	Total	2421 (141)	2160 (164)	2391 (206)
	Scowling	2301 (172)	2226 (200)	2384 (251)
	Smiling	2579 (152)	1957 (177)*	2566 (222)
	Neutral	2385 (163)	2295 (189)	2223 (237)
Face as first percept	Total	0.40 (0.02)	0.34 (0.03)	0.41 (0.03)
	Scowling	0.41 (0.02)	0.31 (0.03)	0.40 (0.03)
	Smiling	0.41 (0.02)	0.33 (0.03)	0.42 (0.03)
	Neutral	0.39 (0.03)	0.36 (0.03)	0.41 (0.04)
Alternation rate	Total	3.25 (0.23)	3.99 (0.27)*	2.97 (0.33)
	Scowling	3.22 (0.23)	3.95 (0.26)	2.85 (0.33)
	Smiling	3.22 (0.24)	4.02 (0.27)	3.03 (0.34)
	Neutral	3.30 (0.25)	4.00 (0.28)	3.05 (0.35)
Face predominance	Total	326 (189)	−155 (216)	244 (269)
	Scowling	97 (210)	−493 (240)	−201 (299)
	Smiling	657 (219)	−9 (250)	705 (312)
	Neutral	223 (218)	37 (249)	228 (310)
Initial bias	Scowling	.023 (.039)	−.132 (.046)*	.019 (.055)
	Smiling	.052 (.037)	−.087 (.044)	.029 (.053)

Note: Standard errors given in parentheses. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, for 2-tailed *t*-tests compared to control participants. Face dominance duration is computed as the mean duration of a dominance cycle for faces. Alternation rate is the mean number of percepts per trial. Faces as first percept is the proportion of trials on which the face was the first percept. Face predominance was calculated as cumulative time a face was visible minus cumulative time a house was visible. Initial bias for scowling was computed as the number of times scowling faces were seen as the first percept minus number of times neutral faces were seen as the first percept over the sum of the number of times scowling plus neutral faces were seen as the first percept (#firstScowl − #firstNeutal)/(#firstScowl + #firstNeutral). Initial bias for smiling faces was calculated in the same way. Some participants did not have usable data in particular conditions (if they reported only blended percepts, for instance), so *n* used in these analyses ranged from 66 to 73 for control, 49–56 for GSAD, and 31–36 for GAD participants.

eliminated from the average of the duration variables because they were artificially shortened by the end of a trial. Very brief percepts (less than 100 ms) were excluded from all analysis as they reflect slight differences in reaction time for pressing or releasing both keys to report blended percepts.

3. Results

3.1. Visual dominance

We found evidence for the hypo-positivity hypothesis but no evidence for the hyper-negativity hypothesis in GSAD. As predicted, smiling faces were less visually salient for individuals with GSAD (Fig. 2). A mixed-model ANOVA with face type as the repeated measure, diagnosis as the between subjects factor, and face dominance duration as the dependent variable, indicated a significant interaction between diagnosis and face type, $F(4,286) = 2.778$, $p < .028$. To explore this interaction, follow-up t-tests were performed. Smiling faces were dominant for a shorter duration in individuals with GSAD: 552 ms shorter for GSAD compared to controls, $t(116) = 2.31$, $p < .023$, and 609 ms shorter for GSAD compared to GAD: $t(78) = 2.649$, $p < .011$. No such interaction was observed between diagnosis and mean smiling face suppression duration, $F(4,282) = .314$, $p > .86$, indicating that the amount of time houses dominate in consciousness does not depend on the type of face being suppressed and the participant's diagnosis. There were no main effects of face type or diagnosis in these analyses. Contrary to the hyper-negativity hypothesis, there was no increase in dominance times for scowling faces for GSAD relative to GAD and healthy controls (Table 2). Of note, we did not replicate the findings by Singer et al. (2012) that neutral faces were seen more in GSAD participants with either our dominance duration measure, $F(2,152) = .212$, $p > .81$, or their predominance score, $F(2,162) = .188$, $p > .83$ (Table 2). This same pattern of results holds when age was entered as a covariate.

To further explore how current affective experience related to visual experience, we correlated self-report measures of positive affect (PANAS) across all participants with the cumulative proportion of time participants saw faces (Table 3). Greater positive affect was associated with seeing faces (of all types) for a larger proportion of time, $r(159) = .278$, $p < .001$. Greater positive affect was also associated with stronger rivalry suppression; blends of the two rivalry images were seen for less time, $r(159) = -.261$, $p < .002$. There was

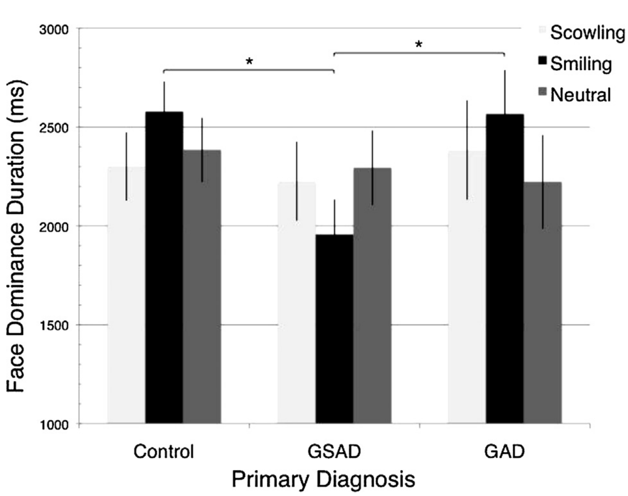

Fig. 2. Face dominance durations. *Note*: Error bars represent standard errors. *$p < 0.05$, for 2-tailed t-tests. Face dominance duration is computed as the mean duration of a dominance cycle for faces.

no relationship between self-reported negative affect and any of our perceptual measures (Table 3).

3.2. Alternation rate

Consistent with non-clinical anxiety studies (Nagamine et al., 2007), anxiety diagnosis influenced the rate at which images alternated in consciousness (Table 2). A mixed-model ANOVA with face type as the repeated measure, diagnosis as the between subjects factor, and alternation rate as the dependent variable, revealed a significant difference in the alternation rate between the different anxiety groups, $F(2,162) = 3.448$, $p < .035$, but no effect of face type, $F(2,162) = 1.86$, $p > .156$, or interaction between the two factors, $F(4,162) = .52$, $p > .72$. Specifically, follow-up t-tests revealed significantly more alternations for GSAD compared to controls, $t(127) = -2.004$, $p < .047$, and compared to GAD participants, $t(90) = -2.309$, $p < .023$. However, previous research has found that alternation rate decreases with age (Ukai, Ando, & Kuze, 2003), and our GSAD participants were significantly younger than the other groups (Table 1). When age was entered as a covariate, the original interaction decreases and is no longer significant, $F(4,322) = .698$, $p = .594$, suggesting that the difference was driven by age.

Across all participants, the alternation rate positively correlated with higher anxiety scores for Trait Anxiety, $r(157) = .167$, $p < .036$, State Anxiety, $r(161) = .140$, $p < .076$, and the Perceived Stress scales, $r(160) = .164$, $p < .038$ (see Table 3). The correlation between alternation rate and State Anxiety is driven by data from control participants (control: $r(70) = .254$, $p < .032$; GSAD: $r(54) = .1$, $p > .464$; GAD: $r(33) = -.016$, $p > .927$) while GSAD participants drive the correlations between alternation rate and Trait Anxiety (control: $r(68) = .094$, $p > .440$; GSAD: $r(53) = .324$, $p < .017$; GAD: $r(32) = -.078$, $p > .663$) and the Perceived Stress Scale (control: $r(71) = .155$, $p > .192$; GSAD: $r(52) = .295$, $p < .031$; GAD: $r(33) = -.074$, $p > .674$). Additionally, for GSAD participants, there was a significant positive relationship between the alternation rate reported and the LSAS Social Fear subscale, $r(51) = .320$, $p < .021$, but not other LSAS subscales. There was also a significant negative correlation between age and alternation rate (as in Ukai et al., 2003), $r(164) = -.369$, $p < .001$ (Table 3).

3.3. First percept

As predicted, there was some evidence that clinical anxiety diagnosis influenced which image was seen first under binocular rivalry conditions. A mixed-model ANOVA with face type as the repeated measure, diagnosis as the between subjects factor, and the proportion of time a faces was seen as the first percept as the dependent variable, revealed a trend difference between anxiety groups, $F(2,162) = 2.631$, $p < .076$ (Table 2). Faces in general were marginally less likely to be the first percept in GSAD compared to controls, $t(127) = 1.99$, $p < .049$, or GAD, $t(90) = 1.904$, $p < .061$. There was no effect of face type, $F(2,162) = 1.364$, $p > .257$, and no interaction between the two factors, $F(4,162) = 1.708$, $p > .148$. Age was not a significant covariate when added to the original analysis, $F(1,161) = .043$, $p = .836$. Across all participants, greater positive affect scores on the PANAS were positively correlated with a higher proportion of time seeing a face as the first percept, $r(159) = .204$, $p < .01$. We found no other relationship between any of the anxiety measures and first percepts (see Table 3).

To more directly compare our results to those of Singer et al. (2012), we calculated the initial bias of seeing a scowling face as the first percept (as in Singer et al., 2012; see Table 2 notes for more details) and compared it across diagnosis group. A mixed-model ANOVA with face type as the repeated measure, diagnosis as the between subjects factor, and the initial bias as the dependent variable revealed a main effect of diagnosis, $F(2,151) = 4.787$, $p < .011$,

Table 3
Pearson correlation coefficients between affective individual difference scores and perception measures.

	Perception measures				
	Face dominance	Face suppression	Blended percept	Alternation rate	Faces as first percepts
Age	.017	.114	−.064	−.369***	.052
PANAS negative affect	−.040	.033	−.005	.097	−.115
PANAS positive affect	.278**	.113	−.261**	−.143	.204**
Perceived stress scale	−.101	−.082	.133	.164*	−.12
STAI state anxiety	−.017	−.053	.049	.14	−.089
STAI trait anxiety	−.085	−.094	.127	.167*	−.131
LSAS social fear+	.085	−.218	.053	.320*	.013

Note: All other correlations were calculated across all participants (*n* range from 159 to 163). Alternation rate is the mean number of percepts per trial. Faces as first percept is the proportion of trials on which the face was the first percept. Face dominance, face suppression and blended percept variables are cumulative totals calculated for each trial. There were no reliable differences in these correlations for the different facial expressions.
*** $p<0.001$, 2-tailed tests.
** $p<0.01$, 2-tailed tests.
* $p<0.05$, 2-tailed tests.
+ LSAS scores were calculated only for GSAD participants because this measure was only collected for them ($n=53$).

but no effect of expression, $F(1,151)=.939$, $p=.334$, or interaction, $F(2,151)=.108$, $p=.898$. The direction of means shows that scowling and smiling faces were seen less frequently as the first percept for GSAD participants compared to the other groups (Table 2), which is opposite of the effect reported by Singer et al. (2012) for fearful faces. This is consistent with our finding above that faces are less likely to be the first percept for GSAD participants. Age was not a significant covariate in this analysis, $F(2,150)=.065$, $p=.779$.

4. Discussion

Consistent with the hypo-positivity hypothesis, this study provides evidence that positive social information has less visual salience for GSAD participants: they consciously experienced less positive social information. In our study employing binocular rivalry, smiling faces were dominant for shorter durations for GSAD participants compared to GAD participants and healthy controls. Contrary to our hyper-negativity hypothesis, we observed no difference in the visual salience of negative social information. All three diagnostic groups showed no difference in the dominance duration for scowling faces, consistent with the previously reported finding of no difference in the duration that fear faces dominate under binocular rivalry conditions (Singer et al., 2012). Our findings suggest that the visual contribution to the psychopathology of GSAD might have more to do with missing or failing to "stick" with positive cues than an over perception of negative cues, which supports the hypo-positivity hypothesis. This perspective is congruent with previous research which found GSAD participants have a deficit in recognizing smiling expressions (Silvia & Allan, 2006). Additionally, highly socially anxious individuals have blunted ERP responses to positive faces within 200 ms of stimulus onset (Moser, Huppert, Duval, & Simons, 2008). At a broader level, our findings suggest the possibility of a novel and theoretically significant understanding of the psychopathology underlying GSAD, suggesting that very early biases occur in how the brain processes affective visual information prior to conscious awareness and attention. Our findings suggest the possibility that perceptual biases might start when visual information is still represented monocularly and ocular competition starts (for review, seeTong et al., 2006). These biases influence what visual information is selected for consciousness among GSAD individuals and might contribute to previous findings linking decreased attention to positive social information to level of performance anxiety in response to a speech task (Taylor et al., 2010), as well as faster attentional disengagement from positive faces in an eye movement tracking task (Chen et al., 2012). To our knowledge, this kind of disordered early perceptual processing and selection for consciousness is a novel way of understanding GSAD and it could lead to novel treatment approaches, as well as help explain some of the previous inconsistencies reported in facial processing studies of GSAD (e.g., see Staugaard, 2010 for review).

Consistent with findings from non-clinical anxiety research (Nagamine et al., 2007), GSAD diagnosis was related to a higher alternation rate, although in our study, this was explained by age differences between the groups. Additionally, across control and GSAD groups, self-reported stress and anxiety was correlated with an increased alternation rate.

It is interesting to note that decreased dominance duration of smiling faces was not found among highly anxious individuals in general but was specific to GSAD participants. One possibility is that the social nature of the stimuli used in this task (faces) was particularly evocative for participants with GSAD due to the social focus of their anxiety compared to the less social, more general nervousness and worry in GAD. Further, this finding does not appear to be explained by greater negative affect or depression symptoms, which were higher in the GAD sample.

Consistent with prior work (Anderson et al., 2011a), we found that participants' current affective state influenced their conscious perception. In the present study, we found that higher levels of self-reported currently experienced positive affect correlated with longer viewing time of faces, increased likelihood of faces being the first percept, and lower reports of blended percepts across all participants. One possible explanation is that positive affect increases the saliency of social information, consistent with the notion that a positive affective state enables a person to focus on social cues and interactions.

To our knowledge, only one prior study has employed binocular rivalry in GSAD (Singer et al., 2012). Like these authors, we found no difference between how long GSAD and control participants saw negative faces. However, contrary to Singer et al., we found no evidence that neutral faces were perceived for longer durations in GSAD participants. Instead we observed reduced conscious awareness of positive social information in GSAD. Furthermore, our study improved on the binocular rivalry methodology by allowing participants to report blended percepts, which could influence what percept was reported as seen.

Because of our methods, we have grounds to infer that visual processing is different in participants with GSAD, and that the disorder involves more than changes in explicit judgments. In the present study, participants were not asked to judge the faces, or cued to distinguish them in any way. They were simply instructed to report whether they saw a house or another object. Therefore it is unlikely that the observed differences in visual experience are due to biased judgments. Of course, there could still be additional judgment differences for participants with GSAD (as in Heuer et al., 2010), but an intriguing possible mechanism for those differences is disordered visual perception.

Investigation into irregularities in the visual experience of socially anxious individuals might provide insight into factors affecting the maintenance of GSAD. For instance, biases in which information is represented in visual consciousness might enhance or sustain affective disturbances in a feed forward fashion. For example, in individuals with GSAD, reduced visual salience of approving smiles in social situations might contribute to an inaccurate belief that they are being negatively evaluated, resulting in heightened anxiety and avoidance that further worsen both performance and symptoms.

More broadly, these findings are consistent with the growing appreciation that the momentary affective state of a person influences not only the interpretation of the world, but also aspects of immediate perception, including visual consciousness (for review, see Barrett & Bar, 2009). In other words, early perception of affective faces depends on the perceiver's affective state and not just on the value of the object being perceived. For instance, affectively potent faces (smiles and scowls) are not perceptually salient and do not dominate when non-psychiatrically ill perceivers are in a neutral state, but when perceivers are in a pleasant affective state, smiling faces dominate in visual consciousness (Anderson et al., 2011a). Such findings suggest that the environment may literally look different to different people depending on their affective state, including their long-term levels of anxiety. Specifically, future studies could utilize neuroimaging to explore which neurobiological pathways may be relevant to our finding of reduced salience of positive emotional expression in GSAD, or may test how psychological or pharmacologic interventions may alter early perception.

A potential limitation of our study was the presence of some secondary GAD in the GSAD group and vice versa; while this cross-comorbidity would be more likely to diminish rather than enhance differences between groups, we did not have sufficient power to examine this question empirically in subgroup analyses. Although exclusion of common comorbidity amongst these conditions could limit generalizability of findings future research with larger samples should examine the impact of comorbidity on our findings. Our finding that GSAD may involve a reduced visual salience for positive social cues suggests that an improved understanding of the nature of the relationship between affect and perception may provide new opportunities to influence these relationships with targeted intervention in anxiety disorders.

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References

Anderson, E., Siegel, E. H., & Barrett, L. F. (2011). What you feel influences what you see: the role of affective feelings in resolving binocular rivalry. *Journal of Experimental Social Psychology*, *47*(4), 856–860. http://dx.doi.org/10.1016/j.jesp.2011.02.009

Anderson, E., Siegel, E. H., Bliss-Moreau, E., & Barrett, L. F. (2011). The visual impact of gossip. *Science*, *332*(6036), 1446–1448, 10.1126/science.1201574 science.1201574 (pii).

Barrett, L. F., & Bar, M. (2009). See it with feeling: affective predictions during object perception. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1521), 1325–1334, 10.1098/rstb.2008.0312 364/1521/1325 (pii).

Blake, R. (2001). A primer on binocular rivalry, including current controversies. *Brain and Mind*, *2*, 5–38.

Chen, N. T., Clarke, P. J., MacLeod, C., & Guastella, A. J. (2012). Biased attentional processing of positive stimuli in social anxiety disorder: an eye movement study. *Cognitive Behaviour Therapy*, *41*(2), 96–107. http://dx.doi.org/10.1080/16506073.2012.666562

Chong, S. C., Tadin, D., & Blake, R. (2005). Endogenous attention prolongs dominance durations in binocular rivalry. *Journal of Vision*, *5*(11), 1004–1012, 10.1167/5.11.6 5/11/6 (pii).

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, *24*(4), 385–396.

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. W. (1994). *Structured clinical interview for Axis I DSM-IV disorders*. New York: Biometrics Research.

Gentili, C., Gobbini, M. I., Ricciardi, E., Vanello, N., Pietrini, P., Haxby, J. V., et al. (2008). Differential modulation of neural activity throughout the distributed neural system for face perception in patients with social phobia and healthy subjects. *Brain Research Bulletin*, *77*(5), 286–292, 10.1016/j.brainresbull.2008.08.003 S0361-9230(08)00272-4 (pii).

Gray, K. L., Adams, W. J., & Garner, M. (2009). The influence of anxiety on the initial selection of emotional faces presented in binocular rivalry. *Cognition*, *113*(1), 105–110. http://dx.doi.org/10.1016/j.cognition.2009.06.009 S0010-0277(09)00140-1 (pii)

Heimberg, R. G., Horner, K. J., Juster, H. R., Safren, S. A., Brown, E. J., Schneier, F. R., et al. (1999). Psychometric properties of the Liebowitz Social Anxiety Scale. *Psychological Medicine*, *29*(1), 199–212.

Heuer, K., Lange, W. G., Isaac, L., Rinck, M., & Becker, E. S. (2010). Morphed emotional faces: emotion detection and misinterpretation in social anxiety. *Journal of Behavior Therapy and Experimental Psychiatry*, *41*(4), 418–425. http://dx.doi.org/10.1016/j.jbtep.2010.04.005 S0005-7916(10)00055-8 (pii)

Kessler, R. C. (2003). The impairments caused by social phobia in the general population: implications for intervention. *Acta psychiatrica Scandinavica Supplementum*, *417*, 19–27, doi: 137 (pii).

Lochner, C., Mogotsi, M., du Toit, P. L., Kaminer, D., Niehaus, D. J., & Stein, D. J. (2003). Quality of life in anxiety disorders: a comparison of obsessive-compulsive disorder, social anxiety disorder, and panic disorder. *Psychopathology*, *36*(5), 255–262, doi: 73451 [73451] (pii).

Meng, M., & Tong, F. (2004). Can attention selectively bias bistable perception? Differences between binocular rivalry and ambiguous figures. *Journal of Vision*, *4*(7), 539–551. http://dx.doi.org/10:1167/4.7.24/7/2 (pii)

Montgomery, S. A., & Asberg, M. (1979). A new depression scale designed to be sensitive to change. *The British Journal of Psychiatry*, *134*, 382–389.

Moser, J. S., Huppert, J. D., Duval, E., & Simons, R. F. (2008). Face processing biases in social anxiety: an electrophysiological study. *Biological Psychology*, *78*(1), 93–103. http://dx.doi.org/10.1016/j.biopsycho.2008.01.005 S0301-0511(08)00025-2 (pii)

Nagamine, M., Yoshino, A., Yamazaki, M., Obara, M., Sato, S., Takahashi, Y., et al. (2007). Accelerated binocular rivalry with anxious personality. *Physiology & Behavior*, *91*(1), 161–165, doi: S0031-9384(07)00068-6 [pii] 10.1016/j.physbeh.2007.02.016.

Pearson, J., Clifford, C. W., & Tong, F. (2008). The functional impact of mental imagery on conscious perception. *Current Biology*, *18*(13), 982–986. http://dx.doi.org/10.1016/j.cub.2008.05.048 S0960-9822(08)00723-9 (pii)

Pineles, S. L., & Mineka, S. (2005). Attentional biases to internal and external sources of potential threat in social anxiety. *Journal of Abnormal Psychology*, *114*(2), 314–318, doi: 2005-04292-013 [pii] 10.1037/0021-843X.114.2.314.

Riskind, J. H., Kelly, K., Moore, R., Harman, W., & Gaines, H. (1992). The looming of danger: does it discriminate focal phobia and general anxiety from depression? *Cognitive Therapy and Research*, *20*, 1–20.

Rosenberg, A., Roth Ledley, D., & Heimberg, R. G. (2010). Social anxiety disorders. In: D. McKay, J. S. Abramowitz, & S. Taylor (Eds.), *Cognitive-behavioral therapy for refractory cases turning failure into success*. Washington, DC: American Psychological Association.

Ruscio, A. M., Brown, T. A., Chiu, W. T., Sareen, J., Stein, M. B., & Kessler, R. C. (2008). Social fears and social phobia in the USA: results from the national comorbidity survey replication. *Psychological Medicine*, *38*(1), 15–28. S0033291707001699 [pii] 10.1017/S0033291707001699.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh: Psychology Software Tools, Inc.

Silvia, P., & Allan, W. (2006). Biased recognition of happy facial expressions in social anxiety. *Journal of Social and Clinical Psychology*, *25*(6), 585–602.

Singer, N., Eapen, M., Grillon, C., Ungerleider, L. G., & Hendler, T. (2012). Through the eyes of anxiety: dissecting threat bias via emotional-binocular rivalry. *Emotion*, *12*(5), 960–969. http://dx.doi.org/10.1037/a0027070 2012-05382-001 (pii)

Spielberger, C. D. (1973). *STAIC preliminary manual*. Palo Alto, CA: Consulting Psychologists Press.

Spielberger, C. D. (1989). *State-trait anxiety inventory: bibliography* (2nd ed.). Palo Alto, CA: Consulting Psychologists Press.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the state-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press.

Staugaard, S. R. (2010). Threatening faces and social anxiety: a literature review. *Clinical Psychology Review*, *30*(6), 669–690. http://dx.doi.org/10.1016/j.cpr.2010.05.001 S0272-7358(10)00075-9 [pii]

Stein, M. B., & Stein, D. J. (2008). Social anxiety disorder. *Lancet*, *371*(9618), 1115–1125. http://dx.doi.org/10.1016/S0140-6736(08)60488-2 S0140-6736(08)60488-2 [pii]

Sterzer, P., Hilgenfeldt, T., Freudenberg, P., Bermpohl, F., & Adli, M. (2011). Access of emotional information to visual awareness in patients with major depressive disorder. *Psychological Medicine*, *41*(8), 1615–1624, 10.1017/S0033291710002540 [0033291710002540S] (pii).

Taylor, C. T., Bomyea, J., & Amir, N. (2010). Attentional bias away from positive social information mediates the link between social anxiety and anxiety vulnerability to a social stressor. *Journal of Anxiety Disorders*, *24*(4), 403–408, 10.1016/j.janxdis.2010.02.004 S0887-6185(10)00031-9 (pii).

Teachman, B. A., Stefanucci, J. K., Clerkin, E. M., Cody, M. W., & Proffitt, D. R. (2008). A new mode of fear expression: perceptual bias in height fear. *Emotion*, *8*(2), 296–301, 10.1037/1528-3542.8.2.296 2008-03871-015 (pii).

Tong, F., Meng, M., & Blake, R. (2006). Neural bases of binocular rivalry. *Trends in Cognitive Sciences*, *10*(11), 502–511, doi: S1364-6613(06)00240-3 [pii] 10.1016/j.tics.2006.09.003.

Tong, F., Nakayama, K., Vaughan, J. T., & Kanwisher, N. (1998). Binocular rivalry and visual awareness in human extrastriate cortex. *Neuron*, *21*(4), 753–759, doi: S0896-6273(00)80592-9 [pii].

Ukai, K., Ando, H., & Kuze, J. (2003). Binocular rivalry alternation rate declines with age. *Perceptual and Motor Skills*, *97*(2), 393–397.

Ventura, J., Liberman, R. P., Green, M. F., Shaner, A., & Mintz, J. (1998). Training and quality assurance with the structured clinical interview for DSM-IV (SCID-I/P). *Psychiatry Research*, *79*(2), 163–173, doi: S0165-1781(98)00038-9 (pii).

Watson, D., & Clark, L. A. (1994). *The PANAS-X: manual for the positive and negative affect schedule – expanded form*. Ames, IA: The University of Iowa.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070.

Wieser, M. J., McTeague, L. M., & Keil, A. (2012). Competition effects of threatening faces in social anxiety. *Emotion*, *12*(5), 1050–1060, doi: 10.1037/a0027069 2012-05383-001 (pii).

Zhou, W., Jiang, Y., He, S., & Chen, D. (2010). Olfaction modulates visual perception in binocular rivalry. *Current Biology*, *20*(15), 1356–1358, doi: 10.1016/j.cub.2010.05.059 S0960-9822(10)00708-6 (pii).