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Stimulus and observer characteristics jointly determine the relevance of threatening facial expressions and their interaction with attention

Michèle Chadwick[1,2] · Hannah Metzler[1,3] · Charles Tijus[2] · Jorge L. Armony[4] · Julie Grèzes[1]

Abstract
Most emotional stimuli, including facial expressions, are judged not only by their intrinsic characteristics, but also by the context in which they appear. Gaze direction, for example, modifies the salience of explicitly presented facial displays. Yet, it is unknown whether this effect persists when facial displays are no longer task-relevant. Here, we first varied the salience of fearful, angry or neutral displays using gaze direction, while participants performed a gender (attended faces) or a scene discrimination task (unattended faces). Best performance occurred when faces were unattended and emotional expressions were highly salient (direct anger and averted fear), suggesting that these combinations are sufficiently important to capture attention and enhance visual processing. In a second experiment, we transiently changed participants' individual characteristics by instructing them to hold either expansive or constrictive postures. Best performance occurred for direct anger and averted fear following expansive and constrictive postures, respectively, demonstrating that stimulus and observer characteristics jointly determine the attribution of relevance of threatening facial expressions and their interaction with attention.

Keywords Emotion · Gaze · Threat · Body posture · Object-based attention

Introduction

Our survival depends on the ability to rapidly detect and attend to what is most important in our immediate environment. Some stimuli can have biological significance in and of themselves, with their survival value dictating their importance (Panksepp and Biven 2012). These are salient stimuli and are said to capture attention involuntarily (Mohanty and Sussman 2013). For others, instead, the attribution of relevance may exist in the person-environment relationship, which can change over time and circumstances (Lazarus 1991, 2006; Speisman et al. 1964) and can alter how these objects are processed (Fecteau and Munoz 2006).

Among the most salient stimuli having a direct bearing on one's goals, needs or well-being (Lazarus 1991; Ohman and Mineka 2001; Sander et al. 2003), are facial expressions of emotion and especially those signaling potential threat (Hansen and Hansen 1988). Yet, their salience appears to be neither fixed nor exclusively dependent upon facial features alone, as the context in which they appear can influence how we judge them (Aviezer et al. 2008; Righart and de Gelder 2006). For example, co-emitted social cues, such as eye gaze direction, act as contextual information which modulates an observer's appraisal of the emotional expression:

Michèle Chadwick and Hannah Metzler have contributed equally to this work. Jorge L. Armony and Julie Grèzes have jointly supervised this work.

✉ Julie Grèzes
julie.grezes@ens.fr

Michèle Chadwick
michele.chadwick@gmail.com

Hannah Metzler
hannahmetzler1@gmail.com

Charles Tijus
charles.tijus@gmail.com

Jorge L. Armony
jorge.armony@mcgill.ca

1 Laboratoire de Neurosciences Cognitives, INSERM U960, Département d'études cognitives, Ecole Normale Supérieure, PSL Research University, Paris, France

2 Laboratoire Cognitions Humaine et Artificielle, EA4004, University Paris 8, Saint-Denis, France

3 Sorbonne Universités, UPMC University Paris 6, Paris, France

4 Department of Psychiatry & Douglas Mental Health University Institute, McGill University, Montreal, QC, Canada

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an angry face with eyes gazing towards the observer signals the observer is the target of that hostility while a fearful face with eyes gazing away from the observer signals a potential danger in the observer's immediate environment. Both these emotion-gaze combinations (direct anger and averted fear) have been shown to be more efficiently processed (El Zein et al. 2015), more quickly categorized (Adams and Kleck 2003, 2005; Hess et al. 2007), rated as more intense (Cristinzio et al. 2010; N'Diaye et al. 2009) and negative (Ewbank et al. 2010), and perceived to signal greater danger than anger with averted gaze and fear with direct gaze (Sander et al. 2007). Together, these findings clearly established that these emotion-gaze combinations (direct anger and averted fear, which we will call Threat+) are more salient than averted anger and direct fear combinations (henceforth, Threat−).

Given the limited capacity of our attentional system to process visual information, the prioritized processing of salient stimuli classically results in the capture of attention to the detriment of other ongoing behaviour (Desimone and Duncan 1995). Accordingly, in the presence of salient distracters such as threat-related displays, most studies have found a deterioration in performance in an ongoing task in the form of slower reaction times (Eastwood et al. 2003; Vuilleumier and Schwartz 2001; see; Carretié 2014 for a review; but see; Phelps et al. 2006 for opposite results). So far, the processing of threat-related stimuli has been shown to be prioritized independently of whether or not the stimulus is attended to (e.g. Dolan and Vuilleumier 2003; Ohman 2002; Vuilleumier et al. 2001). Yet, and although gaze direction is known to modulate the salience of threat-related displays, it remains to be demonstrated whether this influence of gaze persists when threat-related displays are no longer relevant to the task, i.e. presented simultaneously with task-relevant information competing for attention. For these reasons, we investigated the impact of emotional salience on task performances, both when faces were task-relevant and task-irrelevant. To do so, we manipulated, in an orthogonal fashion, the salience of the stimuli and participants' object-based attention; the former by presenting different combinations of facial expressions of emotion and gaze direction, and the latter by changing the task relevance of the faces in face-scene composite images.

Further, if the attribution of relevance depends on the person-environment relationship, our perception of the world must also be constrained by our potential to interact with it. Such constraint has been demonstrated, for example, as participants make lower estimations of hill slant following the unwitting consumption of a caloric, as opposed to a non-caloric beverage (Schnall et al. 2010), and judge distance differently according to whether or not they are carrying a heavy backpack (Proffitt et al. 2003). Such findings suggest that perception is the result of the observer's appraisal of their environment (Proffitt 2006).

Perception has also been shown to be dependent upon the context within which the observers find themselves, notably the context of their own body. Comfortable, as contrasted with uncomfortable, body postures increase the likelihood that neutral faces are judged as happy rather than angry (Fantoni and Gerbino 2014). However, it might be argued that socially meaningful body postures should even more greatly impact our perception of social stimuli. Socially relevant body postures such as expansive or constrictive postures signal dominance or submissiveness, respectively, across a wide variety of species (e.g. de Waal 2007; Hagelin 2002; Grant and Mackintosh 1963). Of interest here, these postures have been shown to alter behaviour in a manner related to the status they embody (see Carney et al. 2015 for a review). To our knowledge, only two studies addressed the influence of power on social perception. Schultheiss and Hale (2007) showed that power-motivated individuals directed their attention towards faces signaling submissiveness but away from faces signaling high dominance. Similarly, Yap et al. (2013) revealed that individuals who currently hold a powerful role under-estimate the others' size, another dominance signal, while individuals in a powerless role over-estimate it. These results suggest that current power status has the potential to distort our perception of the social world.

The questions arise as to whether this influence is still present when the stimulus is competing for attention with task-relevant information, and whether context enters into this competition to further modulate performance. We therefore examined, in Experiment 2, the interactive effect of stimulus and observer characteristics; i.e. whether transient characteristics of dominance modulate the impact of emotional salience on task performance, both when faces are task-relevant and task-irrelevant. We did so by manipulating the posture held by participants using either expansive (dominant) or constrictive (submissive) postures as they completed the same tasks used in Experiment 1.

Experiment 1

Experiment 1 aimed at addressing the impact of emotional salience on task performance under different attention conditions; i.e. whether Threat+ stimuli are sufficiently salient to influence performance of an ongoing task, even when they are task irrelevant. To do so, we manipulated (1) emotional displays and eye gaze direction to vary the intrinsic salience of the stimuli, and (2) the attention of the observer by making the face stimuli portraying emotional displays task-relevant or task-irrelevant, by having participants attend either to scenes or to faces presented in a single overlapping display.

Given the prioritized treatment of threat-related stimuli whether attended or not (e.g. Dolan and Vuilleumier 2003; Ohman 2002; Vuilleumier et al. 2001) we expected threat-related stimuli to impair performance overall. Further, the expression-by-gaze factorial design could yield three possible outcomes: (1) no effect of gaze, suggesting it is the salience of the expression itself, and not of the relation between emotion and gaze direction, which influences performance (2) a main effects of gaze, which would mean that being looked at or not alters the observer's performance, regardless of the face's emotional expression, and (3) an interaction between gaze and expression. Based on the findings from the literature described in the "General Introduction" section, we expected this third outcome; specifically, a difference in performance (possibly modulated by attention) between Threat+ and Threat− displays.

Methods and materials

Participants

Forty-one healthy volunteers (22 males; mean age 24.4 ± 4.2 years) participated in the experiment. All participants had normal or corrected-to-normal vision, were naive to the aim of the experiment and had no neurological or psychiatric history. All individual participants included in the study provided written informed consent according to institutional guidelines of the local research ethics committee and were treated in accordance with the declaration of Helsinki. At the end of the experiment, participants were debriefed and paid for their participation.

Stimuli

A total of 324 face stimuli were created from the Radboud Faces Database (Langner et al. 2010). This consisted of 36 actors (18 male), expressing three emotions: anger, fear and neutral and either a direct or an averted gaze (half left/half right). Using Adobe Photoshop CS5.1 (Adobe Systems, San Jose, CA), faces were modified to remove any visible hair, resized and repositioned so that eyes, nose and mouth appeared at the same level within the same circumference for all face stimuli. All images were then converted to greyscale and adjusted to be of equal contrast and cropped into a 280 × 406 pixel oval centred within a 780 × 1024 pixel black screen.

We created composite face-scene stimuli, similarly to those described in Dickie and Armony (2008). A total of 648 stimuli were created. They consisted of the 36 different actors described above with 3 emotional expressions (neutral, angry and fearful) and 3 gaze directions (direct, left and right) which were then superimposed upon non-copyrighted stock photos of outdoor and indoor scenes consisting primarily of buildings and streets, and rooms with furniture, respectively, without any social information (i.e., no people were present). A total of 36 scenes (18 indoor) were randomized across sex/emotion/gaze direction. Before superimposition, all faces and scenes were adjusted for contrast and luminosity such that no significant differences between emotions or between faces and scenes remained. Both face and scene stimuli were then reduced to 50% transparency and superimposed.

Procedures

An instruction screen presented for 1 s, comprising the letters M + F or E + I, indicated whether participants were cued to attend to the face or to the scene, judging if the face was male or female, or if the scene was exterior or interior. Moreover, the order of the letters was a reminder about which mouse button (left/right) represented which response option. Order of letters and thus mouse clicks was counterbalanced across subjects. The central "+" served as a fixation cross, such that participants had their field of vision located on the centre of the stimuli. Stimuli were 19 cm high × 15 cm wide, presented at a distance of 50 cm (visual angle: 21° h × 17° w).

Immediately following the instruction screen, the composite face-scene stimulus was presented centrally for 250 ms followed by a response screen marked "Respond". Although subjects were allowed a maximum of 2 s to respond, the instruction screen for the subsequent trial appeared as soon as a response was made. Each face-scene composite image was presented twice during the experiment, once with the gender task and once with the scene task for a total of 432 trials. Half the stimuli (216 trials) were presented to each participant and this assignment was counterbalanced across participants. After 72 trials and then again after 144 trials, a "Pause" screen appeared allowing participants to take a break for as long as they wished. During these two breaks, participants were advised to take a pause of at least a few seconds to close their eyes or look away from the screen to avoid excess fatigue.

Training

Prior to testing, participants completed three practice exercises using stimuli created uniquely for the training session. The first training exercise consisted of 15 trials where the participant was only to identify the gender of the face. The second training exercise consisted of 15 trials where the participant was only to identify the type of the scene. Finally, the third training exercise consisted of 15 trials where the participant was only to identify either the gender of the face or the type of scene in mixed order. When participants reached a minimum score of 60% on each of the three exercises they could proceed to the actual experiment, otherwise all three exercises were repeated. All participants obtained at least 60% in all three exercises in either 1 or 2 training sessions.

Data analysis

The data were cleaned so that only responses with a reaction time superior to 200 ms were included in analyses. Reaction times inferior to 200 ms were excluded as they were considered to constitute anticipatory or erroneous key presses rather than actual reaction times. These represented 2.5% of all responses, and including them in the analysis did not alter the findings (i.e., all significant effects remained significant and no new ones arose). The data was analysed using a factorial repeated measures analysis of variance (ANOVA) with task (gender or scene), emotion (angry, fearful or neutral) and gaze (direct, averted) as within-subject factors and sex of subject as a between-subject factor. Reaction time analyses were conducted using only correct responses. Participant's sex was included as a factor given that there are several reports in the literature of sex differences in emotional processing, particularly in processing threat-related stimuli (see review by Kret and De Gelder 2012), as well as in the literature on dominance (Del Giudice 2015). However, it should be noted that results are the same if we remove sex as factor in the analysis. All ANOVAs used Greenhouse–Geisser adjusted degrees of freedom. The threshold for statistical significance in all analyses was set at a *p* value of .05 (two-tailed in the case of t-tests). Partial eta-squared was used as the effect size estimate for ANOVAs. Planned comparisons were used only where main effects or significant interactions were observed and Cohen's d_{av} was used to report effect sizes for dependent t-tests as recommended by Lakens (2013), calculated as the standardized mean difference between conditions divided by the average standard deviation (Fig. 1).

Results

Accuracy collapsed across tasks was 76.7 (SEM = 0.1%), indicating that participants both understood instructions and could correctly perform the task. Importantly, our manipulations were successful in generating sufficiently high percentage of errors to allow accuracy-based analyses. The repeated-measures ANOVA across tasks revealed a main effect of Task (F(1,39) = 30.89, $p < .001$, $\eta_p^2 = 0.44$), related to the fact that the Scene task (71%) was more difficult than the gender task (81%), as in previous studies using similar stimuli (Dickie and Armony 2008). A significant emotion × gaze interaction across tasks (F(2,78) = 4.294, $p = .017$, Greenhouse–Geisser corrected $p = .022$, $\eta_p^2 = 0.099$) was also found. Planned comparisons revealed that participants tended to be more accurate in the presence of direct as opposed to averted anger (t(40) = 1.958, $p = .057$, $d = 0.25$) and were more accurate for averted as opposed to direct fear (t(40) = 2.701, $p = .010$, $d = 0.50$); i.e. for threat + combinations (see Table 1).

Importantly, the ANOVA revealed that the task × emotion × gaze interaction of interest was marginally significant (F(2,78) = 3.12, $p = .049$, Greenhouse–Geisser corrected $p = .057$, $\eta_p^2 = 0.074$). This effect was mainly driven by a strong emotion × gaze interaction in the scene task (F(2,78) = 5.12, $p = .008$, Greenhouse–Geisser corrected $p = .012$, $\eta_p^2 = 0.116$): participants tended to be more accurate at discriminating scenes in the presence of direct anger as opposed to averted anger (t(40) = 1.693, $p = .098$, $d = 0.24$) and were significantly more accurate at discriminating scenes in the presence of a fearful face with an averted as opposed to a direct gaze (t(40) = 2.851, $p = .007$, $d = 0.53$), i.e. for Threat+ combinations, with no differences in accuracy between direct and averted neutral expressions (t(40) = 0.548, $p = .587$, $d = 0.09$) (see Fig. 2).

Finally, a significant task × emotion interaction (F(2,78) = 6.082, $p = .004$, $\eta_p^2 = 0.135$) was also observed,

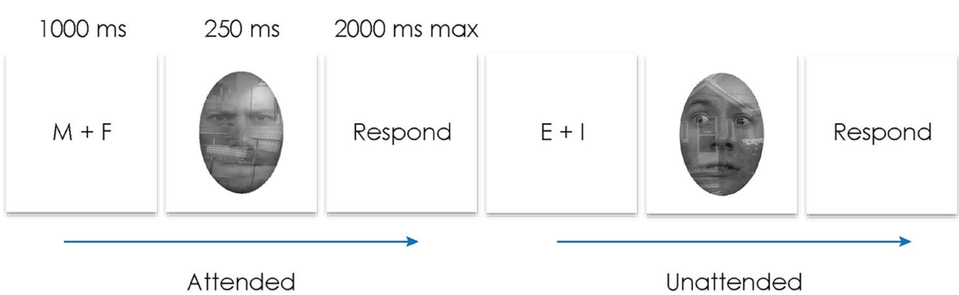

Fig. 1 Time course of the experiment over 2 trials. The instructions screen with M + F, (attended) or E + I, (unattended) and the central fixation cross, presented for 1 s was immediately followed by the stimuli presented centrally for 250 ms. Subjects had a maximum of 2 s to respond using the mouse upon the appearance of the "Respond" screen at which point the next trial began and a new instruction screen appeared. Note that stimuli were created using the Radboud Face Database, developed by the Behavioural Science Institute of the Radboud University, Nijmegen (Langner et al. 2010)

Table 1 Mean accuracy (% ± SEM) and mean reaction times (ms ± SEM) during Experiment 1, for each condition of interest and for the gender and scene tasks overall

Experiment 1	Accuracy (%)				Reaction times (ms)			
	Mean %	SEM	Min	Max	Mean	SEM	Min	Max
Gender task	81.65	1.07	65.00	96.30	564.80	22.98	321.00	898.00
Anger Av	77.59	1.633	53.85	100.00	560.90	21.99916	311.00	905.00
Anger Dir	79.12	1.773	55.56	100.00	582.36	28.25193	331.00	1074.00
Fear Av	82.45	1.493	66.67	100.00	576.75	25.35665	316.00	877.00
Fear Dir	81.51	1.418	61.11	94.44	547.51	22.14024	299.00	1019.00
Neutral Av	85.89	1.678	64.71	100.00	570.09	26.44820	281.00	1003.00
Neutral Dir	83.15	1.929	53.85	100.00	560.90	21.99916	311.00	905.00
Scene Task	71.86	1.55	54.63	90.74	675.49	27.77	362.00	1025.00
Anger Av	71.13	2.109	43.75	100.00	671.41	33.35334	334.00	1187.00
Anger Dir	74.65	2.310	44.44	100.00	655.31	27.69394	344.00	1029.00
Fear Av	75.82	2.112	41.18	100.00	666.07	28.80710	349.00	1110.00
Fear Dir	68.68	2.088	27.78	88.89	727.43	32.85484	358.00	1201.00
Neutral Av	69.74	2.302	33.33	94.44	670.92	29.44736	341.00	1104.00
Neutral Dir	71.09	2.160	38.89	94.44	661.75	27.73588	355.00	1005.00

Av averted gaze, *Dir* direct gaze

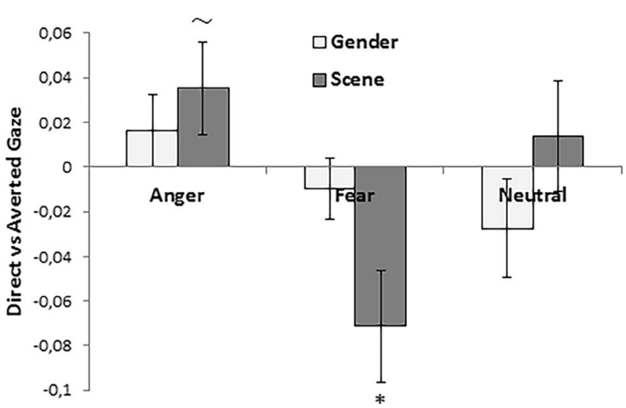

Fig. 2 Experiment 1: mean difference in accuracy (% ± SEM) between direct and averted gaze for angry, fearful, and neutral faces. A significant triple task × emotion × gaze interaction indicates that subjects were significantly more accurate in the discrimination of scenes in the presence of a fearful face with an averted as opposed to a direct gaze and tended to be more accurate in the presence of an angry face with a direct as opposed to an averted gaze. No significant or trend level differences in accuracy were found for neutral stimuli. (*$p < .05$, **$p < .01$, ***$p < .001$)

and separate ANOVAs indicated that this interaction was driven by a significant main effect of emotion for the gender task ($F(2,78) = 8.139$, $p = .001$, $\eta_p^2 = 0.173$). Participants were more accurate in identifying the gender of a neutral, as opposed to an angry face ($t(40) = 3.933$, $p < .001$, $d = 0.65$), and tended to be more accurate for neutral as opposed to fearful faces ($t(40) = 1.805$, $p = .079$, $d = 0.29$). Participants were also more accurate in identifying the gender of fearful, as opposed to an angry face ($t(40) = 2.183$, $p = .035$, $d = 0.40$).

Reaction time analysis mirror the result pattern described for accuracy and is reported in the "Appendix" section and in Table 1.

Discussion

Experiment 1 addressed whether the influence of emotional salience of faces, given by specific combinations of gaze direction and emotional expression, on accuracy persists when they are not relevant to the ongoing task.

When faces were task-relevant (gender task), we observed reduced performance in the presence of fearful and angry as compared to neutral facial expressions, with no effect of gaze direction. This result replicates previous findings showing that threat-related, as compared to neutral displays, can disturb behavioural performance (see Carretié 2014 for a review), notably during a gender discrimination task (e.g. Neath and Itier 2015). Reduced performance possibly arises from the fact that gender discrimination tasks may be associated with negligible attentional costs (Reddy et al. 2004), thus leaving sufficient attentional resources available to process the emotional information conveyed by the facial expressions. We show here that this is the case even for object-based attention, i.e., when faces needed to be segregated from overlapping scenes.

Interestingly, a different pattern emerged when faces were task-irrelevant (scene task). Firstly, we observed an interaction between gaze and expression on accuracy when faces were unattended, suggesting that it is the salience of the emotional display as a whole, and not either the expression or the gaze direction alone (no effects of gaze for neutral), which influences performance. This is in contrast with results obtained when faces were attended, where the salience of the expression alone, and not of the emotion–gaze combination, influenced performance. Moreover, we observed better performance for highly salient combinations (Threat+, i.e., direct anger and averted fear) despite the resources required to discriminate task-relevant indoor and outdoor scenes. Although these results may seem to run counter to the notion of emotion disrupting task performance (Vuilleumier and Schwartz 2001; Eastwood et al. 2003; Fenske and Eastwood 2003; Hartikainen et al. 2000), one other study reported results consistent with ours: Phelps et al. (2006) found that participants were more accurate in identifying the orientation of Gabor patches preceded by a fearful as opposed to a neutral face. While facial cues and targets were presented at two different time points in that study, we observed here that the presence of task-irrelevant Threat+ combinations similarly enhanced early vision of scenes presented at the same time and spatially overlapping with faces.

The question remains as to why performance was best for Threat+ combinations and not simply for emotional versus neutral faces. We might speculate that this may be due to the difficulty of the scene task. We know that we integrate all available external cues, including gaze direction, when emotional expressions become difficult to identify (El Zein et al. 2015; N'Diaye et al. 2009; Graham and LaBar 2007). We argue that only direct anger and averted fear may be sufficiently salient to direct our attention towards the various salient features of the faces (Benuzzi et al. 2007; Adolphs et al. 2005), and may modulate arousal (Peck and Salzman 2014). Consistent with this hypothesis, the "GANE" model (Mather et al. 2016) proposes that arousal biases perception in favour of high-salience stimuli which, in this case, may have led to the preferential processing of overlapping scenes in the presence of highly salient combinations. Further studies using eye-tracking could better discern the precise nature of the attribution of attention with this type of stimuli.

Experiment 2

Results from Experiment 1 demonstrated that altering the salience of task-irrelevant emotional expressions by changing their gaze direction can influence performance, particularly when participants directed their attention to the scene (rather than to the face). In Experiment 2 we wanted to investigate the other side of this issue, namely whether changing the individual characteristics of the observer can influence the attribution of relevance of these expressions/gaze combinations to subsequently alter performance.

Rather than choosing trait differences in dominance and submissiveness, we decided to attempt to induce transient changes in dominance status using postures which, although controversial (see Smith and Apicella 2017), have been shown to induce reliable changes in feelings of power and other associated affective states across several sets of studies (Cuddy et al. 2018; Gronau et al. 2017; Cesario and Johnson 2017). We would like to suggest that some of the controversy surrounding these findings (e.g. Cesario and Johnson 2017; Garrison et al. 2016; Ranehill et al. 2015; Ronay et al. 2016; Smith and Apicella 2017) may arise from the fact that existing studies mainly investigated posture effects outside meaningful social contexts, thus underestimating the fundamentally social and communicative nature of these dominance displays. By manipulating the posture held prior to and at several intervals during the same behavioural experiment presented in Experiment 1, we aimed at prompting transient changes in dominance or submissiveness in the observer to examine differences in how the observer relates to fear and anger.

As an evolutionary ancient behaviour that exists across many animal species, postural expansiveness is usually regulated without awareness and spontaneously adapts to ongoing social interactions in humans (Tiedens et al. 2007). Social status can also be readily inferred from facial characteristics (Oosterhof and Todorov 2008) or "first-glimpse" scenarios (Mast and Hall 2004) as quickly as 40 ms or less (Rule et al. 2012). Moreover, personality trait dominance has been shown to be associated with the processing of cues of aggression and anger only when these cues were masked as opposed to unmasked (Hortensius et al. 2014; Terburg et al. 2012, 2011). We therefore predicted that the influence of individual and transient characteristics of dominance should be stronger when faces were unattended. Yet, we did not have specific predictions regarding the direction of this putative influence.

Methods and materials

Participants

All available studies using similar posture manipulations included between 18 and 38 subjects per posture condition (e.g., Cesario and McDonald 2013; Fischer et al. 2011; Huang et al. 2011). Aiming at including at least as many participants, we tested 45 healthy volunteers (22 males; mean age, 25 ± 3.5 years) in a within-subject design. Inclusion criteria and compliance ethic principles were the same as those described for Experiment 1.

Material

The stimuli and experimental design employed were the same as those described in Experiment 1, with the addition of a self-report questionnaire at the end of each session in which subjects were asked to rate how dominant, in control and powerful they felt on a scale from 1 to 5.

Pose procedure

We adopted a within-subject design with two consecutive sessions, each consisting of 216 trials separated in three blocks. Participants were randomly assigned to begin either with the expansive (n = 24) or constrictive (n = 21) pose condition, and adopted the other pose in the second session. To investigate the impact of postural expansiveness on visual attention to social displays, we had subjects adopt the posture (expansive/constrictive limbs in addition to an erect/slumped upper body with the head upright/lowered) for 3 min before every block of the task, which also lasted about 3 min (see Fig. 3). This experimental design builds on previous studies that applied whole body posture manipulations similar to ours, in which participants adopted postures for varying durations (20 s to 5 min) before they performed the tasks used as dependent measures (e.g. Bohns and Wiltermuth 2012; Carney et al. 2010; Cesario and McDonald 2013; Huang et al. 2011). These studies provide evidence that the effect of such postural manipulations lasts for at least a few minutes. Holding the body posture throughout the task is possible only when tasks allow for verbal responses, or when the chosen posture manipulation involves only the upper body.

In an attempt to dissociate the posture manipulation from the main behavioural task, participants were told that a secondary goal of the experiment was to observe the effects of different postures on heart rate. At this point of the experiment, two adhesive surface electrodes were placed between the radial and ulnar arteries of both wrists of the participant

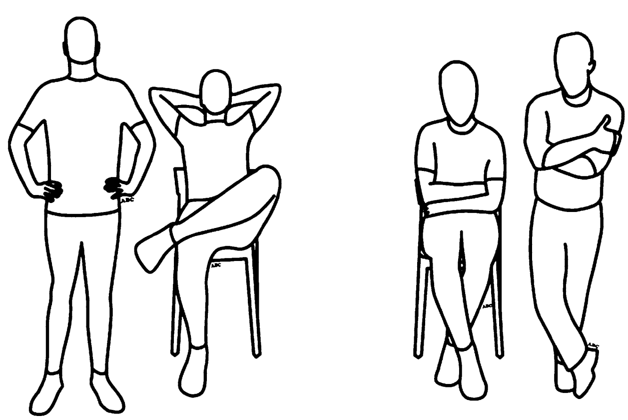

Fig. 3 Expansive and constrictive postures held in Experiment 2 (images created by Antoine Balouka-Chadwick). Note that these postures, when displayed in social contexts, have been shown to signal dominance and submissiveness (de Waal 2007)

and hooked up to the ADInstruments (ML870 P Powerlab 8/30) acquisition system. Yet, the acquisition system itself was switched off and no measures were recorded. Participants were then physically positioned into their assigned pose by an experimenter. To avoid any evocation of power, strength, dominance, or on the contrary, submissiveness, care was taken to avoid demonstrating the posture and using such adjectives as "open", "closed", "expansive" or "constrictive".

Participants were instructed to maintain their position for 3 min before every block (72 trials) and informed they were being watched by the experimenter through a webcam to ensure they did so correctly. At the end of the 3-min period they were to proceed with the next block of the main experiment. In total, they thus adopted the same posture three times in each session. When session 1 was completed, subjects notified the experimenter who then instructed them to take their second posture, which they held for 3 min before beginning session 2 of the behavioural experiment.

After each session, subjects were prompted to complete the on-screen self-report questionnaire described above. Importantly, unlike studies like the one of Carney et al. (2010) wherein participants performed social judgment tasks, our participants were given no task whatsoever while holding the assigned postures.

Data analysis

The data were cleaned so that only correct responses with a reaction time superior to 200 ms were included in analyses. Reaction times inferior to 200 ms were excluded as they were considered to constitute anticipatory or erroneous key presses rather than actual reaction times. As in Experiment 1, including these faster RTs did not alter the results. To account for the within-subject design, we first ran a repeated-measures ANOVA with both sex of subject and order of pose (expansive–constrictive, constrictive–expansive) as between-subject factors and pose (expansive, constrictive), task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors. We then performed exploratory analyses of session 1 and 2 separately, by running two independent repeated measures ANOVAs for each session, with both posture and sex of subject as between-subject factors and task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors.

Results

After excluding one participant due to technical problems during the testing, we analysed data from 23 participants who adopted the expansive posture in session 1 and the constrictive posture in session 2, and 21 participants who adopted postures in the reverse order. Overall accuracy, collapsed across tasks and sessions, was well above chance at M = 74.42 ± 1% (SEM), indicating that subjects understood instructions and could correctly perform the task.

A first repeated ANOVA with both order of pose (expansive–constrictive, constrictive–expansive) and sex of subject as between-subject factors and pose (expansive, constrictive), task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors revealed a tendency for a quintuple order of pose × pose × task × emotion × gaze interaction (F(2,80) = 2.225, p = .115, η_p^2 = 0.053), and a significant quadruple order of pose × task × emotion × gaze interaction (F(2,80) = 3.648, p = .030, η_p^2 = 0.084). These interactions suggest that the impact of pose may be different in Session 1 and Session 2. Since none of the past studies have used within-subject designs in which participants adopt expansive and constrictive postures in consecutive sessions, possible explanations for this order effect could be either related to potential long-term effects of the first posture (adopted three times in Session 1), or to learning effects that might have influenced task performance (suggested by better performance in Session 2 (M = 75.68 ± 1%) as compared to Session 1 (M = 73.38 ± 1%); t(43) = 3.474, p = .001). We therefore decided to perform exploratory analyses of Session 1 and 2 separately, by running two independent repeated measures ANOVAs for each session, with both posture and sex of subject as between-subject factors and task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors. These analyses imply that the pose effect will be assessed between subjects (Group 1 n = 21 and Group 2 n = 23 subjects), rather than within subjects with 44 participants. During Session 1, the task × emotion × gaze interaction for accuracy was modulated by pose. Our ANOVA revealed a significant quadruple pose × task × emotion × gaze interaction (F(2,80) = 3.549, p = .033, η_p^2 = 0.081). Separate ANOVAs for both the gender task and the scene task revealed that this effect was driven by the scene task, where we found a significant triple pose × emotion × gaze interaction (F(2,80) = 4.646, p = .012, η_p^2 = 0.104), which was not significant in the gender task (F(2,80) = 0.007, p = .993, η_p^2 = 0.000). The emotion × gaze interaction was found to be significant in both expansive participants (F(2,42) = 3.922, p = .027, η_p^2 = 0.157) and constrictive participants (F(2,38) = 3.945, p = .028, η_p^2 = 0.172). Planned comparisons of the interaction in the scene task revealed that participants having held an expansive posture discriminated between scenes significantly better in the presence of direct, as opposed to averted anger (t(22) = 3.081, p = .005, d = 0.46), although not for averted as opposed to direct fear (t(22) = 0.233, p = .818, d = 0.05), while participants having held a constrictive, submissive posture discriminated between scenes significantly better in the presence of averted, as opposed to direct fear (t(20) = 2.518, p = .020, d = 0.64), although not for direct as opposed to averted anger (t(20) = 0.225, p = .824, d = 0.04), (see Fig. 4). The difference between direct and averted neutral faces was neither significant for expansive posture (t(22) = 1.668, p = .110, d = 0.49), not for constrictive posture (t(20) = 0.956, p = .350, d = 0.21).

During Session 2, the task × emotion × gaze interaction for accuracy was not modulated by pose. The ANOVA revealed a significant task × emotion × gaze interaction (F(2,80) = 3.868, p = .025, η_p^2 = 0.088), but no significant quadruple pose × task × emotion × gaze interaction (F(2,80) = 1.239, p = .295, η_p^2 = 0.030). Separate ANOVAs for both the gender task and the scene task revealed that the task × emotion × gaze interaction was driven by the scene task, where we found a significant emotion × gaze interaction (F(2,80) = 4.359, p = .016, η_p^2 = 0.098), which was not

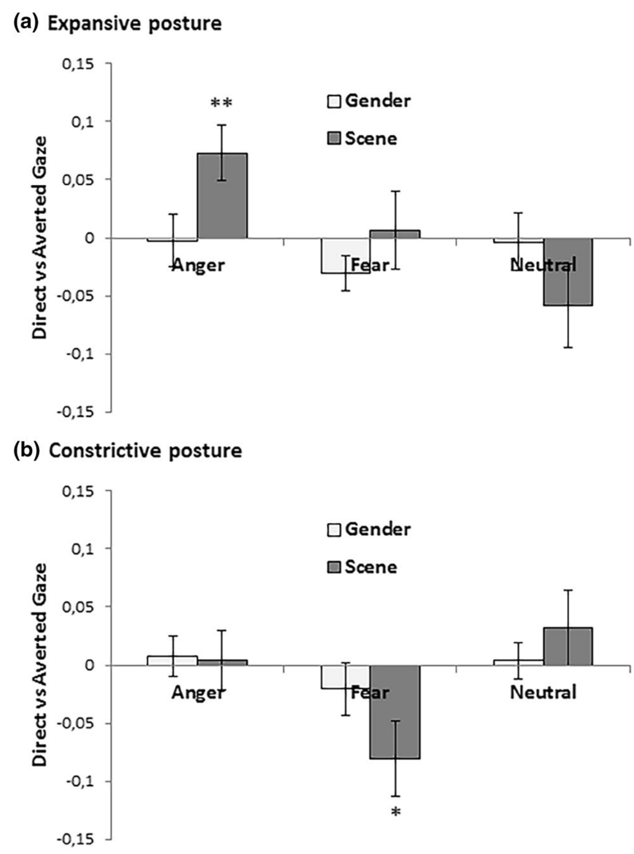

Fig. 4 Experiment 2—Session 1: mean difference in accuracy (% ± SEM) between direct and averted gaze for angry, fearful, and neutral faces split by expansive (dominant) and constrictive (submissive) poses. Participants having held an expansive posture discriminated between scenes significantly better in the presence of direct, as opposed to averted anger, while participants having held a constrictive posture discriminated between scenes significantly better in the presence of averted, as opposed to direct fear (*p < .05, **p < .01, ***p < .001)

significant in the gender task (F(2,80) = 0.556, p = .576, η_p^2 = 0.014). Planned comparisons of the interaction in the scene task revealed that participants discriminated between scenes significantly better in the presence of direct, as opposed to averted fear (t(43) = 2.053, p = .046, d = 0.25), and in the presence of averted, as opposed to direct neutral faces (t(43) = 2.053, p = .046, d = 0.23).

Reaction time analyses revealed faster responses in the gender than the scene task as in Experiment 1, but no significant interactions of pose × task × emotion × gaze or task × emotion × gaze in either session. Further details for the reaction time analyses are reported in the "Appendix" section. Tables 2 and 3 summarize descriptive statistics for Session 1 and 2, respectively, including both accuracy and reaction time measures.

Subjective evaluation of power

Self-reported feelings of dominance, power and control were averaged to one total score. ANOVAs with the total scores at the end of Session 1 or 2 as dependent variable revealed no significant impact of sex or type of pose taken (pose effect Session 1: F(1,42) = 0.86, p = .36, η_p^2 = 0.019, Session 2: F(1,41) = 0.17, p = .68, η_p^2 = 0.004).

Table 2 Mean accuracy (% ± SEM) during Experiment 2—Session 1, for each condition of interest and for the gender and scene tasks overall for the dominant and submissive postures

Experiment 2	Accuracy dominant (%)				Accuracy submissive (%)			
Session 1	Mean	SEM	Min	Max	Mean	SEM	Min	Max
Gender task	79.44	1.68	57.41	92.59	81.81	1.68	64.29	93.46
Anger Av	73.99	2.21	50.00	88.89	78.43	2.44	45.45	93.33
Anger Dir	73.79	2.59	42.86	94.44	79.05	2.36	57.14	94.44
Fear Av	83.35	2.41	55.56	94.44	83.02	2.20	64.71	100.00
Fear Dir	80.14	2.23	50.00	94.44	81.08	2.18	66.67	100.00
Neutral Av	82.51	2.37	55.56	100.00	84.51	2.12	66.67	100.00
Neutral Dir	82.13	2.48	50.00	100.00	85.02	1.99	66.67	100.00
Scene task	66.91	2.07	50.00	86.92	65.72	2.39	43.93	82.41
Anger Av	63.87	3.36	31.25	88.89	64.83	2.95	27.78	82.35
Anger Dir	71.26	2.42	44.44	94.44	65.42	3.21	38.89	83.33
Fear Av	65.09	3.27	38.89	88.89	71.38	2.76	44.44	94.44
Fear Dir	65.86	3.27	38.89	94.44	63.25	2.90	30.00	83.33
Neutral Av	70.59	2.53	50.00	88.89	63.17	3.18	38.89	83.33
Neutral Dir	64.68	3.04	44.44	88.89	66.28	3.50	33.33	94.44

Av averted gaze, *Dir* direct gaze

Table 3 Mean accuracy (% ± SEM) during Experiment 2—Session 2, for each condition of interest and for the gender and scene tasks overall for the dominant and submissive postures

Experiment 2	Accuracy dominant (%)				Accuracy submissive (%)			
Session 2	Mean	SEM	Min	Max	Mean	SEM	Min	Max
Gender task	79.59	1.59	65.74	90.74	83.06	1.37	71.43	91.75
Anger Av	77.45	2.36	50.00	94.44	81.58	2.58	47.06	100.00
Anger Dir	77.45	2.67	40.00	94.44	82.19	2.34	55.56	94.44
Fear Av	78.48	2.29	55.56	100.00	81.69	2.25	61.11	100.00
Fear Dir	76.55	2.63	47.06	100.00	80.84	2.53	50.00	100.00
Neutral Av	81.57	2.13	55.56	94.44	86.32	1.73	72.22	100.00
Neutral Dir	84.21	2.17	64.29	100.00	85.64	2.17	72.22	100.00
Scene task	68.53	2.28	44.44	87.04	72.30	2.02	51.85	86.11
Anger Av	66.44	3.61	27.78	94.44	74.13	3.01	33.33	94.44
Anger Dir	71.04	3.56	44.44	94.44	72.75	3.21	38.89	94.12
Fear Av	66.89	2.58	44.44	94.44	68.27	2.79	44.44	88.89
Fear Dir	69.40	2.71	38.89	83.33	74.26	2.09	53.33	88.89
Neutral Av	71.58	2.80	44.44	94.44	73.48	3.16	43.75	94.44
Neutral Dir	65.73	3.35	27.78	100.00	70.38	2.40	44.44	88.89

Av averted gaze, *Dir* direct gaze

Discussion

The results of Experiment 2 demonstrate that expansive or constrictive body postures dichotomized the impact of Threat+ combinations (direct anger and averted fear) on performance when faces were unattended. Participants having held an expansive posture performed best for anger with a direct gaze while participants having held a constrictive posture performed best for fear with an averted gaze. These effects occurred only in the scene (unattended face) and not in the gender (attended face) task, concurring with effects of trait dominance on the processing of masked as opposed to unmasked aggressive social signals (Hortensius et al. 2014; Terburg et al. 2012, 2011).

The split in performance between postures appears to be driven by a reduction in salience of one of the expressions/gaze combinations. Such a reduction in hitherto salient stimuli has already been demonstrated in attentional shifts towards ecologically relevant targets. Mohanty et al. (2008) found increased covert shifts of spatial attention toward previously neutral targets (tools) and away from previously salient targets (food) as subjects became satiated. This suggests a selective modulation in the motivational value of stimuli following changes in the goals of the observer that may be top-down driven to guide attention and result in enhanced visual encoding of stimuli appraised as most relevant while simultaneously decreasing the visual encoding of stimuli appraised as least relevant (Mohanty and Sussman 2013).

A transient attribution of power has previously been shown to influence social perception, by altering the direction of attention towards or away from dominant or submissive faces (Schultheiss and Hale 2007) or by leading to under-estimate or over-estimate body size (Yap et al. 2013). In light of this, we suggest that the opposing direction of the results following expansive and constrictive postures may be related to the attribution of power to the observer resulting in a modulation of the relevance of threatening social stimuli. Effectively, anger with a direct gaze signals imminent physical aggression and elicits attributions of dominance (Hess et al. 2007) while fear with an averted gaze is often associated with a submissive stance (Vigil 2009). We speculate that body postures, by modifying the agent's capacity to bear their social consequences (e.g. dominant postures and sensitivity to pain in Bohns and Wiltermuth 2012), may have selectively modulated the motivational value of these stimuli to preferentially enhance the visual encoding of the most relevant stimuli (Mohanty and Sussman 2013). Together, our results suggest that while emotional expression and gaze direction interacted to increase the salience of the stimuli, the postures held by our participants appeared to have altered the relevance of these salient stimuli. Nevertheless, we acknowledge that future studies are needed to formally test such a hypothesis.

General discussion

We have demonstrated that gaze direction can sufficiently increase the salience of threatening facial displays to influence performance in an ongoing task, even when these stimuli are task-irrelevant. The direction of our results concurs with previous findings of the influence of gaze on threatening stimuli presented explicitly to participants, that is to say increased salience of anger accompanied by a direct gaze and of fear accompanied by an averted gaze (e.g. El Zein et al. 2015). As mentioned in the discussion of Experiment 1, the improved performance for these highly salient gaze/expression combinations in the case of these task-irrelevant stimuli lead us to speculate that, when emotional expressions become difficult to identify, only sufficiently salient expressions direct our attention towards salient facial features (El Zein et al. 2015; N'Diaye et al. 2009; Graham and LaBar 2007; Benuzzi et al. 2007; Adolphs et al. 2005) that produce sufficient arousal (Mather et al. 2016; Peck and Salzman 2014) to result in the preferential processing of the overlapping scenes. Further, in Experiment 2, the improved performance found for task-irrelevant direct anger following expansive postures concurs with studies demonstrating an association between trait dominance and the processing of aggressive cues only when masked as opposed to unmasked (Hortensius et al. 2014; Terburg et al. 2012, 2011).

Further, our second experiment demonstrated that the attribution of relevance does not occur independently of the observer and highlighted the transient influence of body postures that are similarly meaningful across many species (e.g. (de Waal 2007; Hagelin 2002; Maslow 1943)). More specifically, we found the influence of Threat+ emotional/gaze combinations to be split by posture type such that, following an expansive (dominant) posture, participants performed best in the presence of direct anger and, following a constrictive (submissive) posture, participants performed best in the presence of averted fear. Thus, results from this experiment confirm that adopting expansive and constrictive postures alters the poser's subsequent behaviour in a way that is related to the status they embody (see Carney et al. 2015 for review), in agreement with the embodiment hypothesis (Barsalou 2008), and further demonstrate that postures can influence the perception of social information even when participants perceive no difference in feelings of power themselves.

Finally, we would like to address limitations of our studies, and suggest how future studies could address some of them. Experiment 2 was conceived as a within-subject study, although we only observed significant posture effects between groups in the first session. It is possible that learning effects (evidenced by higher performance in the second session) or potential long-term effects of the first posture (adopted three times in Session 1) could explain why no posture effects occurred in Session 2. While the learning issue is more difficult to tackle, future studies could prevent carry-over effects of posture by using within-subject designs with no posture in the first session. Further, these changes in perception occurred without explicit awareness of differences in feelings of dominance or power on the part of the participants. However, although these subjective measures were modeled after those used in Carney et al. (2010), their possible limitations include their explicit nature which may have dampened the effect of the postures themselves in Session 2, their brevity (only 4 questions) and the fact that they were employed only at the end of each session and not immediately after the postures were held.

Conclusion

Taken together, our two experiments demonstrate that eye gaze direction can sufficiently increase the salience of emotional expressions to persist even when task-irrelevant and that stimulus salience and observer characteristics jointly determine the relevance of threatening facial expressions and their interaction with attention.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Appendix

Experiment 1: supplementary results

The data were cleaned so that only responses with a reaction time superior to 200 ms were included in analyses and for reaction time data analyses, only correct responses were included.

Analyses on reaction times

Reaction times collapsed across tasks reached 620.14 ± 24.97 ms (SEM). The repeated-measures ANOVA across tasks revealed a main effect of task (F(1,39) = 133.76, $p < .001$, $\eta_p^2 = 0.745$), indicating that participants were slower during the scene task (675.49 ms) as compared to gender task (564.80 ms). The ANOVA also showed a main effect of emotion (F(1,39) = 5.399, $p = .006$, $\eta_p^2 = 0.122$). Planned comparisons of this effect found that participants were significantly faster in the presence of fearful, as opposed to angry faces (t(40) = 2.942, $p = .005$, $d = 0.16$) and for fearful as opposed to neutral faces (t(40) = 2.616, $p = .012$, $d = 0.15$). Importantly, the interaction of interest between task, emotion and gaze was significant (F(2,78) = 6.371, $p = .003$, $\eta_p^2 = 0.140$), driven by a significant emotion × gaze interaction in the scene task (F(2,78) = 6.130, $p = .003$, $\eta_p^2 = 0.136$) in which participants were significantly faster at discriminating scenes in the presence of a fearful face with an averted, as opposed to a direct gaze (t(40) = 3.630, $p = .001$, $d = 0.31$). However, the difference in reaction times between direct and averted anger conditions was not significant (t(40) = 1.024, $p = .312$, $d = 0.08$) (see Table 1).

Experiment 2: supplementary results

Analyses on reaction times

The data were cleaned so that only responses with a reaction time superior to 200 ms were included in analyses and only correct responses were included. Reaction times collapsed across sessions reached 628.68 ± 24.77 ms (SEM).

To account for the within-subject design, we first ran a repeated-measures ANOVA with both order of pose and sex of subject (expansive–constrictive, constrictive–expansive) as between-subject factors, and pose (expansive, constrictive), task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors. Significant interactions between order of pose × sex × pose × emotion × gaze (F(2,80) = 3.874, $p = .025$, $\eta_p^2 = 0.088$), order of pose × pose × task (F(1,40) = 14.500, $p < .001$, $\eta_p^2 = 0.266$), order of pose × pose (F(1,40) = 31.643, $p < .001$, $\eta_p^2 = 0.442$)

suggested that the impact of pose may be different in Session 1 and Session 2, akin to accuracy results. We therefore analyzed Session 1 and 2 separately, by running two independent repeated measures ANOVAs for each session, with both posture and sex of subject as between-subject factors and task (gender, scene), emotion (neutral, fear, anger) and gaze (direct, averted) as within-subjects factors.

In session 1, neither the interaction between pose × task × emotion × gaze ($F(2,80) = 0.745$, $p = .478$, $\eta_p^2 = 0.018$) nor the one between task × emotion × gaze ($F(2,80) = 0.845$, $p = .433$, $\eta_p^2 = 0.021$) were significant (see Table 2). Similarly, in Session 2, neither the interaction between pose × task × emotion × gaze ($F(2,80) = 0.096$, $p = .909$, $\eta_p^2 = 0.002$) nor the one between task × emotion × gaze ($F(2,80) = 0.249$, $p = .707$, $\eta_p^2 = 0.009$) were significant (see Table 3).

In both sessions, the ANOVA did reveal a main effect of task (Session 1: $F(1,40) = 86.502$, $p < .001$, $\eta_p^2 = 0.684$; Session 2: $F(1,40) = 80.421$, $p < .001$, $\eta_p^2 = 0.668$), indicating that participants were significantly faster for the gender task (Session 1: 585.07 ± 24.09 ms (SEM); Session 2: 536.27 ± 21.94 ms (SEM)) as opposed to the Scene task (Session 1: 731.52 ± 31.16 ms (SEM); Session 2: 656.64 ± 28.01 ms (SEM)). In summary, reaction time analyses for Experiment 2 demonstrate no impact of pose.

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