Published in final edited form as:
Cogn Emot. 2017 June ; 31(4): 772–780. doi:10.1080/02699931.2016.1152231.

ALL IN THE FIRST GLANCE: FIRST FIXATION PREDICTS INDIVIDUAL DIFFERENCES IN VALENCE BIAS

Maital Neta[1], **Tien T. Tong**[1], **Monica L. Rosen**[1], **Alex Enersen**[1], **M. Justin Kim**[2], and **Michael D. Dodd**[1]

[1]Department of Psychology, University of Nebraska-Lincoln, Lincoln, NE, 68588

[2]Department of Psychological & Brain Sciences, Dartmouth College, Hanover, NH 03755

Abstract

Surprised expressions are interpreted as negative by some people, and as positive by others. When compared to fearful expressions, which are consistently rated as negative, surprise and fear share similar morphological structure (e.g., widened eyes), but these similarities are primarily in the upper part of the face (eyes). We hypothesized, then, that individuals would be more likely to interpret surprise positively when fixating faster to the lower part of the face (mouth). Participants rated surprised and fearful faces as either positive or negative while eye movements were recorded. Positive ratings of surprise were associated with longer fixation on the mouth than negative ratings. There were also individual differences in fixation patterns, with individuals who fixated the mouth earlier exhibiting increased positive ratings. These findings suggest that there are meaningful individual differences in how people process faces.

Keywords

emotional ambiguity; individual differences; eye tracking; surprise; fear

Images of facial expressions have proven a useful tool for examining individual differences in emotion processing (Ekman et al., 1987; Hamann & Canli, 2004). For instance, some expressions (happy or fearful) provide clear information about the emotions and intentions of others, but other expressions (surprise) are ambiguous because they can signal both positive (surprise party) and negative events (witnessing an accident). When experienced in the absence of clarifying contextual information, surprised expressions are stably interpreted as positive by some people and as negative by others (Neta et al., 2009; 2011; 2013; Kim et al., 2003). This study examines these individual differences in *valence bias*, or the extent to which an individual ascribes surprise with positive or negative meaning. We have shown that this bias is stable across time (Neta et al., 2009), and generalizes across types of emotional images (faces, scenes; Neta et al., 2013), though we have yet to elucidate the source of these individual differences in bias.

Correspondence should be addressed to: Maital Neta, B84 East Stadium, Center for Brain, Biology, and Behavior, Lincoln, NE 68588, Phone: (402) 472-3646, mneta2@unl.edu.

DISCLOSURE STATEMENT
No potential conflict of interest was reported by the authors.

Interestingly, surprised and fearful expressions share some morphological features (e.g., widened eyes), and have several overlapping facial action units (AU 1,2,5; Du et al., 2014). Despite these similarities, fearful expressions are consistently rated as negative whereas surprised expressions are not. Indeed, we have shown not only that fearful expressions are rated as more negative than surprise (Neta & Whalen, 2010), but making a valence decision about surprise takes longer than making a valence decision about fear or other clearly valenced stimuli such as anger and happiness (Neta et al., 2009). As such, it appears that surprise and fear represent inherently different signals.

Interestingly, the similarities in facial action units for surprised and fearful faces are primarily in the top half of the face (around the eyes), whereas the bottom half of those facial expressions are somewhat dissimilar (around the mouth; Du et al., 2014; see Figure 1a). Eye tracking has been used to both demonstrate how attention to certain facial features (e.g., mouth) via fixations facilitates recognition of emotional expressions (Calvo et al., 2006; Calvo & Nummenmaa, 2008; 2009) and explain individual differences in the neural circuitry of face processing (Dalton et al., 2005). The present study set out to explore the relationship between eye movements and valence judgments about surprised and fearful facial expressions in order to determine whether participants were looking more at the top or bottom half of the face, and whether this eye movement pattern correlated with their evaluations of each expression. Here, if one expression (fear) is consistently rated as negative, and the other (surprise) is not, we predict that the information in the dissimilar parts of the face (bottom half) may be responsible for these differences in valence ratings. Specifically, we predicted that trials in which surprised faces were rated as positive (dissimilar from fear) would be associated with more attention allocated to the mouth relative to trials in which surprised faces were rated as negative (similar to fear). Moreover, we predicted that an observed difference in eye movement patterns between participants might help to explain individual differences in valence bias, such that participants who attend more to the mouth exhibit a more positive bias. Though we focus here primarily on fixation patterns as they relate to surprised faces, we predict no such effects for fear since fearful faces are consistently rated as negative.

Finally, one common issue with examining fixation during face processing is that individuals tend to fixate the eyes more frequently than other facial features, particularly when processing emotional expressions given that the eyes may convey critical information regarding the emotion being elicited in the image (Baron-Cohen, Jolliffe, Mortimore, & Robertson, M., 1997; Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001; Sullivan, Ruffman, & Hutton, 2007). Even in early infancy, faces are more likely to be fixated within a broader scene and, more specifically, the eyes are more frequently fixated than other facial features (Fletcher-Watson, Findlay, Leekam, & Benson, 2008; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009; Gilga, Elsabbagh, Andravizou, & Johnson, 2009; Hainline, 1978). Given that the present study is focused on relating fixation to individual differences in valence ratings, one concern is that there will not be sufficient variability in fixation patterns if participants are primarily fixating the eyes. In order to address this concern, we examined eye movements when viewing faces that were filtered to convey low- and high-spatial-frequencies. Indeed, previous work has suggested that filtering visual images into different spatial-frequency bands emphasizes differential priorities in information processing (Carretie, Hinojosa, Lopez-Martin, & Tapia, 2007; Vuilleumier, Armony, Driver, & Dolan, 2003; Winston, Vuilleumier, & Dolan, 2003). Low-spatial-frequency (LSF) information is processed first and fast (Bar et al., 2006; Hughes, Nozawa, & Kitterle, 1996), preceding processing of high-spatial-frequency (HSF) information. We previously capitalized on this differentiation to demonstrate that the early, more automatic interpretation of surprised expressions is negative in all people (LSFs were rated as more negative than HSFs of surprise; Neta & Whalen, 2010). Building on this finding, we propose that filtered images would provide us with greater variance in order to examine individual differences in eye movements when processing faces, and to determine if there was a relationship between fixation patterns and differences in valence bias. Specifically, faster processing of LSFs may reduce the general tendency to fixate the eyes, which would in turn allow us to measure individual differences in fixation to the eyes versus the mouth under these conditions. With this in mind, we predicted for the current study that individual differences in ratings of LSFs might be particularly sensitive to the a priori effects, such that eye movements to the bottom half of the face would be associated with a more positive valence bias. We predict that this effect will be unique to the LSFs, which emphasize faster processing, and that this effect will not be observed with the HSFs.

MATERIALS AND METHODS

Participants

Fifty-seven healthy adults volunteered to participate. Six participants were excluded due to low accuracy (i.e., they rated intact fearful faces as positive on more than 30% of trials). The final sample included 51 participants (37 females, Mean Age = 19.35, *SD* = 1.61). All participants had normal or corrected-to-normal vision. None of the participants were aware of the purpose of the experiment, and they were all compensated for their participation through course credit. Written informed consent was obtained from each participant before the session, and all procedures were exempted by University of Nebraska - Lincoln Committee for the Protection of Human Subjects.

Stimuli

The stimuli were drawn from previous work (Neta & Whalen, 2010). This included 66 identities (33 males) of individuals exhibiting fearful or surprised expression from the NimStim set (Tottenham et al., 2009), the Pictures of Facial Affect (Ekman & Friesen, 1976), and the Averaged Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998). The facial expressions in this stimulus set were validated by a separate set of subjects who labeled each expression; only faces that were correctly labeled as surprise or fear respectively, by more than 60% of subjects were included. In the final set of stimuli, some of these 66 identities were included only in one expression condition (i.e., they were represented only in the surprised or fearful stimulus set), while others were represented in both sets, for a total of 88 discrete stimuli. All pictures were gray-scaled and were normalized in terms of resolution (75 dots per inch), contrast and luminance. Each intact image (broad spatial frequency; BSF) was filtered using the procedure described in Neta and Whalen (2010) in order to create two versions of each face: one comprising primarily the HSF information and one comprising primarily the LSF information (see Figure 1b).

Spatial-frequency content in the original image was filtered in order to create two versions of each face: one comprising primarily the HSF information (high-pass cutoff of 24 cycles per image) and one comprising primarily the LSF information (low-pass cutoff of 6 cycles per image), consistent with previous work (e.g., Vuilleumier et al., 2003). Moreover, prior to filtering, we adjusted the contrast and luminance of each image in order to equate these elements across stimulus conditions and stimulus sets.

Procedure

As in previous work (Neta & Whalen, 2010), faces of the three frequency types (i.e., BSF, HSF, and LSF) were presented in pseudorandom order. For each participant, each of the 88 discrete faces (a given identity posing a given expression) was presented twice, for a total of 176 trials. Face identities were counterbalanced, such that each subject viewed a given face as either filtered (the HSF and LSF versions in a counterbalanced order) or intact (two presentations of the BSF version). We avoided presenting the same identity in both BSF and filtered versions to a given subject so that the BSF versions would not affect ratings of the filtered images (see Vuilleumier et al., 2003). We made two counterbalanced and pseudorandom presentation orders, where each participant viewed one of these presentation orders, and an approximately equal number of participants viewed each order.

Eye movements and fixations were measured utilizing an SR Research Ltd. EyeLink II system (Mississauga, Ontario, Canada), with high spatial resolution and a sampling rate of 500 Hz. The dominant eye was monitored for all participants. Thresholds for detecting the onset of a saccadic movement were acceleration of 8000º/s2, velocity of 30º/s, and distance of 0.5º of visual angle. Movement offset was detected when velocity fell below 30º/s and remained at that level for 10 consecutive samples. Stimulus displays were presented on two monitors, one for the participant and the other for the experimenter (real-time feedback to the experimenter allowed for recalibration when necessary). The average error in the computation of gaze position was less than 0.5º. A nine-point calibration procedure was performed at the beginning of the experiment, followed by a nine-point calibration accuracy test. Calibration was repeated if any point was in error by more than 11 or if the average error for all points was greater than 0.5º.

Participants were seated approximately 40 cm from the computer screen and initiated each trial by pressing the spacebar while fixating a central point on a blank computer screen. The fixation point was then replaced by a fearful or surprised face on a black background for 2000 ms, with each image being 6º (width) x 10º (height). Eye movements were recorded as each image was viewed. The presentation of the face was followed by an instruction to rate – as quickly and accurately as possible – whether each face had a positive or negative valence (i.e., two-alternative forced choice). Upon button response from the participants, the trial terminated. The experiment lasted approximately 30 minutes.

Due to technical difficulties, we noticed that some images were not presented at the correct 75 dpi resolution for the first half of subjects (26 of the final sample of 51 participants). To clean these data, we ran an item analysis on ratings and dwell time, and we excluded any trials that were more than 2 SD away from the mean. In one version, this resulted in exclusion of 12 trials (1 Fear HSF, 1 Fear LSF, 2 Fear Intact, 2 Surprise HSF, 2 Surprise

LSF, 4 Surprise Intact), for a total of 164 trials in the final analysis. In the second version, this resulted in exclusion of 10 trials (2 Fear HSF, 2 Fear LSF, 3 Surprise HSF, 3 Surprise LSF), for a total of 166 trials in the final analysis. For the final 25 participants, the technical issue was resolved and all 176 trials were included in the final analysis.

Analyses

For behavioral ratings, our dependent measure was percent negative ratings—the percentage of trials that participants rated an item as negative for each face condition (i.e., surprised and fearful expressions displayed as intact, LSF, or HSF) —out of the total items for that condition.

Given our specific interest in gaze behavior towards the mouth and the eyes, these regions were identified as interest areas (Figure 1b). For each interest area, we examined two commonly studied dependent measures that emphasize early eye movements: first run dwell time (FRDT – the amount of time spent in an interest area the first time it was fixated) and first fixation time (FFT – relative to the onset of the image, how quickly an interest area was fixated). We compared eye movements when processing intact images to one another, across expressions of surprise and fear. Subsequently, we compared filtered images to one another, comparing eye movements when processing filtered images (HSF and LSF) across expressions, separately. The LSF and HSF images could not be compared to intact images in a meaningful way given that intact images had not been degraded and that both the LSF and HSF images had been degraded to some extent (see also Neta & Whalen, 2010).

RESULTS

Comparing Surprised to Fearful Expressions Using Intact Images

Behavioral—As expected, fearful expressions were rated as more negative than surprise ($t(50) = 16.25$, $p < .001$, Cohen's $d = 2.28$; mean ± SE: fear = 95.0% ± 0.8, surprise = 48.0% ± 3.2). As in previous work, we used a median split to divide subjects on the basis of the percentage of surprised intact images that they rated as negative (Neta et al., 2009; Neta & Whalen, 2010). This approach allowed us to examine the response to fearful faces as it relates to one's tendency to interpret surprise as positive or negative. We identified the 25 subjects showing a tendency to interpret surprise as having a negative valence, (20 females; mean ± SE = 66.9 ± 2.79 % negative ratings) and the other 25 subjects showing a tendency to interpret these expressions as having a positive valence (16 females; mean ± SE = 28.9 ± 2.50% negative ratings). Even in the group of participants that tended to interpret surprise negatively, fearful expressions were still rated as more negative than surprise ($p < .001$, Cohen's $d = 2.43$).

Eye tracking—First, for each participant, we separated surprise trials based on their valence ratings: trials in which surprise was rated as positive, and trials in which surprise was rated as negative. We then compared eye tracking measures on these trials. We found that FRDT on the mouth was significantly longer for positive trials than negative trials ($t(50) = 3.05$, $p < .005$, $d = 0.43$). There was no significant difference in FRDT on the eyes (t(50)

= .47, p > .6, *d* = 0.07).[1] Also, there was no significant difference between trials on which fear was rated positive and negative for both FRDT on the mouth and on the eyes (*p*'s > .5).

Next, in order to examine individual differences across participants, we tested the relationship between valence bias and eye tracking measures on surprise trials. PROCESS (Hayes, 2013) for SPSS was used, which is a tool for testing moderation hypotheses. The conditional effects of FFT of the eyes on valence bias, at varying levels of FFT on the mouth, were estimated. FFT Scores (eyes and mouth) were z-scored prior to running the moderation analysis in order to remove inherent variability between these conditions. There was a marginally significant interaction between FFT of the eyes and FFT of the mouth ($t(47) = 1.98$, $p = .05$, 95% CI [.00, .16]). To the extent that FFT of the mouth was faster, the association between FFT of the eyes and valence bias was stronger (more negative). The Johnson-Neyman technique was used to define regions of significance, which revealed an inverse association between FFT of the eyes and valence bias at or below scores of −1.43 of FFT of the mouth (i.e., at least 1.43 SDs below the mean of FFT of the mouth). The conditional effect of FFT of the eyes on valence bias was significant for approximately 11.76% of the sample. In other words, in individuals that showed fast FFT to the mouth, slower FFT to the eyes was associated with more positive valence bias. Interestingly, this effect was also significant when relating FFT on fearful faces to ratings of ($t(47) = 2.00$, $p = .05$, 95% CI [.00, .14]). In other words, in individuals that showed fast FFT to the mouth of fearful faces, slower FFT to the eyes of fearful faces was associated with more positive valence bias when rating surprise.

It could be that these effects are moderated in part by the eyes because eyes have a strong tendency to be fixated first when processing intact faces. To test this, we examined the effects of filtered images, specifically predicting that low-spatial-frequency images would emphasize faster processing of the faces, and potentially de-emphasize the role of the eyes. As such, in the subsequent analyses, we examined LSF and HSF images of surprised and fearful faces. We do not include the BSF images in this approach, as intact images are inherently different, providing much more visual information, than the filtered images.

Comparing LSFs to HSFs of Surprise

Behavioral—We replicated previous work (Neta & Whalen, 2010) demonstrating that LSFs of surprise were rated as more negative than HSFs of surprise ($t(50) = 2.26$, $p < .03$, $d = 0.32$; mean ± SE: LSF = 62.7% ± 3.3, HSF = 58.8% ± 3.2). This effect was not significant for fearful faces ($t(50) = 0.63$, $p > .5$, $d = 0.09$, mean ± *SE*: LSF = 92.2% ± 1.4, HSF = 93.1% ± 1.3). Finally, even for the more negative LSF versions of surprise, ratings of fear were more negative than surprise ($t(50) = 10.66$, $p < .001$, $d = 1.49$).

Eye tracking—First, we focus on FFT of LSFs and HSFs of surprised faces, as this measure previously showed a relationship with valence bias in intact images. Specifically, we ran Pearson pairwise correlations between valence ratings and FFT to the eyes and

[1]The results were the same for dwell time: significantly longer DT on the mouth for positive trials than negative trials ($t(50) = 2.28$, $p < .03$, $d = 0.32$), and no significant differences for the eyes ($t(50) = 1.56$, $p > .1$, $d = 0.22$). Also, there was no significant difference between trials in which fear was rated positive and negative for both DT on the mouth and on the eyes (*p*'s > .1).

mouth for LSF and HSF images of surprised facial expressions. We found that, for LSFs that emphasized faster processing, there was a significant correlation between valence ratings and FFT on the mouth ($r(50) = .30$, $p < .04$), such that the individuals that attended faster to the mouth showed a more positive bias (Figure 2). This effect was not significant for FFT of the eyes ($r(50) = .001$, $p > .9$), and it was also not significant for HSF images (mouth: $r(50) = .19$, $p > .15$; eyes: $r(50) = .003$, $p > .9$).[2]

DISCUSSION

Surprised and fearful expressions share some similar morphological features (widened eyes), but fear is consistently rated as negative, whereas surprised expressions are rated as positive by some people, and as negative by others. Importantly, the shared features are more heavily represented in the top half of the face (eyes) as compared to the bottom half (mouth; Du et al., 2014). The present study used eye-tracking technology, which provides information about how and when facial information is perceived, to offer an explanation for valence ratings of surprise. As predicted, we found that length of time spent attending to the mouth of surprised faces influences trial-by-trial ratings such that people looked longer at the mouth on trials when surprise was rated positively.

We also predicted that eye movements to the mouth would offer some explanation for the individual differences in valence bias, or the tendency for each participant to rate surprised expressions as either positive or negative. However, one common issue with examining eye movements during face processing is that the people tend to fixate the eyes more frequently than other facial features, and that this robust effect may diminish our variability in fixation patterns that would allow us to explore individual differences in these processes. In order to better target individual differences in fixation during face processing, we examined: a) a moderation analysis taking into account First Fixation Time (FFT) to both the eyes and mouth in order to explain individual differences in valence bias, and b) differences in eye movement patterns when viewing faces that were filtered to convey low- and high-spatial-frequencies, as previous work has suggested that filtering visual images into different spatial-frequency bands emphasizes differential priorities in information processing (Carretie et al., 2007; Vuilleumier et al., 2003; Winston et al., 2003), and could enable us to examine these individual differences despite the greater attention focused on the eyes.

We found a relationship between first fixation to the eyes and valence bias that was moderated by first fixation to the mouth. In other words, people who were slower to fixate the eyes showed a more positive bias across trials (i.e., a behavioral tendency to rate surprise as positive), but this effect was moderated such that it was only observed in individuals who looked to the mouth early on in the trial. This is consistent with other work showing that

[2]There was a trend difference between correlations for LSFs (eyes vs. mouth, $p = .07$), where the correlation for the mouth was significant but the correlation for the eyes was not. As expected, there was no difference between the HSF correlations (eyes and mouth, $p = .18$), or between the correlations for the eyes (LSF and HSF; $p = .49$). However, there was also no significant difference between the correlations for the mouth (LSF and HSF, $p = .29$). In other words, it appears that the correlation between the FFT on the mouth and ratings of surprise LSF images was distinct from the non-significant correlations for the eyes, but not distinct from the correlation between the mouth and ratings of surprise HSF images. For the fear faces, there was a trend correlation between FFT to the eyes and ratings of HSF images ($r(50) = -.27$, $p=.07$), such that faster FFT to the eyes were associated with more negative ratings of fear. All other correlations for the fear faces were not significant (p's > .2).

time spent looking at the mouth is associated with individual differences in behavior, including a reduced cross race effect (i.e., participants that looked longer at the mouth of Black faces were better able to recognize those face identities than participants that looked less at the mouth; McDonnell et al., 2014). It could be that fixating the mouth is important in a way that either reduces holistic processing or gives more discernible information that is not conveyed by the eyes. Importantly, we found that this relationship between first fixation and ratings extended to fixation on other expressions (fear). In other words, individuals that look quickly to the mouth when viewing these expressions show an increasingly positive valence bias as their fixation to the eyes is slower. This suggests that the scanning pattern – or the interaction of first fixations to the eyes and mouth – when processing these expressions may represent an individual difference that relates to the ultimate decisions made about those faces.

Given that the effect was only moderated by fixation to the mouth, we hypothesized that perhaps the eyes were interfering with the relationship between fixations and valence bias. Indeed, previous work has shown that, when processing intact faces, the eyes are more frequently fixated than other facial features (Fletcher-Watson et al., 2008; Fletcher-Watson et al., 2009; Gilga et al., 2009; Hainline, 1978). To explore potential individual differences in eye movements during face processing, we examined the relationship between fixations on images that were filtered to low- (LSF) and high-spatial-frequency information (HSF). We have previously leveraged this spatial-frequency manipulation to demonstrate that people are more likely to interpret a coarse, elemental presentation (LSF) of an ambiguous surprised facial expression as negatively valenced, than a fine presentation (HSF) of the same expression. This suggests that a negative interpretation is early and automatic (Neta & Whalen, 2010). Here, we predicted that motivating a faster processing of faces might provide greater variance in eye movements during face processing and emphasize the important relationship between eye movements to the mouth and individual differences in valence bias. Indeed, we found that, when viewing LSFs of surprised faces, people that showed a more positive bias looked faster to the mouth than people that showed a more negative bias. Importantly, we did not observe a similar effect for HSFs of surprised faces, and there were no significant effects between the eye movements to the eyes (for both LSFs and HSFs) and valence bias.

One potential explanation of the present data is that individuals with a negative bias (who consistently rate surprise as negative) might be confusing surprised and fearful expressions. It may even be the case that these individuals are looking almost exclusively at the eyes, not attending to the mouth region, which would be consistent with work that has suggested that viewing just the top half of the face is associated with chance discrimination between the two expressions (unpublished). However, when viewing complete and intact faces, we found that ratings of surprise were more positive than ratings of fear on average, even for subjects demonstrating a negative valence bias, and even when viewing more negative LSF representations of surprise (see also Neta & Whalen, 2010). Moreover, participants are slower to make a valence decision about surprise compared to clearly valenced expressions (i.e., angry and happy), suggesting that, even for individuals with a negative bias that consistently rate surprise as negative, they take longer to make that judgment about surprise than clearly valenced expressions (Neta et al., 2009). These findings are consistent with a dual-valence representation associated with surprised expressions, which makes them fundamentally distinct from fear (but see Katsikitis, 1997). Thus, it could be that individuals with a negative bias are not exactly confusing surprised and fearful expressions, but that they are interpreting surprise as negative, like fear, because of the similarity in the emotional signals around the eyes. In future studies, we will investigate the relationship between eye movements and facial expression discrimination, in order to adjudicate between these alternative explanations.

The present findings are correlative in nature, so it remains unclear whether looking faster to the mouth actually causes a more positive rating, per se. In future studies, we will use an experimental manipulation whereby participants will be instructed to focus on specific facial features in separate blocks of trials, allowing us to determine if, across subjects, faster fixation to the mouth results in a more positive rating of surprise.

Finally, this work demonstrates the important role of eye tracking methodologies in understanding decision-making about faces. Rather than presenting incomplete images of facial expressions, we were able to leverage these methodologies to show that eye movements across complete and intact images of faces explained not only trial-wise decisions about those faces, but also offered some explanation for individual differences in valence bias for surprise.

Acknowledgments

We thank Rebecca L. Brock for help with statistical analyses. M. Justin Kim was supported by the National Institute of Mental Health (F31 MH090672).

References

Bar M, Neta M, Linz H. Very first impressions. Emotion. 2006; 6(2):269. [PubMed: 16768559]

Baron-Cohen S, Jolliffe T, Mortimore C, Robertson M. Another advanced test of theory of mind: evidence from very high functioning adults with autism or Asperger Syndrome. Journal of Child Psychology and Psychiatry. 1997; 38:813–822. [PubMed: 9363580]

Baron-Cohen S, Wheelwright S, Spong A, Scahill V, Lawson J. Are intuitive physics and intuitive psychology independent? A test with children with Asperger Syndrome. Journal of Developmental and Learning Disorders. 2001; 5:47–48.

Calvo MG, Avero P, Lundqvist D. Facilitated detection of angry faces: Initial orienting and processing efficiency. Cognition & Emotion. 2006; 20(6):785–811.

Calvo MG, Nummenmaa L. Detection of emotional faces: Salient physical features guide effective visual search. Journal of Experimental Psychology: General. 2008 Aug; 137(3):471–494. [PubMed: 18729711]

Calvo MG, Nummenmaa L. Eye-movement assessment of the time course in facial expression recognition: Neurophysiological implications. Cognitive, Affective, & Behavioral Neuroscience. 2009; 9(4):398–411.

Carretié L, Hinojosa JA, López-Martín S, Tapia M. An electrophysiological study on the interaction between emotional content and spatial frequency of visual stimuli. Neuropsychologia. 2007; 45(6): 1187–1195. [PubMed: 17118408]

Dalton KM, Nacewicz BM, Johnstone T, Schaefer HS, Gernsbacher MA, Goldsmith HH, Alexander AL, Davidson RJ. Gaze fixation and the neural circuitry of face processing in autism. Nature Neuroscience. 2005; 8:519–526. [PubMed: 15750588]

Du S, Tao Y, Martinez AM. Compound facial expressions of emotion. Proceedings of the National Academy of Sciences, USA. 2014; 111(15):E1454–E1462.

Ekman P, Friesen WV. Measuring facial movement. Environmental psychology and nonverbal behavior. 1976; 1(1):56–75.

Ekman P, Friesen WV, O'Sullivan M, Chan A, Diacoyanni-Tarlatzis I, Heider K, … Tzavaras A. Universals and cultural differences in the judgments of facial expressions of emotion. Journal of personality and social psychology. 1987; 53(4):712. [PubMed: 3681648]

Fletcher-Watson S, Findlay JM, Leekam SR, Benson V. Rapid detection of person information in a naturalistic scene. Perception. 2008; 37:571–583. [PubMed: 18546664]

Fletcher-Watson S, Leekam SR, Benson V, Frank MC, Findlay JM. Eye movements reveal attention to social information in autism spectrum disorder. Neuropsychologia. 2009; 47:248–257. [PubMed: 18706434]

Gliga T, Elsabbagh M, Andravizou A, Johnson MH. Faces attract infants' attention in complex displays. Infancy. 2009; 14:550–562.

Hainline L. Developmental changes in visual scanning of face and nonface patterns by infants. Journal of Experimental Child Psychology. 1978; 25:90–115. [PubMed: 641446]

Hamann S, Canli T. Individual differences in emotion processing. Current opinion in neurobiology. 2004; 14(2):233–238. [PubMed: 15082330]

Hayes, A. Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. New York, NY: Guilford Press; 2013.

Hughes HC, Nozawa G, Kitterle F. Global precedence, spatial frequency channels, and the statistics of natural images. Journal of cognitive neuroscience. 1996; 8(3):197–230. [PubMed: 23968149]

Katsikitis M. The classification of facial expressions of emotion: a multidimensional-scaling approach. Perception. 1997; 26(5):613–26. [PubMed: 9488885]

Kim H, Somerville LH, Johnstone T, Alexander AL, Whalen PJ. Inverse amygdala and medial prefrontal cortex responses to surprised faces. Neuroreport. 2003; 14(18):2317–2322. [PubMed: 14663183]

Lundqvist, D., Flykt, A., Öhman, A. The Karolinska Directed Emotional Faces-KDEF. Department of Clinical Neuroscience, Psychology section, Karolinska Institutet; Stockholm, Sweden: 1998. CD-ROM

McDonnell GP, Bornstein BH, Laub CE, Mills M, Dodd MD. Perceptual processes in the cross-race effect: Evidence from eyetracking. Basic and Applied Social Psychology. 2014; 36(6):478–493.

Neta M, Davis FC, Whalen PJ. Valence resolution of facial expressions using an emotional oddball task. Emotion. 2011; 11(6):1425–1433. [PubMed: 21707167]

Neta M, Kelley WM, Whalen PJ. Neural responses to ambiguity involve domain-general and specific emotion processing systems. Journal of Cognitive Neuroscience. 2013; 25(4):547–557. [PubMed: 23363410]

Neta M, Norris CJ, Whalen PJ. Corrugator muscle responses to surprised facial expressions are associated with individual differences in positivity-negativity bias. Emotion. 2009; 9(5):640–648. [PubMed: 19803586]

Neta M, Whalen PJ. The primacy of negative interpretations when resolving the valence of ambiguous facial expressions. Psychological Science. 2010; 21(7):901–907. [PubMed: 20534779]

Sullivan S, Ruffman T, Hutton S. Age differences in emotion recognition skills and the visual scanning of emotion faces. Journal of Gerontology: Psychological Sciences. 2007; 62B:53–60.

Tottenham N, Tanaka JW, Leon AC, McCarry T, Nurse M, Hare TA, … Nelson C. The NimStim set of facial expressions: judgments from untrained research participants. Psychiatry research. 2009; 168(3):242–249. [PubMed: 19564050]

Vuilleumier P, Armony JL, Driver J, Dolan RJ. Distinct spatial frequency sensitivities for processing faces and emotional expressions. Nature neuroscience. 2003; 6(6):624–631. [PubMed: 12740580]

Winston JS, Vuilleumier P, Dolan RJ. Effects of low-spatial frequency components of fearful faces on fusiform cortex activity. Current Biology. 2003; 13(20):1824–1829. [PubMed: 14561410]

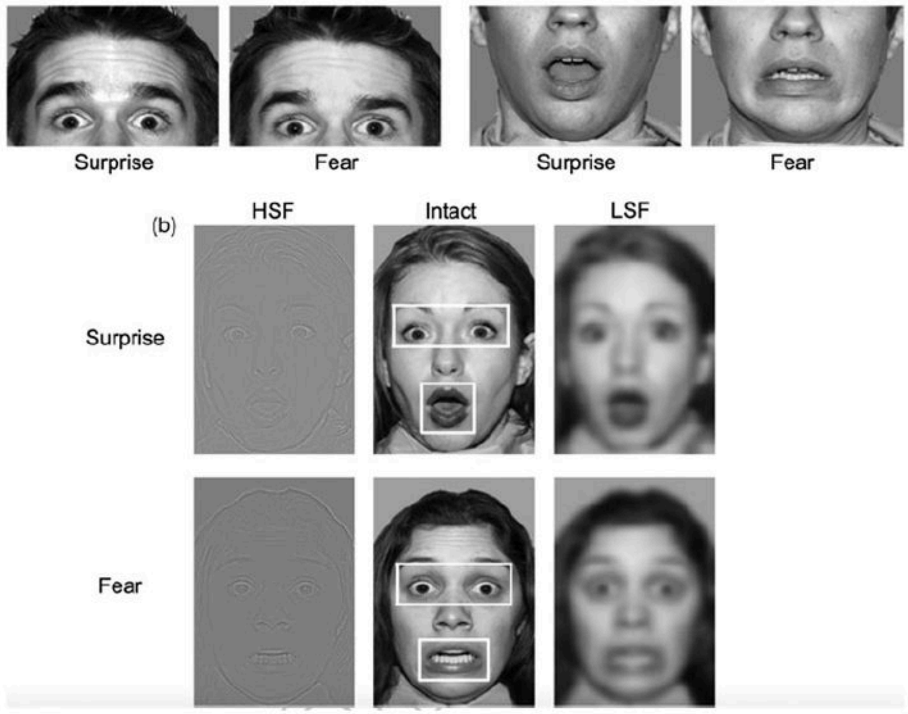

Figure 1.

(a) Surprise and fearful expressions share similar morphological features primarily in the top half of the face. **(b)** An example of the stimuli used across all levels of valence and image filters. Interest areas, indicated by the white box around the eyes and mouth, are exemplified here on the Intact stimuli.

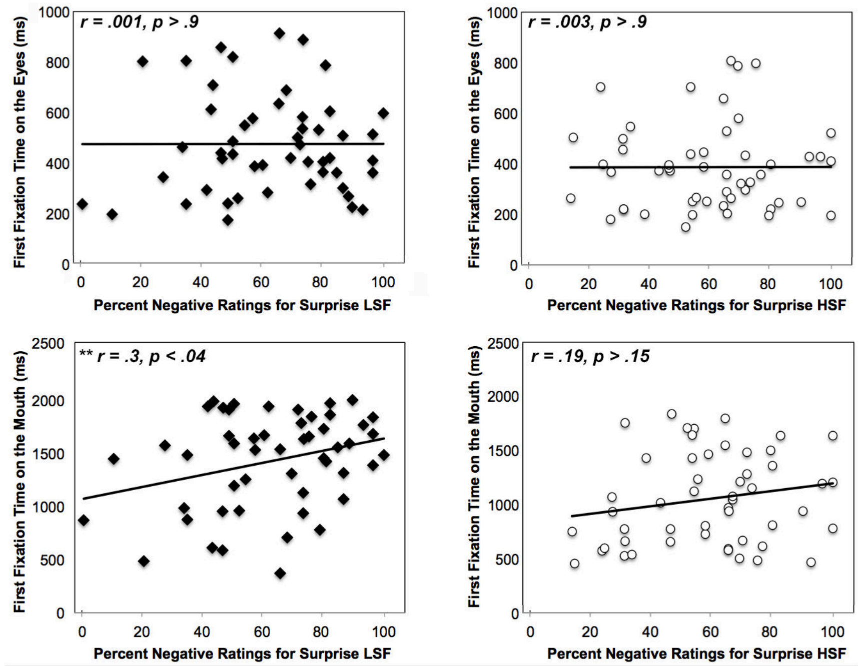

Figure 2.

Correlations between first fixation time to either the eyes (top graphs) or mouth (bottom graphs) and the percentage of negative ratings as a function of image filter, low spatial frequencies (leftward graphs) and high spatial frequencies (rightward graphs).