Emotion

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What's in a Gaze, What's in a Face?: The Direct Gaze Effect Can Be Modulated by Emotion Expression

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Gaze direction and emotion expression are salient facial features that facilitate social interactions. Previous studies addressed how gaze direction influences the evaluation and recognition of emotion expressions, but few have tested how emotion expression influences attentional processing of direct versus averted gaze faces. The present study examined whether the prioritization of direct gaze (toward the observer) relative to averted gaze (away from the observer) is modulated by the emotional expression of the observed face. Participants identified targets presented on the forehead of one of four faces in a 2 × 2 design (gaze direction: direct/averted; motion: sudden/static). Emotion expressions of the faces (neutral, angry, fearful, happy, disgusted) differed across participants. Direct gaze effects emerged—response times were shorter for targets on direct gaze than on averted gaze faces. This direct gaze effect was enhanced in angry faces (approach-oriented) and reduced in fearful faces (avoidance-oriented). "Weaker" approach- and avoidance-oriented expressions (happy and disgusted) did not modulate the direct gaze effect. These findings suggest that the context of facial emotion expressions influences attentional processing.

Keywords: emotion expression, gaze direction, social attention, social cognition, visual attention

Facial expressions provide important nonverbal information in social interaction. Thus, it is not surprising that there is a long history of studies on emotion recognition. Recognizing a person's emotional state based on their facial expression helps the observer to act or respond adaptively, and doing so may foster strong interpersonal relationships. Many studies indicate that facial *emotion expressions* capture and guide attention (Frijda, 1986; Lundqvist & Öhman, 2005; Öhman et al., 2001) and broadly shape social interactions (Hartikainen et al., 2000; Keltner et al., 2006; Mathews et al., 2003; Van Kleef, 2009). In addition to facial expressions, the eyes provide a particularly relevant signal. Where someone is looking (i.e., gaze direction) plays an important role in identifying that persons' attentional, emotional, and intentional states (Ricciardelli et al., 2016; Schilbach, 2015). Changes in gaze provide additional dynamic information about others' mental states. Together with other basic social signals such as emotion expression, eye gaze constitutes the foundation for sending, receiving, and responding to social information (Bishop et al., 2019; Chervonsky & Hunt, 2017).

Previous work indicates that *direct gaze*—when another individual's gaze is directed at the observer—is a particularly salient cue that is prioritized in cognitive processing (cf., eye contact/watching eyes effects; Argyle & Cook, 1976; Conty et al., 2016; Kleinke, 1986; Senju & Johnson, 2009). This social gaze cue has been shown to broadly influence human cognition, for instance by capturing attention, enhancing self awareness and self-referential processing, and promoting prosocial behavior (e.g., Ernest-Jones et al., 2011; Hietanen & Hietanen, 2017; Nettle et al., 2012; Powell et al., 2012). Understanding the processes that underlie and shape direct gaze effects and changes in gaze direction are critical for the understanding of social cognition (Conty et al., 2016).

The current experiments were designed to address how gaze cues and facial emotion expressions influence attentional processing. Although previous studies have addressed how observed gaze direction influences the *evaluation* and *recognition* of emotion expressions on faces (e.g., McCrackin & Itier, 2019), few studies have tested how facial emotion expression and gaze cues influence attentional processing in general. The present study was designed to investigate how facial emotion expression shape gaze processing by

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The authors declare no conflict of interest. The data set, results, and concluded interpretations have not been published elsewhere. Data and code are available at OSF (https://osf.io/8t2kw/).

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adapting a task that shed new light on the influence of gaze direction and changes in gaze direction on attention capture. By manipulating the emotional expressions of the faces in the direct gaze task (Böckler et al., 2014), the present study assessed how emotion expression, gaze direction, and gaze shifts together influence attention using a setup in which these social cues were not relevant for successful performance.

The task designed by Böckler et al. (2014; see also Böckler et al., 2015; Boyer & Wang, 2018; van der Wel et al., 2018) examined how gaze direction and the motion associated with changes in gaze direction independently and/or interactively influence attentional processing. The investigation of the influences of gaze direction and sudden onset motion involved a 2 × 2 design target identification paradigm. Participants had to identify a target letter that appeared randomly on one of four faces by pushing one of two buttons. A distractor letter appeared on the other three faces. Two faces started with gaze directed toward the participant (direct gaze face) and the other two faces started with gaze directed away from the participant (averted gaze face). Coincident with the appearance of the target and distractors, one of the averted gaze faces suddenly changed orientation to a direct gaze face and one of the direct gaze faces suddenly changed orientation to an averted gaze face. Thus, at target onset, two faces maintained a static orientation (with one being a static direct gaze face and one being a static averted gaze face—*no motion*) and two faces suddenly established a different gaze (with one being a sudden direct gaze face changing from averted to direct gaze and one being a sudden averted gaze face changing from direct to averted gaze—*motion*). The analysis of response times (RTs) in the search task revealed that participants identified targets more efficiently when the targets appeared on the face that suddenly established direct gaze (switched from an averted to a direct gaze) compared with when the target appeared on the faces that remained static or that suddenly established averted gaze. Interestingly, the statistical analysis revealed a main effect for gaze direction ($RT_{direct} < RT_{averted}$), a main effect for motion ($RT_{sudden} < RT_{static}$), but no interaction between gaze direction and motion. It was suggested that this pattern of effects and the more efficient processing of sudden direct faces emerged via the existence of parallel processing channels for gaze and motion processing as the effects of gaze and motion cues were additive when temporally co-occurring (see also Pitcher & Ungerleider, 2021; van der Wel et al., 2018).

Exploring the influence of emotion expression on the sudden direct gaze effect is of particular theoretical importance because the approach-avoidance congruency model (Adams & Kleck, 2003, 2005) argues that gaze direction in emotional faces represents behavioral tendencies on the approach avoidance dimension. Adams and Kleck (2003, 2005) tested this claim and found that participants recognized approach-oriented emotions, like anger and joy, more efficiently when the faces with these emotions were depicted with direct than when the faces were depicted with averted gaze. In addition, participants ascribed more intensity to approach-oriented emotions when the respective faces established direct gaze. In contrast, avoidance-oriented emotions, like fear or sadness, showed stronger recognition and intensity effects when presented by faces with averted than direct gaze. The authors suggested the *shared signal hypothesis* (Adams & Kleck, 2005; cf. Bindemann, 2008), postulating that when gaze direction matches the approach avoidance behavioral intent that is communicated by an emotion expression (i.e., congruence in signal value), the perception of the respective emotion expression would be enhanced. Through such enhancement, congruent gaze and emotion signals (direct gaze and approach-oriented emotions as well as averted gaze and avoidance-oriented emotions) help to identify the source of a specific emotional state and enable fast and adequate (social) reactions. Similar observations for dynamic emotion expressions were reported by N'Diaye et al. (2009), who found that angry faces with direct gaze (signaling aggressiveness) and fearful faces with averted gaze (signaling a peripheral danger) were perceived with higher emotional intensity and enhanced neural activity in the amygdala (see also Sato et al., 2010).

Together, the previous studies indicate that gaze direction matters for the recognition and evaluation of facial expressions. The current study was designed to determine how facial emotions, gaze direction, and gaze shifts interact to influence attentional processing of stimuli that are not in and of themselves social in nature. To this end, the first experiments tested the influences of angry and fearful expressions because those emotions are of particular theoretical significance in the approach-avoidance model. Predictions based on previous findings on emotion recognition were that angry faces would enhance attention capture by direct gaze and fearful faces would enhance attention capture by averted gaze, respectively.

Some previous work examined the link between emotion expression and gaze direction on a task that did not always (i.e., not in all conditions) involve emotion recognition. Ganel et al. (2005) argued for the interdependence of processing gaze direction and emotional expression. In their studies, participants either judged the emotion expression or the gaze direction of a face in a forced-choice paradigm. When judging emotion expression (happy or angry), participants responded by pressing one of two buttons, depending on the displayed emotion. Based on an interaction between gaze direction and emotion expression, the authors argued that judgements of emotion expression involve an obligatory computation of gaze direction. A follow-up study indicated that changes in head orientation could override the interdependency between gaze direction and emotion recognition (Ganel, 2011). Importantly, these studies did not test for the influence of emotion expression and gaze direction on attentional processing beyond these features, or for the additional effect of dynamic changes in gaze.

Finally, Stoyanova et al. (2007) examined whether a fearful expression and gaze direction of an observed face would influence attentional processes of peripheral locations in a gaze cuing paradigm. In particular, they used a peripheral cuing paradigm to determine whether attentional shifts to the periphery (as indexed by the presence and magnitude of the inhibition of return [IOR] effect) by a sudden onset stimulus would be reduced or abolished by a fearful expression on the observed face. The authors based this prediction on previous work suggesting that fear face processing in the brain has special priority (e.g., Vuilleumier, 2002) because a fear face provides a potentially salient cue for survival purposes (a threat in the environment). A single cue stimulus (face with a fearful expression or a luminance-matched scrambled non-face stimulus) was briefly flashed at one of two potential target locations and the target was randomly presented at the location of the cue or at an uncued location after the onset of the cue. The results failed to indicate a modulation of IOR effects between neutral and fearful faces. These findings raise the question whether emotion expressions could modulate the effects of gaze direction on attentional processes beyond tasks involving emotion recognition. Here, the present study sought to test this possibility.

The core task used in the present experiments was adopted from the studies in Böckler et al. (2014). This paradigm is suitable to investigate both direct gaze as well as sudden direct gaze (i.e., motion) effects and allows discriminating whether social cues like gaze direction and emotion expression are integrated. Across a series of experiments, different approach- and avoidance-oriented emotion expressions were employed in a between subject design (Pilot Experiment: neutral, angry, fearful; Main Experiment: neutral, angry, fearful, happy, disgusted). If gaze cues and emotional expression are not integrated and processed separately, then a pattern of RTs consistent with Böckler et al. (2014) should emerge for each of the emotional expressions. That is, the analysis of RTs to detect the target should reveal a main effect for gaze direction ($RT_{direct} < RT_{averted}$), a main effect for motion ($RT_{sudden} < RT_{static}$), but no interaction between gaze direction and emotion expression. If the emotion expression interacts with the gaze direction as may be predicted following the approach-avoidance model (Adams & Kleck, 2003, 2005; cf. Bindemann, 2008), then angry faces would elicit an enhanced direct gaze effect because anger and direct gaze both convey approach orientation. By contrast, the direct gaze effect should be reduced or even inverted on fearful faces, because they convey the incongruent orientation, avoidance. If the approach-avoidance model also holds for somewhat weaker, less prioritized emotion expressions, then happy faces (approach oriented) may enhance the direct gaze effect and disgusted faces (avoidance oriented) may reduce or diminish the direct gaze effect.

Method

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. All data and analysis code are available at OSF (https://osf.io/8t2kw/; Böckler, 2021). Data were analyzed using R and SPSS. Experiments in this study were not preregistered.

Participants

Pilot Experiment

To demonstrate the feasibility of the experiment, the task of Böckler et al. (2014, 2015) was employed using neutral, angry (approach-oriented), and fearful (avoidance-oriented) faces in a pilot experiment with 56 participants (neutral: n = 18, angry: n = 20, fearful: n = 18). The pilot experiment was conducted during an empirical-experimental seminar with a predetermined sample size of 60 participants. Average age was 21.0 years (SD =4.7 years; range 18−51). Participants in the different emotion expression groups matched comparing age, gender (91.1% female), and handedness (89.3% right-handed). Participants in the neutral condition were slightly older than the angry or fearful groups (M_{age} neutral = 23.8, angry = 19.8, fearful =19.6; F = 5.608; p = .006), but age did not affect RTs.

Main Experiment

G*Power 3.1 (Faul et al., 2007) was used to calculate the sample size needed to achieve 80% power, for an α of .05 with at least medium sized main effects (η_p^2 = .1; based on previous studies, e.g., Böckler et al., 2014) and medium sized within-between interactions in an ANOVA (η_p^2 = .1; based on results of the pilot experiment). One hundred seventy-two participants (neutral: n = 36, angry: n = 34, fearful: n = 34, happy n = 35, disgusted n = 33) were randomly assigned to expression condition. Participants chose between monetary compensation (7 Euro; 98.3%) or course credits. Average age was 24.6 years (SD = 5.5 years, range 18−61). The sample consisted of 78.5% female and 86.6% right-handed participants. Participants in the five emotion expression groups did not differ concerning age, gender, and handedness. Participants had normal or corrected-to-normal vision. They completed a written informed consent form, and an experimental investigator presented a standardized instruction. The local ethics committee at Würzburg University approved both experiments (EK-GZ 2017-04). All procedures complied with the ethical standards of the 1964 Declaration of Helsinki regarding the treatment of human participants in psychological research.

Materials

Stimuli of the Pilot experiment were selected from the Radboud Face Database (RaFD; Langner et al., 2010). Faces of the Radboud Face Database have been extensively validated and available with different head and gaze directions. Because sudden onset motion in the faces from this database (i.e., switching from averted to direct gaze faces and vice versa) seemed not to elicit apparent motion effects (cf., results), we generated and validated new stimuli that were more similar to the head orientation of the original faces (30°)[1] for the main experiment. In each experiment, pictures of one female person showing different emotional expressions and different gaze/head directions were used. Before the main experiment, basic demographic information (age, gender, handedness) were assessed and participants were asked to fill in two standardized questionnaires that measure different temperament factors (Adult Temperament Questionnaire [ATQ]; Evans & Rothbart, 2007; German version of Wiltink et al., 2006) as well as state and trait anxiety (State–Trait Anxiety Inventory [STAI]; Spielberger et al., 2015). Results of self-assessments are not presented here.

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[1] Emotion expressions were validated in an independent sample of N = 50 participants (M_{age} = 26.4, SD = 8.3; 76.0% female). Each participant rated all ten stimuli (averted and direct gaze for all five emotion expressions). Different emotion expressions as well as direct and averted gaze stimuli showed comparable high correct classifications (direct: 94.4%, averted: 93.6%; neutral: 97.0%, angry: 94.0%, fearful: 84.0%, happy: 100.0%, disgusted: 95.0%). Emotion detection accuracy did not differ between direct and averted faces ($t < 1$).Binomial tests indicate significant correct classifications better than chance (proportions $\geq$ 0.82; $ps < .001$). Confusion patterns of emotion expressions (fearful with disgusted, notably) matched those reviewed by Calvo and Nummenmaa (2016) but were not relevant for the investigation of gaze direction and emotion expression integration and are therefore not described in detail.

Procedure

The experimental design was based on previous studies conducted by Böckler et al. (2014, 2015). Here, we describe sample sizing and selection, all manipulations, all data exclusions (drop-out/outlier procedures) as well as all measures (Simmons et al., 2012). Participants sat at a distance of 80 cm in front of a 17-in TFT monitor (screen resolution: 1,680 × 1,050 pixels). Participants were instructed to place their index fingers of the left and right hand on the "S" and "H" buttons on a standard keyboard. Each trial consisted of two displays (see Figure 1). In the first display, participants saw four faces of the identical female around a fixation cross on a gray background. Participants were instructed to continuously look at the fixation cross and promptly return after drifting. All four faces showed the number "8" on their forehead. Each face sized 200 × 250 pixels (3.8 × 4.7° visual angle). Two faces showed direct gaze and the remaining two faces showed averted gaze (gaze direction). After 1,500 ms, the second display appeared. In the second display, two faces remained unchanged (one with direct and one with averted gaze) and two faces changed gaze direction (motion). Furthermore, the "8" on the forehead of the faces were replaced by one target letter ("H" or "S") and three distractors ("E" or "U"). Participants had to identify the target letter as fast as possible by pressing either the "S" or "H" button. Gaze direction (direct, averted), motion condition (sudden, static), target distractor combination ("S" "E," "S" "U," "H" "E," "H" "U"), and face position (top, right, bottom, left) were randomized across trials. In the pilot study and main experiments, emotion expressions (neutral, angry, fearful, happy, disgusted) were randomized between participants; hence any given participant perceived one and the same emotion expression throughout the experiment. After performing eight practice trials, participants started with the 384 experimental trials. An experimental instructor observed participants' performance during the example trials and repeated the instructions when necessary. Participants could take a break after half of the trials. PsychoPy (psychopy.org) was used for stimulus presentation and response recording. R toolboxes were used for data formatting. R and SPSS were used for data analyses.

Balancing gaze direction, motion, position, and identity of target and distraction letters and their combinations leads to 384 trials and an experiment duration of approximately 30 minutes. To prevent participant fatigue, the factor emotion expression was implemented between subjects. For every participant, emotion expression hence remained the same throughout the experiment.

Results

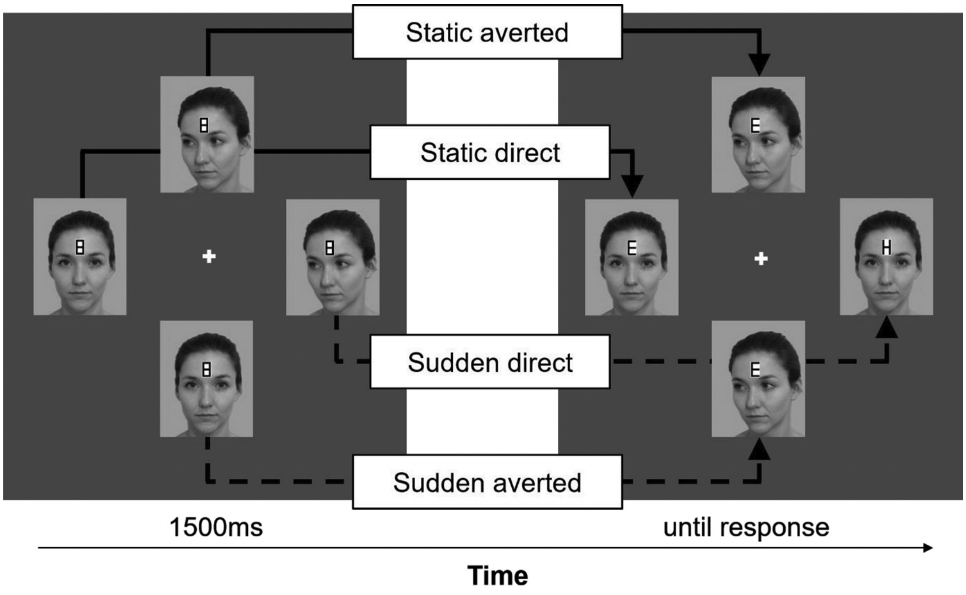
Pilot Experiment

RT was defined as the interval from the target display onset until the first response key was pressed. Gaze direction refers to the final orientation of target display faces, not to the original orientation presented at the beginning of the trial. Data for one participant (neutral condition) were eliminated due to overall high error rates (> 2 standard deviations). RTs of trials with incorrect responses were removed from the data set (2.89%, range = .78−6.51% across participants). In the next step, RT outliers above or below two standard deviations from the mean in each condition and participant were eliminated from the data set (3.96% of the data). Mean RTs and error rates for each emotion group were calculated and submitted to a series of analyses.

The first analysis involved a comparison of sudden direct gaze effects across all emotion expression groups using a three-factor mixed effects ANOVA including the between-subjects factor Emotion Expression (neutral, angry, fearful) and the within-subject factors Gaze Direction (direct, averted) and Motion (sudden,

Figure 1

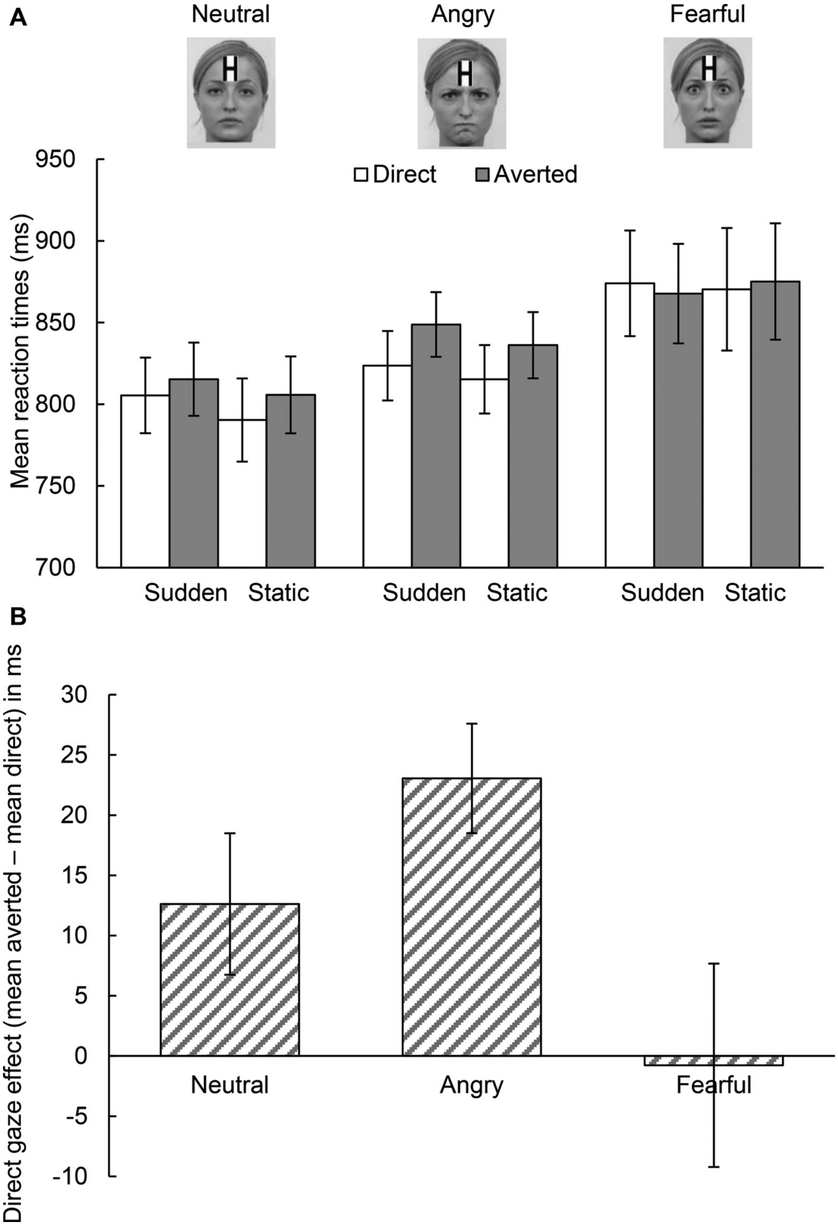
Illustration of an Example Trial With the Within-Subject Conditions Resulting From the 2 × 2 Design (Gaze Direction, Motion)



Note. The person displayed in this figure provided consent to publishing their pictures.

static). The second set of analyses consisted of separate 2 (Gaze Direction: direct, averted) × 2 (Motion: sudden, static) repeated measures ANOVAs on the data from each emotion group (see results in Figure 2A) to determine whether the direct gaze and the sudden onset motion effect emerged for neutral, angry and fearful faces. This analysis directly tested the a priori predictions regarding the presence versus absence of sudden direct gaze effects in neutral and angry versus fearful faces, respectively. Note that the analyses of error rates across both the first and second set of analyses did not reveal any statistically significant effects in any of the analyses reported below (all ps $> .115$, η_p^2s $\leq .080$), suggesting that the effects in RTs were not attributable to speed-accuracy trade-offs (see Table 1). Hence, only the results of the analysis of RT data are reported in the following sections.

Figure 2
Results of the Pilot Experiment



Note. Panel A shows the mean response times as a function of gaze direction and motion within each group. Panel B shows the mean direct gaze effect for each of the groups. The mean direct gaze effects were calculated by averaging across sudden and static faces in each direct and averted face and then subtracting the mean RTs for target on all direct gaze faces from the mean RT for target on all averted faces. The error bars represent standard error of the mean. Photographs displayed in this figure are taken from the Radboud Face Database (Langner et al., 2010).

Table 1

Mean Error Rates (%) and Standard Errors in Brackets for Gaze Direction (Direct, Averted) and Motion (Sudden, Static) for All Emotion Conditions for the Pilot Experiment and the Main Experiment

	Pilot experiment			Main experiment				
Condition	Neutral	Angry	Fearful	Neutral	Angry	Fearful	Happy	Disgusted
Sudden direct	3.55 [0.49]	2.86 [0.52]	2.84 [0.49]	4.58 [0.66]	3.88 [0.54]	3.28 [0.52]	2.85 [0.51]	2.78 [0.43]
Sudden averted	3.80 [0.90]	2.50 [0.29]	2.66 [0.53]	4.10 [0.59]	3.35 [0.46]	3.88 [0.59]	2.73 [0.39]	2.75 [0.44]
Static direct	3.19 [0.38]	3.23 [0.45]	2.20 [0.32]	5.27 [0.62]	3.73 [0.55]	4.10 [0.74]	3.77 [0.53]	2.49 [0.49]
Static averted	3.86 [0.67]	3.39 [0.39]	2.26 [0.51]	4.89 [0.82]	3.63 [0.60]	4.45 [0.69]	3.55 [0.53]	3.13 [0.40]

Results of the 3 (Emotion Expression: neutral, angry, fearful) × 2 (Gaze Direction: direct, averted) × 2 (Motion: sudden, static) mixed effects ANOVA revealed a main effect of Gaze Direction, $F(1, 52) = 9.86$, $p = .003$, $\eta_p^2 = .159$, with shorter RTs to targets appearing on direct gaze faces than on averted faces (see Figure 2A). The main effects for Emotion Expression, $F(2, 52) = 1.67$, $p = .198$, $\eta_p^2 = .060$, and Motion, $F(1, 52) = 2.36$, $p = .130$, $\eta_p^2 = .043$, were not statistically significant. The two-way interaction between Gaze Direction and Motion and the three-way interaction between Emotion Expression, Gaze Direction, and Motion were not statistically significant, $F\text{s} < 1$, $p\text{s} > 39$, $\eta_p^2 = .035$. Crucially, the interaction between Gaze Direction and Emotion Expression was significant, $F(2, 52) = 3.58$, $p = .035$, $\eta_p^2 = .121$, pointing toward a modulating effect of emotion expression on the effect of gaze direction. Further *t*-test comparisons (see Figure 2B) showed that direct gaze effects (RTs for averted gaze faces minus RTs for direct gaze faces) differed significantly between angry versus fearful faces, $t(36) = 2.54$, $p < .05$, $d_z = .83$, with a significantly larger direct gaze effect in angry faces. There were no statistically significant differences between neutral versus angry, $t(35) = 1.42$, $p = .166$, $d_z = .47$, or neutral versus fearful faces, $t(33) = 1.28$, $p = .21$, $d_z = .43$.

As we stated before, separate 2 (Gaze Direction) × 2 (Motion) analyses for each emotion group were also conducted. The results of the RT analysis for the neutral face group revealed a main effect for Gaze Direction, $F(1, 16) = 4.62$, $p = .047$, $\eta_p^2 = .224$, with shorter RTs to targets appearing on direct gaze faces than on averted faces. Neither the main effect for Motion, $F(1, 16) = 3.60$, $p = .076$, $\eta_p^2 = .183$, nor the interaction between Gaze Direction and Motion, $F(1, 16) = .22$, $p = .65$, $\eta_p^2 = .013$, were statistically significant. Thus, there was a direct gaze effect for neutral faces overall, but the motion effect was not statistically significant.

Similar to the results of the neutral face group, the results of the RT analysis for the group viewing the angry face revealed a main effect for Gaze Direction, $F(1, 19) = 25.73$, $p < .001$, $\eta_p^2 = .575$, with shorter RTs to targets appearing on direct gaze faces than on averted faces. There was no statistically significant main effect for Motion, $F(1, 19) = 1.57$, $p = .23$, $\eta_p^2 = .076$, and the interaction between Gaze Direction and Motion, $F(1, 19) < 1$, $p = .77$, $\eta_p^2 = .005$, was not statistically significant. Thus, there was a direct gaze effect for angry faces, but no significant effect of apparent motion.

Finally, the results of the RT analysis for the group that viewed the fearful face did not reveal any statistically significant effects: main effect of Gaze Direction, $F(1, 17) < 1$, $\text{p} = .93$, $\eta_p^2 < .001$; main effect of Motion, $F(1, 17) < 1$, $\text{p} = .82$, $\eta_p^2 = .003$; the interaction between Gaze Direction and Motion, $F(1, 17) < 1$, $p = .37$, $\eta_p^2 = .048$.

In sum, the results of the pilot experiment revealed that direct gaze effects were detected in both the neutral and angry face conditions, but not in the fearful face conditions. Further, direct gaze effects were significantly larger for angry than for fearful faces. This modulation of the direct gaze effect by emotion expression is broadly consistent with the approach-avoidance model (e.g., Adams & Kleck, 2005) that is based on the notion that direct gaze is inherently associated with angry faces (both expressing approach) and fear is inherently associated with averted faces (both expressing avoidance). In contrast to previous findings, there were no effects of face motion (static vs sudden faces) in these pilot data set. This lack of a motion effect suggests that the present set of stimuli might not have been sufficiently dynamic or realistic to generate a reliable bottom-up motion effect. This could be because the pictures in the Radboud Face Database were taken simultaneously from different angles rather than having the person look away and look toward the camera. To address this potential issue, the main experiment involved a new set of direct/averted face stimuli. Further, the main experiment additionally included happy (approach-oriented) and disgust (avoidance-oriented) emotions.

Main Experiment

Owing to error rates above 2 *SD*s of the group mean, data of six participants (three in the neutral condition and one in each of the angry, fearful, and happy conditions) were eliminated.[2] Afterward, trials with incorrect responses (3.66%, range = 0−12.50% across participants) were removed and RT outliers (RTs above 2 *SD*s of the condition mean) were eliminated from the data set (3.49% of the data). The neutral condition served to replicate previous findings, both in terms of the direct gaze effect and the motion effect (cf., Böckler et al., 2014, 2015, Pilot Experiment). The angry and the fearful condition served to replicate the pilot experiment using a larger sample size. Additional less threat-related emotion expressions, happy and disgusted, served to test whether the modulation of the direct gaze effect by emotion expression generalizes across other approach (happy) and avoidance (disgust) oriented emotions.

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[2] Identical statistical analyses with the whole study sample yielded similar results.

Consistent with the pilot experiment, the first analysis included the between-subjects factor Emotion Expression and was conducted to determine whether the relative magnitudes of direct gaze effects differed across emotions. Subsequent analyses directly tested whether the direct gaze and motion effects emerged in each emotion group and consisted of a series of 2 (Gaze Direction: direct, averted) × 2 (Motion: sudden, static) repeated measures ANOVAs. These repeated-measures ANOVAs determined whether or not the pattern of RTs consistent with the original study emerged in each of the emotion conditions. Results of direct gaze and motion effects for each emotion expression are displayed in Figure 3.

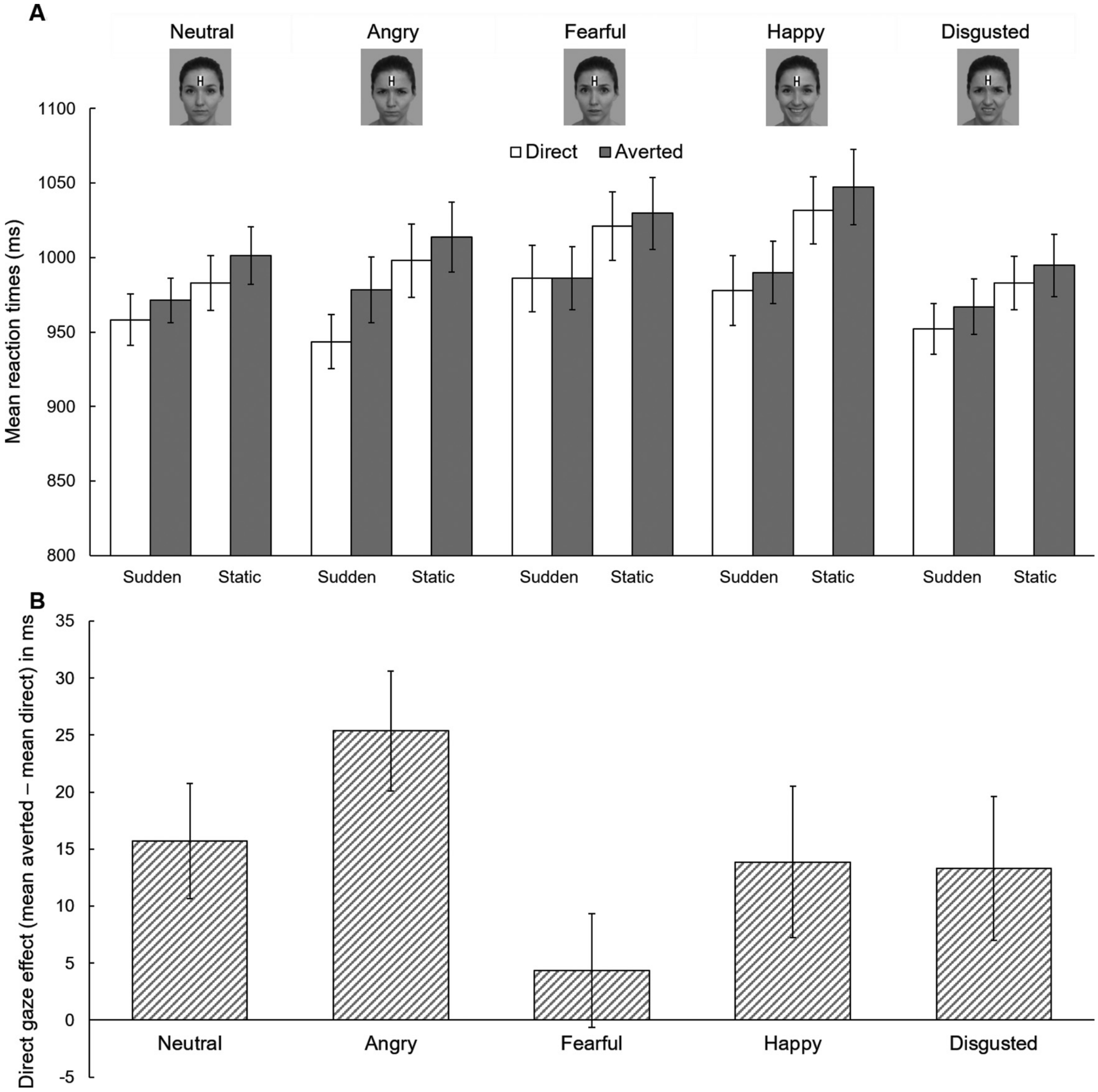
Between-Group Analyses

Neutral–Angry–Fearful Expressions

Before testing the main a priori predictions by determining the presence (or absence) of the sudden direct gaze effect within each of the emotion conditions, we first assessed the differences in the relative magnitudes of the sudden gaze effect across emotions. To this end, two between-subjects analyses were conducted. The first analysis (which was consistent with the pilot study) focused on the main conditions of the present study and involved a 3 (Emotion Expression: neutral, angry, and fearful) × 2 (Gaze Direction: direct, averted) × 2 (Motion: sudden, static) mixed effects ANOVAs with

Figure 3

Results of the Main Experiment



Note. Panel A shows mean response times (ms) for gaze direction (direct, averted) and motion (sudden, static) for all five emotion expressions. Panel B displays the mean direct gaze effects (ms) for all five emotion expressions. Standard errors of the mean bars are shown. The person displayed in this figure provided consent to publishing their pictures.

Emotion Expression as a between-subjects factor and Gaze Direction and Motion as within-subject factors. Post hoc analyses of relevant effects are described below.

The RT analysis revealed main effects of Gaze Direction, $F(1, 96) = 26.53$, $p < .001$, $\eta_p^2 = .217$, and Motion, $F(1, 96) = 49.87$, $p < .001$, $\eta_p^2 = .342$ (see Figure 3). There were shorter RTs to targets appearing on faces with direct gaze versus averted gaze and on suddenly moving versus static faces. Overall, mean RTs did not differ between emotions—the main effect for Emotion was not statistically significant ($F < 1$). Critically, and consistent with the results of the pilot experiment, the interaction between Gaze Direction and Emotion Expression was significant, $F(2, 96) = 4.26$, $p = .017$, $\eta_p^2 = .082$. The presence of the direct gaze effect in the neutral and angry face conditions (and the absence of the direct gaze effect in the fearful face condition) will be shown in the condition-specific analyses reported in the next section and will not be reported here. For now, the post hoc analyses of the Gaze Direction x Emotion Expression interaction focused on comparing the magnitudes of the direct gaze effects across groups. These *t*-test comparisons (see Figure 3) revealed that the direct gaze effects (RTs for averted gaze faces minus RTs for direct gaze faces) did not differ between angry and neutral, $t(64) = 1.33$, $p = .189$, or fearful and neutral faces, $t(64) = 1.60$, $p = .114$. As in the pilot experiment, the direct gaze effects did, however, differ significantly between angry and fearful faces, $t(64) = 2.90$, $p = .005$. The interaction between Emotion Expression and Motion, $F(2, 96) = .98$, $p > .38$, $\eta_p^2 = .020$, and the three-way interaction between Emotion Expression, Motion, and Gaze Direction, $F(2, 96) = 1.87$, $p > .15$, $\eta_p^2 = .038$, were not statistically significant suggesting that the effect of motion was not modulated by emotion.

Note that each of our participants saw one and the same emotional expression throughout the experiment. To explore whether effects of emotion expressions on the direct gaze effect wore out over time, we compared main and interaction effects between the first and the second half of the experiment by means of an ANOVA with the additional within-subject factor Experiment Half (first, second). In short, while participants became faster in the second half of the experiment, $F(1, 96) = 101.95$, $p < .001$, $\eta_p^2 = .515$, the effects of Gaze Direction, Emotion Expression, or their interaction were not significantly modulated by Experiment Half (Gaze Direction, Gaze Direction × Emotion Expression: Fs < 1, *p*s ≥ .23; Emotion Expression: $F(2, 96) = 2.52$, $p = .085$, $\eta_p^2 = .05$).

Error rate analyses showed a significant main effect of Motion, $F(1, 96) = 5.58$, $p = .02$, $\eta_p^2 = .055$, attributable to lower error rates for sudden onset motion faces. No other effects reached significance, *F*s < 2.38, *p*s > .098, η_p^2s ≤ .047. Hence, RT results do not seem to be caused by speed-accuracy trade-offs. In sum, the results of the combined analysis revealed a modulation of the direct gaze effect by emotional expression. Specifically, the direct gaze effect for the fearful face was significantly smaller than for the angry face. The effect of direct gaze for the neutral face was of an intermediate magnitude, but not statistically significant from those of the angry and fearful faces.

Neutral–Angry–Fearful–Happy–Disgusted Expressions

The second analysis compared the relative magnitudes of the gaze effects across all emotion conditions in an omnibus 5 (Emotion Expression: neutral, angry, fearful, happy, disgusted) × 2 (Gaze Direction: direct, averted) × 2 (Motion: sudden, static) mixed ANOVA. The results of this analysis on mean RTs revealed a main effect for Gaze Direction, $F(1, 161) = 32.51$, $p < .001$, $\eta_p^2 = .168$, and Motion, $F(1, 161) = 92.60$, $p < .001$, $\eta_p^2 = .365$. None of the interactions were statistically significant, *F*s < 1.72, *p*s > .149. Even though the interaction between Emotion Expression and Gaze Direction was not significant, post hoc comparisons were conducted to determine whether the direct gaze effect was different between the happy, the disgusted, and all other conditions (neutral, angry, and fearful). The comparison between the happy and disgusted emotion condition revealed that the magnitudes of the direct gaze effect were not statistically different from each other, $t(65) = .06$, $p = .95$. Hence, the increase of the direct gaze effect for approach-oriented emotions, as revealed for angry versus fearful faces, was not replicated for happy (approach-oriented) versus disgusted (avoidance-oriented) faces. The results of *t* test comparisons of all other faces revealed that, similar to the neutral face, the direct gaze effects for the happy and disgusted faces were intermediate and not statistically different from those of any other emotions (*t*s < 1.70, *p*s > .14).

Note that we again explored whether effects of emotion expressions on the direct gaze effect wore out over time by means of an ANOVA with the additional within-subject factor Experiment Half (first, second). This analysis was conducted to determine whether there was a change in RTs to the stimuli given that there was a repeated exposure to the emotion expression. Participants responded faster overall in the second half of the experiment, $F(1, 161) = 100.17$, $p < .001$, $\eta_p^2 = .384$, but the effects of Gaze Direction, Emotion Expression, or their interaction were not significantly modulated by Experiment Half, *F*s < 1, ps ≥ .47.

Error rate analysis revealed only a significant main effect of Motion, $F(1, 161) = 10.60$, $p = .001$, $\eta_p^2 = .062$. Static faces (3.90%) were associated with slighted higher error rates than sudden motion faces (3.41%). The effects of Gaze Direction, Emotion Expression, and the interactions were not significant, *F*s < 2.2, *p*s > .073, η_p^2s < .052.

Within-Group Analyses

Neutral Expression

Consistent with the pilot study, we also conducted separate analyses for each emotion group. The analysis of the mean RTs in the neutral expression group revealed a significant main effect of Gaze Direction, $F(1, 32) = 9.73$, $p = .004$, $\eta_p^2 = .233$ (see Figure 3), owing to shorter RTs to targets appearing on faces with direct gaze than with averted gaze. In addition, the main effect of Motion was significant, $F(1, 32) = 13.12$, $p < .001$, $\eta_p^2 = .291$, indicating the RTs for targets on sudden motion faces were shorter than for targets on static faces. This effect of motion suggests that the new stimuli successfully elicited an apparent motion effect, as observed in earlier studies. The interaction of Gaze Direction and Motion was not significant, $F(1, 32) < 1$, p = .601, $\eta_p^2 = .009$. Overall, this pattern of results is consistent with the previous studies on neutral faces (Böckler et al., 2014; Boyer & Wang, 2018; van der Wel et al., 2018).

Error rate analysis revealed a significant main effect of Motion, $F(1, 32) = 5.67$, $p = .023$, $\eta_p^2 = .150$. Here, static faces (4.69%) were associated with slightly higher error rates than sudden motion faces (4.34%). The effects of Gaze Direction and the interaction between Gaze Direction and Motion were not significant, Fs (1, 32) ≤ 1.44, ps $\geq .23$, η_p^2s $\leq .043$. Hence, because participants had both longer RTs and more errors to static than sudden faces, there does not appear to be a speed-accuracy trade-off (see Table 1).

Angry Expression

RT analyses revealed main effects of Gaze Direction, $F(1, 32) = 23.25$, $p < .001$ $\eta_p^2 = .421$, and Motion, $F(1, 32) = 15.82$, $p < .001$, $\eta_p^2 = .331$, owing to shorter RTs to targets appearing on direct gaze versus averted gaze faces, and on sudden motion faces than on static faces. The interaction between Gaze Direction and Motion was not significant, $F(1, 32) = 2.16$, $p = .151$, $\eta_p^2 = .063$.

Error rates analysis did not reveal any statistically significant effects, Fs(1, 32) < 1.10, ps $> .3$, η_p^2s$< .33$. Overall, these data are consistent with previous work and replicate the sudden direct gaze effect in faces with angry expressions.

Fearful Expression

The analysis of RTs revealed a main effect of Motion, $F(1, 32) = 23.79$, $p < .001$, $\eta_p^2 = .426$, owing to shorter RTs to targets appearing on moving versus static faces. Consistent with the pilot data and the avoidance-approach model, the main effect for Gaze Direction, $F(1, 32) = .77$, $p = .39$, $\eta_p^2 = .023$ was not significant. There was no interaction between Gaze Direction and Motion, $F(1, 32) = .75$, $p = .39$, $\eta_p^2 = .023$.

Error rates analysis did not reveal any statistically significant effects, Fs(1, 32) < 2.76, ps $> .10$, η_p^2s $< .080$. Overall, although the effect of motion emerged, these data are generally consistent with the pilot study and reveal that the sudden direct gaze effect does not emerge in faces with fearful expressions.

Happy Expression

RT analyses revealed main effects of Gaze Direction, $F(1, 33) = 4.38$, $p = .044$, $\eta_p^2 = .117$, and Motion, $F(1, 33) = 33.73$, $p < .001$, $\eta_p^2 = .505$, owing to shorter RTs to targets appearing on direct gaze versus averted gaze faces, and on sudden motion versus static faces. The interaction between Gaze Direction and Motion was not significant, $F(1, 33) < 1$, $p = .829$, $\eta_p^2 = .001$.

Error rates analysis revealed a significant main effect of Motion, $F(1, 33) = 8.31$, $p = .007$, $\eta_p^2 = .201$. Here, static faces (3.25%) were associated with slighted higher error rates than sudden motion faces (2.79%). The effects of Gaze Direction and the interaction between Gaze Direction and Motion were not significant, Fs < 1, ps $> .43$, η_p^2s $< .020$. Hence, because participants had both longer RTs and more errors to static than sudden faces, there does not appear to be a speed–accuracy trade-off. Overall, these data are consistent with previous work and replicate the sudden direct gaze effect in faces with happy expressions.

Disgusted Expression

RT analyses revealed main effects of Gaze Direction, $F(1, 32) = 4.46$, $p = .043$ $\eta_p^2 = .122$, and Motion, $F(1, 32) = 11.44$, $p = .002$ $\eta_p^2 = .263$, owing to shorter RTs to targets appearing on direct gaze versus averted gaze faces, and on sudden motion faces than on static faces. The interaction between Gaze Direction and Motion was not statistically significant, $F(1, 32) < 1$, $p = .774$, $\eta_p^2 = .003$.

Error rates analysis did not reveal any statistically significant effects, Fs(1, 32) < 1.63, ps $> .21$, η_p^2s $< .048$. Overall, these data reveal that the sudden direct gaze effect emerges in people who view faces with expressions of disgust.

Discussion

Previous research indicated that direct gaze (e.g., Argyle & Cook, 1976; Böckler et al., 2014; Boyer & Wang, 2018; Conty et al., 2016; Kleinke, 1986; Senju & Johnson, 2009; van der Wel et al., 2018) as well as emotion expressions (e.g., Lundqvist & Öhman, 2005; Öhman et al., 2001) play a fundamental role in social attention. Addressing the interplay of those social cues, several studies demonstrated effects of observed gaze direction on the evaluation and recognition of emotion expressions on faces (Adams & Kleck, 2003, 2005; Ganel et al., 2005; N'Diaye et al., 2009; Stoyanova et al., 2007). The current study addressed how gaze cues and facial emotion expressions interact to influence attentional processing. We did so by asking participants to identify nonsocial target letters presented on the foreheads of faces (one face per trial) while gaze direction, gaze shifts, and emotion expression on these faces were manipulated.

Previous work (Böckler et al., 2014, 2015; van der Wel et al., 2018) found a direct gaze effect and a motion effect, such that targets on faces with direct rather than averted gaze, and faces with dynamic gaze shifts rather than static gaze, showed processing advantages. Importantly, results of the current study generally showed a robust direct gaze effect. Given that the present study used two distinct stimulus sets that also differed from the set used in the original study, this finding provides a conceptual replication of previous work. In addition, novel face stimuli of the main experiment successfully induced an apparent motion effect, such that targets presented on faces with dynamic gaze shifts showed a processing advantage over targets presented on faces with static gaze.

In line with the *shared signal hypothesis* (Adams & Kleck, 2003, 2005), the present study demonstrates that emotion expressions can modulate the direct gaze effect. The present results showed an enhanced direct gaze effect in angry compared with fearful faces. Angry faces with direct gaze have repeatedly been found to most intensively signal threat directed at the observer. In contrast, fearful faces with averted gaze are assumed to indicate an external source of threat in the immediate environment of the observer (e.g., Adams & Kleck, 2005; Caruana et al., 2019; Sander et al., 2007). Although we found an enhanced direct gaze effect for angry emotion expressions, there was no response time benefit for fearful faces showing averted gaze—in fact, there was no difference between averted and direct gaze in fearful faces. Hence, although the direct gaze effect was diminished in fearful faces, the avoidance-oriented expression of fear did not seem strong enough to create an averted gaze advantage. The enhanced direct gaze advantage for angry faces and the entirely abolished effect of direct gaze in fearful faces suggest that the facial expression of anger and fear may have activated basic threat-related behavioral tendencies and shape the processing of gaze information (Cacioppo & Gardner, 1999).

The pattern of results for angry and fearful faces also supports the shared signal hypothesis by indicating that different facial features might share processing capacities. This idea is further emphasized by findings from brain imaging studies showing that gaze direction and emotion expressions activate distinct, though partially overlapping, neural systems with the right superior temporal sulcus (STS) representing an area responsible for the integration of both signals (Engell & Haxby, 2007).

Although the conceptualization of emotion expressions along the approach-avoidance dimension neatly fits the pattern of results for angry and fearful faces, this is not the case for other emotions. According to the shared signal hypothesis as outlined in Adams and Kleck (2003, 2005), congruency of gaze direction and emotion expression in terms of approach versus avoidance should lead to processing benefits, independent of the specific emotion that is expressed. According to this framework, the direct gaze effect should have been enhanced in happy (approach-oriented) as compared with disgusted (avoidance-oriented) faces. By contrast, the present results revealed a direct gaze effect that was equally large for happy, neutral, and disgusted faces. The absence of a statistical difference between direct gaze effects in neutral, happy, and disgusted faces is mirrored by highly similar magnitudes of direct gaze effects in all three conditions and is unlikely to be due to insufficient statistical power.

Given that the present experiments demonstrate that emotion expression can, in principle, modulate direct gaze processing, the question arises why this was not observed for faces displaying happiness or disgust. One possible explanation might be that facial expressions of disgust and anger were confused, a pattern that has been repeatedly reported in the literature on facial expression discrimination (e.g., 3–13% in Palermo & Coltheart, 2004; Tottenham et al., 2009). However, results of the emotion expression validation render this explanation unlikely, as accurate recognition of disgusted faces was extremely high and only very small confusions with angry (4% direct, 4% averted faces) and fearful emotion expressions (4% direct, 8% averted faces) were observed.

Another explanation is linked to the evolutionary advantages of fast and reliable emotion recognition: Emotions prepare the organism to respond adaptively to environmentally recurrent stimuli (Shariff & Tracy, 2011). Threat related emotions, namely anger and fear, entail a maximum of survival relevance (Ortony & Turner, 1990) by eliciting *fast* attentional and behavioral responses (for an overview see Vuilleumier, 2002). Adequate behavioral response to nonthreat related emotions like happiness and disgust also brings evolutionary advantages for example, social bonding following happy expressions (Rychlowska et al., 2017) or contamination avoidance in response to disgusted expressions (Chapman & Anderson, 2012; Oaten et al., 2009). Critically however, the latter responses do not require similarly fast visual processing and perception. Threat related emotions might therefore have a stronger behavioral activation tendency than nonthreat related emotions (Vuilleumier, 2002). This framework may explain why the approach avoidance paradigm would only be suitable to explain some modulatory effects of emotion expressions on attention capture by direct gaze.

Although some emotion expressions modulated the direct gaze effect, we did not find an influence of emotion expression on the effect of sudden onset motion. This differential susceptibility of the direct gaze and sudden onset motion effects to manipulations of the stimuli suggest that they rely on distinct processing channels (see also Böckler et al., 2014; Pitcher & Ungerleider, 2021). An issue that should be clarified in future studies is how the effects of direct gaze and of sudden onset motion depend on the extent of low-level pixel-based change between the direct and averted pictures. It could be generally advisable to establish experiments that use various different facial identities within one task to make results of a given experiment less dependent on the specifics of the employed picture.

Because a modulatory effect of emotion was only found for threat-related emotions, it would be of interest to investigate other basic emotions such as sadness and surprise to further scrutinize the approach avoidance concept in the context of facial feature integration. An alternative explanation for the emotional modulation might be associated with attributions of social dominance (Jones et al., 2010). For example, direct gaze and angry as well as happy emotion expressions are both associated with perceptions of trait dominance and dominance associated reactions (Hess et al., 2000; Tang & Schmeichel, 2015). Effects of dominance have previously been reported for gaze following (Jones et al., 2010), but it is yet unknown whether direct gaze effects are also moderated by manipulation of dominance.

In the present study, emotion expression remained constant throughout the experiments (as emotion expression was a between-subjects factor) and was visible before gaze direction shifts and target appearance in every trial. Thus, participants processed emotion expressions before gaze direction and sudden onset motion elicited their influence. Despite this resulting in a predictable emotion display for each participant, the results still indicated some significant data patterns that were in line with our predictions (namely for angry and fearful expressions). Conceivably, running the emotion expression manipulations within participants should yield stronger effects, possibly also for happy and disgusted expressions.

Finally, future studies should target the temporal integration of gaze and face information. To investigate *when* gaze direction and emotion expression are integrated in the course of visual processing, information on gaze direction and emotion expressions could be presented simultaneously. This should shed light on the question whether gaze and expression cues are integrated at early processing stages of visual processing (e.g., Adams & Kleck, 2005) or whether they interact only later in visual processing (e.g., Bindemann et al., 2008). Because we presented emotion expressions before (sudden onset) direct gaze, our current results do not provide a straightforward basis to differentiate whether gaze and face information are integrated early (Adams & Kleck, 2003) or later (Bindemann et al., 2008). However, they can be interpreted within the context of an account provided by Bindemann et al. (2008). In their account, eye gaze is analyzed faster than facial expression. For averted gaze, this implies that visual attention is allocated away from the target face, impairing emotion categorization. In our paradigm, it is conceivable that the impact of this diverted allocation of attention may wane by the time the target letter on a face is identified. The added time required for the process of finding the target location and then categorizing it may allow for the emotion expression to shape gaze processing in our task. In other words, next to showing only one emotion expression per participant, our task differed in two further respects from both Adams and Kleck (2003) and Bindemann et al. (2008); first, participants responded by categorizing a target letter on a face, rather than by categorizing the expressed emotion. Second, participants needed to find the location of the target letter in a set of four faces, rather than just one face. Both of these differences slowed down reaction times and may thus have provided ample time for emotion expression and gaze to interactively influence reaction times. In line with this possibility, it should be noted that whereas average reaction times in Adams and Kleck (2003; Experiment 2) as well as in the replication attempts by Bindemann et al. (2008; their first four experiments) were in the 500–700 ms range, average RTs in our paradigm were around 200–300 ms slower. Interestingly, when Bindemann et al. (2008) increased task complexity in their paradigm by blending expressed emotions (Experiment 5; see also Adams & Kleck, 2003; Experiment 1) or by including happy, sad, angry, and fearful faces across trials within an experiment (Experiment 6), their results showed a slowing in reaction times. Once this occurred, results suggested an interactive influence of gaze direction and expressed emotion for emotion categorization.

In closing, then, these observations suggest that it would be prudent in future studies to (a) examine the time course of gaze, motion, and emotion processing in our paradigm when their presentation temporally co-occur and (b) examine the impact of a host of factors related to task complexity, including what participants respond to (target letters or expressed emotions), how many possible target locations there are, and whether different emotion expressions are intermixed or blended within the same experiment. Answers to these issues would enhance our understanding of the influence of gaze and emotion expression on attentional processing of facial expressions as well as nonsocial targets (e.g., letters) appearing on the face.

To conclude, the present study demonstrates a modulation of the direct gaze effect by emotion expression for some, but not all, emotions. Threat-related, in contrast to nonthreat, emotion expressions such as anger and fear seem to be powerful enough to shape the processing of gaze direction, a pattern that is in line with the shared signal hypothesis. The integrating of gaze direction and emotion expression could support adaptive human behavioral responses to our (social) environment.

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