The Shared Signal Hypothesis in the Visual Search Paradigm with Real Faces

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Abstract

According to the shared signal hypothesis, the perception of faces is enhanced when the emotion, gaze, and motivation are congruent. When threatening emotions are congruent with gaze and motivation, it becomes relevant to the observer. For example, an angry face looking at you is a direct threat whereas a fearful face looking away signals threat in the environment relevant to you. Visual search studies using faces have yielded mixed results and most studies have been compromised by low ecological validity. This study aims to tackle this limitation by using real faces. 32 non-clinical participants completed a visual search task with multiple trials representing each combination between the levels of emotion (angry, fearful), gaze (direct, averted) and set-size (4, 8, 16). Gaze data were retrieved with an eye-tracker and trait-anxiety was measured with a questionnaire afterwards. Multilevel models were performed to assess differences in response times between all possible combinations. The results showed that the shared signal hypothesis was only true for anger. Furthermore, fearful faces were found faster than angry faces and once found, they were also faster identified as the emotional target. Lastly, trait-anxiety levels did not moderate reaction times for self-relevant threat, but did bias the individual to direct gazes compared to indirect gazes. Limitations include the lack of an emotional intensity measurement of the stimuli and the small sample of models used for the stimuli. The current study is a great stepping stone for future research investigating the ecological validity of attentional biases to self-relevant facial threat.

The Shared Signal Hypothesis in the Visual Search Paradigm with Real Faces

To select useful information to guide our behaviour, many attentional and pre-attentional mechanisms are involved. Pre-attentional mechanisms process the accumulation of information from the environment subconsciously, after which the attentional mechanisms process and analyse the information with the highest salience or relevance to the observer (Heijden, 1991). Throughout evolution, these mechanisms are shaped to maximise our chance for survival. Attention is biased towards threats that are relevant to the observer; Muench et al. (2016) found that self-relevant threat enhances early processing of faces.

A mechanism of the attentional bias towards this self-relevant facial threat can be explained by the shared signal hypothesis, which states that the perception of an emotion is enhanced when the perceived emotion and gaze are congruent to the underlying behavioural motivation (Adams & Kleck, 2005). According to the motivational approach and avoidance model, emotions reflect two basic motivational systems: the appetitive and the aversive systems. These systems underlie approach and avoidance behaviour, respectively (Lang et al., 1998). More specifically, happiness, surprise, and anger are classified as approach emotions, as they indicate a drive of the individual toward environmental stimuli, whereas sadness, fear, and disgust are associated with avoidance behaviours, because they tend to lead the individual away from the environmental sources of aversive stimuli (Alves et al., 2008). Thus, anger in someone else tells the observer that that someone has an approaching behavioural motivation, whereas fear in someone else indicates an avoiding behavioural motivation. Moreover, the perception of facial emotional displays is influenced by gaze, as someone’s gaze indicates the target of actions implied by the emotion (Emery, 2000). For example, an angry person will direct their gaze toward stimuli they want to approach. If this gaze is towards the observer, this angry person might be a direct threat to the observer, whereas an averted gaze signals that the angry person will approach something or someone else. Vice versa for fearful faces; an observer will not perceive a fearful person looking at the observer as a threat, as fear is associated with avoidance. A fearful person looking away, however, might signal threat in the environment that could also be a threat to the observer. Emotion, gaze, and behavioural motivation thus share the same signal when they are congruent, which causes a faster detection of self-relevant threats. Adams and Kleck (2003) tested this shared signal hypothesis by asking participants to indicate whether a face on the screen was displaying anger or fear. They indeed found that angry faces were recognised faster when presented with a direct gaze compared to an indirect gaze and vice versa for fearful faces (Adams & Kleck, 2003).

The effect of self-relevant threat to attentional processes has also been tested in a crowd, using the visual search paradigm. In an evolutionary perspective, the interpretation of faces in a crowd could be relevant to one's survival (Öhman et al., 2001). A single hostile face among an otherwise peaceful crowd calls for caution because it might indicate a threat that the whole group could turn against you. This means that focusing attention on group members with a discrepant facial expression might be an important functional strategy of potential evolutionary basis (Öhman et al., 2001). Many studies have found the anger superiority effect, also known as the face in the crowd (FITC) effect, which states that angry faces are detected more efficiently among a crowd of distractor faces compared to nonthreatening faces (e.g., Calvo et al., 2006; Mather & Knight, 2006; Öhman et al., 2001). However, these effects are mostly found when schematic faces were used as stimuli, whereas the use of real faces demonstrated inconsistent results; with findings confirming the anger superiority effect (e.g., Horstmann & Bauland, 2006; Pinkham et al., 2010; Pitica et al., 2011), findings without a significant difference between threatening and nonthreatening faces (e.g., Williams et al., 2005) and findings of faster detection of nonthreatening (happy) faces instead of threatening (angry) faces (e.g., Juth et al., 2005). Furthermore, most studies compare angry faces to happy faces, both being approaching emotions (e.g., Fox et al., 2000; Hansen &

Hansen, 1988; Juth et al., 2005). Only few studies have looked into the difference between approaching and avoiding emotions, among which Williams et al. (2005). Although they hypothesized that threatening faces (angry, fearful) would be located faster than nonthreatening faces (happy, sad), they also found that approaching emotions (angry, happy) were located faster than avoiding emotions (fearful, sad). Overall, fearful faces have not been widely researched with visual search studies, even though fearful faces signal potential threat in the environment (Wieser & Keil, 2014).

The mixed results of studies using real faces might suggest that it is not the emotional expression that causes a more efficient search of emotional faces, but the (un)related low-level perceptual features (Savage et al., 2013). For example, Savage et al. (2013) found that the choice of stimulus materials is important in finding either an angry superiority effect or a happy superiority effect. To control for low-level facial features, Terburg et al. (2018) used averaged faces to filter out as many salient details as possible and to make the stimuli more similar to each other. By controlling for low-level image-statistics, the researchers could ascribe any effects on the emotional expression. Indeed, congruent expression × gaze combinations were still found faster compared to incongruent expression × gaze combinations, proving the shared signal hypothesis. However, they found an unexpected combination of effects. On one hand, angry faces elicited more search-efficiency than fear, as angry faces had a lower search slope than fearful faces. That is, when there are more distractors, the increase in search time for fearful faces was higher than the increase in search time for angry faces. On the other hand, fearful faces were more rapidly found when there are fewer distractors. In a follow-up study, Terburg et al. (2018) isolated the true search time by splitting the reaction time into search time, the latency until first target fixation, and decision time, the latency from first target fixation until manual response. By doing so, the researchers hoped to explain the previously found unexpected combination of effects. They, again, found that a fearful face is found faster with few distractors and anger is found faster with many distractors. Additionally, the difference in reaction time between angry and fearful faces increased with the amount of distractors. By exploring the search and decision time, they found that this increase in difference between reaction times of angry and fearful faces was caused by an anger search efficiency and a fear decision advantage. That is, participants could locate the angry faces faster, but they could more easily distinguish fearful faces from the neutral distractor faces compared to angry faces. Where the search time increases with the amount of distractors, the decision time stays roughly the same, causing the increase in reaction time differences between the two emotional stimuli. However, a considerable limitation to this study is the low ecological validity, as multiple faces averaged into one will not be encountered in daily life.

To avoid this limitation, the current study will use real faces as stimuli in the visual search task. Consequently, the scientific relevance of the current study is to fill in the gap in the literature on visual search studies comparing approaching and avoiding emotions, including fearful faces, and using photographs. Therefore, the main research question involves the extent to which the self-relevant facial threat effect exists when real faces are used in a visual search task. The first hypothesis reflects the shared signal hypothesis and states that angry faces with a direct gaze and fearful faces with an averted gaze will be detected faster than angry faces with an averted gaze and fearful faces with a direct gaze when real faces are used in a visual search task. The second hypothesis regards the search efficiency: angry faces are expected to have a lower search slope compared to fearful faces, independent of (in)congruence. The third hypothesis states that fearful faces require less decision time compared to angry faces.

In addition, the perception of emotional facial expressions is moderated by individual differences in the observer. A FITC study by Juth et al. (2005) compared participants with high social anxiety with controls. They found that people with high social anxiety showed more effective detection of angry faces than happy faces, compared to the control group, when using schematic faces. When they used real faces, they found that effects of social anxiety levels were small and inconsistent. Ashwin et al. (2012) replicated the finding with schematic faces and showed that individuals with high levels of anxiety display enhanced attentional biases towards threatening information compared to healthy controls.

By using real faces and taking trait-anxiety into account as a moderator, the current study is scientifically and clinically relevant. There is growing evidence that attentional biases to emotional stimuli could contribute to the onset and prevalence of anxiety disorders (Lau & Waters, 2016). By investigating the relationship between trait-anxiety and attentional bias, the mechanisms of anxiety disorders will be better understood. This might aid the development of behavioural treatments, e.g. by incorporating the explanations of these mechanisms in the psychoeducation of patients with an anxiety disorder. Conversely, tests of attentional bias could be used to detect vulnerability for developing anxiety disorders. Therefore, the extent to which trait-anxiety moderates reaction times (RTs) in the visual search will be investigated as well. The fourth and final hypothesis, then, states that trait-anxiety levels will negatively correlate with RTs for self-relevant facial threat.

Method

Participants

The study population consisted of 32 non-clinical participants (N = 32). Only participants with significant mental health issues were not eligible for inclusion. The recruitment of participants started on 25th of November 2020 and ended on 10th of February 2021. The collection of data took place between the 1st and 11th of February 2021 in a laboratory room at Utrecht University. 34% of the participants were recruited through SONA systems, a platform for students of Utrecht University to sign up for studies as participants (*n*

= 11). These participants received participation credits, which are needed to complete their bachelor's programme. 66% of the participants were recruited from the direct environment of the researcher (*n* = 21), making the total sample a nonprobability and convenience sample. The participants were on average 21 years old (*M* = 21.00, *SD* = 1.48) and, of the total sample, 41% was male (*n* = 13) and 59% was female (*n* = 19). One participant completed 309 trials of the 384, as the E-Prime software stopped working during the visual search experiment. The recorded data of this participant were included in the analysis.

Research Design

The research design has been replicated from the study of Terburg et al. (2018). RTs were measured in a visual search task in which the visual field fitted a maximum of sixteen faces, with four rows and four columns. The task had three set-sizes; with four, eight or sixteen faces. Each set-size occurred in four blocks of 32 trials each, resulting in 128 trials for each set-size, and resulting in 384 trials divided in twelve blocks in total. The order of the twelve blocks was counterbalanced.

The target stimuli were either 1) male or female, 2) angry or fearful, 3) with a direct or an averted gaze, and 4) of eight different identities. These four variables resulted in sixty-four combinations, of which each was presented twice within each set-size. All four emotion × gaze combinations occurred eight times on each possible target location within each set-size. The averted gaze was a random pick between left and right.

The distractors were neutral faces, either male or female, with either a direct or an averted gaze and being of eight different identities. Each gender was equally frequent within each trial, the gaze for each distractor was randomly picked from the options direct, left, and right, and identity was randomly picked and could not appear twice in a trial. All faces, including the target face, were randomly jittered.

The RTs were split into two components: the search time (ST) and the decision time (DT). Both were compared over the conditions, as well as the total RT, to test the first three hypotheses. For the fourth hypothesis, trait-anxiety was added as a continuous predictor in the main analyses. Trait-anxiety was measured after the visual search task to prevent any influence on the visual search task.

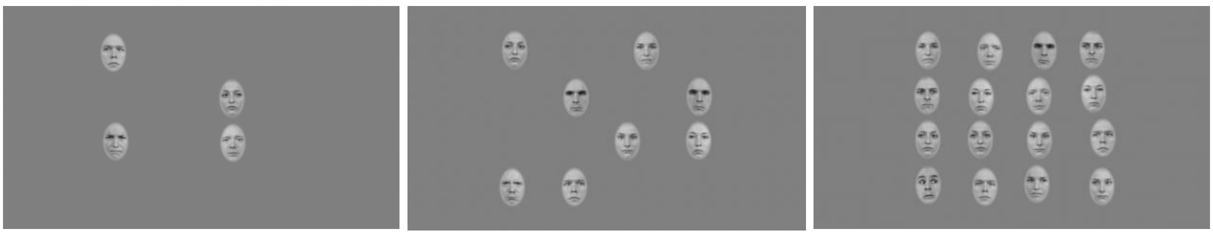
Materials

Faces

The faces for the target stimuli were retrieved from the Radboud Faces Database (RaFD; Langner et al., 2010). Photographs were chosen from Caucasian models, based on the subjective judgment of the researcher and her supervisor on the clarity of the emotional expression and on distracting features of the face. Faces showing hair and teeth were excluded as much as possible. The selection resulted in four female and four male models, of whom the photographs have been mirrored to create eight female and eight male identities. Furthermore, the photographs have been cropped, centred, grey-scaled and corrected for luminance, as was done in the study of Terburg et al. (2018). See Figure 1 for examples.

Figure 1

Examples of Trials



Reaction Times

The visual search was conducted on a computer using the E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA). The RT is the time of the onset of the visual field until the participant pressed a button on the keyboard. As mentioned earlier, ST is the time until the participant lands their eyes on the target stimulus for the first time and DT is the time from the first target fixation to when the participant pressed the button declaring they found the target face. These were recorded using an eye-tracker, the Tobii TX300, with a sampling rate of 300 Hz, a timestamp precision of < 0.1 ms and a gaze precision of 0.07º (Tobii Technology AB, 2010).

Trait-Anxiety

To measure trait-anxiety, the trait-anxiety (T-anxiety) scale of the State-Trait-anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was used. The T-anxiety scale consisted of 20 items which have to be answered on a 4-point Likert scale (1 = Almost Never, 4 = Almost Always). Items include: *"I worry too much over something that really doesn't matter"*. The total score is the sum of the answers on the Likert scale, ranging from 20 to 80, where higher scores indicate greater trait-anxiety. Internal consistency coefficients have ranged from .86 to .95 and construct and concurrent validity are attested by considerable evidence (Spielberger, 1989). In the current study, the Cronbach's alpha coefficient for trait-anxiety was $\alpha = .89$.

Procedure

The research protocol was approved by the *Faculty Ethical Admission Committee* through the *Student Ethics Review & Registration Site* of Utrecht University. All participants provided written informed consent. This research was conducted in English and took approximately an hour per participant. First, the visual search task began with the following instruction: *"Find the emotional face, look at it, and press the button"*, after which sixteen practice trials started. These practice trials had a set-size of sixteen, in which emotion × gaze combinations were equally represented and with a random pick of location, gender and identity. After these trials, the participant had to complete the 384 trials in twelve blocks. After each block, the participant got the chance to take a break. Before each trial, there was a gaze-contingent central fixation-cross, on which participants had to fixate in order to start the trial. After each trial, there was a gaze-contingent visual feedback in which the fixated face was outlined in green if it was the target and in red if it was a distractor. After the visual search task, participants filled in the T-anxiety scale of the STAI.

Statistical Analyses

First, the data retrieved from the eye-tracker were prepared. Gaze fixations were defined as the average location of all subsequent gaze points within 1.5° visual angle, with a minimal duration of 100 ms. This was done using an in-house code of the software MATLAB. Then, all trials with less than 80% valid eye-tracking data, e.g. blinks, were excluded, similar to the study by Terburg et al. (2018).

To test the first hypothesis, a multilevel model was conducted to compare RTs between the repeatedly measured task conditions: the different combinations of set-size, emotion, and gaze. This analysis was performed two more times, with ST and DT as the continuous dependent variables to test the second and third hypotheses. When effects were significant, post-hoc analyses were performed. To test the fourth hypothesis, trait-anxiety was added to all three analyses as a continuous predictor. When effects were significant, simple effects analyses were conducted. For all analyses, jamovi 1.2.27 was used and a significance level of $\alpha = .05$ was chosen.

Results

The 32 participants yielded 11505 trials in total, of which 4.3% were left out because they contained less than 80% valid eye-tracking data, leaving 11009 trials for analyses (N = 11009). The models included a random intercept across participants, improving the model-fit for RT, ST, DT, with and without trait-anxiety as continuous predictor, $p < .001$ for all.

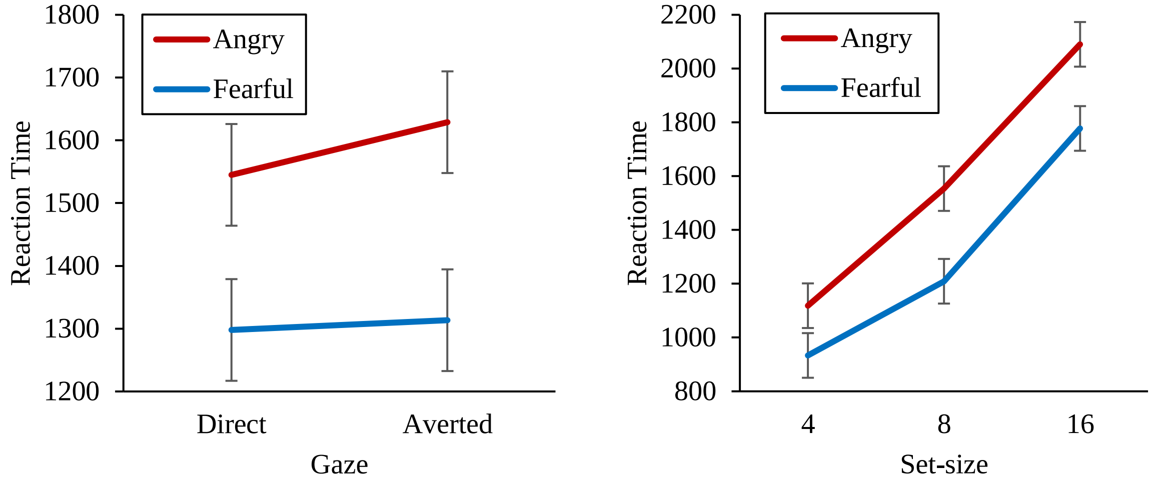
Shared Signal Hypothesis

The first hypothesis is that congruent faces (angry faces with a direct gaze and fearful faces with an averted gaze) will be detected faster than incongruent faces (angry faces with an averted gaze and fearful faces with a direct gaze). Significant effects were found for the main effects of emotion, gaze and set-size, $F(1, 10966) = 410.94$, $F(1, 10966) = 12.85$, and $F(2, 10967) = 1428.70$ respectively, $p < .001$ for all. Post-hoc tests, firstly, showed that fearful faces were found faster than angry faces ($M_{difference} = -281.24$, $SE = 13.87$), $t(10966) = -20.27$, $p < .001$. Secondly, they showed that faces with a direct gaze were found faster than faces with an averted gaze ($M_{difference} = -49.72$, $SE = 13.87$), $t(10966) = -3.58$, $p < .001$. Thirdly, the post-hoc tests showed that a set-size of four resulted in a faster RT compared to a set-size of eight ($M_{difference} = -355.53$, $SE = 16.84$), $t(10966) = -21.11$, $p < .001$, and compared to a set-size of sixteen faces ($M_{difference} = -907.72$, $SE = 17.09$), $t(10967) = -53.13$, $p < .001$. The RT was also significantly faster for a set-size of eight compared to a set-size of sixteen faces ($M_{difference} = -552.19$, $SE = 17.06$), $t(10967) = -32.36$, $p < .001$.

Besides these main effects, there were two significant interaction effects found for RT. The data showed a significant interaction effect between emotion and gaze, $F(1, 10966) = 6.07$, $p = .014$. The post-hoc comparisons indicated that angry faces with a direct gaze have faster RTs than angry faces with an averted gaze ($M_{difference} = -83.91$, $SE = 19.76$), $t(10966) = -4.24$, $p < .001$. However, fearful faces with an averted gaze did not have significantly faster RTs than fearful faces with a direct gaze ($M_{difference} = 15.53$, $SE = 19.47$), $t(10966) = 0.80$, $p = .425$. Thus, congruent faces were found faster than incongruent faces for only anger, not fear, see Figure 2. Therefore, these results partially confirm the first hypothesis.

Figure 2

Changes in Reaction Times for Angry and Fearful Faces as a Function of Gaze and of Set-size



Note. The 95% confidence intervals are represented in the figure by the error bars attached to the estimated marginal means.

The second significant interaction effect found was between emotion and set-size, $F(2, 10966) = 12.66$, $p < .001$. Upon analysing the post-hoc comparisons, it seems that fear is found faster than anger in all set-sizes: four faces ($M_{difference} = -184.83$, $SE = 23.85$), $t(10966) = -7.75$, eight faces ($M_{difference} = -345.13$, $SE = 23.78$), $t(10966) = -14.51$, and sixteen faces ($M_{difference} = -313.78$, $SE = 24.45$), $t(10966) = -12.83$, $p < .001$ for all, see Figure 2. To study whether the difference between RTs for fearful and angry faces is mediated by set-size, separate models were performed in which pairs of set-sizes were compared. The interaction effect between emotion and set-sizes four and eight was significant, $F(1, 7424) = 810.51$, $p < .001$. The increase in RTs for fearful faces in a set-size of four ($M = 933.79$, $SE = 40.02$) a set-size of eight ($M = 1209.04$, $SE = 40.01$) was significantly smaller than the increase in RTs for angry faces in a set-size of four ($M = 1118.55$, $SE = 40.05$) to a set-size of eight ($M = 1554.60$, $SE = 40.04$). The interaction effect between emotion and set-sizes eight and sixteen was insignificant, $F(1, 7249) = 0.62$, $p = .433$, indicating that the increase in RT from set-size eight to set-size sixteen is statistically equal for both emotions. For the model excluding set-sizes with eight faces, there was a significant interaction effect for emotion and set-size, $F(1, 7227) = 12.94$, $p < .001$. This means that the increase in RTs for fearful faces in a set-size of four (*M* = 932.07, *SE* = 41.62) to a set-size of sixteen (*M* = 1775.82, *SE* = 41.73) differed significantly from the increase in RTs for angry faces in a set-size of four (*M* = 1117.47, *SE* = 41.67) to a set-size of sixteen (*M* = 2089.56, *SE* = 41.95).

The interaction effects for gaze and set-size and for emotion, gaze and set-size were not significant, $p = .415$ and $p = .247$ respectively. See Table 1 for descriptive statistics of the RTs per condition. In summary, the two significant interaction effects found were in line with the shared signal hypothesis, but could not fully support this first hypothesis. By testing the second and third hypothesis, i.e. by analysing the ST and DT of which the RT is made of, the interpretation of the RT might be more insightful.

Table 1

Descriptive Statistics of Reaction Times in Milliseconds per Condition

		Set-size								
		4			8			16		
Emotion	Gaze	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Angry	Direct	925	1090	467	934	1485	745	870	2054	1112
	Averted	922	1140	476	922	1623	825	853	2111	1088
Fearful	Direct	937	934	405	944	1206	588	903	1754	960
	Averted	937	933	410	943	1212	575	919	1791	968

Search Efficiency

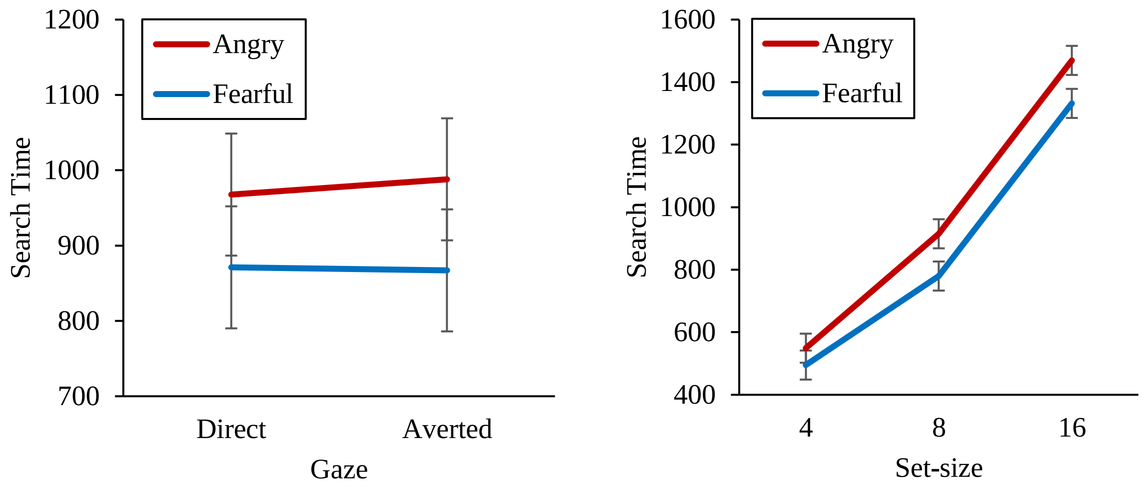
The second hypothesis regards the search efficiency: angry faces are postulated to have a lower search slope compared to fearful faces, independent of (in)congruence. To test this hypothesis, ST has been used as the dependent variable in the multilevel model. Significant main effects were found for emotion, $F(1, 10864) = 70.84$, $p < .001$, and set-size, $F(2, 10866) = 1549.86$, $p < .001$. Post-hoc comparisons indicated that fearful faces were found faster than angry faces ($M_{difference}$ = -108.91, *SE* = 12.94), *t*(10864) = -8.42, $p < .001$. Next to that, a set-size with four faces resulted in a faster ST compared to a set-size with eight faces ($M_{difference}$ = -325.32, *SE* = 15.72), *t*(10865) = -20.70, $p < .001$, and compared to a set-size with sixteen faces ($M_{difference}$ = -878.67, *SE* = 15.93), *t*(10867) = -55.16, $p < .001$. The ST was also significantly faster for eight faces than for sixteen faces ($M_{difference}$ = -553.35, *SE* = 15.91), *t*(10868) = -34.78, $p < .001$. Furthermore, no significant interaction was found between emotion and gaze, *F*(1, 10864) = 0.91, *p* = .340, meaning that congruent faces were found equally fast as incongruent faces.

A significant interaction effect was found between emotion and set-size, *F*(2, 10864) = 4.54, *p* = .011, suggesting a significant difference in search slope between angry and fearful faces. Post-hoc comparisons showed that fearful faces were found faster than angry faces on all set-sizes: four faces ($M_{difference}$ = -53.99, *SE* = 22.26), *t*(10864) = -2.43, *p* = .015, eight faces ($M_{difference}$ = -135.22, *SE* = 22.19), *t*(10864) = -135.22, $p < .001$, and sixteen faces ($M_{difference}$ = -53.99, *SE* = 22.26), *t*(10864) = -137.51, $p <.001$. The interaction effect between emotion and set-sizes four and eight was significant, *F*(1, 7348) = 14.75, $p < .001$. The increase in STs for fearful faces in a set-size of four (*M* = 495.94, *SE* = 18.26) to fearful faces in a set-size of eight (*M* = 780.63, *SE* = 18.23) was significantly smaller than the increase in STs for angry faces in a set-size of four (*M* = 549.45, *SE* = 18.28) to angry faces in a set-size of eight (*M* = 916.09, *SE* =18.28). The interaction effect between emotion and set-sizes eight and sixteen was insignificant, *F*(1, 7186.40) = 0.00, *p* = .948, indicating that the increase in RT from set-size eight to set-size sixteen is statistically equal for both emotions. For the model excluding set-sizes with eight faces, there was a significant interaction effect for emotion and set-size, *F*(1, 7164) = 5.97, *p* = .015. The increase in STs for fearful faces in a set-size of four (*M* = 494.30, *SE* = 24.28) to fearful faces in a set-size of sixteen (*M* = 1331.60, *SE* = 24.40) differed significantly from the increase in STs for angry faces in a set-size of four (M = 548.60, SE = 24.32) to angry faces in a set-size of sixteen (M = 1469.14, SE = 24.75).

This indicates that search efficiency is better for fearful faces than for angry faces, rejecting the second hypothesis, see Figure 3. Lastly, no significant effects were found for the main effect gaze, p = .528, nor for the interaction effects between set-size and gaze, and between emotion, set-size, and gaze, p = .590 and p = .231 respectively. See Table 2 for descriptive statistics of the STs per condition.

Figure 3

Changes in Search Times for Angry and Fearful Faces as a Function of Gaze and of Set-size



Note. The 95% confidence intervals are represented in the figure by the error bars attached to the estimated marginal means.

Table 2

Descriptive Statistics of Search Times per Condition

		Set-size								
		4			8			16		
Emotion	Gaze	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Angry	Direct	919	553	331	925	881	609	860	1466	1039

	Averted	915	543	319	913	949	632	849	1467	1040
Fearful	Direct	923	498	299	933	788	547	896	1326	949
	Averted	925	492	296	933	770	527	915	1335	943

Decision Advantage

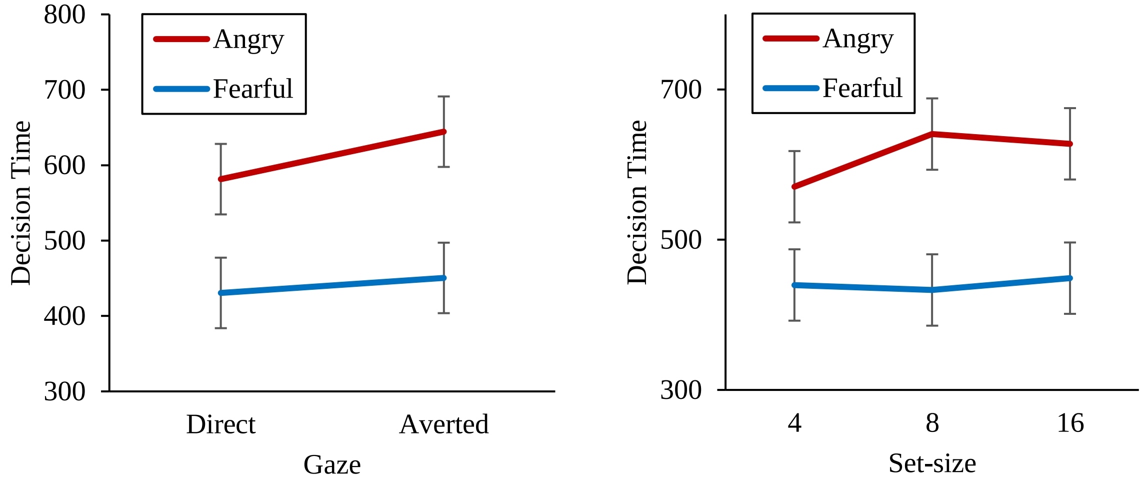
The third hypothesis states that fearful faces require less decision time compared to angry faces. This hypothesis is tested using DT as a dependent variable in the multilevel model. Results showed a significant main effect for emotion, $F(1, 10863) = 731.53$, $p < .001$. Fearful faces were distinguished faster from the neutral distractor faces compared to angry faces ($M_{difference} = -172.45$, $SE = 6.38$), $t(10863) = -27.05$, $p < .001$, suggesting a fear decision advantage and thereby confirming the third hypothesis. Other significant effects were found for gaze, $F(1, 10863) = 42.01$, $p < .001$, and set-size $F(2, 10864) = 11.56$, $p < .001$. Emotional faces with a direct gaze were distinguished faster than emotional faces with an averted gaze ($M_{difference} = -41.32$, $SE = 6.38$), $t(10863) = -6.48$, $p < .001$. Besides, emotional faces in a set-size of four faces were distinguished faster compared to emotional faces in a set-size of eight faces ($M_{difference} = -31.63$, $SE = 7.75$), $t(10863) = -4.08$, $p < .001$ and compared to emotional faces in a set-size of sixteen faces ($M_{difference} = -33.18$, $SE = 7.85$), $t(10864) = -4.23$, $p < .001$. However, emotional faces were distinguished equally fast from the distractors in a set-size of eight compared to a set-size of sixteen ($M_{difference} = -1.55$, $SE = 7.84$), $t(10864) = -6.48$, $p = .843$.

Furthermore, results showed a significant interaction effect between emotion and gaze, $F(2, 10863) = 11.45$, $p < .001$. The post-hoc comparisons indicated that angry faces with a direct gaze were distinguished faster from neutral faces compared to angry faces with an averted gaze ($M_{difference} = -62.90$, $SE = 9.08$), $t(10863) = 6.93$, $p < .001$. However, fearful faces with a direct gaze were distinguished faster than fearful faces with an averted gaze ($M_{difference}$

= -19.7, *SE* = 8.95), *t*(10863) = 2.21, *p* = .027. These results suggest that for anger, congruent faces had a decision advantage, whereas for fear, incongruent faces had a decision advantage. In addition, there was a significant interaction effect found between emotion and set-size, *F*(2, 10863) = 12.60, *p* < .001. The interaction effects between gaze and set-size, and between emotion, gaze, and set-size were insignificant, *p* = .614 and *p* = .712 respectively. See Figure 4 for the changes in DT as a function of gaze and of set-size, and see Table 3 for the descriptive statistics of DTs per condition.

Figure 4

Changes in Decision Times for Angry and Fearful Faces as a Function of Gaze and of Set-size



Note. The 95% confidence intervals are represented in the figure by the error bars attached to the estimated marginal means.

Table 3

Descriptive Statistics of Decision Times per Condition

		Set-size								
		4			8			16		
Emotion	Gaze	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*

Angry	Direct	919	539	335	925	604	459	860	596	429
	Averted	915	598	406	913	678	564	849	648	459
Fearful	Direct	923	438	257	933	421	217	896	434	161
	Averted	925	443	286	933	446	227	915	459	206

In summary, results showed faster RTs for congruent angry faces than for incongruent angry faces, and that congruent fearful faces yielded comparable RTs as incongruent fearful faces. The shared signal effect for angry faces is further supported by a congruent angry decision advantage and the lack of a shared signal effect for fearful faces might be explained by the incongruent fear decision advantage.

Trait-anxiety

The fourth hypothesis states that trait-anxiety levels will negatively correlate with RTs for self-relevant facial threat. The previously stated significant findings for RT remained significant after taking trait-anxiety levels into account. The addition of the scores on the STAI as a continuous predictor in the multilevel model analysis with RT as dependent variable, resulted in a non-significant main effect for trait-anxiety, $F(1, 30) = 0.25$, $p = .623$. For the interaction effects including trait-anxiety, no significant effects were found, $p > .057$, except for the three-way interaction effect between gaze, set-size and trait-anxiety, $F(2, 10955) = 3.55$, $p = .029$. Simple effects analyses were conducted to break down the significant interaction effect, but the results showed no significant simple effects, $p > .179$.

In the model of ST, the previously found significant effects for ST remained significant after the addition of STAI. No significant main or interaction effects were found with trait-anxiety, $p > .108$, except for the three-way interaction between gaze, set-size, and trait-anxiety, $F(2, 10853) = 4.65$, $p = .010$. Results of the simple effects analyses showed only a significant effect for a direct gaze on the target face in a set-size of sixteen faces, $F(1, 81) =$

5.11, $p = .026$. Higher levels of trait-anxiety were associated with faster STs when the target face had a direct gaze and was presented in a set-size of sixteen faces $t(81) = -2.26$, $p = .026$. All other simple effects were insignificant, $p > .314$.

Finally, in the model of DT, the previously stated significant findings for DT remained significant after the addition of STAI. The interaction effect between emotion and trait-anxiety was significant, $F(1, 10852) = 4.51$, $p = .034$, as well as the interaction effect between set-size and trait-anxiety, $F(2, 10854) = 5.17$, $p = .006$. Simple effects analyses, however, showed no significant correlations between DT and trait-anxiety for angry faces, $t(31) = -0.85$, $p = .395$ nor for fearful faces, $t(31) = -0.25$ $p = .807$. The simple effects were also insignificant for the different set-sizes, $p > .239$.

In summary, results showed a significant correlation between RT and trait-anxiety for combinations of gaze and set-size, but no significant simple effects were found. By analysing the correlation of trait-anxiety with ST and DT, the correlation with RT can be further explored. Accordingly, results showed a similar significant correlation between ST and trait-anxiety for combinations of gaze and set-size. Here a significant simple effect was found when the target face had a direct gaze and was presented in a set-size of sixteen faces. The correlation between DT and trait-anxiety was also significant, but for difference in target emotion and for difference in set-size, but no significant simple effects were found for these two-way interactions. The fourth hypothesis is thus rejected, as no correlations were found for self-relevant threats.

Discussion

In the present study, the extent to which the self-relevant facial threat effect exists when using real faces in a visual search task, was investigated. First, RTs were postulated to be faster for congruent faces (angry×direct and fearful×averted) compared to incongruent faces (angry×averted and fearful×direct). Second, participants were postulated to need less time finding the target, e.g. ST, when the face depicted anger compared to when the face depicted fear. Third, participants were postulated to need less time to identify the emotional face as such, e.g. DT, when it displayed fear compared to when it displayed anger. Fourth, trait-anxiety levels were postulated to negatively correlate with RTs for self-relevant facial threat.

Results showed that the self-relevant facial threat effect was only found for anger, not fear, therefore partially confirming the first hypothesis. Angry faces with a direct gaze were found faster than angry faces with averted gazes in the study of Terburg et al. (2018) as well, which used the same research design, except for the usage of averaged photographs instead of real photographs. However, Terburg et al. (2018) additionally found that fearful faces with averted gazes were found faster than fearful faces with direct gazes, a finding that is not replicated using real photographs. No other studies have looked into emotion × gaze interaction in a visual search paradigm to the knowledge of the author. A possible explanation of the null result of the effects of gaze on fearful faces will be discussed in the following section.

The second hypothesis was rejected as the results showed that the search was more efficient for fearful faces compared to angry faces. This is inconsistent with the finding of Terburg et al. (2018), who found that angry faces had a lower slope and therefore drawing more attention. In the study of Williams et al. (2005), who also used photographs as stimuli, angry faces amongst neutral faces drew attention faster compared to fearful faces as well. However, no other studies besides Terburg et al. (2018) and the current study have looked at the isolated ST in an emotional visual search task. The combination of the unexpected search efficiency for fear and the unexpected null result of the effects of target gaze on finding fearful faces, might indicate that possible explanations should regard the fearful face stimuli. A limitation of the study, namely, is that the intensity of the emotional expressions is not controlled for in the current study. The fearful faces, on average, could have been of higher emotional intensity compared to the angry faces. This would then explain why fearful faces were found faster in terms of ST and the total RT. Regarding the null result for the first hypothesis, it might then be that the intensity of the fearful emotion was that high, that the gaze became irrelevant to the observer.

The third hypothesis was confirmed as fearful faces were distinguished faster from the neutral distractor faces compared to angry faces, suggesting a fear decision advantage. This is in line with previous work by Terburg et al. (2018), who used averaged photographs. The replication with real photographs by the current study has the implication that the fear decision advantage effect is one step closer to generalisability to real life. However, the earlier mentioned limitation and possible explanation might suggest caution in interpreting this result, as the faster distinction of fearful faces might be due to a higher intensity of the emotional expression.

Moreover, results showed a congruent angry decision advantage, meaning that angry faces with a direct gaze were faster identified as the emotional face compared to angry faces with an averted gaze. This finding supports the shared signal hypothesis as described by Adams and Kleck (2003), who used real faces as stimuli in a task in which participants did not have to search for faces, but only judge the emotional expression of a presented face. However, they also found that fearful faces with averted gazes were decoded faster than fearful faces with direct gazes, a finding that is contradicted by the results of the current study. Here, the opposite was true: direct gazes facilitated the decoding of fearful faces more than averted gazes. Thus, there are inconsistencies in the literature regarding the effects of gaze direction on distinguishing an emotional face from the neutral distractors.

Finally, the fourth hypothesis was rejected as no significant relationships were found between trait-anxiety and RTs on self-relevant threats in this study. No other studies have been conducted on trait-anxiety and self-relevant facial threats to the knowledge of the author. However, the current study found that higher anxiety levels are associated with faster RTs. Upon zooming in on the RT by looking at the ST, it was found that this association was evident when the set-size was biggest and when the gaze was direct. Therefore, it seems that a direct gaze in a big crowd draws more attention when the observer has higher levels of trait-anxiety. In previous research, Juth et al. (2005) and Ashwin et al. (2012) found that higher levels of trait-anxiety enhanced the detection of threatening information, when schematic faces were used as stimuli. However, Juth et al. (2005) could not find this difference when real faces were used, in line with the scarce significant findings in the current study which also used real faces. The scarce significant findings in the current research are however not in line with the study of Mogg et al. (2007), who compared gaze data and RTs of high- and low-anxious individuals on a visual-probe task with real faces depicting fear and anger. They found that high-anxious individuals had a greater tendency, compared to low-anxious individuals, to direct gaze at threat-related faces, regardless of whether the faces depicted fear or anger. The current study could only replicate these findings under specific circumstances. These results therefore reveal the complexity of trying to generalise the individual differences in emotional visual search from the use of schematic faces to the use of real faces.

The current study does carry some limitations that need to be considered when interpreting the results. First of all, as mentioned earlier, the intensity of the emotions was not controlled for. In the study of Terburg et al. (2018), this might have been controlled by averaging twelve different models into one, which reduced the intensity of the emotion. In the current study, however, the expression on the faces might have been clearer without the noise of the averaging process, and the models might have showed greater intensity for their fearful expressions compared to their angry expressions. A second limitation regards the stimuli as well, namely that only four models were used, because photographs with salient features such as too much teeth or hair on the face were excluded. Calvo and Nummenmaa (2008) mentioned that visual search studies using real faces often only present twelve or fewer different models, often two or three. These authors suggest that this limitation could possibly account for inconsistent findings in existing literature. Becker and Rheem (2020) also recommended the use of many different targets and distractors in studies investigating the anger superiority effect. Thirdly, due to time constraints, no post-hoc trial-by-trial quantification was performed on the stimuli. Although the current study already controlled for non-emotional image-statistics such as luminance, a trial-by-trial quantification could correct for any residual low-level image-statistics, like in the study of Terburg et al. (2018).

Directions for future research are thus, firstly, to control for the intensity of the emotions. Langner et al. (2010) provide several ratings of the faces in the RaFD which can be included in the analyses. Secondly, it is recommended to use more different faces (models) in future studies, to ensure a greater variability and thus a greater generalisability to the real world. Thirdly, a trial-by-trial quantification is advised to be included in the analyses, to be able to ascribe effects to the emotional valence of the face.

The scientific implication of the current study is that the first steps have been made to gain knowledge on the effects of the shared signal hypothesis in a visual search paradigm using real faces of diverse models. The current study is also one of the firsts to investigate effects of trait-anxiety levels on performance on the visual search task using real, emotional faces. The importance of using real faces lies in the ecological validity of the studies. If these visual search studies become more ecologically valid, the practical relevance will be more useful. Practically, this study has strengthened the knowledge that high-anxious individuals are more vigilant to direct gazes in a big crowd. However, the current study was unable to show an attentional bias to emotions sharing a signal with gaze, implicating that the shared signal hypothesis cannot be used in early diagnosing of anxiety, nor in psychoeducation for individuals with anxiety.

Conclusion

In sum, this study confirmed the shared signal hypothesis in real faces only for anger, not fear. Fearful faces, regardless of gaze, elicited more search efficiency and resulted in a fear decision advantage. Lastly, anxiety levels did not moderate the shared signal hypothesis. This study does not convincingly confirm the existing literature and therefore calls for more replication studies with real faces. However, the findings are of great scientific relevance as the first steps are made to a better understanding of the ecological validity of the attentional biases to threat-related emotional faces previously found with isolated stimuli, e.g. not in a crowd, and with schematic faces.

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