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Threatening scenes but not threatening faces shorten time-to-contact estimates

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Abstract We previously reported that time-to-contact (TTC) judgments of threatening scene pictures (e.g., frontal attacks) resulted in shortened estimations and were mediated by cognitive processes, and that judgments of threatening (e.g., angry) face pictures resulted in a smaller effect and did not seem cognitively mediated. In the present study, the effects of threatening scenes and faces were compared in two different tasks. An effect of threatening scene pictures occurred in a prediction-motion task, which putatively requires cognitive motion extrapolation, but not in a relative TTC judgment task, which was designed to be less reliant on cognitive processes. An effect of threatening face pictures did not occur in either task. We propose that an object's explicit potential of threat per se, and not only emotional valence, underlies the effect of threatening scenes on TTC judgments and that such an effect occurs only when the task allows sufficient cognitive processing. Results are consistent with distinctions between predator and social fear systems and different underlying physiological mechanisms. Not all threatening information elicits the same responses, and whether an effect occurs at all may depend on the task and the degree to which the task involves cognitive processes.

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Estimating the time-to-contact (TTC) of approaching objects is a crucial perceptual ability of any mobile animal. In principle, such estimation could rely on simple optical characteristics that are defined by looming visual stimuli and that can provide an exact measure of TTC without the need to estimate velocities and distances (Lee, 1976). Such a simple, optical computation of TTC does not seem to be realized in humans. Many factors influence TTC estimation, including nonoptical factors such as limits in cognitive processing (Baurès, Oberfeld, & Hecht, 2010; DeLucia & Novak, 1997; Novak, 1998). Recent studies show that TTC estimation is also affected by emotion: Threatening pictures of frontal attacks (Brendel, DeLucia, Hecht, Stacy, & Larsen, 2012) or of feared animals (Vagnoni, Lourenco, & Longo, 2012) shortened TTC estimates in a prediction-motion (PM) paradigm. Pictures of angry faces had a similar, albeit smaller effect (Brendel et al., 2012). Interestingly, the effect of threatening pictures occurred with relatively longer presentations and the effect of facial expression did not take as long to surface. This suggests that the recognition of frontal attacks was more cognitively mediated and the effect of facial expressions was more direct. However, the distinction between the effects of threatening pictures and emotional expressions on TTC estimation was mostly speculative and still needs to be resolved (Brendel et al., 2012).

There are good reasons to believe that faces and attack scenes or feared animals should have different effects on TTC estimation. As stated eloquently by Arne Öhman, who distinguished between predator fear and social fear:

> It is only in the encounter with the beast that one tries hard to avoid the real threat, the animal. In the social

> conflict what one primarily seeks to avoid is being humiliated, and this is even more important than avoiding getting oneself killed. (Öhman, 1986, p. 124)

Indeed, there seem to be distinct neural fear circuits that process fear of predators, fear of pain, and fear of aggressive conspecifics (social fear). These distinct fear circuits seem to process information independently and in parallel, and they are evolutionarily conserved across vertebrates (Gross & Canteras, 2012). Thus, although pictures of angry faces are effective stimuli for human conditioning (Lang, Davis, & Öhman, 2000), they likely trigger a different mechanism than do other threatening stimuli.

The predator fear system and the social fear system evoke different brain patterns and physiological reactions: A recent meta-analysis of 157 fMRI studies examining emotional face processing and emotional scene processing revealed great overlapping activity patterns, but also several differences—among them, greater amygdala activation in response to emotional faces as compared with emotional scenes (Sabatinelli et al., 2011). The authors attributed this difference to the amygdala's role in facial recognition and identification. Analyzing facial features is probably the most important aspect of emotional face processing. Facial features are used to decode the social signal conveyed through the facial expression and to predict an aggressor's intentions specifically when conveyed by a threatening or angry face. Consistent with this notion, the amygdala is no longer thought to be activated by the experience of fear but rather by the perception of fear (Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012; Wager et al., 2008) or, more generally, by the perception of "motivationally salient events that require attention and learning" (Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011).

Moreover, various psychophysiological responses (heart rate, electrodermal activity, startle reflex) are modulated differently by faces and scenes in spite of comparable valence and arousal ratings (Alpers, Adolph, & Pauli, 2011). For example, psychophysiological measures (electrodermal reactivity and startle reflex potentiation) and event-related brain potentials (the centroparietal late positive potential) are modulated much less by emotional face expressions than by emotional scenes (Wangelin, Bradley, Kastner, & Lang, 2012). Differences between the social fear system and the predator fear system make sense because the social fear system has to be flexible and cognitively controllable to assess the actual threat in the given situation, whereas the predator fear system has evolved to prepare the organism quickly for a survival-ensuring fight-or-flight reaction (Öhman, 1986). It has been proposed that the predator fear system responds in situations of grave physical threat or potential for death (Gross & Canteras, 2012). Thus, it is reasonable to expect response differences between pictures of scenes showing an overt attack and pictures of angry faces for which the threat is ambiguous.

In principle, any solid object approaching on a direct collision course poses a direct threat of physical harm to the observer. The semantic content of the approaching virtual pictures used in our experiments, however, can be classified into a predator threat context (presumed to activate the predator fear system) and a social threat context (presumed to activate the social fear system). The distinction between the two kinds of stimuli is not as clear-cut as one would wish for this kind of experiment: An approaching predator may be seen as a welcome opportunity to impress conspecifics, and an aggressive human can be thought to activate the predator fear system instead of the social fear system, depending on the context; for example, whether there are spectators to acknowledge the outcome of a fight. However, whereas the social threat posed by an angry face may be ambiguous, the physical threat posed by an approaching knife-wielding attacker is obvious and may represent even more of a predator threat than does an animal predator—even more so if the facial features of the attacker are occluded by a black face mask. Therefore, we used both a masked attacker with a knife and a biting snake as scene pictures depicting physical threat, and compared them with neutral and friendly scene pictures. We used angry facial expressions without any contextual information as face pictures depicting social threat, and compared them with neutral and friendly face expressions.

This classification of stimuli into threatening scenes and threatening faces with respective links to the predator and social fear systems is consistent with methods used in previous studies investigating emotional reactions to different stimuli. These include comparisons of emotional scene processing and emotional face processing based on a meta-analysis of fMRI studies that reported studying "scenes" and "faces" (Sabatinelli et al., 2011), and comparisons based on the labels and the source of the pictures (i.e., databases of scene and face images; Alpers et al., 2011). For example, Alpers et al. reported that physiological responses to emotional scenes (e.g., attacking animals, human attack; from the International Affective Picture System; Lang, Bradley, & Cuthbert, 2005) differed from responses to emotional faces (e.g., angry, neutral faces; from the NimStim set of images, Tottenham et al., 2009). Our stimuli also are consistent with the idea that the predator fear system is activated when there is potential for grave physical harm or death and the social fear system is activated by aggressive conspecific cues (Gross & Canteras, 2012).

In short, it is important to determine whether the threat portrayed in scenes and the threat portrayed by emotional facial expressions affect TTC estimation, which is critical for evading an approaching physical threat but not necessarily for averting a social threat. Öhman, Lundqvist, and Esteves (2001) reported that visual search for a discrepant face in a matrix of distracting faces was faster and more accurate when the discrepant face was angry than when it was friendly. At first glance, it is reasonable to expect that this "threat advantage" would occur in TTC judgments (as suggested by our initial results; Brendel et al., 2012). However, if the social fear system and the predator fear system activate different mechanisms (e.g., cognitive vs. direct), the results may depend on experimental parameters, particularly the nature of the task.

We report five experiments aimed to differentiate the effects of threatening scenes (human; snake posing an attack) and threatening faces (angry facial expressions) on TTC estimation of approaching objects in two different tasks considered to differ in their reliance on cognitive processes. In Experiments 1 (face pictures) and 2 (scene pictures), we tested whether faces constitute a special class of stimuli, using the prediction-motion (PM) task (absolute TTC judgments) described by Brendel et al. (2012). In Experiment 3, we examined whether the abstract facial stimuli used in visual search tasks (Öhman et al., 2001b) affected TTC estimation. In Experiments 4 and 5, participants made relative TTC judgments in a two-alternative forced-choice paradigm that used the same stimuli as in Experiments 1 and 2. We will see that there is an effect of threatening scenes but not of threatening faces and that this effect occurs only when the task involves cognitive processing.

Experiments 1 and 2

The purpose of Experiments 1 and 2 was to compare the effects of threatening faces (i.e., angry face) and threatening scenes (i.e., frontal attack) on TTC judgments in a PM task. Shortened TTC judgments for threatening faces and scenes in both categories would extend Brendel et al.'s (2012) results and suggest similar mechanisms for effects of threat in both types of stimuli.

Method

Participants Thirty-two students from Texas Tech University participated for course credit in Experiment 1 (16 men, 16 women; ages 18–53, M = 20.19; SD = 6.20). Thirty-two different students participated in Experiment 2 (16 men, 16 women; ages 18–22, M = 18.81; SD = 1.12). All reported having normal or corrected visual acuity. Sample size was motivated by the relatively high variability of PM judgments compared with relative TTC judgments in Experiments 4 and 5 (see Tresilian, 1995).

Displays Displays were presented on a 43-cm monitor at 25 frames/s and were viewed with a chin rest from 45.72 cm. We simulated an object that approached the participant directly for 3 s and then disappeared from view. To create a variety of trials, we made the initial distance between the approaching object and the viewpoint relatively near or far, and the actual TTC at the time of the object's disappearance was .75 s, 1.5 s, or 3 s.

In Experiment 1 (threatening faces), the object depicted a digitized photograph of a real face. The set of photographs consisted of angry, happy, and neutral facial stimuli from the NimStim Set of Facial Expressions that were used by Brendel et al. (2012). Two different models were included (Tottenham et al., 2009; models 20 and 23, open-mouthed version) in addition to an "empty" face with all facial features erased.

In Experiment 2 (threatening scenes), the object depicted pictures from the International Affective Picture System (IAPS; Lang et al., 2005) rather than facial expressions. Pictures were selected from the sample used by Brendel et al. (2012). A masked attacker with a knife and a biting snake represented threatening stimuli; a lamp and a clock represented neutral stimuli; and a boy and a baby represented friendly stimuli. The IAPS numbers of the pictures used were 1120, 2070, 2650, 6510, 7175, and 7190. In addition, empty colored squares were included as a control stimulus without affective content.

In both experiments, the orientation of the approaching object was upright or inverted. Facial recognition and discrimination are degraded when faces are inverted, suggesting that faces are processed holistically rather than analytically (Pallett & MacLeod, 2011). However, studies indicate that the processes involved in facial recognition are different from the processes involved in the identification of emotional expressions, and that the processing of facial expressions of emotion is not degraded when inversion is used to disrupt holistic processing (Lipp, Price, & Tellegen, 2009; Öhman et al. 2001b). In Öhman et al.'s (2001b) visual search study, the threat advantage occurred with inverted faces. We included this orientation manipulation to ascertain whether we would obtain the same pattern of results and thus presumably activate the same type of processing.

Procedure

Participants were instructed to press a mouse button when they thought that the object would hit them if the simulation of the object's motion had continued after the object disappeared. Participants viewed each of 96 unique trials three times, in randomized orders.

Results

Results of Experiments 1 and 2 were analyzed separately with 2 (Orientation) × 4 (Affective content) repeated-measures analyses of variance (ANOVAs) and are shown in Fig. 1 and Fig. 2. In Experiment 1 (threatening faces), the effect of emotional expression on mean TTC estimates was not significant [$F(3, 93) = 2.15$, $p = .099$, $\eta_p^2 = .06$]. Mean TTC estimates were greater for the inverted faces ($M = 2.94$ s) than

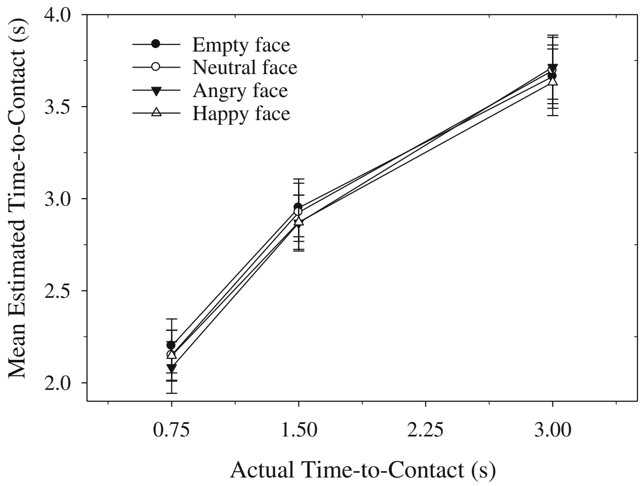

Fig. 1 Experiment 1: Mean estimated time-to-contact as a function of actual time-to-contact for neutral, angry, happy, and empty faces (averaged over final distance and orientation). Error bars represent standard errors of the means

for the upright faces (M = 2.88 s) [$F(1, 31) = 9.83$, $p = .0037$, $\eta_p^2 = .24$].

In contrast, results of Experiment 2 (threatening scenes) indicated a main effect of affective content of the scene pictures [F (3, 93) = 12.69, $p = .0001$, $\eta_p^2 = .29$], but not of orientation or their interaction (Fs < 1.33, ps > .27). Results of Tukey's HSD tests indicated that the mean TTC estimate was shorter for the threatening pictures (attacker, snake) than for the neutral (lamp, clock) and friendly (baby, boy) pictures. The difference between threatening pictures and empty squares was not significant.

The results of Experiments 1 and 2 were directly compared with a 2 (Orientation) × 2 (Experiment) × 4 (Affective content) mixed ANOVA. Only significant effects of experiment or interactions with experiment are reported. There was a main effect of experiment [F (1, 62) = 7.95, $p = .0064$, $\eta_p^2 = .11$] and an interaction between experiment and affective content [F (3, 186) = 9.64, $p = .0001$, $\eta_p^2 = .13$]. Overall, mean TTC estimates were shorter for scene pictures (M = 2.33 s) than for face pictures (M = 2.91 s). A 2 (Orientation) × 2 (Experiment) ANOVA conducted at each level of affective content indicated that mean TTC estimates were greater in Experiment 1 (face pictures) than in Experiment 2 (scene pictures) at all levels of affect (Fs > 5.6, ps < .02). Means are shown in Fig. 3. Analyses of effects of affective content for each experiment separately were reported above for results of Experiments 1 and 2.

Discussion

Threatening scene pictures (attacks) were judged to arrive earlier than neutral and friendly pictures in a PM task. This finding replicates the effect of threatening scene pictures reported by Brendel et al. (2012). However, TTC judgments were not affected by threatening faces (angry face expressions). Taken together, the results of Experiments 1 and 2 support our previous observation that the effect of facial expressions is weaker than that of threatening scene pictures (Brendel et al., 2012). We discuss the differences between facial and other pictorial emotional stimuli in the General Discussion.

Interestingly, empty pictures (colored squares) were judged to arrive as early as threatening pictures. A similar finding was observed in a related study (Brendel & Hecht, 2013); namely, stimuli without meaningful content were judged to arrive as early as those with threatening content. This may be explained by a general distraction effect of content; that is, pictorial content generally distracts from the task, and this distraction

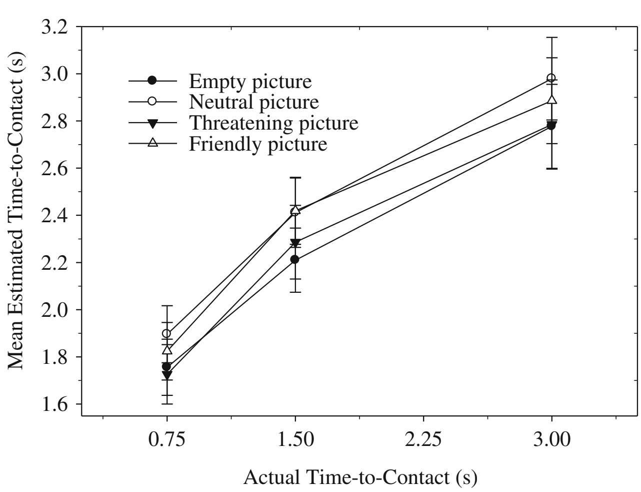

Fig. 2 Experiment 2: Mean estimated time-to-contact as a function of actual time-to-contact for neutral, threatening, and friendly pictures (averaged over final distance and orientation). Error bars represent standard errors of the means

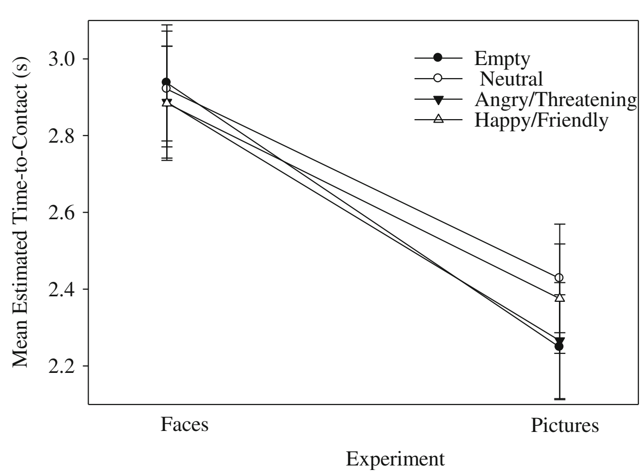

Fig. 3 Experiments 1 and 2: Mean estimated time-to-contact in Experiment 1 (face pictures) and Experiment 2 (scene pictures) for empty, neutral, angry/threatening, and happy/friendly pictures. Error bars represent standard errors of the means

leads to longer TTC estimates. Threatening content can diminish this effect and lead to TTC estimates as short as those of pictures without meaningful content (the empty squares). Emotionally neutral or friendly content may allow for more interpretation and may impose less urgency to correctly solve the task, thus leading to the observed overestimation. A similar effect was reported in time perception (Lambrechts, Mella, Pouthas, & Noulhiane, 2011): In a time-reproduction task, participants estimated the 2-s duration of a gray square as shorter than that of a picture with content, regardless of whether the content was neutral or emotional. At longer durations, however, this general content effect on time estimation diminished and an emotional content effect appeared. Specifically, the 4-s duration of an emotional picture was estimated as longer than that of a neutral picture. It is debatable whether the general content effect putatively observed in our measures of TTC judgments is comparable to the effect reported in time-estimation studies. In Experiments 1 and 2, although TTC judgments of threatening and content-free pictures were similar (general content affect), there were also differences between threatening pictures and pictures with neutral content (effect of emotional content). Specifically, TTC judgments of neutral and friendly pictures were overestimated, whereas TTC judgments of threatening pictures were overestimated by a smaller magnitude and were comparable to judgments of content-free pictures.

Experiment 3

The results of Experiments 1 and 2 indicated that threatening scene pictures but not threatening face pictures affected TTC judgments in a PM task. An effect of faces was expected on the basis of Öhman et al.'s (2001b) finding that visual search for discrepant faces among a matrix of faces was faster and more accurate when the discrepant face was threatening than when it was friendly. In addition, Brendel et al. (2012) found a small effect of emotional facial expressions in their study. One possible explanation of our results is that (digitized photographs of) real faces were used in the present study and in Brendel et al.'s study, whereas Öhman et al. used abstract faces. Although previous studies have shown that the threat advantage in visual search can occur with real faces (Lipp et al., 2009), an experiment was conducted to determine whether an effect of facial expression on TTC judgments would be obtained with Öhman's abstract face stimuli.

Method

Participants Thirty-two students at Texas Tech University participated for course credit (16 men, 16 women; ages 18–25, M = 18.75; SD = 1.65). All reported having normal or corrected visual acuity and had not participated in Experiments 1 or 2.

Displays Displays were presented on a 43-cm monitor at 25 frames/s and were viewed with a chin rest from 45.72 cm. The stimuli are represented in Fig. 4; they depicted an abstract face that approached the participant directly for 3 s and then disappeared from view. The emotional expression of the face was threatening, friendly, or neutral, and was created from Öhman et al. (2001b: Fig. 1). An "empty" face, without facial features, was included. To control for local stimulus features apart from emotional expression, in three additional stimuli the facial features were rearranged (scrambled). As in Experiments 1 and 2, the initial distance between the face and the viewpoint was relatively near or far, actual TTC was .75 s, 1.5 s, or 3 s, and orientation was upright or inverted.

Procedure Participants were instructed to press a mouse button when they thought that the object would hit them, had the simulation of the object's motion continued after the object disappeared. Participants viewed each of 84 unique scenes three times, in a randomized order.

Results

A 2 (Orientation) × 2 (Scrambledness) × 3 (Emotion) repeated-measures ANOVA was used to analyze TTC estimates. The empty face was omitted because it could not be crossed with scrambledness. Results indicated that main effects of emotional expression and orientation were not significant (Fs < 2.2, ps > .15). There was an interaction between scrambledness and orientation [$F(1, 31) = 6.04$, $p < .020$, $\eta_p^2 = .16$]. A 2 (Scrambledness) × 3 (Emotion) repeated-

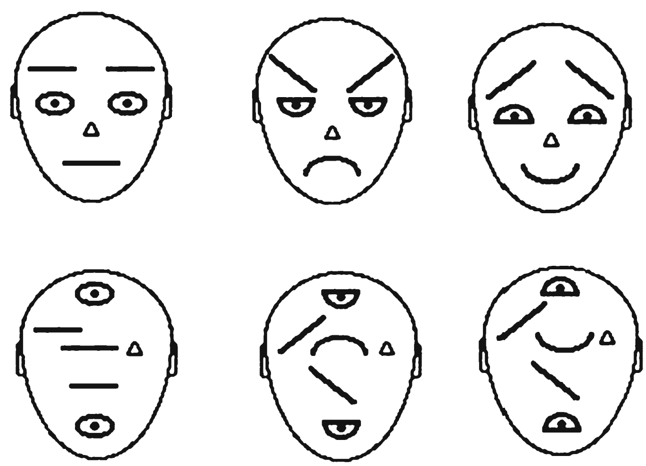

Fig. 4 Representations of upright face pictures used in Experiment 3. Left, middle, and right columns depict neutral, threatening, and friendly faces, respectively. Top row: Unscrambledfacial features. Copyright © 2001 by the American Psychological Association. Reproduced with permission. The official citation that should be used in referencing this material is Öhman, A.,Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*(3), 381–396. Retrieved March 09, 2011, from doi:10.1037/0022-3514.80.3.381. The use of APA information does not imply endorsement by APA. Bottom row. Scrambled facial features.

measures ANOVA on each level of orientation indicated that mean TTC estimates were greater when pictures were unscrambled than when they were scrambled, but only when orientation was inverted [$F(1,31) = 15.47$, $p < .0004$]. Such results are again consistent with a general content effect: When pictures were inverted, the scrambled faces were probably not recognizable and thus were treated like a meaningless pattern (similar to the empty squares in Experiment 2). The unscrambled faces, however, were recognizable even when inverted, and thus led to longer TTC estimates, similar to the neutral scene pictures in Experiment 2. Finally, a separate analysis including empty faces (averaging over the scrambledness variable) indicated that mean TTC estimates for the empty face were greater than for the neutral, threatening, and friendly faces [$F(3, 93) = 5.91$, $p < .002$, $\eta_p^2 = .16$] ($p < .05$ for Tukey's HSD tests).

Discussion

Emotional expression did not affect TTC estimates in a PM task even with Öhman et al.'s (2001b) facial stimuli. It has been argued that the effect of Öhman's schematic faces could have been driven by low-level features instead of emotional relevance—that is, by a different relationship between the facial surround and the facial features (Mak-Fan, Thompson, & Green, 2011; Purcell & Stewart, 2010). Öhman et al. (2001b) reported the threat advantage with inverted faces. We included inverted and scrambled schematic faces to control for this possibility in case we found an effect of emotional expression. The absence of an effect of emotional expression on TTC judgments with all of these stimuli suggests that low-level features of schematic faces are effective in visual search tasks but not in TTC estimation tasks.

Generally, not all results from studies using visual search tasks are consistent with an effect of threat. Granted, pictures of snakes or spiders were found more quickly in picture arrays of flowers or mushrooms than vice versa (Öhman, Flykt, & Esteves, 2001). This effect was even more pronounced when the participants were specifically fearful of those animals (Öhman et al. 2001a). Further, the effect emerges independently of the threat's phylogenetic origin—it was also shown for pictures of modern threats such as guns and syringes (Blanchette, 2006; Brosch & Sharma, 2005). However, while replicating the threat advantage effect with snakes and spiders, Tipples, Young, Quinlan, Broks, and Ellis (2002) also found faster visual search for harmless animals (e.g., bunnies, puppies, kittens) and fruits, which indicates that the effect may depend not on threat or fear but rather on different features of the stimuli or on different aspects of attentional or emotional reactions.

Critical to our experiments, not all photographic emotional face stimuli seem to be able to affect visual search tasks (Öhman, Juth, & Lundqvist, 2010). Clearly, the abstract face drawings we used here were not sufficient to produce the threat effect on TTC judgments that we observed with the threatening scene pictures in Experiment 2. We considered the possibility that our specific emotional faces were not the most effective ones in eliciting the threat effect, which seems to depend on several features of the stimulus material, such as male sex (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Öhman et al., 2010) and familiarity (i.e., small sample size) of the faces (Öhman et al., 2010). In additional experiments, we validated that visual search was faster and more accurate for threatening faces than for friendly faces even when the photographic facial stimuli from Experiment 1 were used rather than the abstract faces used in Experiment 3.[1] Thus, the absence of an effect of emotional facial expression on TTC judgments in Experiment 1 was not due to our use of digitized photographs of real faces. The implication is that Öhman's abstract faces and our photographic faces have a threat advantage effect in visual search but not in time-to-contact estimation. In other words, the effects of facial expressions are task-specific. This result is not surprising from an evolutionary point of view: The involvement of the social fear system to improve the detection of an angry face in a crowd seems to be quite useful, whereas the interpretation of social threat cues should be less valuable for the timing of evasive or interceptive actions—which are the most important functions of the perception of TTC.

Experiments 4 and 5

The purpose of Experiments 4 and 5 was to determine whether the differences between the effects of threatening scene and

[1] Two experiments (N = 20 in each) replicated Öhman et al.'s (2001b) visual search task with digitized photographs of upright and inverted faces, respectively, using the neutral, happy, and angry faces from Experiment 1. The faces were arranged in 3 × 3 matrices. In half of the matrices, there was one "discrepant" face that was different from the remaining "distractor" faces. The discrepant face depicted an emotional expression of angry, happy, or neutral, and appeared with equal frequency in each of the nine locations of the matrix. The discrepant face was present amid distractor faces that were either emotional or neutral (e.g., angry discrepant face presented with all happy distractor faces or all neutral distractor faces). In the remaining matrices, all the faces were angry, happy, or neutral. Whereas Öhman et al. (2001b) used presentations of only 1 s and 2 s, we added a 3-s duration to match the duration of our approach scenes in Experiment 3. Results replicated Öhman, Lundqvist, and Esteves's primary finding that mean response time was significantly faster [upright: $F(1, 19) = 14.49$, $p = .0012$, $\eta_p^2 = .43$; inverted: $F(1, 19) = 10.06$, $p = .0050$, $\eta_p^2 = .35$] and percentage accuracy was significantly higher [upright: $F(1, 19) = 27.59$, $p = .0001$, $\eta_p^2 = .59$; inverted: $F(1, 19) = 55.14$, $p = .0001$, $\eta_p^2 = .74$] when the discrepant face was angry, in comparison with happy. These findings also occurred with the 3-s presentation duration. As reported by Öhman et al. (2001b), the threat advantage also occurred with inverted faces. This speaks for the position that the processing of emotional face expressions, which is not degraded by inversion, is separable from the processing of facial recognition, which is degraded by inversion (Lipp et al. 2009; Öhman et al. 2001b).

face pictures obtained in Experiments 1 and 2 were specific to the PM task. In Experiments 4 and 5, relative TTC judgments were measured. Two objects, side by side, approached the observer and were occluded before the first object reached the observer's eye plane. Observers had to pick the object that would reach them first. This relative TTC task is less reliant on cognitive processes than the PM task used in Experiments 1 and 2, because in the relative TTC task the viewing time of the approaching objects was 1 s rather than 3 s, and the participant's response occurred immediately after the target disappeared (see Tresilian, 1995). Reducing a reliance on cognitive processes may cause the effect of threatening pictures not to occur in Experiments 4 or 5. Although we did not find an effect of facial expressions on TTC judgments in Experiment 1, we examined the effect of facial expressions in Experiment 4 to determine whether the absence of an effect was specific to the PM task used in Experiment 1.

Method

Participants Twelve new students participated in Experiment 4 (six men, six women; ages 17–20, M = 18.75; SD = .87). Twelve different students participated in Experiment 5 (six men, six women; ages 18–22, M = 18.67; SD = 1.15). All reported having normal or corrected visual acuity and had not participated in Experiments 1, 2, or 3.

Displays Displays simulated two objects, positioned side by side, that approached the viewpoint on a noncollision path for 1 s and then disappeared from view. In Experiment 4, the angry, happy, and neutral face pictures from Experiment 1 were used but only one model was included (model 23, open-mouthed version), and the empty face was excluded. In Experiment 5, the attacker, baby, and lamp scene pictures from Experiment 2 were used. In both experiments, the stimuli were oriented upright or inverted, and the pairings of the pictures were manipulated. In Experiment 4, the pairings were neutral and happy, neutral and angry, and happy and angry. In Experiment 5, the pairings were lamp and baby, lamp and attacker, and baby and attacker. On one third of the trials, both objects arrived simultaneously (ties). To eliminate relative optical size as a cue for relative TTC judgments, we ensured that the object that arrived first did not always have the smaller (or larger) optical size at the beginning of the scene. Brendel et al. (2012) reported that the effects of the threatening pictures on TTC estimation occurred with relatively long actual TTC values. Consequently, in Experiment 4, participants were instructed to view the entire approach scene before responding. Responses could not be entered until a "Respond Now" prompt was displayed after the approach scene ended. Trials with early responses were repeated and the repeated trials were used in the data analysis instead of the early responses (this occurred on 1.67% of the trials).

Procedure Participants reported which object would reach or pass them first, had the objects continued moving after they disappeared. To ensure processing of affective content, participants reported the name of the picture (e.g., angry, attacker) that would reach them first rather than its spatial position (left, right).

Results

We analyzed percentage accuracy and response time for nontie approach events separately, with 2 (Orientation) × 3 (Picture pairing) repeated-measures ANOVAs. We analyzed response times for tie events similarly, but percentage accuracy was not applicable. Instead, we conducted two-tailed t-tests to determine whether participants selected angry face pictures or threatening scene pictures more often as arriving first than the corresponding neutral stimuli.

Results of nontie events in both experiments indicated that effects of picture pairing, orientation, and their interaction on mean response time and percentage accuracy were not significant (Faces: Fs < 1.84, ps > .20; Scenes: Fs < 2.55, ps > .10).

Results of tie events indicated that the effect of picture pairing on mean response time was not significant in either experiment. The results remained nonsignificant for tie and nontie events when the data from both experiments were combined to increase statistical power. In addition, participants were not any more likely to select angry face pictures or threatening scene pictures as arriving earlier than neutral stimuli (t < .13). Finally, mean response time was greater for inverted faces (M = 1.31 s) than for upright faces (M = 1.17 s) [$F(1, 11) = 4.92$, $p = .0485$, $\eta_p^2 = .31$], but this inversion effect was not significant for scene pictures (Fs < .57, ps > .46).

Results of Experiments 4 and 5 were directly compared (separately for tie and nontie scenes) with 2 (Experiment) × 2 (Orientation) × 3 (Picture pairing) mixed ANOVAs. For nontie scenes, mean response time was greater for scene pictures (M = 1.66 s) than for faces (M = 1.11 s) [$F(1, 22) = 30.34$, $p = .0001$, $\eta_p^2 = .58$]. All other effects were nonsignificant (Fs < 2.04, ps > .14). For tie scenes, mean response time was greater for scene pictures (M = 1.78 s) than for faces (M = 1.24 s) [$F(1, 22) = 14.06$, $p = .0011$, $\eta_p^2 = .39$] and greater for the inverted than for the upright orientation [$F(1,22) = 4.85$, $p = .0384$, $\eta_p^2 = .18$]. All other effects were nonsignificant (Fs < 1.98, ps > .15).

Discussion

Consistent with the results of the PM task in Experiment 1, emotional facial expression did not affect relative TTC estimates. In contrast to the results of the PM task in Experiment 2, threatening scene pictures did not affect relative TTC estimates. Thus, the task made a decisive difference and suggests that threatening pictures exert their influence on TTC estimation during the postperceptual cognitive processing (e.g., cognitive extrapolation of motion after the object disappeared) that was mandated by the PM paradigm. In contrast, the effect that inversion produces longer TTC estimates was consistent across paradigms, suggesting that it is a perceptual effect.

General Discussion

When observers judged the TTC of objects that were about to collide with them (PM task), threatening pictures (i.e., frontal attacks) were judged to arrive earlier than neutral pictures (e.g., a lamp) or friendly (e.g., baby) pictures (Exp. 1). However, this effect did not surface with threatening face pictures (i.e., angry emotional facial expressions) in the same PM task that was used for the threatening scene pictures—neither with Öhman et al.'s (2001b) schematic face stimuli (Exp. 3), nor with photographed faces (Exp. 2), even though faces were shown to elicit a threat advantage effect in a visual search task. When observers had to judge which of two simultaneously approaching objects would arrive earlier (relative TTC task), neither emotional facial expressions (Exp. 4) nor threatening scene pictures (Exp. 5) affected TTC estimates.

Previous studies of the "threat advantage" in visual search for faces have characterized the effect as being due to the perception of threat expressed by an emotional facial expression (see, e.g., Öhman et al., 2001a, b). Previous studies also showed a threat advantage effect in TTC estimation (e.g., Brendel et al., 2012), which is important when one wants to take action to evade the threat. Here we aimed to clarify whether the threat advantage effect depends on the potential of the threat (direct threat of overt attack pictures vs. more ambiguous threat of facial expressions), and whether the effect depends more on the stimulus material (real faces vs. abstract faces) or on the specifics of the task (visual search vs. PM task vs. relative TTC judgment). Our results clarify these issues.

Emotional effects are determined by threat potential

Both threatening scene pictures and threatening face pictures represent negative emotional content. If this emotional content underlies our previously reported effect of threatening scene pictures on TTC judgments (Brendel et al., 2012), threatening facial expressions should produce a similar effect. However, if our previous finding was due to the unequivocal threat, facial expressions may not modulate TTC estimates because their potential threat is merely implicit in the emotional expression. In other words, a threatening picture of a frontal attack shows the actual threat, but a picture of an angry face implies a variety of possible outcomes including different degrees of threats and even nonthreats. On the basis of the present results, we argue that the manifest threat is the primary variable producing a TTC effect. A facial expression may be characterized as threatening, but the threat is not explicit and may range from an insult or rebuke to physical attack. Thus, the effects of a threatening face may also vary widely and may depend on the task (visual search vs. TTC judgment).

The mechanism responsible for the differing results between the emotional facial expressions and the threatening pictures in the PM task may be their different potentials for physiological arousal. As described in the introduction, threatening pictures of frontal attacks should activate the predator fear system, resulting in a heightened state of arousal that is meant to prepare the body for quick and exhaustive action. Threatening or angry faces should instead activate the social fear system, which does not have the same physiological automaticity. Thus, if the emotional influence on TTC judgments depends on a heightened state of arousal, the effect would appear only for the threatening attack pictures and not for angry facial expressions. This is consistent with the previous finding that psychophysiological measures and event-related brain potentials are less modulated by emotional face expressions than by emotional scenes (Wangelin, Bradley, Kastner, & Lang, 2012).

Such an account may be related to the mechanism through which general time perception is affected by emotional pictures. This seems to depend on the level of arousal, with low-arousal stimuli triggering an attention effect—that is, temporal underestimation of negative pictures relative to positive ones—and high-arousal stimuli triggering an arousal effect—that is, temporal overestimation of negative pictures relative to positive ones (Angrilli, Cherubini, Pavese, & Manfredini, 1997). Maybe our facial stimuli elicited a medium state of arousal at which perception is either not affected at all or is affected by both mechanisms at the same time, resulting in no net distortion.

Droit-Volet and Meck (2007) suggested that "the urgency of action for incoming events is one of the crucial factors affecting our perception of time" and took angry faces as an example of a stimulus implying especially urgent action. Within the context of facial expressions, this is undoubtedly the case. However, compared with pictures of overt attacks, an angry face is signaling less urgency and definitely leaving more room for speculation and alternatives to immediate fight-or-flight reactions.

In addition, distortions of time perception due to facial stimuli seem to depend on processes of empathy and imitation (Droit-Volet & Gil, 2009). An impressive example of this is given by Effron, Niedenthal, Gil, and Droit-Volet (2006), who demonstrated that emotional face expressions led to distorted time perception only when participants were able to (unintentionally) imitate the emotional expressions. This speaks for a more indirect and flexible processing of emotional face expressions in comparison with threatening scenes. However, it contradicts our initial assumption of a more direct processing of the emotional face expressions based on a shorter presentation time needed to influence time-to-contact judgments, compared with the presentation time needed for threatening scenes (Brendel et al., 2012). This need not be a contradiction but could reflect two different aspects of the processing: Emotional face expressions may be processed more quickly for the very reason (evolutionarily speaking) that an angry face is a less direct threat and needs more interpretation (more processing time after its initial detection and possibly some reinforcement by embodiment) than an overt attack. This second-step processing may be more easily disrupted by other task demands—or it may be irrelevant if the facial stimulus is intense and threatening enough to influence behavior, as was probably the case in our earlier study (Brendel et al., 2012), in which the angry face was presented on a very large projection screen (cinema effect).

In the context of our experiments, it may be easier in the relative TTC judgment task than in the PM task to direct attention to the edges of the two pictures (or to their relative sizes, etc.) and to ignore the content of the two pictures. Consequently, if an angry face needs some interpretational reinforcement (or an extremely large display) to be an effective threatening stimulus in our PM task, such interpretation should arise even less in the relative TTC task.

Emotional effects are determined by task specifics

Threatening scene pictures having an effect in the PM task but not in the relative TTC judgments can be explained by their different involvement of cognitive processes. The PM task putatively involves cognitive motion extrapolation and requires a timed response. In contrast, our relative TTC task was less dependent on cognitive processes because the viewing time of the approaching objects was only 1 s, and the participant's response occurred shortly after the target disappeared (see Tresilian, 1995). Our results suggest that not only is threat the driving force; it also must have a chance to manifest itself in the cognitive extrapolation that occurs between visual stimulus offset and collision time (in a PM task). More generally, if one assumes that the evaluation of threat in a stimulus can involve cognitive assessment (Brendel et al., 2012), influences of affective content may depend on the degree to which the task involves cognitive processes.

Another possible explanation for the absence of an effect of emotional content on relative TTC judgments may be their dependency on spatial attention. At least for emotional face expressions, it has been shown that "all brain regions responding differentially to emotional faces, including the amygdala, did so only when sufficient attentional resources were available to process the faces" (Pessoa, Kastner, & Ungerleider, 2002). Especially concerning spatial attention, the emotional modulation of a face-specific early event-related brain potential (ERP) positivity is diminished when foveally presented stimuli are unattended, and the emotional modulation of the ERP positivity is even absent when peripherally presented stimuli are unattended (Eimer & Holmes, 2007). In addition, amygdala and anterior cingulate cortex reactivity to emotional faces is greater when the focus of attention is directed to the face stimuli than when the emotional faces are just present on the display while attention is directed to objects placed beside the faces (Klumpp, Angstadt, & Phan, 2012).

In our relative TTC judgment task, two stimuli were presented simultaneously, side by side, and were thus presented more peripherally than the one stimulus in the PM task. In addition, the relative judgment task may direct attention away from the content of each picture and toward the pictures' edges or relative motions, and may leave fewer attentional resources for the processing of the images' content. This task may even involve a more deliberate ignoring of the pictures' content than the PM task; ignoring angry faces has been shown to reduce sensitivity to the previously ignored face's expression (Gómez-Cuerva & Raymond, 2011). The same dependency on attention may occur with nonfacial pictures, rendering the effect of the threatening scene pictures nonsignificant. In the PM task (Exp. 1 and Exp. 2), it may be easier for participants to ignore the emotional content of the faces and focus on the edges of the face, and more difficult to ignore the emotional content in the pictures when it comprises the entire picture.

Discrepancy between the present results and those of Brendel et al. (2012)

Although we replicated our previously reported effect of threatening scene pictures on TTC estimates (Brendel et al., 2012), we did not replicate the (small) effect of emotional facial expression. We consider several reasons for this apparent discrepancy. First, stimuli in the previous study, which were presented stereoscopically on a large screen (78-deg diagonal), likely created greater arousal than did the present stimuli, which were presented nonstereoscopically on a smaller screen (50-deg diagonal). This account is aligned with our previously reported supposition that the effect of angry faces was smaller than the effect of threatening pictures as a result of relatively lower arousal (as indicated by significantly lower arousal ratings on the SAM scale). The smaller, nonstereoscopic displays in the present study may have resulted in even lower arousal, eliminating the face effect. If validated, this account would suggest that arousal is an important component of the threat effect.

Second, the longer presentation duration in the present study (3 s) provided more time for the facial expression to be processed and thus be influential, but at the same time provided more time for observers to resolve ambiguities regarding threat than did the durations in our previous study

(200 ms, 800 ms). Because there was no change in the face over the course of 3 s, the observer's perceived likelihood of a manifest threat may have decreased, ultimately eliminating the face effect. This account is aligned with our supposition that manifest threat rather than emotional valence underlies the threat effect.

Finally, the longer TTC values in the present study (.75 s, 1.5 s, 3 s) required longer mental extrapolation times than those in our previous study (.6 s, .8 s, 1 s). This putatively greater cognitive demand may have interfered with the processing, and ultimately the influence, of the angry face. When we reanalyzed the data using only the .75-s TTC condition, the difference between the angry face and the neutral or happy face still did not emerge, rendering this account less viable.

Conclusions

Our results add to the growing number of studies that indicate that TTC judgments of approaching objects are not based solely on TTC information available in the optical expansion pattern, and that the affective information presented in the optical pattern can influence such judgments. We show, further, that not all affective information has the same effect, and whether an effect occurs at all may depend on the task and the degree to which the task involves cognitive processes. Whereas threat carried by scene pictures of overt attacks may affect TTC judgments, threat carried by pictures of facial expressions may not. We propose that it is the picture's explicit potential of the threat per se, and not only the emotional valence of the picture, that underlies the effect of threatening pictures on TTC judgments. Moreover, this effect occurs only when the task allows sufficient cognitive processing of the stimuli. The effect of threatening pictures occurred in the PM task, which putatively required cognitive motion extrapolation, but not in a relative TTC judgment task, which was designed to rely less on cognitive processes. The distinction between the effects of threatening pictures and emotional expressions may reflect the different underlying fear systems and associated physiological mechanisms and demands. Whereas the predator fear system has to prepare immediate and rapid evasion responses, the social fear system must assess a range of threatening outcomes and appropriate responses.

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